

Spring Framework Reference Documentation

4.1.2.RELEASE

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Part I. Overview of Spring Framework

The Spring Framework is a lightweight solution and a potential one-stop-shop for building your enterprise-ready applications. However, Spring is modular, allowing you to use only those parts that you need, without having to bring in the rest. You can use the IoC container, with any web framework on top, but you can also use only the Hibernate integration code or the JDBC abstraction layer. The Spring Framework supports declarative transaction management, remote access to your logic through RMI or web services, and various options for persisting your data. It offers a full-featured MVC framework, and enables you to integrate AOP transparently into your software.

Spring is designed to be non-intrusive, meaning that your domain logic code generally has no dependencies on the framework itself. In your integration layer (such as the data access layer), some dependencies on the data access technology and the Spring libraries will exist. However, it should be easy to isolate these dependencies from the rest of your code base.

This document is a reference guide to Spring Framework features. If you have any requests, comments, or questions on this document, please post them on the user mailing list. Questions on the Framework itself should be asked on StackOverflow (see https://spring.io/questions).

1. Getting Started With Spring

This reference guide provides detailed information about the Spring Framework. It provides comprehensive documentation for all features, as well as some background about the underlying concepts (such as *"Dependency Injection"*) that Spring has embraced.

If you are just getting started with Spring, you may want to begin with the lighter "Getting Started" guides that are available from https://spring.io. As well as being easier to digest, these guide are very *task focused*. They also cover other projects from the Spring portfolio that you might want to consider when solving a particular problem.

Getting Started Building a RESTful Web Service would be an excellent first choice to get your feet wet.

2. Introduction to Spring Framework

Spring Framework is a Java platform that provides comprehensive infrastructure support for developing Java applications. Spring handles the infrastructure so you can focus on your application.

Spring enables you to build applications from "plain old Java objects" (POJOs) and to apply enterprise services non-invasively to POJOs. This capability applies to the Java SE programming model and to full and partial Java EE.

Examples of how you, as an application developer, can use the Spring platform advantage:

- Make a Java method execute in a database transaction without having to deal with transaction APIs.
- Make a local Java method a remote procedure without having to deal with remote APIs.
- Make a local Java method a management operation without having to deal with JMX APIs.
- Make a local Java method a message handler without having to deal with JMS APIs.

2.1 Dependency Injection and Inversion of Control

Background

"*The question is, what aspect of control are [they] inverting?*" Martin Fowler posed this question about Inversion of Control (IoC) on his site in 2004. Fowler suggested renaming the principle to make it more self-explanatory and came up with *Dependency Injection*.

For insight into IoC and DI, refer to Fowler's article at http://martinfowler.com/articles/injection.html.

Java applications — a loose term that runs the gamut from constrained applets to n-tier server-side enterprise applications — typically consist of objects that collaborate to form the application proper. Thus the objects in an application have *dependencies* on each other.

Although the Java platform provides a wealth of application development functionality, it lacks the means to organize the basic building blocks into a coherent whole, leaving that task to architects and developers. True, you can use design patterns such as *Factory*, *Abstract Factory*, *Builder*, *Decorator*, and *Service Locator* to compose the various classes and object instances that make up an application. However, these patterns are simply that: best practices given a name, with a description of what the pattern does, where to apply it, the problems it addresses, and so forth. Patterns are formalized best practices that *you must implement yourself* in your application.

The Spring Framework *Inversion of Control* (IoC) component addresses this concern by providing a formalized means of composing disparate components into a fully working application ready for use. The Spring Framework codifies formalized design patterns as first-class objects that you can integrate into your own application(s). Numerous organizations and institutions use the Spring Framework in this manner to engineer robust, *maintainable* applications.

2.2 Modules

The Spring Framework consists of features organized into about 20 modules. These modules are grouped into Core Container, Data Access/Integration, Web, AOP (Aspect Oriented Programming), Instrumentation, Messaging, and Test, as shown in the following diagram.

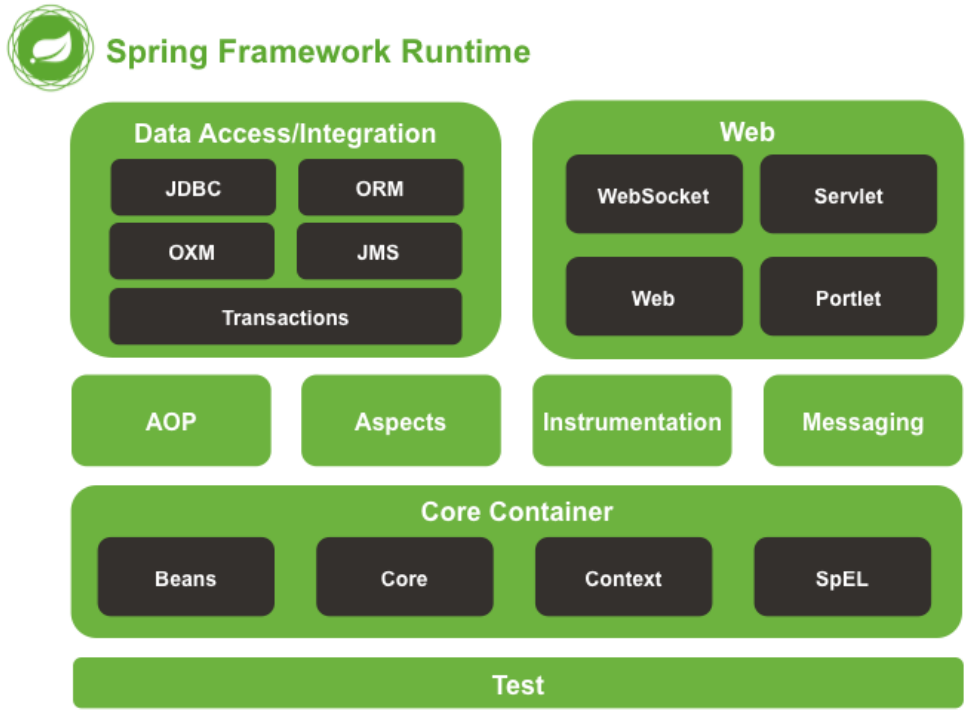


Figure 2.1. Overview of the Spring Framework

The following sections list the available modules for each feature along with their artifact name and the topics they cover. Artifact names correlate to *artifact IDs* used in Dependency Management tools.

Core Container

The *Core Container* consists of the `spring-core`, `spring-beans`, `spring-context`, and `spring-expression` (Spring Expression Language) modules.

The `spring-core` and `spring-beans` modules provide the fundamental parts of the framework, including the IoC and Dependency Injection features. The `BeanFactory` is a sophisticated implementation of the factory pattern. It removes the need for programmatic singletons and allows you to decouple the configuration and specification of dependencies from your actual program logic.

The *Context* (`spring-context`) module builds on the solid base provided by the *Core and Beans* modules: it is a means to access objects in a framework-style manner that is similar to a JNDI registry. The Context module inherits its features from the Beans module and adds support for internationalization (using, for example, resource bundles), event propagation, resource loading, and the transparent creation of contexts by, for example, a Servlet container. The Context module also supports Java EE features such as EJB, JMX, and basic remoting. The `ApplicationContext` interface is the focal point of the Context module.

The `spring-expression` module provides a powerful *Expression Language* for querying and manipulating an object graph at runtime. It is an extension of the unified expression language (unified EL) as specified in the JSP 2.1 specification. The language supports setting and getting property values, property assignment, method invocation, accessing the content of arrays, collections and indexers, logical and arithmetic operators, named variables, and retrieval of objects by name from Spring's IoC container. It also supports list projection and selection as well as common list aggregations.

AOP and Instrumentation

The `spring-aop` module provides an *AOP* Alliance-compliant aspect-oriented programming implementation allowing you to define, for example, method interceptors and pointcuts to cleanly decouple code that implements functionality that should be separated. Using source-level metadata functionality, you can also incorporate behavioral information into your code, in a manner similar to that of .NET attributes.

The separate `spring-aspects` module provides integration with AspectJ.

The `spring-instrument` module provides class instrumentation support and classloader implementations to be used in certain application servers.

Messaging

Spring Framework 4 includes a `spring-messaging` module with key abstractions from the *Spring Integration* project such as `Message`, `MessageChannel`, `MessageHandler`, and others to serve as a foundation for messaging-based applications. The module also includes a set of annotations for mapping messages to methods, similar to the Spring MVC annotation based programming model.

Data Access/Integration

The *Data Access/Integration* layer consists of the JDBC, ORM, OXM, JMS, and Transaction modules.

The `spring-jdbc` module provides a JDBC-abstraction layer that removes the need to do tedious JDBC coding and parsing of database-vendor specific error codes.

The `spring-tx` module supports programmatic and declarative transaction management for classes that implement special interfaces and for *all your POJOs (Plain Old Java Objects)*.

The `spring-orm` module provides integration layers for popular object-relational mapping APIs, including JPA, JDO, and Hibernate. Using the `spring-orm` module you can use all of these O/R-mapping frameworks in combination with all of the other features Spring offers, such as the simple declarative transaction management feature mentioned previously.

The `spring-oxm` module provides an abstraction layer that supports Object/XML mapping implementations such as JAXB, Castor, XMLBeans, JiBX and XStream.

The `spring-jms` module (Java Messaging Service) contains features for producing and consuming messages. Since Spring Framework 4.1, it provides integration with the `spring-messaging` module.

Web

The *Web* layer consists of the `spring-web`, `spring-webmvc`, `spring-websocket`, and `spring-webmvc-portlet` modules.

The `spring-web` module provides basic web-oriented integration features such as multipart file upload functionality and the initialization of the IoC container using Servlet listeners and a web-oriented application context. It also contains the web-related parts of Spring's remoting support.

The `spring-webmvc` module (also known as the *Web-Servlet* module) contains Spring's model-view-controller (*MVC*) implementation for web applications. Spring's MVC framework provides a clean

separation between domain model code and web forms and integrates with all of the other features of the Spring Framework.

The `spring-webmvc-portlet` module (also known as the *Web-Portlet* module) provides the MVC implementation to be used in a Portlet environment and mirrors the functionality of the `spring-webmvc` module.

Test

The `spring-test` module supports the unit testing and integration testing of Spring components with JUnit or TestNG. It provides consistent loading of Spring `ApplicationContexts` and caching of those contexts. It also provides mock objects that you can use to test your code in isolation.

2.3 Usage scenarios

The building blocks described previously make Spring a logical choice in many scenarios, from applets to full-fledged enterprise applications that use Spring's transaction management functionality and web framework integration.

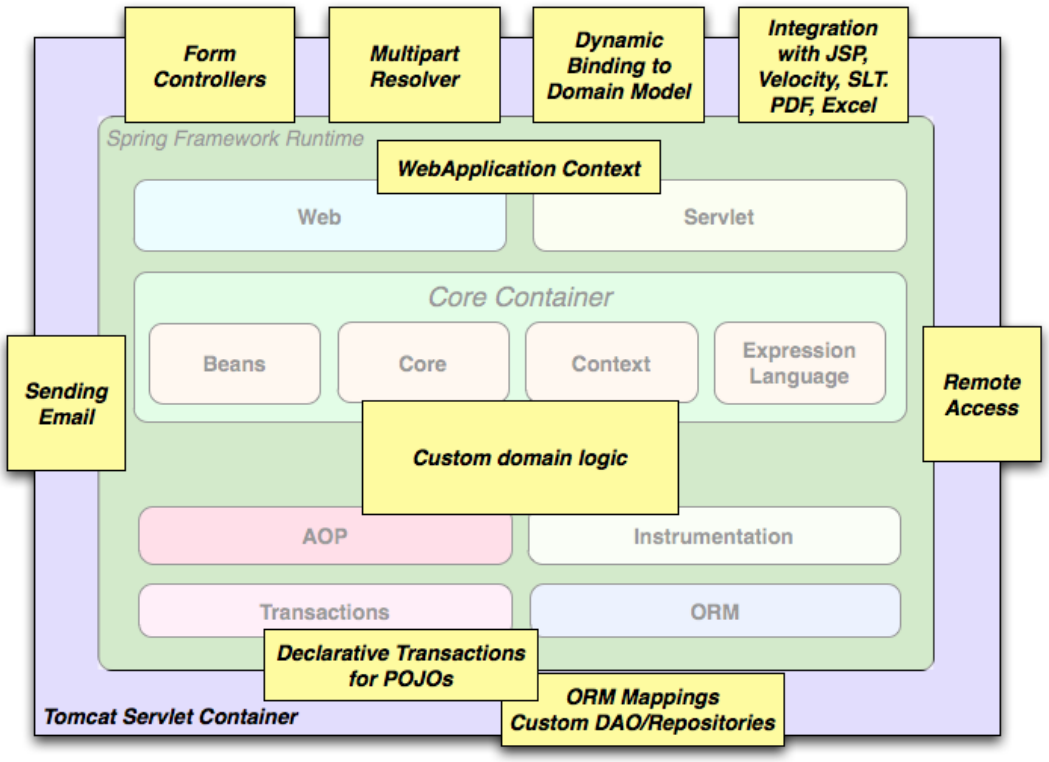


Figure 2.2. Typical full-fledged Spring web application

Spring's declarative transaction management features make the web application fully transactional, just as it would be if you used EJB container-managed transactions. All your custom business logic can be implemented with simple POJOs and managed by Spring's IoC container. Additional services include support for sending email and validation that is independent of the web layer, which lets you choose where to execute validation rules. Spring's ORM support is integrated with JPA, Hibernate and and JDO; for example, when using Hibernate, you can continue to use your existing mapping files and standard Hibernate `SessionFactory` configuration. Form controllers seamlessly integrate the web-layer with the domain model, removing the need for `ActionForms` or other classes that transform HTTP parameters to values for your domain model.

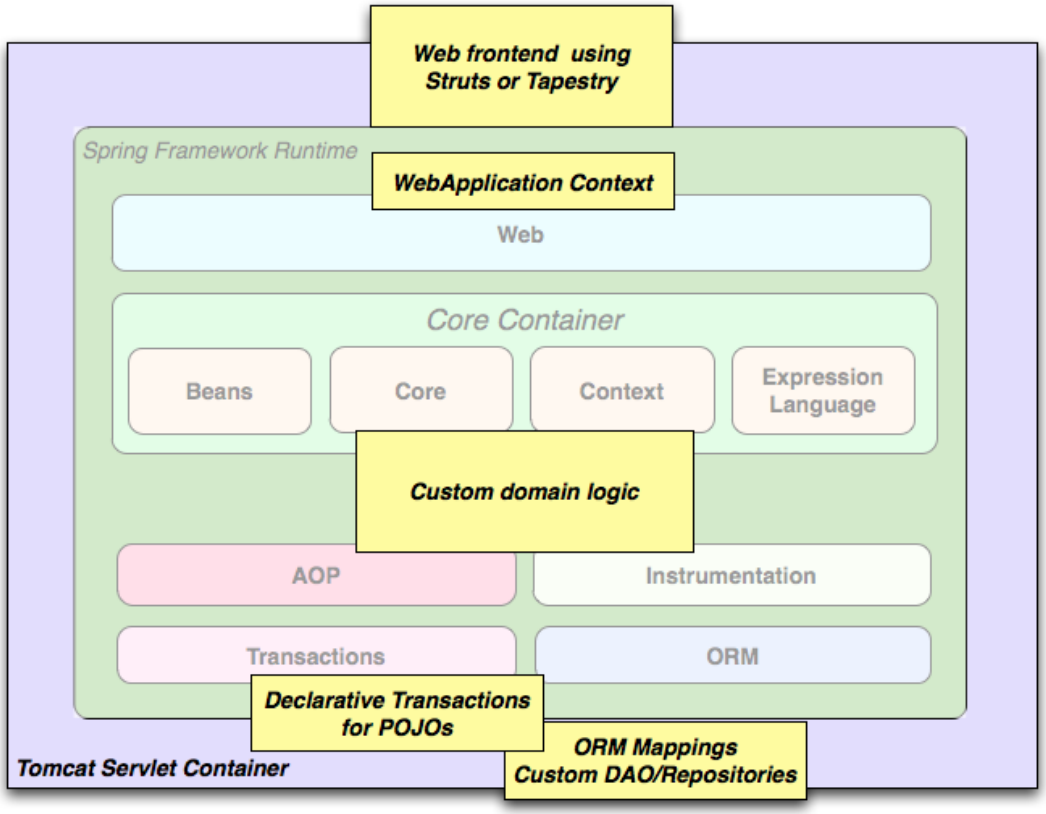


Figure 2.3. Spring middle-tier using a third-party web framework

Sometimes circumstances do not allow you to completely switch to a different framework. The Spring Framework does *not* force you to use everything within it; it is not an *all-or-nothing* solution. Existing front-ends built with Struts, Tapestry, JSF or other UI frameworks can be integrated with a Spring-based middle-tier, which allows you to use Spring transaction features. You simply need to wire up your business logic using an `ApplicationContext` and use a `WebApplicationContext` to integrate your web layer.

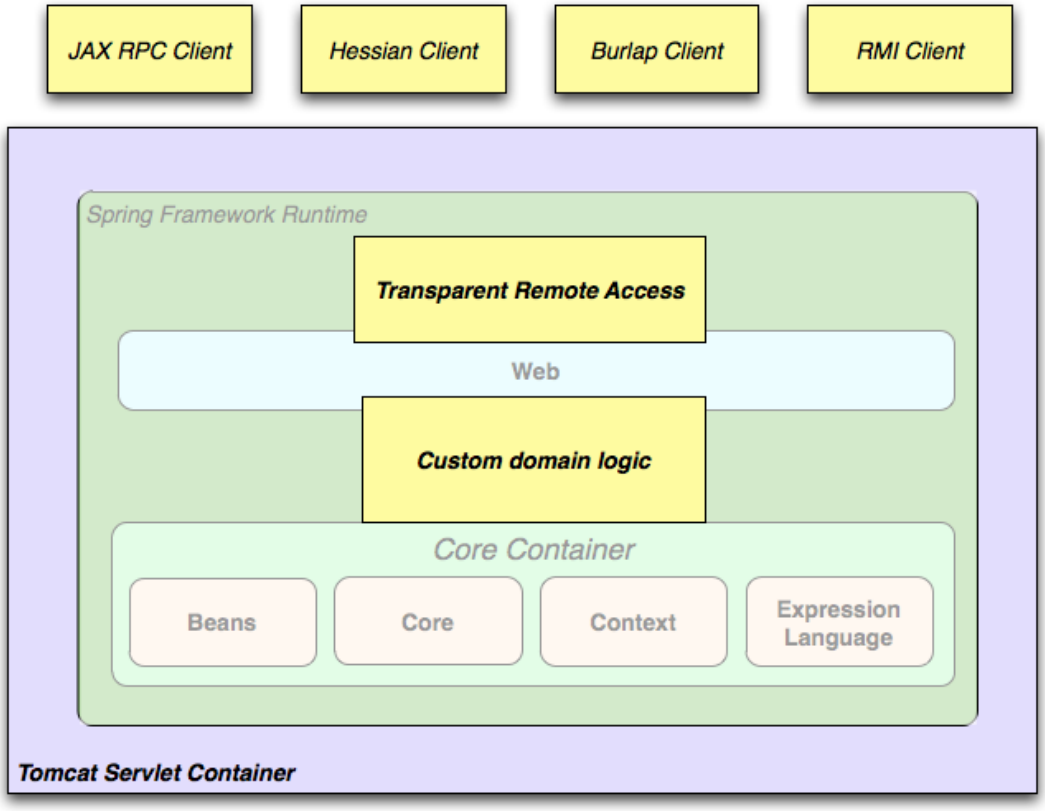


Figure 2.4. Remoting usage scenario

When you need to access existing code through web services, you can use Spring's `Hessian-`, `Burlap-`, `Rmi-` or `JaxRpcProxyFactory` classes. Enabling remote access to existing applications is not difficult.

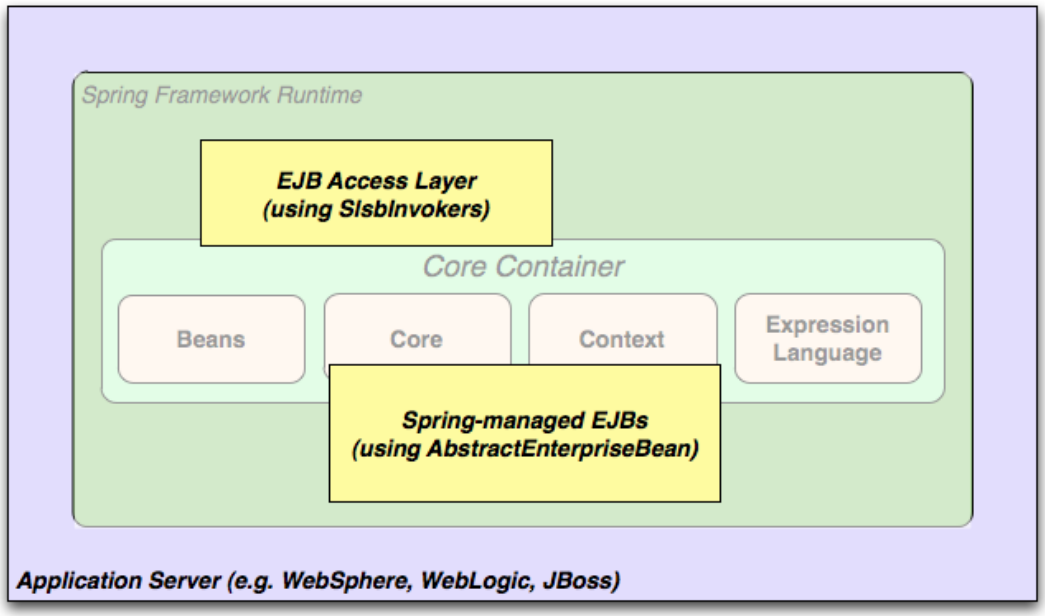


Figure 2.5. EJBs - Wrapping existing POJOs

The Spring Framework also provides an access and abstraction layer for Enterprise JavaBeans, enabling you to reuse your existing POJOs and wrap them in stateless session beans for use in scalable, fail-safe web applications that might need declarative security.

Dependency Management and Naming Conventions

Dependency management and dependency injection are different things. To get those nice features of Spring into your application (like dependency injection) you need to assemble all the libraries needed (jar files) and get them onto your classpath at runtime, and possibly at compile time. These dependencies are not virtual components that are injected, but physical resources in a file system (typically). The process of dependency management involves locating those resources, storing them and adding them to classpaths. Dependencies can be direct (e.g. my application depends on Spring at runtime), or indirect (e.g. my application depends on `commons-dbcp` which depends on `commons-pool`). The indirect dependencies are also known as "transitive" and it is those dependencies that are hardest to identify and manage.

If you are going to use Spring you need to get a copy of the jar libraries that comprise the pieces of Spring that you need. To make this easier Spring is packaged as a set of modules that separate the dependencies as much as possible, so for example if you don't want to write a web application you don't need the spring-web modules. To refer to Spring library modules in this guide we use a shorthand naming convention `spring-*` or `spring-*.jar`, where `*` represents the short name for the module (e.g. `spring-core`, `spring-webmvc`, `spring-jms`, etc.). The actual jar file name that you use is normally the module name concatenated with the version number (e.g. *spring-core-4.1.2.RELEASE.jar*).

Each release of the Spring Framework will publish artifacts to the following places:

- Maven Central, which is the default repository that Maven queries, and does not require any special configuration to use. Many of the common libraries that Spring depends on also are available from Maven Central and a large section of the Spring community uses Maven for dependency management, so this is convenient for them. The names of the jars here are in the form `spring-*-<version>.jar` and the Maven groupId is `org.springframework`.
- In a public Maven repository hosted specifically for Spring. In addition to the final GA releases, this repository also hosts development snapshots and milestones. The jar file names are in the same form as Maven Central, so this is a useful place to get development versions of Spring to use with other libraries deployed in Maven Central. This repository also contains a bundle distribution zip file that contains all Spring jars bundled together for easy download.

So the first thing you need to decide is how to manage your dependencies: we generally recommend the use of an automated system like Maven, Gradle or Ivy, but you can also do it manually by downloading all the jars yourself. We provide detailed instructions later in this chapter.

Spring Dependencies and Depending on Spring

Although Spring provides integration and support for a huge range of enterprise and other external tools, it intentionally keeps its mandatory dependencies to an absolute minimum: you shouldn't have to locate and download (even automatically) a large number of jar libraries in order to use Spring for simple use cases. For basic dependency injection there is only one mandatory external dependency, and that is for logging (see below for a more detailed description of logging options).

Next we outline the basic steps needed to configure an application that depends on Spring, first with Maven and then with Gradle and finally using Ivy. In all cases, if anything is unclear, refer to the documentation of your dependency management system, or look at some sample code - Spring itself uses Gradle to manage dependencies when it is building, and our samples mostly use Gradle or Maven.

Maven Dependency Management

If you are using Maven for dependency management you don't even need to supply the logging dependency explicitly. For example, to create an application context and use dependency injection to configure an application, your Maven dependencies will look like this:

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-context</artifactId>
        <version>4.1.2.RELEASE</version>
        <scope>runtime</scope>
    </dependency>
</dependencies>
```

That's it. Note the scope can be declared as runtime if you don't need to compile against Spring APIs, which is typically the case for basic dependency injection use cases.

The example above works with the Maven Central repository. To use the Spring Maven repository (e.g. for milestones or developer snapshots), you need to specify the repository location in your Maven configuration. For full releases:

```
<repositories>
    <repository>
        <id>io.spring.repo.maven.release</id>
        <url>http://repo.spring.io/release/</url>
        <snapshots><enabled>false</enabled></snapshots>
    </repository>
</repositories>
```

For milestones:

```
<repositories>
    <repository>
        <id>io.spring.repo.maven.milestone</id>
        <url>http://repo.spring.io/milestone/</url>
        <snapshots><enabled>false</enabled></snapshots>
    </repository>
</repositories>
```

And for snapshots:

```
<repositories>
    <repository>
        <id>io.spring.repo.maven.snapshot</id>
        <url>http://repo.spring.io/snapshot/</url>
        <snapshots><enabled>true</enabled></snapshots>
    </repository>
</repositories>
```

Maven "Bill Of Materials" Dependency

It is possible to accidentally mix different versions of Spring JARs when using Maven. For example, you may find that a third-party library, or another Spring project, pulls in a transitive dependency to an older release. If you forget to explicitly declare a direct dependency yourself, all sorts of unexpected issues can arise.

To overcome such problems Maven supports the concept of a "bill of materials" (BOM) dependency. You can import the `spring-framework-bom` in your `dependencyManagement` section to ensure that all spring dependencies (both direct and transitive) are at the same version.

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>org.springframework</groupId>
            <artifactId>spring-framework-bom</artifactId>
            <version>4.1.2.RELEASE</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
    </dependencies>
</dependencyManagement>
```

An added benefit of using the BOM is that you no longer need to specify the `<version>` attribute when depending on Spring Framework artifacts:

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-context</artifactId>
    </dependency>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-web</artifactId>
    </dependency>
<dependencies>
```

Gradle Dependency Management

To use the Spring repository with the Gradle build system, include the appropriate URL in the `repositories` section:

```
repositories {
    mavenCentral()
    // and optionally...
    maven { url "http://repo.spring.io/release" }
}
```

You can change the `repositories` URL from `/release` to `/milestone` or `/snapshot` as appropriate. Once a repository has been configured, you can declare dependencies in the usual Gradle way:

```
dependencies {
    compile("org.springframework:spring-context:4.1.2.RELEASE")
    testCompile("org.springframework:spring-test:4.1.2.RELEASE")
}
```

Ivy Dependency Management

If you prefer to use Ivy to manage dependencies then there are similar configuration options.

To configure Ivy to point to the Spring repository add the following resolver to your `ivysettings.xml`:

```
<resolvers>
    <ibiblio name="io.spring.repo.maven.release"
            m2compatible="true"
            root="http://repo.spring.io/release/"/>
</resolvers>
```

You can change the `root` URL from `/release/` to `/milestone/` or `/snapshot/` as appropriate.

Once configured, you can add dependencies in the usual way. For example (in `ivy.xml`):

```
<dependency org="org.springframework"
    name="spring-core" rev="4.1.2.RELEASE" conf="compile->runtime"/>
```

Distribution Zip Files

Although using a build system that supports dependency management is the recommended way to obtain the Spring Framework, it is still possible to download a distribution zip file.

Distribution zips are published to the Spring Maven Repository (this is just for our convenience, you don't need Maven or any other build system in order to download them).

To download a distribution zip open a web browser to http://repo.spring.io/release/org/springframework/spring and select the appropriate subfolder for the version that you want. Distribution files end `-dist.zip`, for example `spring-framework-4.1.2.RELEASE-RELEASE-dist.zip`. Distributions are also published for milestones and snapshots.

Logging

Logging is a very important dependency for Spring because *a)* it is the only mandatory external dependency, *b)* everyone likes to see some output from the tools they are using, and *c)* Spring integrates with lots of other tools all of which have also made a choice of logging dependency. One of the goals of an application developer is often to have unified logging configured in a central place for the whole application, including all external components. This is more difficult than it might have been since there are so many choices of logging framework.

The mandatory logging dependency in Spring is the Jakarta Commons Logging API (JCL). We compile against JCL and we also make JCL `Log` objects visible for classes that extend the Spring Framework. It's important to users that all versions of Spring use the same logging library: migration is easy because backwards compatibility is preserved even with applications that extend Spring. The way we do this is to make one of the modules in Spring depend explicitly on `commons-logging` (the canonical implementation of JCL), and then make all the other modules depend on that at compile time. If you are using Maven for example, and wondering where you picked up the dependency on `commons-logging`, then it is from Spring and specifically from the central module called `spring-core`.

The nice thing about `commons-logging` is that you don't need anything else to make your application work. It has a runtime discovery algorithm that looks for other logging frameworks in well known places on the classpath and uses one that it thinks is appropriate (or you can tell it which one if you need to). If nothing else is available you get pretty nice looking logs just from the JDK (java.util.logging or JUL for short). You should find that your Spring application works and logs happily to the console out of the box in most situations, and that's important.

Not Using Commons Logging

Unfortunately, the runtime discovery algorithm in `commons-logging`, while convenient for the end-user, is problematic. If we could turn back the clock and start Spring now as a new project it would use a different logging dependency. The first choice would probably be the Simple Logging Facade for Java (SLF4J), which is also used by a lot of other tools that people use with Spring inside their applications.

There are basically two ways to switch off `commons-logging`:

1. Exclude the dependency from the `spring-core` module (as it is the only module that explicitly depends on `commons-logging`)

2. Depend on a special `commons-logging` dependency that replaces the library with an empty jar (more details can be found in the SLF4J FAQ)

To exclude commons-logging, add the following to your `dependencyManagement` section:

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-core</artifactId>
        <version>4.1.2.RELEASE</version>
        <exclusions>
            <exclusion>
                <groupId>commons-logging</groupId>
                <artifactId>commons-logging</artifactId>
            </exclusion>
        </exclusions>
    </dependency>
</dependencies>
```

Now this application is probably broken because there is no implementation of the JCL API on the classpath, so to fix it a new one has to be provided. In the next section we show you how to provide an alternative implementation of JCL using SLF4J as an example.

Using SLF4J

SLF4J is a cleaner dependency and more efficient at runtime than `commons-logging` because it uses compile-time bindings instead of runtime discovery of the other logging frameworks it integrates. This also means that you have to be more explicit about what you want to happen at runtime, and declare it or configure it accordingly. SLF4J provides bindings to many common logging frameworks, so you can usually choose one that you already use, and bind to that for configuration and management.

SLF4J provides bindings to many common logging frameworks, including JCL, and it also does the reverse: bridges between other logging frameworks and itself. So to use SLF4J with Spring you need to replace the `commons-logging` dependency with the SLF4J-JCL bridge. Once you have done that then logging calls from within Spring will be translated into logging calls to the SLF4J API, so if other libraries in your application use that API, then you have a single place to configure and manage logging.

A common choice might be to bridge Spring to SLF4J, and then provide explicit binding from SLF4J to Log4J. You need to supply 4 dependencies (and exclude the existing `commons-logging`): the bridge, the SLF4J API, the binding to Log4J, and the Log4J implementation itself. In Maven you would do that like this

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-core</artifactId>
        <version>4.1.2.RELEASE</version>
        <exclusions>
            <exclusion>
                <groupId>commons-logging</groupId>
                <artifactId>commons-logging</artifactId>
            </exclusion>
        </exclusions>
    </dependency>
    <dependency>
        <groupId>org.slf4j</groupId>
        <artifactId>jcl-over-slf4j</artifactId>
        <version>1.5.8</version>
    </dependency>
    <dependency>
        <groupId>org.slf4j</groupId>
        <artifactId>slf4j-api</artifactId>
        <version>1.5.8</version>
    </dependency>
    <dependency>
        <groupId>org.slf4j</groupId>
        <artifactId>slf4j-log4j12</artifactId>
        <version>1.5.8</version>
    </dependency>
    <dependency>
        <groupId>log4j</groupId>
        <artifactId>log4j</artifactId>
        <version>1.2.14</version>
    </dependency>
</dependencies>
```

That might seem like a lot of dependencies just to get some logging. Well it is, but it *is* optional, and it should behave better than the vanilla `commons-logging` with respect to classloader issues, notably if you are in a strict container like an OSGi platform. Allegedly there is also a performance benefit because the bindings are at compile-time not runtime.

A more common choice amongst SLF4J users, which uses fewer steps and generates fewer dependencies, is to bind directly to Logback. This removes the extra binding step because Logback implements SLF4J directly, so you only need to depend on two libraries not four (`jcl-over-slf4j` and `logback`). If you do that you might also need to exclude the slf4j-api dependency from other external dependencies (not Spring), because you only want one version of that API on the classpath.

Using Log4J

Many people use Log4j as a logging framework for configuration and management purposes. It's efficient and well-established, and in fact it's what we use at runtime when we build and test Spring. Spring also provides some utilities for configuring and initializing Log4j, so it has an optional compile-time dependency on Log4j in some modules.

To make Log4j work with the default JCL dependency (`commons-logging`) all you need to do is put Log4j on the classpath, and provide it with a configuration file (`log4j.properties` or `log4j.xml` in the root of the classpath). So for Maven users this is your dependency declaration:

```
<dependencies>
    <dependency>
        <groupId>org.springframework</groupId>
        <artifactId>spring-core</artifactId>
        <version>4.1.2.RELEASE</version>
    </dependency>
    <dependency>
        <groupId>log4j</groupId>
        <artifactId>log4j</artifactId>
        <version>1.2.14</version>
    </dependency>
</dependencies>
```

And here's a sample log4j.properties for logging to the console:

```
log4j.rootCategory=INFO, stdout

log4j.appender.stdout=org.apache.log4j.ConsoleAppender
log4j.appender.stdout.layout=org.apache.log4j.PatternLayout
log4j.appender.stdout.layout.ConversionPattern=%d{ABSOLUTE} %5p %t %c{2}:%L - %m%n

log4j.category.org.springframework.beans.factory=DEBUG
```

Runtime Containers with Native JCL

Many people run their Spring applications in a container that itself provides an implementation of JCL. IBM Websphere Application Server (WAS) is the archetype. This often causes problems, and unfortunately there is no silver bullet solution; simply excluding `commons-logging` from your application is not enough in most situations.

To be clear about this: the problems reported are usually not with JCL per se, or even with `commons-logging`: rather they are to do with binding `commons-logging` to another framework (often Log4J). This can fail because `commons-logging` changed the way they do the runtime discovery in between the older versions (1.0) found in some containers and the modern versions that most people use now (1.1). Spring does not use any unusual parts of the JCL API, so nothing breaks there, but as soon as Spring or your application tries to do any logging you can find that the bindings to Log4J are not working.

In such cases with WAS the easiest thing to do is to invert the class loader hierarchy (IBM calls it "parent last") so that the application controls the JCL dependency, not the container. That option isn't always open, but there are plenty of other suggestions in the public domain for alternative approaches, and your mileage may vary depending on the exact version and feature set of the container.

Part II. What's New in Spring Framework 4.x

3. New Features and Enhancements in Spring Framework 4.0

The Spring Framework was first released in 2004; since then there have been significant major revisions: Spring 2.0 provided XML namespaces and AspectJ support; Spring 2.5 embraced annotation-driven configuration; Spring 3.0 introduced a strong Java 5+ foundation across the framework codebase, and features such as the Java-based `@Configuration` model.

Version 4.0 is the latest major release of the Spring Framework and the first to fully support Java 8 features. You can still use Spring with older versions of Java, however, the minimum requirement has now been raised to Java SE 6. We have also taken the opportunity of a major release to remove many deprecated classes and methods.

A migration guide for upgrading to Spring 4.0 is available on the Spring Framework GitHub Wiki.

3.1 Improved Getting Started Experience

The new spring.io website provides a whole series of "Getting Started" guides to help you learn Spring. You can read more about the guides in the Chapter 1, *Getting Started With Spring* section in this document. The new website also provides a comprehensive overview of the many additional projects that are released under the Spring umbrella.

If you are a Maven user you may also be interested in the helpful bill of materials POM file that is now published with each Spring Framework release.

3.2 Removed Deprecated Packages and Methods

All deprecated packages, and many deprecated classes and methods have been removed with version 4.0. If you are upgrading from a previous release of Spring, you should ensure that you have fixed any deprecated calls that you were making to outdated APIs.

For a complete set of changes, check out the API Differences Report.

Note that optional third-party dependencies have been raised to a 2010/2011 minimum (i.e. Spring 4 generally only supports versions released in late 2010 or later now): notably, Hibernate 3.6+, EhCache 2.1+, Quartz 1.8+, Groovy 1.8+, and Joda-Time 2.0+. As an exception to the rule, Spring 4 requires the recent Hibernate Validator 4.3+, and support for Jackson has been focused on 2.0+ now (with Jackson 1.8/1.9 support retained for the time being where Spring 3.2 had it; now just in deprecated form).

3.3 Java 8 (as well as 6 and 7)

Spring Framework 4.0 provides support for several Java 8 features. You can make use of *lambda expressions* and *method references* with Spring's callback interfaces. There is first-class support for `java.time` (JSR-310), and several existing annotations have been retrofitted as `@Repeatable`. You can also use Java 8's parameter name discovery (based on the `-parameters` compiler flag) as an alternative to compiling your code with debug information enabled.

Spring remains compatible with older versions of Java and the JDK: concretely, Java SE 6 (specifically, a minimum level equivalent to JDK 6 update 18, as released in January 2010) and above are still fully

supported. However, for newly started development projects based on Spring 4, we recommend the use of Java 7 or 8.

3.4 Java EE 6 and 7

Java EE version 6 or above is now considered the baseline for Spring Framework 4, with the JPA 2.0 and Servlet 3.0 specifications being of particular relevance. In order to remain compatible with Google App Engine and older application servers, it is possible to deploy a Spring 4 application into a Servlet 2.5 environment. However, Servlet 3.0+ is strongly recommended and a prerequisite in Spring's test and mock packages for test setups in development environments.

> **Note**
>
> If you are a WebSphere 7 user, be sure to install the JPA 2.0 feature pack. On WebLogic 10.3.4 or higher, install the JPA 2.0 patch that comes with it. This turns both of those server generations into Spring 4 compatible deployment environments.

On a more forward-looking note, Spring Framework 4.0 supports the Java EE 7 level of applicable specifications now: in particular, JMS 2.0, JTA 1.2, JPA 2.1, Bean Validation 1.1, and JSR-236 Concurrency Utilities. As usual, this support focuses on individual use of those specifications, e.g. on Tomcat or in standalone environments. However, it works equally well when a Spring application is deployed to a Java EE 7 server.

Note that Hibernate 4.3 is a JPA 2.1 provider and therefore only supported as of Spring Framework 4.0. The same applies to Hibernate Validator 5.0 as a Bean Validation 1.1 provider. Neither of the two are officially supported with Spring Framework 3.2.

3.5 Groovy Bean Definition DSL

With Spring Framework 4.0 it is now possible to define external bean configuration using a Groovy DSL. This is similar in concept to using XML bean definitions, but allows for a more concise syntax. Using Groovy also allows you to easily embed bean definitions directly in your bootstrap code. For example:

```
def reader = new GroovyBeanDefinitionReader(myApplicationContext)
reader.beans {
    dataSource(BasicDataSource) {
        driverClassName = "org.hsqldb.jdbcDriver"
        url = "jdbc:hsqldb:mem:grailsDB"
        username = "sa"
        password = ""
        settings = [mynew:"setting"]
    }
    sessionFactory(SessionFactory) {
        dataSource = dataSource
    }
    myService(MyService) {
        nestedBean = { AnotherBean bean ->
            dataSource = dataSource
        }
    }
}
```

For more information consult the `GroovyBeanDefinitionReader` javadocs.

3.6 Core Container Improvements

There have been several general improvements to the core container:

- Spring now treats *generic types as a form of qualifier* when injecting Beans. For example, if you are using a Spring Data `Repository` you can now easily inject a specific implementation: `@Autowired Repository<Customer> customerRepository`.
- If you use Spring's meta-annotation support, you can now develop custom annotations that expose specific attributes from the source annotation.
- Beans can now be *ordered* when they are autowired into lists and arrays. Both the `@Order` annotation and `Ordered` interface are supported.
- The `@Lazy` annotation can now be used on injection points, as well as on `@Bean` definitions.
- The `@Description` annotation has been introduced for developers using Java-based configuration.
- A generalized model for conditionally filtering beans has been added via the `@Conditional` annotation. This is similar to `@Profile` support but allows for user-defined strategies to be developed programmatically.
- CGLIB-based proxy classes no longer require a default constructor. Support is provided via the objenesis library which is repackaged *inline* and distributed as part of the Spring Framework. With this strategy, no constructor at all is being invoked for proxy instances anymore.
- There is managed time zone support across the framework now, e.g. on `LocaleContext`.

3.7 General Web Improvements

Deployment to Servlet 2.5 servers remains an option, but Spring Framework 4.0 is now focused primarily on Servlet 3.0+ environments. If you are using the Spring MVC Test Framework you will need to ensure that a Servlet 3.0 compatible JAR is in your *test classpath*.

In addition to the WebSocket support mentioned later, the following general improvements have been made to Spring's Web modules:

- You can use the new `@RestController` annotation with Spring MVC applications, removing the need to add `@ResponseBody` to each of your `@RequestMapping` methods.
- The `AsyncRestTemplate` class has been added, allowing non-blocking asynchronous support when developing REST clients.
- Spring now offers comprehensive timezone support when developing Spring MVC applications.

3.8 WebSocket, SockJS, and STOMP Messaging

A new `spring-websocket` module provides comprehensive support for WebSocket-based, two-way communication between client and server in web applications. It is compatible with JSR-356, the Java WebSocket API, and in addition provides SockJS-based fallback options (i.e. WebSocket emulation) for use in browsers that don't yet support the WebSocket protocol (e.g. Internet Explorer < 10).

A new `spring-messaging` module adds support for STOMP as the WebSocket sub-protocol to use in applications along with an annotation programming model for routing and processing STOMP messages from WebSocket clients. As a result an `@Controller` can now contain both `@RequestMapping` and `@MessageMapping` methods for handling HTTP requests and messages from WebSocket-connected clients. The new `spring-messaging` module also contains key abstractions formerly from the Spring

Integration project such as `Message`, `MessageChannel`, `MessageHandler`, and others to serve as a foundation for messaging-based applications.

For further details, including a more thorough introduction, see the Chapter 21, *WebSocket Support* section.

3.9 Testing Improvements

In addition to pruning of deprecated code within the `spring-test` module, Spring Framework 4.0 introduces several new features for use in unit and integration testing.

- Almost all annotations in the `spring-test` module (e.g., `@ContextConfiguration`, `@WebAppConfiguration`, `@ContextHierarchy`, `@ActiveProfiles`, etc.) can now be used as meta-annotations to create custom *composed annotations* and reduce configuration duplication across a test suite.
- Active bean definition profiles can now be resolved programmatically, simply by implementing a custom `ActiveProfilesResolver` and registering it via the `resolver` attribute of `@ActiveProfiles`.
- A new `SocketUtils` class has been introduced in the `spring-core` module which enables you to scan for free TCP and UDP server ports on localhost. This functionality is not specific to testing but can prove very useful when writing integration tests that require the use of sockets, for example tests that start an in-memory SMTP server, FTP server, Servlet container, etc.
- As of Spring 4.0, the set of mocks in the `org.springframework.mock.web` package is now based on the Servlet 3.0 API. Furthermore, several of the Servlet API mocks (e.g., `MockHttpServletRequest`, `MockServletContext`, etc.) have been updated with minor enhancements and improved configurability.

4. New Features and Enhancements in Spring Framework 4.1

4.1 JMS Improvements

Spring 4.1 introduces a much simpler infrastructure to register JMS listener endpoints by annotating bean methods with `@JmsListener`. The XML namespace has been enhanced to support this new style (`jms:annotation-driven`), and it is also possible to fully configure the infrastructure using Java config (`@EnableJms`, `JmsListenerContainerFactory`). It is also possible to register listener endpoints programmatically using `JmsListenerConfigurer`.

Spring 4.1 also aligns its JMS support to allow you to benefit from the `spring-messaging` abstraction introduced in 4.0, that is:

- Message listener endpoints can have a more flexible signature and benefit from standard messaging annotations such as `@Payload`, `@Header`, `@Headers`, and `@SendTo`. It is also possible to use a standard `Message` in lieu of `javax.jms.Message` as method argument.
- A new `JmsMessageOperations` interface is available and permits `JmsTemplate` like operations using the `Message` abstraction.

Finally, Spring 4.1 provides additional miscellaneous improvements:

- Synchronous request-reply operations support in `JmsTemplate`
- Listener priority can be specified per `<jms:listener/>` element
- Recovery options for the message listener container are configurable using a `BackOff` implementation
- JMS 2.0 shared consumers are supported

4.2 Caching Improvements

Spring 4.1 supports JCache (JSR-107) annotations using Spring's existing cache configuration and infrastructure abstraction; no changes are required to use the standard annotations.

Spring 4.1 also improves its own caching abstraction significantly:

- Caches can be resolved at runtime using a `CacheResolver`. As a result the `value` argument defining the cache name(s) to use is no longer mandatory.
- More operation-level customizations: cache resolver, cache manager, key generator
- A new `@CacheConfig` class-level annotation allows common settings to be shared at the class level **without** enabling any cache operation.
- Better exception handling of cached methods using `CacheErrorHandler`

Spring 4.1 also has a breaking change in the `CacheInterface` as a new `putIfAbsent` method has been added.

4.3 Web Improvements

- The existing support for resource handling based on the `ResourceHttpRequestHandler` has been expanded with new abstractions `ResourceResolver`, `ResourceTransformer`, and `ResourceUrlProvider`. A number of built-in implementations provide support for versioned resource URLs (for effective HTTP caching), locating gzipped resources, generating an HTML 5 AppCache manifests, and more. See the section called “Serving of Resources”.
- JDK 1.8’s `java.util.Optional` is now supported for `@RequestParam`, `@RequestHeader`, and `@MatrixVariable` controller method arguments.
- `ListenableFuture` is supported as a return value alternative to `DeferredResult` where an underlying service (or perhaps a call to `AsyncRestTemplate`) already returns `ListenableFuture`.
- `@ModelAttribute` methods are now invoked in an order that respects inter-dependencies. See SPR-6299.
- Jackson’s `@JsonView` is supported directly on `@ResponseBody` and `ResponseEntity` controller methods for serializing different amounts of detail for the same POJO (e.g. summary vs. detail page). This is also supported with View-based rendering by adding the serialization view type as a model attribute under a special key. See the section called “Jackson Serialization View Support” for details.
- JSONP is now supported with Jackson. See the section called “Jackson JSONP Support”.
- A new lifecycle option is available for intercepting `@ResponseBody` and `ResponseEntity` methods just after the controller method returns and before the response is written. To take advantage declare an `@ControllerAdvice` bean that implements `ResponseBodyAdvice`. The built-in support for `@JsonView` and JSONP take advantage of this. See the section called “Intercepting requests with a HandlerInterceptor”.
- There are three new `HttpMessageConverter` options:
  - Gson — lighter footprint than Jackson; has already been in use in Spring Android.
  - Google Protocol Buffers — efficient and effective as an inter-service communication data protocol within an enterprise but can also be exposed as JSON and XML for browsers.
  - Jackson based XML serialization is now supported through the jackson-dataformat-xml extension. When using `@EnableWebMvc` or `<mvc:annotation-driven/>`, this is used by default instead of JAXB2 if `jackson-dataformat-xml` is in the classpath.
- Views such as JSPs can now build links to controllers by referring to controller mappings by name. A default name is assigned to every `@RequestMapping`. For example `FooController` with method `handleFoo` is named "FC#handleFoo". The naming strategy is pluggable. It is also possible to name an `@RequestMapping` explicitly through its name attribute. A new `mvcUrl` function in the Spring JSP tag library makes this easy to use in JSP pages. See the section called “Building URIs to Controllers and methods from views”.
- `ResponseEntity` provides a builder-style API to guide controller methods towards the preparation of server-side responses, e.g. `ResponseEntity.ok()`.
- `RequestEntity` is a new type that provides a builder-style API to guide client-side REST code towards the preparation of HTTP requests.

- MVC Java config and XML namespace:
  - View resolvers can now be configured including support for content negotiation, see the section called “View Resolvers”.
  - View controllers now have built-in support for redirects and for setting the response status. An application can use this to configure redirect URLs, render 404 responses with a view, send "no content" responses, etc. Some use cases are listed here.
  - Path matching customizations are frequently used and now built-in. See the section called “Path Matching”.
- Groovy markup template support (based on Groovy 2.3). See the `GroovyMarkupConfigurer` and respecitve `ViewResolver` and ‘View’ implementations.

4.4 WebSocket STOMP Messaging Improvements

- SockJS (Java) client-side support. See `SockJsClient` and classes in same package.
- New application context events `SessionSubscribeEvent` and `SessionUnubscribeEvent` published when STOMP clients subscribe and unsubscribe.
- New "websocket" scope. See the section called “WebSocket Scope”.
- `@SendToUser` can target only a single session and does not require an authenticated user.
- `@MessageMapping` methods can use dot "." instead of slash "/" as path separator. See SPR-11660.
- STOMP/WebSocket monitoring info collected and logged. See the section called “Runtime Monitoring”.
- Significantly optimized and improved logging that should remain very readable and compact even at DEBUG level.
- Optimized message creation including support for temporary message mutability and avoiding automatic message id and timestamp creation. See Javadoc of `MessageHeaderAccessor`.
- STOMP/WebSocket connections that have not activity 60 seconds after the WebSocket session is established. See SPR-11884.

4.5 Testing Improvements

- Groovy scripts can now be used to configure the `ApplicationContext` loaded for integration tests in the TestContext framework.
  - See the section called “Context configuration with Groovy scripts” for details.
- Test-managed transactions can now be programmatically started and ended within transactional test methods via the new `TestTransaction` API.
  - See the section called “Programmatic transaction management” for details.
- SQL script execution can now be configured declaratively via the new `@Sql` and `@SqlConfig` annotations on a per-class or per-method basis.

  - See the section called “Executing SQL scripts” for details.
- Test property sources which automatically override system and application property sources can be configured via the new `@TestPropertySource` annotation.
  - See the section called “Context configuration with test property sources” for details.
- Default `TestExecutionListeners` can now be automatically discovered.
  - See the section called “Automatic discovery of default TestExecutionListeners” for details.
- Custom `TestExecutionListeners` can now be automatically merged with the default listeners.
  - See the section called “Merging TestExecutionListeners” for details.
- The documentation for transactional testing support in the TestContext framework has been improved with more thorough explanations and additional examples.
  - See the section called “Transaction management” for details.
- Various improvements to `MockServletContext`, `MockHttpServletRequest`, and other Servlet API mocks.
- `AssertThrows` has been refactored to support `Throwable` instead of `Exception`.
- In Spring MVC Test, JSON responses can be asserted with JSON Assert as an extra option to using JSONPath much like it has been possible to do for XML with XMLUnit.
- `MockMvcBuilder` *recipes* can now be created with the help of `MockMvcConfigurer`. This was added to make it easy to apply Spring Security setup but can be used to encapsulate common setup for any 3rd party framework or within a project.
- `MockRestServiceServer` now supports the `AsyncRestTemplate` for client-side testing.

Part III. Core Technologies

This part of the reference documentation covers all of those technologies that are absolutely integral to the Spring Framework.

Foremost amongst these is the Spring Framework's Inversion of Control (IoC) container. A thorough treatment of the Spring Framework's IoC container is closely followed by comprehensive coverage of Spring's Aspect-Oriented Programming (AOP) technologies. The Spring Framework has its own AOP framework, which is conceptually easy to understand, and which successfully addresses the 80% sweet spot of AOP requirements in Java enterprise programming.

Coverage of Spring's integration with AspectJ (currently the richest - in terms of features - and certainly most mature AOP implementation in the Java enterprise space) is also provided.

Finally, the adoption of the test-driven-development (TDD) approach to software development is certainly advocated by the Spring team, and so coverage of Spring's support for integration testing is covered (alongside best practices for unit testing). The Spring team has found that the correct use of IoC certainly does make both unit and integration testing easier (in that the presence of setter methods and appropriate constructors on classes makes them easier to wire together in a test without having to set up service locator registries and suchlike)… the chapter dedicated solely to testing will hopefully convince you of this as well.

- Chapter 5, *The IoC container*
- Chapter 6, *Resources*
- Chapter 7, *Validation, Data Binding, and Type Conversion*
- Chapter 8, *Spring Expression Language (SpEL)*
- Chapter 9, *Aspect Oriented Programming with Spring*
- Chapter 10, *Spring AOP APIs*
- Chapter 11, *Testing*

5. The IoC container

5.1 Introduction to the Spring IoC container and beans

This chapter covers the Spring Framework implementation of the Inversion of Control (IoC) [1] principle. IoC is also known as *dependency injection* (DI). It is a process whereby objects define their dependencies, that is, the other objects they work with, only through constructor arguments, arguments to a factory method, or properties that are set on the object instance after it is constructed or returned from a factory method. The container then *injects* those dependencies when it creates the bean. This process is fundamentally the inverse, hence the name *Inversion of Control* (IoC), of the bean itself controlling the instantiation or location of its dependencies by using direct construction of classes, or a mechanism such as the *Service Locator* pattern.

The `org.springframework.beans` and `org.springframework.context` packages are the basis for Spring Framework's IoC container. The `BeanFactory` interface provides an advanced configuration mechanism capable of managing any type of object. `ApplicationContext` is a sub-interface of `BeanFactory`. It adds easier integration with Spring's AOP features; message resource handling (for use in internationalization), event publication; and application-layer specific contexts such as the `WebApplicationContext` for use in web applications.

In short, the `BeanFactory` provides the configuration framework and basic functionality, and the `ApplicationContext` adds more enterprise-specific functionality. The `ApplicationContext` is a complete superset of the `BeanFactory`, and is used exclusively in this chapter in descriptions of Spring's IoC container. For more information on using the `BeanFactory` instead of the `ApplicationContext`, refer to Section 5.16, "The BeanFactory".

In Spring, the objects that form the backbone of your application and that are managed by the Spring IoC *container* are called *beans*. A bean is an object that is instantiated, assembled, and otherwise managed by a Spring IoC container. Otherwise, a bean is simply one of many objects in your application. Beans, and the *dependencies* among them, are reflected in the *configuration metadata* used by a container.

5.2 Container overview

The interface `org.springframework.context.ApplicationContext` represents the Spring IoC container and is responsible for instantiating, configuring, and assembling the aforementioned beans. The container gets its instructions on what objects to instantiate, configure, and assemble by reading configuration metadata. The configuration metadata is represented in XML, Java annotations, or Java code. It allows you to express the objects that compose your application and the rich interdependencies between such objects.

Several implementations of the `ApplicationContext` interface are supplied out-of-the-box with Spring. In standalone applications it is common to create an instance of `ClassPathXmlApplicationContext` or `FileSystemXmlApplicationContext`. While XML has been the traditional format for defining configuration metadata you can instruct the container to use Java annotations or code as the metadata format by providing a small amount of XML configuration to declaratively enable support for these additional metadata formats.

In most application scenarios, explicit user code is not required to instantiate one or more instances of a Spring IoC container. For example, in a web application scenario, a simple eight (or so) lines

[1] See Background

of boilerplate web descriptor XML in the `web.xml` file of the application will typically suffice (see the section called “Convenient ApplicationContext instantiation for web applications”). If you are using the Spring Tool Suite Eclipse-powered development environment this boilerplate configuration can be easily created with few mouse clicks or keystrokes.

The following diagram is a high-level view of how Spring works. Your application classes are combined with configuration metadata so that after the `ApplicationContext` is created and initialized, you have a fully configured and executable system or application.

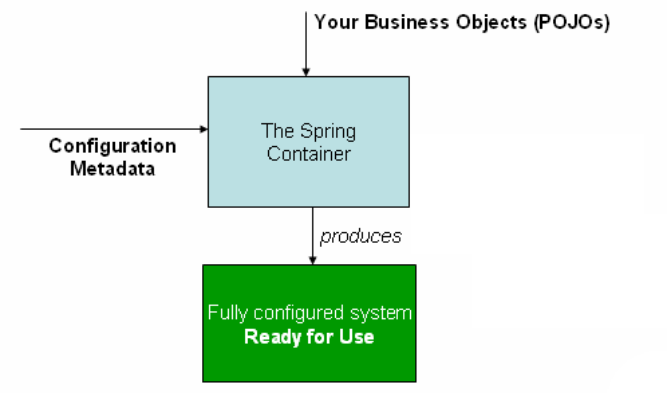


Figure 5.1. The Spring IoC container

Configuration metadata

As the preceding diagram shows, the Spring IoC container consumes a form of *configuration metadata*; this configuration metadata represents how you as an application developer tell the Spring container to instantiate, configure, and assemble the objects in your application.

Configuration metadata is traditionally supplied in a simple and intuitive XML format, which is what most of this chapter uses to convey key concepts and features of the Spring IoC container.

> **Note**
>
> XML-based metadata is *not* the only allowed form of configuration metadata. The Spring IoC container itself is *totally* decoupled from the format in which this configuration metadata is actually written. These days many developers choose Java-based configuration for their Spring applications.

For information about using other forms of metadata with the Spring container, see:

- Annotation-based configuration: Spring 2.5 introduced support for annotation-based configuration metadata.
- Java-based configuration: Starting with Spring 3.0, many features provided by the Spring JavaConfig project became part of the core Spring Framework. Thus you can define beans external to your application classes by using Java rather than XML files. To use these new features, see the `@Configuration`, `@Bean`, `@Import` and `@DependsOn` annotations.

Spring configuration consists of at least one and typically more than one bean definition that the container must manage. XML-based configuration metadata shows these beans configured as `<bean/>` elements inside a top-level `<beans/>` element. Java configuration typically uses `@Bean` annotated methods within a `@Configuration` class.

These bean definitions correspond to the actual objects that make up your application. Typically you define service layer objects, data access objects (DAOs), presentation objects such as Struts `Action` instances, infrastructure objects such as Hibernate `SessionFactories`, JMS `Queues`, and so forth. Typically one does not configure fine-grained domain objects in the container, because it is usually the responsibility of DAOs and business logic to create and load domain objects. However, you can use Spring's integration with AspectJ to configure objects that have been created outside the control of an IoC container. See Using AspectJ to dependency-inject domain objects with Spring.

The following example shows the basic structure of XML-based configuration metadata:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="..." class="...">
        <!-- collaborators and configuration for this bean go here -->
    </bean>

    <bean id="..." class="...">
        <!-- collaborators and configuration for this bean go here -->
    </bean>

    <!-- more bean definitions go here -->

</beans>
```

The `id` attribute is a string that you use to identify the individual bean definition. The `class` attribute defines the type of the bean and uses the fully qualified classname. The value of the id attribute refers to collaborating objects. The XML for referring to collaborating objects is not shown in this example; see Dependencies for more information.

Instantiating a container

Instantiating a Spring IoC container is straightforward. The location path or paths supplied to an `ApplicationContext` constructor are actually resource strings that allow the container to load configuration metadata from a variety of external resources such as the local file system, from the Java `CLASSPATH`, and so on.

```
ApplicationContext context =
    new ClassPathXmlApplicationContext(new String[] {"services.xml", "daos.xml"});
```

> **Note**
>
> After you learn about Spring's IoC container, you may want to know more about Spring's `Resource` abstraction, as described in Chapter 6, *Resources*, which provides a convenient mechanism for reading an InputStream from locations defined in a URI syntax. In particular, `Resource` paths are used to construct applications contexts as described in Section 6.7, "Application contexts and Resource paths".

The following example shows the service layer objects `(services.xml)` configuration file:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <!-- services -->

    <bean id="petStore" class="org.springframework.samples.jpetstore.services.PetStoreServiceImpl">
        <property name="accountDao" ref="accountDao"/>
        <property name="itemDao" ref="itemDao"/>
        <!-- additional collaborators and configuration for this bean go here -->
    </bean>

    <!-- more bean definitions for services go here -->

</beans>
```

The following example shows the data access objects `daos.xml` file:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="accountDao"
        class="org.springframework.samples.jpetstore.dao.jpa.JpaAccountDao">
        <!-- additional collaborators and configuration for this bean go here -->
    </bean>

    <bean id="itemDao" class="org.springframework.samples.jpetstore.dao.jpa.JpaItemDao">
        <!-- additional collaborators and configuration for this bean go here -->
    </bean>

    <!-- more bean definitions for data access objects go here -->

</beans>
```

In the preceding example, the service layer consists of the class `PetStoreServiceImpl`, and two data access objects of the type `JpaAccountDao` and `JpaItemDao` (based on the JPA Object/Relational mapping standard). The `property name` element refers to the name of the JavaBean property, and the `ref` element refers to the name of another bean definition. This linkage between `id` and `ref` elements expresses the dependency between collaborating objects. For details of configuring an object's dependencies, see Dependencies.

Composing XML-based configuration metadata

It can be useful to have bean definitions span multiple XML files. Often each individual XML configuration file represents a logical layer or module in your architecture.

You can use the application context constructor to load bean definitions from all these XML fragments. This constructor takes multiple `Resource` locations, as was shown in the previous section. Alternatively, use one or more occurrences of the `<import/>` element to load bean definitions from another file or files. For example:

```
<beans>
    <import resource="services.xml"/>
    <import resource="resources/messageSource.xml"/>
    <import resource="/resources/themeSource.xml"/>

    <bean id="bean1" class="..."/>
    <bean id="bean2" class="..."/>
</beans>
```

In the preceding example, external bean definitions are loaded from three files: `services.xml`, `messageSource.xml`, and `themeSource.xml`. All location paths are relative to the definition file doing the importing, so `services.xml` must be in the same directory or classpath location as the file doing the importing, while `messageSource.xml` and `themeSource.xml` must be in a `resources` location below the location of the importing file. As you can see, a leading slash is ignored, but given that these paths are relative, it is better form not to use the slash at all. The contents of the files being imported, including the top level `<beans/>` element, must be valid XML bean definitions according to the Spring Schema.

> **Note**
>
> It is possible, but not recommended, to reference files in parent directories using a relative "../" path. Doing so creates a dependency on a file that is outside the current application. In particular, this reference is not recommended for "classpath:" URLs (for example, "classpath:../services.xml"), where the runtime resolution process chooses the "nearest" classpath root and then looks into its parent directory. Classpath configuration changes may lead to the choice of a different, incorrect directory.
>
> You can always use fully qualified resource locations instead of relative paths: for example, "file:C:/config/services.xml" or "classpath:/config/services.xml". However, be aware that you are coupling your application's configuration to specific absolute locations. It is generally preferable to keep an indirection for such absolute locations, for example, through "${…}" placeholders that are resolved against JVM system properties at runtime.

Using the container

The `ApplicationContext` is the interface for an advanced factory capable of maintaining a registry of different beans and their dependencies. Using the method `T getBean(String name, Class<T> requiredType)` you can retrieve instances of your beans.

The `ApplicationContext` enables you to read bean definitions and access them as follows:

```
// create and configure beans
ApplicationContext context =
    new ClassPathXmlApplicationContext(new String[] {"services.xml", "daos.xml"});

// retrieve configured instance
PetStoreService service = context.getBean("petStore", PetStoreService.class);

// use configured instance
List<String> userList = service.getUsernameList();
```

You use `getBean()` to retrieve instances of your beans. The `ApplicationContext` interface has a few other methods for retrieving beans, but ideally your application code should never use them. Indeed, your application code should have no calls to the `getBean()` method at all, and thus no dependency on Spring APIs at all. For example, Spring's integration with web frameworks provides for dependency injection for various web framework classes such as controllers and JSF-managed beans.

5.3 Bean overview

A Spring IoC container manages one or more *beans*. These beans are created with the configuration metadata that you supply to the container, for example, in the form of XML `<bean/>` definitions.

Within the container itself, these bean definitions are represented as `BeanDefinition` objects, which contain (among other information) the following metadata:

- *A package-qualified class name:* typically the actual implementation class of the bean being defined.
- Bean behavioral configuration elements, which state how the bean should behave in the container (scope, lifecycle callbacks, and so forth).
- References to other beans that are needed for the bean to do its work; these references are also called *collaborators* or *dependencies*.
- Other configuration settings to set in the newly created object, for example, the number of connections to use in a bean that manages a connection pool, or the size limit of the pool.

This metadata translates to a set of properties that make up each bean definition.

Table 5.1. The bean definition

Property	**Explained in…**
class	the section called “Instantiating beans”
name	the section called “Naming beans”
scope	Section 5.5, “Bean scopes”
constructor arguments	the section called “Dependency injection”
properties	the section called “Dependency injection”
autowiring mode	the section called “Autowiring collaborators”
lazy-initialization mode	the section called “Lazy-initialized beans”
initialization method	the section called “Initialization callbacks”
destruction method	the section called “Destruction callbacks”

In addition to bean definitions that contain information on how to create a specific bean, the `ApplicationContext` implementations also permit the registration of existing objects that are created outside the container, by users. This is done by accessing the ApplicationContext's BeanFactory via the method `getBeanFactory()` which returns the BeanFactory implementation `DefaultListableBeanFactory`. `DefaultListableBeanFactory` supports this registration through the methods `registerSingleton(..)` and `registerBeanDefinition(..)`. However, typical applications work solely with beans defined through metadata bean definitions.

Naming beans

Every bean has one or more identifiers. These identifiers must be unique within the container that hosts the bean. A bean usually has only one identifier, but if it requires more than one, the extra ones can be considered aliases.

In XML-based configuration metadata, you use the `id` and/or `name` attributes to specify the bean identifier(s). The `id` attribute allows you to specify exactly one id. Conventionally these names are alphanumeric (*myBean*, *fooService*, etc.), but may contain special characters as well. If you want to introduce other aliases to the bean, you can also specify them in the `name` attribute, separated by a comma (`,`), semicolon (`;`), or white space. As a historical note, in versions prior to Spring 3.1, the `id` attribute was defined as an `xsd:ID` type, which constrained possible characters. As of 3.1, it is defined as an `xsd:string` type. Note that bean `id` uniqueness is still enforced by the container, though no longer by XML parsers.

You are not required to supply a name or id for a bean. If no name or id is supplied explicitly, the container generates a unique name for that bean. However, if you want to refer to that bean by name, through the use of the `ref` element or Service Locator style lookup, you must provide a name. Motivations for not supplying a name are related to using inner beans and autowiring collaborators.

> **Bean Naming Conventions**
>
> The convention is to use the standard Java convention for instance field names when naming beans. That is, bean names start with a lowercase letter, and are camel-cased from then on. Examples of such names would be (without quotes) `'accountManager'`, `'accountService'`, `'userDao'`, `'loginController'`, and so forth.
>
> Naming beans consistently makes your configuration easier to read and understand, and if you are using Spring AOP it helps a lot when applying advice to a set of beans related by name.

Aliasing a bean outside the bean definition

In a bean definition itself, you can supply more than one name for the bean, by using a combination of up to one name specified by the `id` attribute, and any number of other names in the `name` attribute. These names can be equivalent aliases to the same bean, and are useful for some situations, such as allowing each component in an application to refer to a common dependency by using a bean name that is specific to that component itself.

Specifying all aliases where the bean is actually defined is not always adequate, however. It is sometimes desirable to introduce an alias for a bean that is defined elsewhere. This is commonly the case in large systems where configuration is split amongst each subsystem, each subsystem having its own set of object definitions. In XML-based configuration metadata, you can use the `<alias/>` element to accomplish this.

```
<alias name="fromName" alias="toName"/>
```

In this case, a bean in the same container which is named `fromName`, may also, after the use of this alias definition, be referred to as `toName`.

For example, the configuration metadata for subsystem A may refer to a DataSource via the name `subsystemA-dataSource`. The configuration metadata for subsystem B may refer to a DataSource via the name `subsystemB-dataSource`. When composing the main application that uses both these subsystems the main application refers to the DataSource via the name `myApp-dataSource`. To have all three names refer to the same object you add to the MyApp configuration metadata the following aliases definitions:

```
<alias name="subsystemA-dataSource" alias="subsystemB-dataSource"/>
<alias name="subsystemA-dataSource" alias="myApp-dataSource" />
```

Now each component and the main application can refer to the dataSource through a name that is unique and guaranteed not to clash with any other definition (effectively creating a namespace), yet they refer to the same bean.

> **Java-configuration**
>
> If you are using Java-configuration, the `@Bean` annotation can be used to provide aliases see the section called “Using the @Bean annotation” for details.

Instantiating beans

A bean definition essentially is a recipe for creating one or more objects. The container looks at the recipe for a named bean when asked, and uses the configuration metadata encapsulated by that bean definition to create (or acquire) an actual object.

If you use XML-based configuration metadata, you specify the type (or class) of object that is to be instantiated in the `class` attribute of the `<bean/>` element. This `class` attribute, which internally is a `Class` property on a `BeanDefinition` instance, is usually mandatory. (For exceptions, see the section called “Instantiation using an instance factory method” and Section 5.7, “Bean definition inheritance”.) You use the `Class` property in one of two ways:

- Typically, to specify the bean class to be constructed in the case where the container itself directly creates the bean by calling its constructor reflectively, somewhat equivalent to Java code using the `new` operator.
- To specify the actual class containing the `static` factory method that will be invoked to create the object, in the less common case where the container invokes a `static` *factory* method on a class to create the bean. The object type returned from the invocation of the `static` factory method may be the same class or another class entirely.

> **Inner class names.** If you want to configure a bean definition for a `static` nested class, you have to use the *binary* name of the inner class.
>
> For example, if you have a class called `Foo` in the `com.example` package, and this `Foo` class has a `static` inner class called `Bar`, the value of the `'class'` attribute on a bean definition would be…
>
> `com.example.Foo$Bar`
>
> Notice the use of the `$` character in the name to separate the inner class name from the outer class name.

Instantiation with a constructor

When you create a bean by the constructor approach, all normal classes are usable by and compatible with Spring. That is, the class being developed does not need to implement any specific interfaces or to be coded in a specific fashion. Simply specifying the bean class should suffice. However, depending on what type of IoC you use for that specific bean, you may need a default (empty) constructor.

The Spring IoC container can manage virtually *any* class you want it to manage; it is not limited to managing true JavaBeans. Most Spring users prefer actual JavaBeans with only a default (no-argument) constructor and appropriate setters and getters modeled after the properties in the container. You can also have more exotic non-bean-style classes in your container. If, for example, you need to use a legacy connection pool that absolutely does not adhere to the JavaBean specification, Spring can manage it as well.

With XML-based configuration metadata you can specify your bean class as follows:

```
<bean id="exampleBean" class="examples.ExampleBean"/>

<bean name="anotherExample" class="examples.ExampleBeanTwo"/>
```

For details about the mechanism for supplying arguments to the constructor (if required) and setting object instance properties after the object is constructed, see Injecting Dependencies.

Instantiation with a static factory method

When defining a bean that you create with a static factory method, you use the `class` attribute to specify the class containing the `static` factory method and an attribute named `factory-method` to specify the name of the factory method itself. You should be able to call this method (with optional arguments as described later) and return a live object, which subsequently is treated as if it had been created through a constructor. One use for such a bean definition is to call `static` factories in legacy code.

The following bean definition specifies that the bean will be created by calling a factory-method. The definition does not specify the type (class) of the returned object, only the class containing the factory method. In this example, the `createInstance()` method must be a *static* method.

```
<bean id="clientService"
    class="examples.ClientService"
    factory-method="createInstance"/>
```

```
public class ClientService {
    private static ClientService clientService = new ClientService();
    private ClientService() {}

    public static ClientService createInstance() {
        return clientService;
    }
}
```

For details about the mechanism for supplying (optional) arguments to the factory method and setting object instance properties after the object is returned from the factory, see Dependencies and configuration in detail.

Instantiation using an instance factory method

Similar to instantiation through a static factory method, instantiation with an instance factory method invokes a non-static method of an existing bean from the container to create a new bean. To use this mechanism, leave the `class` attribute empty, and in the `factory-bean` attribute, specify the name of a bean in the current (or parent/ancestor) container that contains the instance method that is to be invoked to create the object. Set the name of the factory method itself with the `factory-method` attribute.

```
<!-- the factory bean, which contains a method called createInstance() -->
<bean id="serviceLocator" class="examples.DefaultServiceLocator">
    <!-- inject any dependencies required by this locator bean -->
</bean>

<!-- the bean to be created via the factory bean -->
<bean id="clientService"
    factory-bean="serviceLocator"
    factory-method="createClientServiceInstance"/>
```

```
public class DefaultServiceLocator {

    private static ClientService clientService = new ClientServiceImpl();
    private DefaultServiceLocator() {}

    public ClientService createClientServiceInstance() {
        return clientService;
    }
}
```

One factory class can also hold more than one factory method as shown here:

```
<bean id="serviceLocator" class="examples.DefaultServiceLocator">
    <!-- inject any dependencies required by this locator bean -->
</bean>

<bean id="clientService"
    factory-bean="serviceLocator"
    factory-method="createClientServiceInstance"/>

<bean id="accountService"
    factory-bean="serviceLocator"
    factory-method="createAccountServiceInstance"/>
```

```
public class DefaultServiceLocator {

    private static ClientService clientService = new ClientServiceImpl();
    private static AccountService accountService = new AccountServiceImpl();

    private DefaultServiceLocator() {}

    public ClientService createClientServiceInstance() {
        return clientService;
    }

    public AccountService createAccountServiceInstance() {
        return accountService;
    }

}
```

This approach shows that the factory bean itself can be managed and configured through dependency injection (DI). See Dependencies and configuration in detail.

> **Note**
>
> In Spring documentation, *factory bean* refers to a bean that is configured in the Spring container that will create objects through an instance or static factory method. By contrast, `FactoryBean` (notice the capitalization) refers to a Spring-specific `FactoryBean`.

5.4 Dependencies

A typical enterprise application does not consist of a single object (or bean in the Spring parlance). Even the simplest application has a few objects that work together to present what the end-user sees as a coherent application. This next section explains how you go from defining a number of bean definitions that stand alone to a fully realized application where objects collaborate to achieve a goal.

Dependency injection

Dependency injection (DI) is a process whereby objects define their dependencies, that is, the other objects they work with, only through constructor arguments, arguments to a factory method, or properties that are set on the object instance after it is constructed or returned from a factory method. The container then *injects* those dependencies when it creates the bean. This process is fundamentally the inverse, hence the name *Inversion of Control* (IoC), of the bean itself controlling the instantiation or location of its dependencies on its own by using direct construction of classes, or the *Service Locator* pattern.

Code is cleaner with the DI principle and decoupling is more effective when objects are provided with their dependencies. The object does not look up its dependencies, and does not know the location or class of the dependencies. As such, your classes become easier to test, in particular when the dependencies are on interfaces or abstract base classes, which allow for stub or mock implementations to be used in unit tests.

DI exists in two major variants, Constructor-based dependency injection and Setter-based dependency injection.

Constructor-based dependency injection

Constructor-based DI is accomplished by the container invoking a constructor with a number of arguments, each representing a dependency. Calling a `static` factory method with specific arguments to construct the bean is nearly equivalent, and this discussion treats arguments to a constructor and to a `static` factory method similarly. The following example shows a class that can only be dependency-injected with constructor injection. Notice that there is nothing *special* about this class, it is a POJO that has no dependencies on container specific interfaces, base classes or annotations.

```
public class SimpleMovieLister {

    // the SimpleMovieLister has a dependency on a MovieFinder
    private MovieFinder movieFinder;

    // a constructor so that the Spring container can inject a MovieFinder
    public SimpleMovieLister(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // business logic that actually uses the injected MovieFinder is omitted...

}
```

Constructor argument resolution

Constructor argument resolution matching occurs using the argument's type. If no potential ambiguity exists in the constructor arguments of a bean definition, then the order in which the constructor arguments are defined in a bean definition is the order in which those arguments are supplied to the appropriate constructor when the bean is being instantiated. Consider the following class:

```
package x.y;

public class Foo {

    public Foo(Bar bar, Baz baz) {
        // ...
    }

}
```

No potential ambiguity exists, assuming that `Bar` and `Baz` classes are not related by inheritance. Thus the following configuration works fine, and you do not need to specify the constructor argument indexes and/or types explicitly in the `<constructor-arg/>` element.

```
<beans>
    <bean id="foo" class="x.y.Foo">
        <constructor-arg ref="bar"/>
        <constructor-arg ref="baz"/>
    </bean>

    <bean id="bar" class="x.y.Bar"/>

    <bean id="baz" class="x.y.Baz"/>
</beans>
```

When another bean is referenced, the type is known, and matching can occur (as was the case with the preceding example). When a simple type is used, such as `<value>true</value>`, Spring cannot determine the type of the value, and so cannot match by type without help. Consider the following class:

```
package examples;

public class ExampleBean {

    // Number of years to calculate the Ultimate Answer
    private int years;

    // The Answer to Life, the Universe, and Everything
    private String ultimateAnswer;

    public ExampleBean(int years, String ultimateAnswer) {
        this.years = years;
        this.ultimateAnswer = ultimateAnswer;
    }

}
```

In the preceding scenario, the container *can* use type matching with simple types if you explicitly specify the type of the constructor argument using the `type` attribute. For example:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg type="int" value="7500000"/>
    <constructor-arg type="java.lang.String" value="42"/>
</bean>
```

Use the `index` attribute to specify explicitly the index of constructor arguments. For example:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg index="0" value="7500000"/>
    <constructor-arg index="1" value="42"/>
</bean>
```

In addition to resolving the ambiguity of multiple simple values, specifying an index resolves ambiguity where a constructor has two arguments of the same type. Note that the *index is 0 based*.

You can also use the constructor parameter name for value disambiguation:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <constructor-arg name="years" value="7500000"/>
    <constructor-arg name="ultimateAnswer" value="42"/>
</bean>
```

Keep in mind that to make this work out of the box your code must be compiled with the debug flag enabled so that Spring can look up the parameter name from the constructor. If you can't compile your code with debug flag (or don't want to) you can use @ConstructorProperties JDK annotation to explicitly name your constructor arguments. The sample class would then have to look as follows:

```
package examples;

public class ExampleBean {

    // Fields omitted

    @ConstructorProperties({"years", "ultimateAnswer"})
    public ExampleBean(int years, String ultimateAnswer) {
        this.years = years;
        this.ultimateAnswer = ultimateAnswer;
    }

}
```

Setter-based dependency injection

Setter-based DI is accomplished by the container calling setter methods on your beans after invoking a no-argument constructor or no-argument `static` factory method to instantiate your bean.

The following example shows a class that can only be dependency-injected using pure setter injection. This class is conventional Java. It is a POJO that has no dependencies on container specific interfaces, base classes or annotations.

```
public class SimpleMovieLister {

    // the SimpleMovieLister has a dependency on the MovieFinder
    private MovieFinder movieFinder;

    // a setter method so that the Spring container can inject a MovieFinder
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // business logic that actually uses the injected MovieFinder is omitted...

}
```

The `ApplicationContext` supports constructor-based and setter-based DI for the beans it manages. It also supports setter-based DI after some dependencies have already been injected through the constructor approach. You configure the dependencies in the form of a `BeanDefinition`, which you use in conjunction with `PropertyEditor` instances to convert properties from one format to another. However, most Spring users do not work with these classes directly (i.e., programmatically) but rather with XML `bean` definitions, annotated components (i.e., classes annotated with `@Component`, `@Controller`, etc.), or `@Bean` methods in Java-based `@Configuration` classes. These sources are then converted internally into instances of `BeanDefinition` and used to load an entire Spring IoC container instance.

Constructor-based or setter-based DI?

Since you can mix constructor-based and setter-based DI, it is a good rule of thumb to use constructors for *mandatory dependencies* and setter methods or configuration methods for *optional dependencies*. Note that use of the @Required annotation on a setter method can be used to make the property a required dependency.

The Spring team generally advocates constructor injection as it enables one to implement application components as *immutable objects* and to ensure that required dependencies are not `null`. Furthermore constructor-injected components are always returned to client (calling) code in a fully initialized state. As a side note, a large number of constructor arguments is a *bad code smell*, implying that the class likely has too many responsibilities and should be refactored to better address proper separation of concerns.

Setter injection should primarily only be used for optional dependencies that can be assigned reasonable default values within the class. Otherwise, not-null checks must be performed everywhere the code uses the dependency. One benefit of setter injection is that setter methods make objects of that class amenable to reconfiguration or re-injection later. Management through JMX MBeans is therefore a compelling use case for setter injection.

Use the DI style that makes the most sense for a particular class. Sometimes, when dealing with third-party classes for which you do not have the source, the choice is made for you. For example,

if a third-party class does not expose any setter methods, then constructor injection may be the only available form of DI.

Dependency resolution process

The container performs bean dependency resolution as follows:

- The `ApplicationContext` is created and initialized with configuration metadata that describes all the beans. Configuration metadata can be specified via XML, Java code, or annotations.
- For each bean, its dependencies are expressed in the form of properties, constructor arguments, or arguments to the static-factory method if you are using that instead of a normal constructor. These dependencies are provided to the bean, *when the bean is actually created*.
- Each property or constructor argument is an actual definition of the value to set, or a reference to another bean in the container.
- Each property or constructor argument which is a value is converted from its specified format to the actual type of that property or constructor argument. By default Spring can convert a value supplied in string format to all built-in types, such as `int`, `long`, `String`, `boolean`, etc.

The Spring container validates the configuration of each bean as the container is created. However, the bean properties themselves are not set until the bean *is actually created*. Beans that are singleton-scoped and set to be pre-instantiated (the default) are created when the container is created. Scopes are defined in Section 5.5, “Bean scopes”. Otherwise, the bean is created only when it is requested. Creation of a bean potentially causes a graph of beans to be created, as the bean’s dependencies and its dependencies' dependencies (and so on) are created and assigned. Note that resolution mismatches among those dependencies may show up late, i.e. on first creation of the affected bean.

Circular dependencies

If you use predominantly constructor injection, it is possible to create an unresolvable circular dependency scenario.

For example: Class A requires an instance of class B through constructor injection, and class B requires an instance of class A through constructor injection. If you configure beans for classes A and B to be injected into each other, the Spring IoC container detects this circular reference at runtime, and throws a `BeanCurrentlyInCreationException`.

One possible solution is to edit the source code of some classes to be configured by setters rather than constructors. Alternatively, avoid constructor injection and use setter injection only. In other words, although it is not recommended, you can configure circular dependencies with setter injection.

Unlike the *typical* case (with no circular dependencies), a circular dependency between bean A and bean B forces one of the beans to be injected into the other prior to being fully initialized itself (a classic chicken/egg scenario).

You can generally trust Spring to do the right thing. It detects configuration problems, such as references to non-existent beans and circular dependencies, at container load-time. Spring sets properties and

resolves dependencies as late as possible, when the bean is actually created. This means that a Spring container which has loaded correctly can later generate an exception when you request an object if there is a problem creating that object or one of its dependencies. For example, the bean throws an exception as a result of a missing or invalid property. This potentially delayed visibility of some configuration issues is why `ApplicationContext` implementations by default pre-instantiate singleton beans. At the cost of some upfront time and memory to create these beans before they are actually needed, you discover configuration issues when the `ApplicationContext` is created, not later. You can still override this default behavior so that singleton beans will lazy-initialize, rather than be pre-instantiated.

If no circular dependencies exist, when one or more collaborating beans are being injected into a dependent bean, each collaborating bean is *totally* configured prior to being injected into the dependent bean. This means that if bean A has a dependency on bean B, the Spring IoC container completely configures bean B prior to invoking the setter method on bean A. In other words, the bean is instantiated (if not a pre-instantiated singleton), its dependencies are set, and the relevant lifecycle methods (such as a configured init method or the InitializingBean callback method) are invoked.

Examples of dependency injection

The following example uses XML-based configuration metadata for setter-based DI. A small part of a Spring XML configuration file specifies some bean definitions:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <!-- setter injection using the nested ref element -->
    <property name="beanOne">
        <ref bean="anotherExampleBean"/>
    </property>

    <!-- setter injection using the neater ref attribute -->
    <property name="beanTwo" ref="yetAnotherBean"/>
    <property name="integerProperty" value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>
```

```
public class ExampleBean {

    private AnotherBean beanOne;
    private YetAnotherBean beanTwo;
    private int i;

    public void setBeanOne(AnotherBean beanOne) {
        this.beanOne = beanOne;
    }

    public void setBeanTwo(YetAnotherBean beanTwo) {
        this.beanTwo = beanTwo;
    }

    public void setIntegerProperty(int i) {
        this.i = i;
    }

}
```

In the preceding example, setters are declared to match against the properties specified in the XML file. The following example uses constructor-based DI:

```
<bean id="exampleBean" class="examples.ExampleBean">
    <!-- constructor injection using the nested ref element -->
    <constructor-arg>
        <ref bean="anotherExampleBean"/>
    </constructor-arg>

    <!-- constructor injection using the neater ref attribute -->
    <constructor-arg ref="yetAnotherBean"/>

    <constructor-arg type="int" value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>
```

```
public class ExampleBean {

    private AnotherBean beanOne;
    private YetAnotherBean beanTwo;
    private int i;

    public ExampleBean(
        AnotherBean anotherBean, YetAnotherBean yetAnotherBean, int i) {
        this.beanOne = anotherBean;
        this.beanTwo = yetAnotherBean;
        this.i = i;
    }

}
```

The constructor arguments specified in the bean definition will be used as arguments to the constructor of the `ExampleBean`.

Now consider a variant of this example, where instead of using a constructor, Spring is told to call a `static` factory method to return an instance of the object:

```
<bean id="exampleBean" class="examples.ExampleBean" factory-method="createInstance">
    <constructor-arg ref="anotherExampleBean"/>
    <constructor-arg ref="yetAnotherBean"/>
    <constructor-arg value="1"/>
</bean>

<bean id="anotherExampleBean" class="examples.AnotherBean"/>
<bean id="yetAnotherBean" class="examples.YetAnotherBean"/>
```

```
public class ExampleBean {

    // a private constructor
    private ExampleBean(...) {
        ...
    }

    // a static factory method; the arguments to this method can be
    // considered the dependencies of the bean that is returned,
    // regardless of how those arguments are actually used.
    public static ExampleBean createInstance (
        AnotherBean anotherBean, YetAnotherBean yetAnotherBean, int i) {

        ExampleBean eb = new ExampleBean (...);
        // some other operations...
        return eb;
    }

}
```

Arguments to the `static` factory method are supplied via `<constructor-arg/>` elements, exactly the same as if a constructor had actually been used. The type of the class being returned by the factory

method does not have to be of the same type as the class that contains the `static` factory method, although in this example it is. An instance (non-static) factory method would be used in an essentially identical fashion (aside from the use of the `factory-bean` attribute instead of the `class` attribute), so details will not be discussed here.

Dependencies and configuration in detail

As mentioned in the previous section, you can define bean properties and constructor arguments as references to other managed beans (collaborators), or as values defined inline. Spring's XML-based configuration metadata supports sub-element types within its `<property/>` and `<constructor-arg/>` elements for this purpose.

Straight values (primitives, Strings, and so on)

The `value` attribute of the `<property/>` element specifies a property or constructor argument as a human-readable string representation. Spring's conversion service is used to convert these values from a `String` to the actual type of the property or argument.

```
<bean id="myDataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
    <!-- results in a setDriverClassName(String) call -->
    <property name="driverClassName" value="com.mysql.jdbc.Driver"/>
    <property name="url" value="jdbc:mysql://localhost:3306/mydb"/>
    <property name="username" value="root"/>
    <property name="password" value="masterkaoli"/>
</bean>
```

The following example uses the p-namespace for even more succinct XML configuration.

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:p="http://www.springframework.org/schema/p"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
    http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="myDataSource" class="org.apache.commons.dbcp.BasicDataSource"
        destroy-method="close"
        p:driverClassName="com.mysql.jdbc.Driver"
        p:url="jdbc:mysql://localhost:3306/mydb"
        p:username="root"
        p:password="masterkaoli"/>

</beans>
```

The preceding XML is more succinct; however, typos are discovered at runtime rather than design time, unless you use an IDE such as IntelliJ IDEA or the Spring Tool Suite (STS) that support automatic property completion when you create bean definitions. Such IDE assistance is highly recommended.

You can also configure a `java.util.Properties` instance as:

```
<bean id="mappings"
    class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">

    <!-- typed as a java.util.Properties -->
    <property name="properties">
        <value>
            jdbc.driver.className=com.mysql.jdbc.Driver
            jdbc.url=jdbc:mysql://localhost:3306/mydb
        </value>
    </property>
</bean>
```

The Spring container converts the text inside the `<value/>` element into a `java.util.Properties` instance by using the JavaBeans `PropertyEditor` mechanism. This is a nice shortcut, and is one of a few places where the Spring team do favor the use of the nested `<value/>` element over the `value` attribute style.

The idref element

The `idref` element is simply an error-proof way to pass the *id* (string value - not a reference) of another bean in the container to a `<constructor-arg/>` or `<property/>` element.

```
<bean id="theTargetBean" class="..."/>

<bean id="theClientBean" class="...">
    <property name="targetName">
        <idref bean="theTargetBean" />
    </property>
</bean>
```

The above bean definition snippet is *exactly* equivalent (at runtime) to the following snippet:

```
<bean id="theTargetBean" class="..." />

<bean id="client" class="...">
    <property name="targetName" value="theTargetBean" />
</bean>
```

The first form is preferable to the second, because using the `idref` tag allows the container to validate *at deployment time* that the referenced, named bean actually exists. In the second variation, no validation is performed on the value that is passed to the `targetName` property of the `client` bean. Typos are only discovered (with most likely fatal results) when the `client` bean is actually instantiated. If the `client` bean is a prototype bean, this typo and the resulting exception may only be discovered long after the container is deployed.

> **Note**
>
> The `local` attribute on the `idref` element is no longer supported in the 4.0 beans xsd since it does not provide value over a regular `bean` reference anymore. Simply change your existing `idref local` references to `idref bean` when upgrading to the 4.0 schema.

A common place (at least in versions earlier than Spring 2.0) where the `<idref/>` element brings value is in the configuration of AOP interceptors in a `ProxyFactoryBean` bean definition. Using `<idref/>` elements when you specify the interceptor names prevents you from misspelling an interceptor id.

References to other beans (collaborators)

The `ref` element is the final element inside a `<constructor-arg/>` or `<property/>` definition element. Here you set the value of the specified property of a bean to be a reference to another bean (a collaborator) managed by the container. The referenced bean is a dependency of the bean whose property will be set, and it is initialized on demand as needed before the property is set. (If the collaborator is a singleton bean, it may be initialized already by the container.) All references are ultimately a reference to another object. Scoping and validation depend on whether you specify the id/name of the other object through the `bean`, `local`, or `parent` attributes.

Specifying the target bean through the `bean` attribute of the `<ref/>` tag is the most general form, and allows creation of a reference to any bean in the same container or parent container, regardless of

whether it is in the same XML file. The value of the `bean` attribute may be the same as the `id` attribute of the target bean, or as one of the values in the `name` attribute of the target bean.

```
<ref bean="someBean"/>
```

Specifying the target bean through the `parent` attribute creates a reference to a bean that is in a parent container of the current container. The value of the `parent` attribute may be the same as either the `id` attribute of the target bean, or one of the values in the `name` attribute of the target bean, and the target bean must be in a parent container of the current one. You use this bean reference variant mainly when you have a hierarchy of containers and you want to wrap an existing bean in a parent container with a proxy that will have the same name as the parent bean.

```
<!-- in the parent context -->
<bean id="accountService" class="com.foo.SimpleAccountService">
    <!-- insert dependencies as required as here -->
</bean>
```

```
<!-- in the child (descendant) context -->
<bean id="accountService" <!-- bean name is the same as the parent bean -->
    class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="target">
        <ref parent="accountService"/> <!-- notice how we refer to the parent bean -->
    </property>
    <!-- insert other configuration and dependencies as required here -->
</bean>
```

> **Note**
>
> The `local` attribute on the `ref` element is no longer supported in the 4.0 beans xsd since it does not provide value over a regular `bean` reference anymore. Simply change your existing `ref local` references to `ref bean` when upgrading to the 4.0 schema.

Inner beans

A `<bean/>` element inside the `<property/>` or `<constructor-arg/>` elements defines a so-called *inner bean*.

```
<bean id="outer" class="...">
    <!-- instead of using a reference to a target bean, simply define the target bean inline -->
    <property name="target">
        <bean class="com.example.Person"> <!-- this is the inner bean -->
            <property name="name" value="Fiona Apple"/>
            <property name="age" value="25"/>
        </bean>
    </property>
</bean>
```

An inner bean definition does not require a defined id or name; the container ignores these values. It also ignores the `scope` flag. Inner beans are *always* anonymous and they are *always* created with the outer bean. It is *not* possible to inject inner beans into collaborating beans other than into the enclosing bean.

Collections

In the `<list/>`, `<set/>`, `<map/>`, and `<props/>` elements, you set the properties and arguments of the Java `Collection` types `List`, `Set`, `Map`, and `Properties`, respectively.

```
<bean id="moreComplexObject" class="example.ComplexObject">
    <!-- results in a setAdminEmails(java.util.Properties) call -->
    <property name="adminEmails">
        <props>
            <prop key="administrator">administrator@example.org</prop>
            <prop key="support">support@example.org</prop>
            <prop key="development">development@example.org</prop>
        </props>
    </property>
    <!-- results in a setSomeList(java.util.List) call -->
    <property name="someList">
        <list>
            <value>a list element followed by a reference</value>
            <ref bean="myDataSource" />
        </list>
    </property>
    <!-- results in a setSomeMap(java.util.Map) call -->
    <property name="someMap">
        <map>
            <entry key="an entry" value="just some string"/>
            <entry key ="a ref" value-ref="myDataSource"/>
        </map>
    </property>
    <!-- results in a setSomeSet(java.util.Set) call -->
    <property name="someSet">
        <set>
            <value>just some string</value>
            <ref bean="myDataSource" />
        </set>
    </property>
</bean>
```

The value of a map key or value, or a set value, can also again be any of the following elements:

```
bean | ref | idref | list | set | map | props | value | null
```

Collection merging

The Spring container also supports the *merging* of collections. An application developer can define a parent-style `<list/>`, `<map/>`, `<set/>` or `<props/>` element, and have child-style `<list/>`, `<map/>`, `<set/>` or `<props/>` elements inherit and override values from the parent collection. That is, the child collection's values are the result of merging the elements of the parent and child collections, with the child's collection elements overriding values specified in the parent collection.

This section on merging discusses the parent-child bean mechanism. Readers unfamiliar with parent and child bean definitions may wish to read the relevant section before continuing.

The following example demonstrates collection merging:

```
<beans>
    <bean id="parent" abstract="true" class="example.ComplexObject">
        <property name="adminEmails">
            <props>
                <prop key="administrator">administrator@example.com</prop>
                <prop key="support">support@example.com</prop>
            </props>
        </property>
    </bean>
    <bean id="child" parent="parent">
        <property name="adminEmails">
            <!-- the merge is specified on the child collection definition -->
            <props merge="true">
                <prop key="sales">sales@example.com</prop>
                <prop key="support">support@example.co.uk</prop>
            </props>
        </property>
    </bean>
<beans>
```

Notice the use of the `merge=true` attribute on the `<props/>` element of the `adminEmails` property of the `child` bean definition. When the `child` bean is resolved and instantiated by the container, the resulting instance has an `adminEmails` `Properties` collection that contains the result of the merging of the child's `adminEmails` collection with the parent's `adminEmails` collection.

```
administrator=administrator@example.com
sales=sales@example.com
support=support@example.co.uk
```

The child `Properties` collection's value set inherits all property elements from the parent `<props/>`, and the child's value for the `support` value overrides the value in the parent collection.

This merging behavior applies similarly to the `<list/>`, `<map/>`, and `<set/>` collection types. In the specific case of the `<list/>` element, the semantics associated with the `List` collection type, that is, the notion of an `ordered` collection of values, is maintained; the parent's values precede all of the child list's values. In the case of the `Map`, `Set`, and `Properties` collection types, no ordering exists. Hence no ordering semantics are in effect for the collection types that underlie the associated `Map`, `Set`, and `Properties` implementation types that the container uses internally.

Limitations of collection merging

You cannot merge different collection types (such as a `Map` and a `List`), and if you do attempt to do so an appropriate `Exception` is thrown. The `merge` attribute must be specified on the lower, inherited, child definition; specifying the `merge` attribute on a parent collection definition is redundant and will not result in the desired merging.

Strongly-typed collection

With the introduction of generic types in Java 5, you can use strongly typed collections. That is, it is possible to declare a `Collection` type such that it can only contain `String` elements (for example). If you are using Spring to dependency-inject a strongly-typed `Collection` into a bean, you can take advantage of Spring's type-conversion support such that the elements of your strongly-typed `Collection` instances are converted to the appropriate type prior to being added to the `Collection`.

```
public class Foo {

    private Map<String, Float> accounts;

    public void setAccounts(Map<String, Float> accounts) {
        this.accounts = accounts;
    }
}
```

```
<beans>
    <bean id="foo" class="x.y.Foo">
        <property name="accounts">
            <map>
                <entry key="one" value="9.99"/>
                <entry key="two" value="2.75"/>
                <entry key="six" value="3.99"/>
            </map>
        </property>
    </bean>
</beans>
```

When the `accounts` property of the `foo` bean is prepared for injection, the generics information about the element type of the strongly-typed `Map<String, Float>` is available by reflection. Thus Spring's type conversion infrastructure recognizes the various value elements as being of type `Float`, and the string values `9.99`, `2.75`, and `3.99` are converted into an actual `Float` type.

Null and empty string values

Spring treats empty arguments for properties and the like as empty `Strings`. The following XML-based configuration metadata snippet sets the email property to the empty `String` value ("").

```
<bean class="ExampleBean">
    <property name="email" value=""/>
</bean>
```

The preceding example is equivalent to the following Java code:

```
exampleBean.setEmail("")
```

The `<null/>` element handles `null` values. For example:

```
<bean class="ExampleBean">
    <property name="email">
        <null/>
    </property>
</bean>
```

The above configuration is equivalent to the following Java code:

```
exampleBean.setEmail(null)
```

XML shortcut with the p-namespace

The p-namespace enables you to use the `bean` element's attributes, instead of nested `<property/>` elements, to describe your property values and/or collaborating beans.

Spring supports extensible configuration formats with namespaces, which are based on an XML Schema definition. The `beans` configuration format discussed in this chapter is defined in an XML Schema document. However, the p-namespace is not defined in an XSD file and exists only in the core of Spring.

The following example shows two XML snippets that resolve to the same result: The first uses standard XML format and the second uses the p-namespace.

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:p="http://www.springframework.org/schema/p"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean name="classic" class="com.example.ExampleBean">
        <property name="email" value="foo@bar.com"/>
    </bean>

    <bean name="p-namespace" class="com.example.ExampleBean"
        p:email="foo@bar.com"/>
</beans>
```

The example shows an attribute in the p-namespace called email in the bean definition. This tells Spring to include a property declaration. As previously mentioned, the p-namespace does not have a schema definition, so you can set the name of the attribute to the property name.

This next example includes two more bean definitions that both have a reference to another bean:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:p="http://www.springframework.org/schema/p"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean name="john-classic" class="com.example.Person">
        <property name="name" value="John Doe"/>
        <property name="spouse" ref="jane"/>
    </bean>

    <bean name="john-modern"
        class="com.example.Person"
        p:name="John Doe"
        p:spouse-ref="jane"/>

    <bean name="jane" class="com.example.Person">
        <property name="name" value="Jane Doe"/>
    </bean>
</beans>
```

As you can see, this example includes not only a property value using the p-namespace, but also uses a special format to declare property references. Whereas the first bean definition uses `<property name="spouse" ref="jane"/>` to create a reference from bean `john` to bean `jane`, the second bean definition uses `p:spouse-ref="jane"` as an attribute to do the exact same thing. In this case `spouse` is the property name, whereas the `-ref` part indicates that this is not a straight value but rather a reference to another bean.

> **Note**
>
> The p-namespace is not as flexible as the standard XML format. For example, the format for declaring property references clashes with properties that end in `Ref`, whereas the standard XML format does not. We recommend that you choose your approach carefully and communicate this to your team members, to avoid producing XML documents that use all three approaches at the same time.

XML shortcut with the c-namespace

Similar to the the section called “XML shortcut with the p-namespace”, the *c-namespace*, newly introduced in Spring 3.1, allows usage of inlined attributes for configuring the constructor arguments rather then nested `constructor-arg` elements.

Let's review the examples from the section called "Constructor-based dependency injection" with the `c:` namespace:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:c="http://www.springframework.org/schema/c"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="bar" class="x.y.Bar"/>
    <bean id="baz" class="x.y.Baz"/>

    <!-- traditional declaration -->
    <bean id="foo" class="x.y.Foo">
        <constructor-arg ref="bar"/>
        <constructor-arg ref="baz"/>
        <constructor-arg value="foo@bar.com"/>
    </bean>

    <!-- c-namespace declaration -->
    <bean id="foo" class="x.y.Foo" c:bar-ref="bar" c:baz-ref="baz" c:email="foo@bar.com"/>

</beans>
```

The `c:` namespace uses the same conventions as the `p:` one (trailing `-ref` for bean references) for setting the constructor arguments by their names. And just as well, it needs to be declared even though it is not defined in an XSD schema (but it exists inside the Spring core).

For the rare cases where the constructor argument names are not available (usually if the bytecode was compiled without debugging information), one can use fallback to the argument indexes:

```
<!-- c-namespace index declaration -->
<bean id="foo" class="x.y.Foo" c:_0-ref="bar" c:_1-ref="baz"/>
```

> **Note**
>
> Due to the XML grammar, the index notation requires the presence of the leading _ as XML attribute names cannot start with a number (even though some IDE allow it).

In practice, the constructor resolution mechanism is quite efficient in matching arguments so unless one really needs to, we recommend using the name notation through-out your configuration.

Compound property names

You can use compound or nested property names when you set bean properties, as long as all components of the path except the final property name are not `null`. Consider the following bean definition.

```
<bean id="foo" class="foo.Bar">
    <property name="fred.bob.sammy" value="123" />
</bean>
```

The `foo` bean has a `fred` property, which has a `bob` property, which has a `sammy` property, and that final `sammy` property is being set to the value `123`. In order for this to work, the `fred` property of `foo`, and the `bob` property of `fred` must not be `null` after the bean is constructed, or a `NullPointerException` is thrown.

Using depends-on

If a bean is a dependency of another that usually means that one bean is set as a property of another. Typically you accomplish this with the <ref/> element in XML-based configuration metadata. However, sometimes dependencies between beans are less direct; for example, a static initializer in a class needs to be triggered, such as database driver registration. The depends-on attribute can explicitly force one or more beans to be initialized before the bean using this element is initialized. The following example uses the depends-on attribute to express a dependency on a single bean:

```
<bean id="beanOne" class="ExampleBean" depends-on="manager"/>
<bean id="manager" class="ManagerBean" />
```

To express a dependency on multiple beans, supply a list of bean names as the value of the depends-on attribute, with commas, whitespace and semicolons, used as valid delimiters:

```
<bean id="beanOne" class="ExampleBean" depends-on="manager,accountDao">
    <property name="manager" ref="manager" />
</bean>

<bean id="manager" class="ManagerBean" />
<bean id="accountDao" class="x.y.jdbc.JdbcAccountDao" />
```

> **Note**
>
> The depends-on attribute in the bean definition can specify both an initialization time dependency and, in the case of singleton beans only, a corresponding destroy time dependency. Dependent beans that define a depends-on relationship with a given bean are destroyed first, prior to the given bean itself being destroyed. Thus depends-on can also control shutdown order.

Lazy-initialized beans

By default, ApplicationContext implementations eagerly create and configure all singleton beans as part of the initialization process. Generally, this pre-instantiation is desirable, because errors in the configuration or surrounding environment are discovered immediately, as opposed to hours or even days later. When this behavior is *not* desirable, you can prevent pre-instantiation of a singleton bean by marking the bean definition as lazy-initialized. A lazy-initialized bean tells the IoC container to create a bean instance when it is first requested, rather than at startup.

In XML, this behavior is controlled by the lazy-init attribute on the <bean/> element; for example:

```
<bean id="lazy" class="com.foo.ExpensiveToCreateBean" lazy-init="true"/>
<bean name="not.lazy" class="com.foo.AnotherBean"/>
```

When the preceding configuration is consumed by an ApplicationContext, the bean named lazy is not eagerly pre-instantiated when the ApplicationContext is starting up, whereas the not.lazy bean is eagerly pre-instantiated.

However, when a lazy-initialized bean is a dependency of a singleton bean that is *not* lazy-initialized, the ApplicationContext creates the lazy-initialized bean at startup, because it must satisfy the singleton's dependencies. The lazy-initialized bean is injected into a singleton bean elsewhere that is not lazy-initialized.

You can also control lazy-initialization at the container level by using the default-lazy-init attribute on the <beans/> element; for example:

```
<beans default-lazy-init="true">
    <!-- no beans will be pre-instantiated... -->
</beans>
```

Autowiring collaborators

The Spring container can *autowire* relationships between collaborating beans. You can allow Spring to resolve collaborators (other beans) automatically for your bean by inspecting the contents of the `ApplicationContext`. Autowiring has the following advantages:

- Autowiring can significantly reduce the need to specify properties or constructor arguments. (Other mechanisms such as a bean template discussed elsewhere in this chapter are also valuable in this regard.)
- Autowiring can update a configuration as your objects evolve. For example, if you need to add a dependency to a class, that dependency can be satisfied automatically without you needing to modify the configuration. Thus autowiring can be especially useful during development, without negating the option of switching to explicit wiring when the code base becomes more stable.

When using XML-based configuration metadata [10], you specify autowire mode for a bean definition with the `autowire` attribute of the `<bean/>` element. The autowiring functionality has five modes. You specify autowiring *per* bean and thus can choose which ones to autowire.

Table 5.2. Autowiring modes

Mode	Explanation
no	(Default) No autowiring. Bean references must be defined via a `ref` element. Changing the default setting is not recommended for larger deployments, because specifying collaborators explicitly gives greater control and clarity. To some extent, it documents the structure of a system.
byName	Autowiring by property name. Spring looks for a bean with the same name as the property that needs to be autowired. For example, if a bean definition is set to autowire by name, and it contains a *master* property (that is, it has a *setMaster(..)* method), Spring looks for a bean definition named `master`, and uses it to set the property.
byType	Allows a property to be autowired if exactly one bean of the property type exists in the container. If more than one exists, a fatal exception is thrown, which indicates that you may not use *byType* autowiring for that bean. If there are no matching beans, nothing happens; the property is not set.

[10] See the section called “Dependency injection”

Mode	Explanation
constructor	Analogous to *byType*, but applies to constructor arguments. If there is not exactly one bean of the constructor argument type in the container, a fatal error is raised.

With *byType* or *constructor* autowiring mode, you can wire arrays and typed-collections. In such cases *all* autowire candidates within the container that match the expected type are provided to satisfy the dependency. You can autowire strongly-typed Maps if the expected key type is `String`. An autowired Maps values will consist of all bean instances that match the expected type, and the Maps keys will contain the corresponding bean names.

You can combine autowire behavior with dependency checking, which is performed after autowiring completes.

Limitations and disadvantages of autowiring

Autowiring works best when it is used consistently across a project. If autowiring is not used in general, it might be confusing to developers to use it to wire only one or two bean definitions.

Consider the limitations and disadvantages of autowiring:

- Explicit dependencies in `property` and `constructor-arg` settings always override autowiring. You cannot autowire so-called *simple* properties such as primitives, `Strings`, and `Classes` (and arrays of such simple properties). This limitation is by-design.
- Autowiring is less exact than explicit wiring. Although, as noted in the above table, Spring is careful to avoid guessing in case of ambiguity that might have unexpected results, the relationships between your Spring-managed objects are no longer documented explicitly.
- Wiring information may not be available to tools that may generate documentation from a Spring container.
- Multiple bean definitions within the container may match the type specified by the setter method or constructor argument to be autowired. For arrays, collections, or Maps, this is not necessarily a problem. However for dependencies that expect a single value, this ambiguity is not arbitrarily resolved. If no unique bean definition is available, an exception is thrown.

In the latter scenario, you have several options:

- Abandon autowiring in favor of explicit wiring.
- Avoid autowiring for a bean definition by setting its `autowire-candidate` attributes to `false` as described in the next section.
- Designate a single bean definition as the *primary* candidate by setting the `primary` attribute of its `<bean/>` element to `true`.
- Implement the more fine-grained control available with annotation-based configuration, as described in Section 5.9, “Annotation-based container configuration”.

Excluding a bean from autowiring

On a per-bean basis, you can exclude a bean from autowiring. In Spring’s XML format, set the `autowire-candidate` attribute of the `<bean/>` element to `false`; the container makes that specific

bean definition unavailable to the autowiring infrastructure (including annotation style configurations such as `@Autowired`).

You can also limit autowire candidates based on pattern-matching against bean names. The top-level `<beans/>` element accepts one or more patterns within its `default-autowire-candidates` attribute. For example, to limit autowire candidate status to any bean whose name ends with *Repository,* provide a value of *Repository. To provide multiple patterns, define them in a comma-separated list. An explicit value of `true` or `false` for a bean definitions `autowire-candidate` attribute always takes precedence, and for such beans, the pattern matching rules do not apply.

These techniques are useful for beans that you never want to be injected into other beans by autowiring. It does not mean that an excluded bean cannot itself be configured using autowiring. Rather, the bean itself is not a candidate for autowiring other beans.

Method injection

In most application scenarios, most beans in the container are singletons. When a singleton bean needs to collaborate with another singleton bean, or a non-singleton bean needs to collaborate with another non-singleton bean, you typically handle the dependency by defining one bean as a property of the other. A problem arises when the bean lifecycles are different. Suppose singleton bean A needs to use non-singleton (prototype) bean B, perhaps on each method invocation on A. The container only creates the singleton bean A once, and thus only gets one opportunity to set the properties. The container cannot provide bean A with a new instance of bean B every time one is needed.

A solution is to forego some inversion of control. You can make bean A aware of the container by implementing the `ApplicationContextAware` interface, and by making a getBean("B") call to the container ask for (a typically new) bean B instance every time bean A needs it. The following is an example of this approach:

```
// a class that uses a stateful Command-style class to perform some processing
package fiona.apple;

// Spring-API imports
import org.springframework.beans.BeansException;
import org.springframework.context.ApplicationContext;
import org.springframework.context.ApplicationContextAware;

public class CommandManager implements ApplicationContextAware {

    private ApplicationContext applicationContext;

    public Object process(Map commandState) {
        // grab a new instance of the appropriate Command
        Command command = createCommand();
        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
        return command.execute();
    }

    protected Command createCommand() {
        // notice the Spring API dependency!
        return this.applicationContext.getBean("command", Command.class);
    }

    public void setApplicationContext(
            ApplicationContext applicationContext) throws BeansException {
        this.applicationContext = applicationContext;
    }
}
```

The preceding is not desirable, because the business code is aware of and coupled to the Spring Framework. Method Injection, a somewhat advanced feature of the Spring IoC container, allows this use case to be handled in a clean fashion.

> You can read more about the motivation for Method Injection in this blog entry.

Lookup method injection

Lookup method injection is the ability of the container to override methods on *container managed beans*, to return the lookup result for another named bean in the container. The lookup typically involves a prototype bean as in the scenario described in the preceding section. The Spring Framework implements this method injection by using bytecode generation from the CGLIB library to generate dynamically a subclass that overrides the method.

> **Note**
>
> For this dynamic subclassing to work, the class that the Spring container will subclass cannot be `final`, and the method to be overridden cannot be `final` either. Also, testing a class that has an `abstract` method requires you to subclass the class yourself and to supply a stub implementation of the `abstract` method. Finally, objects that have been the target of method injection cannot be serialized. As of Spring 3.2 it is no longer necessary to add CGLIB to your classpath, because CGLIB classes are repackaged under org.springframework and distributed within the spring-core JAR. This is done both for convenience as well as to avoid potential conflicts with other projects that use differing versions of CGLIB.

Looking at the `CommandManager` class in the previous code snippet, you see that the Spring container will dynamically override the implementation of the `createCommand()` method. Your `CommandManager` class will not have any Spring dependencies, as can be seen in the reworked example:

```
package fiona.apple;

// no more Spring imports!

public abstract class CommandManager {

    public Object process(Object commandState) {
        // grab a new instance of the appropriate Command interface
        Command command = createCommand();
        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
        return command.execute();
    }

    // okay... but where is the implementation of this method?
    protected abstract Command createCommand();
}
```

In the client class containing the method to be injected (the `CommandManager` in this case), the method to be injected requires a signature of the following form:

```
<public|protected> [abstract] <return-type> theMethodName(no-arguments);
```

If the method is `abstract`, the dynamically-generated subclass implements the method. Otherwise, the dynamically-generated subclass overrides the concrete method defined in the original class. For example:

```
<!-- a stateful bean deployed as a prototype (non-singleton) -->
<bean id="command" class="fiona.apple.AsyncCommand" scope="prototype">
    <!-- inject dependencies here as required -->
</bean>

<!-- commandProcessor uses statefulCommandHelper -->
<bean id="commandManager" class="fiona.apple.CommandManager">
    <lookup-method name="createCommand" bean="command"/>
</bean>
```

The bean identified as *commandManager* calls its own method `createCommand()` whenever it needs a new instance of the *command* bean. You must be careful to deploy the `command` bean as a prototype, if that is actually what is needed. If it is deployed as a [singleton], the same instance of the `command` bean is returned each time.

> **Tip**
>
> The interested reader may also find the `ServiceLocatorFactoryBean` (in the `org.springframework.beans.factory.config` package) to be of use. The approach used in ServiceLocatorFactoryBean is similar to that of another utility class, `ObjectFactoryCreatingFactoryBean`, but it allows you to specify your own lookup interface as opposed to a Spring-specific lookup interface. Consult the javadocs of these classes for additional information.

Arbitrary method replacement

A less useful form of method injection than lookup method Injection is the ability to replace arbitrary methods in a managed bean with another method implementation. Users may safely skip the rest of this section until the functionality is actually needed.

With XML-based configuration metadata, you can use the `replaced-method` element to replace an existing method implementation with another, for a deployed bean. Consider the following class, with a method computeValue, which we want to override:

```
public class MyValueCalculator {

    public String computeValue(String input) {
        // some real code...
    }

    // some other methods...

}
```

A class implementing the `org.springframework.beans.factory.support.MethodReplacer` interface provides the new method definition.

```
/**
 * meant to be used to override the existing computeValue(String)
 * implementation in MyValueCalculator
 */
public class ReplacementComputeValue implements MethodReplacer {

    public Object reimplement(Object o, Method m, Object[] args) throws Throwable {
        // get the input value, work with it, and return a computed result
        String input = (String) args[0];
        ...
        return ...;
    }
}
```

The bean definition to deploy the original class and specify the method override would look like this:

```
<bean id="myValueCalculator" class="x.y.z.MyValueCalculator">
    <!-- arbitrary method replacement -->
    <replaced-method name="computeValue" replacer="replacementComputeValue">
        <arg-type>String</arg-type>
    </replaced-method>
</bean>

<bean id="replacementComputeValue" class="a.b.c.ReplacementComputeValue"/>
```

You can use one or more contained `<arg-type/>` elements within the `<replaced-method/>` element to indicate the method signature of the method being overridden. The signature for the arguments is necessary only if the method is overloaded and multiple variants exist within the class. For convenience, the type string for an argument may be a substring of the fully qualified type name. For example, the following all match `java.lang.String`:

```
java.lang.String
String
Str
```

Because the number of arguments is often enough to distinguish between each possible choice, this shortcut can save a lot of typing, by allowing you to type only the shortest string that will match an argument type.

5.5 Bean scopes

When you create a bean definition, you create a *recipe* for creating actual instances of the class defined by that bean definition. The idea that a bean definition is a recipe is important, because it means that, as with a class, you can create many object instances from a single recipe.

You can control not only the various dependencies and configuration values that are to be plugged into an object that is created from a particular bean definition, but also the *scope* of the objects created from a particular bean definition. This approach is powerful and flexible in that you can *choose* the scope of the objects you create through configuration instead of having to bake in the scope of an object at the Java class level. Beans can be defined to be deployed in one of a number of scopes: out of the box, the Spring Framework supports five scopes, three of which are available only if you use a web-aware `ApplicationContext`.

The following scopes are supported out of the box. You can also create a custom scope.

Table 5.3. Bean scopes

Scope	Description
singleton	(Default) Scopes a single bean definition to a single object instance per Spring IoC container.
prototype	Scopes a single bean definition to any number of object instances.
request	Scopes a single bean definition to the lifecycle of a single HTTP request; that is, each HTTP request has its own instance of a bean created off the back of a single bean definition. Only

Scope	Description
	valid in the context of a web-aware Spring `ApplicationContext`.
session	Scopes a single bean definition to the lifecycle of an HTTP `Session`. Only valid in the context of a web-aware Spring `ApplicationContext`.
global session	Scopes a single bean definition to the lifecycle of a global HTTP `Session`. Typically only valid when used in a portlet context. Only valid in the context of a web-aware Spring `ApplicationContext`.
application	Scopes a single bean definition to the lifecycle of a `ServletContext`. Only valid in the context of a web-aware Spring `ApplicationContext`.

> **Note**
>
> As of Spring 3.0, a *thread scope* is available, but is not registered by default. For more information, see the documentation for `SimpleThreadScope`. For instructions on how to register this or any other custom scope, see the section called “Using a custom scope”.

The singleton scope

Only one *shared* instance of a singleton bean is managed, and all requests for beans with an id or ids matching that bean definition result in that one specific bean instance being returned by the Spring container.

To put it another way, when you define a bean definition and it is scoped as a singleton, the Spring IoC container creates *exactly one* instance of the object defined by that bean definition. This single instance is stored in a cache of such singleton beans, and *all subsequent requests and references* for that named bean return the cached object.

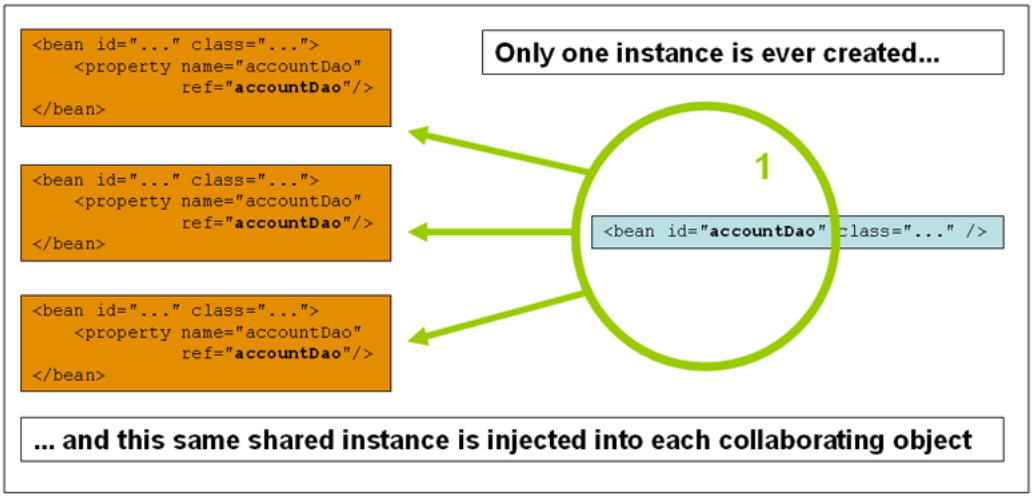


Figure 5.2.

Spring's concept of a singleton bean differs from the Singleton pattern as defined in the Gang of Four (GoF) patterns book. The GoF Singleton hard-codes the scope of an object such that one *and only one* instance of a particular class is created *per ClassLoader*. The scope of the Spring singleton is best described as *per container and per bean*. This means that if you define one bean for a particular class in a single Spring container, then the Spring container creates one *and only one* instance of the class defined by that bean definition. *The singleton scope is the default scope in Spring*. To define a bean as a singleton in XML, you would write, for example:

```
<bean id="accountService" class="com.foo.DefaultAccountService"/>

<!-- the following is equivalent, though redundant (singleton scope is the default) -->
<bean id="accountService" class="com.foo.DefaultAccountService" scope="singleton"/>
```

The prototype scope

The non-singleton, prototype scope of bean deployment results in the *creation of a new bean instance* every time a request for that specific bean is made. That is, the bean is injected into another bean or you request it through a `getBean()` method call on the container. As a rule, use the prototype scope for all stateful beans and the singleton scope for stateless beans.

The following diagram illustrates the Spring prototype scope. *A data access object (DAO) is not typically configured as a prototype, because a typical DAO does not hold any conversational state; it was just easier for this author to reuse the core of the singleton diagram.*

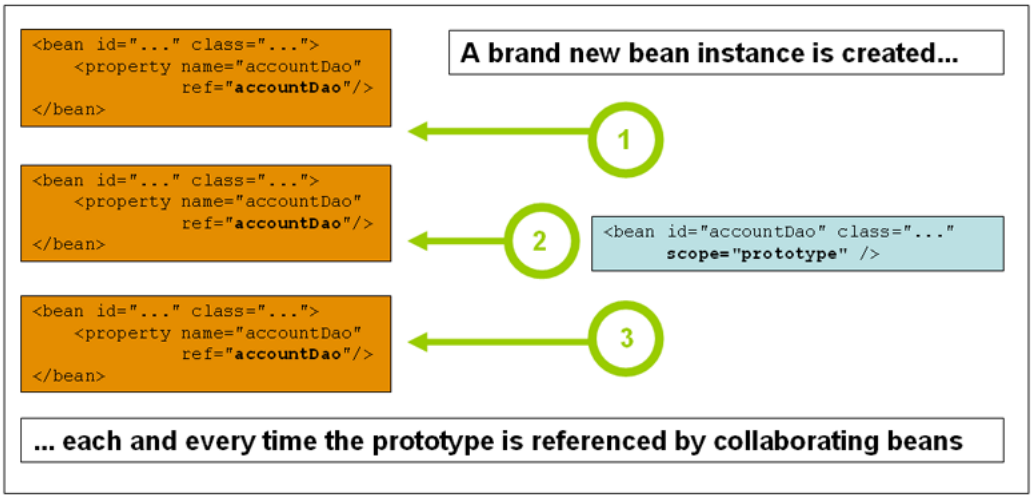


Figure 5.3.

The following example defines a bean as a prototype in XML:

```
<bean id="accountService" class="com.foo.DefaultAccountService" scope="prototype"/>
```

In contrast to the other scopes, Spring does not manage the complete lifecycle of a prototype bean: the container instantiates, configures, and otherwise assembles a prototype object, and hands it to the client, with no further record of that prototype instance. Thus, although *initialization* lifecycle callback methods are called on all objects regardless of scope, in the case of prototypes, configured *destruction* lifecycle callbacks are *not* called. The client code must clean up prototype-scoped objects and release expensive resources that the prototype bean(s) are holding. To get the Spring container to release resources held by prototype-scoped beans, try using a custom bean post-processor, which holds a reference to beans that need to be cleaned up.

In some respects, the Spring container's role in regard to a prototype-scoped bean is a replacement for the Java `new` operator. All lifecycle management past that point must be handled by the client. (For details on the lifecycle of a bean in the Spring container, see the section called "Lifecycle callbacks".)

Singleton beans with prototype-bean dependencies

When you use singleton-scoped beans with dependencies on prototype beans, be aware that *dependencies are resolved at instantiation time*. Thus if you dependency-inject a prototype-scoped bean into a singleton-scoped bean, a new prototype bean is instantiated and then dependency-injected into the singleton bean. The prototype instance is the sole instance that is ever supplied to the singleton-scoped bean.

However, suppose you want the singleton-scoped bean to acquire a new instance of the prototype-scoped bean repeatedly at runtime. You cannot dependency-inject a prototype-scoped bean into your singleton bean, because that injection occurs only *once*, when the Spring container is instantiating the singleton bean and resolving and injecting its dependencies. If you need a new instance of a prototype bean at runtime more than once, see the section called "Method injection"

Request, session, and global session scopes

The `request`, `session`, and `global session` scopes are *only* available if you use a web-aware Spring `ApplicationContext` implementation (such as `XmlWebApplicationContext`). If you use these scopes with regular Spring IoC containers such as the `ClassPathXmlApplicationContext`, you get an `IllegalStateException` complaining about an unknown bean scope.

Initial web configuration

To support the scoping of beans at the `request`, `session`, and `global session` levels (web-scoped beans), some minor initial configuration is required before you define your beans. (This initial setup is *not* required for the standard scopes, singleton and prototype.)

How you accomplish this initial setup depends on your particular Servlet environment..

If you access scoped beans within Spring Web MVC, in effect, within a request that is processed by the Spring `DispatcherServlet`, or `DispatcherPortlet`, then no special setup is necessary: `DispatcherServlet` and `DispatcherPortlet` already expose all relevant state.

If you use a Servlet 2.5 web container, with requests processed outside of Spring's DispatcherServlet (for example, when using JSF or Struts), you need to register the `org.springframework.web.context.request.RequestContextListener` `ServletRequestListener`. For Servlet 3.0+, this can done programmatically via the `WebApplicationInitializer` interface. Alternatively, or for older containers, add the following declaration to your web application's `web.xml` file:

```
<web-app>
    ...
    <listener>
        <listener-class>
            org.springframework.web.context.request.RequestContextListener
        </listener-class>
    </listener>
    ...
</web-app>
```

Alternatively, if there are issues with your listener setup, consider the provided `RequestContextFilter`. The filter mapping depends on the surrounding web application configuration, so you have to change it as appropriate.

```
<web-app>
    ...
    <filter>
        <filter-name>requestContextFilter</filter-name>
        <filter-class>org.springframework.web.filter.RequestContextFilter</filter-class>
    </filter>
    <filter-mapping>
        <filter-name>requestContextFilter</filter-name>
        <url-pattern>/*</url-pattern>
    </filter-mapping>
    ...
</web-app>
```

`DispatcherServlet`, `RequestContextListener` and `RequestContextFilter` all do exactly the same thing, namely bind the HTTP request object to the `Thread` that is servicing that request. This makes beans that are request- and session-scoped available further down the call chain.

Request scope

Consider the following bean definition:

```
<bean id="loginAction" class="com.foo.LoginAction" scope="request"/>
```

The Spring container creates a new instance of the `LoginAction` bean by using the `loginAction` bean definition for each and every HTTP request. That is, the `loginAction` bean is scoped at the HTTP request level. You can change the internal state of the instance that is created as much as you want, because other instances created from the same `loginAction` bean definition will not see these changes in state; they are particular to an individual request. When the request completes processing, the bean that is scoped to the request is discarded.

Session scope

Consider the following bean definition:

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="session"/>
```

The Spring container creates a new instance of the `UserPreferences` bean by using the `userPreferences` bean definition for the lifetime of a single HTTP `Session`. In other words, the `userPreferences` bean is effectively scoped at the HTTP `Session` level. As with `request-scoped` beans, you can change the internal state of the instance that is created as much as you want, knowing that other HTTP `Session` instances that are also using instances created from the same `userPreferences` bean definition do not see these changes in state, because they are particular to an individual HTTP `Session`. When the HTTP `Session` is eventually discarded, the bean that is scoped to that particular HTTP `Session` is also discarded.

Global session scope

Consider the following bean definition:

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="globalSession"/>
```

The `global session` scope is similar to the standard HTTP `Session` scope (described above), and applies only in the context of portlet-based web applications. The portlet specification defines the notion

of a global `Session` that is shared among all portlets that make up a single portlet web application. Beans defined at the `global session` scope are scoped (or bound) to the lifetime of the global portlet `Session`.

If you write a standard Servlet-based web application and you define one or more beans as having `global session` scope, the standard HTTP `Session` scope is used, and no error is raised.

Application scope

Consider the following bean definition:

```
<bean id="appPreferences" class="com.foo.AppPreferences" scope="application"/>
```

The Spring container creates a new instance of the `AppPreferences` bean by using the `appPreferences` bean definition once for the entire web application. That is, the `appPreferences` bean is scoped at the `ServletContext` level, stored as a regular `ServletContext` attribute. This is somewhat similar to a Spring singleton bean but differs in two important ways: It is a singleton per `ServletContext`, not per Spring *ApplicationContext* (or which there may be several in any given web application), and it is actually exposed and therefore visible as a `ServletContext` attribute.

Scoped beans as dependencies

The Spring IoC container manages not only the instantiation of your objects (beans), but also the wiring up of collaborators (or dependencies). If you want to inject (for example) an HTTP request scoped bean into another bean, you must inject an AOP proxy in place of the scoped bean. That is, you need to inject a proxy object that exposes the same public interface as the scoped object but that can also retrieve the real, target object from the relevant scope (for example, an HTTP request) and delegate method calls onto the real object.

> **Note**
>
> You *do not* need to use the `<aop:scoped-proxy/>` in conjunction with beans that are scoped as `singletons` or `prototypes`.

The configuration in the following example is only one line, but it is important to understand the "why" as well as the "how" behind it.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- an HTTP Session-scoped bean exposed as a proxy -->
    <bean id="userPreferences" class="com.foo.UserPreferences" scope="session">
        <!-- instructs the container to proxy the surrounding bean -->
        <aop:scoped-proxy/>
    </bean>

    <!-- a singleton-scoped bean injected with a proxy to the above bean -->
    <bean id="userService" class="com.foo.SimpleUserService">
        <!-- a reference to the proxied userPreferences bean -->
        <property name="userPreferences" ref="userPreferences"/>
    </bean>
</beans>
```

To create such a proxy, you insert a child `<aop:scoped-proxy/>` element into a scoped bean definition. See the section called “Choosing the type of proxy to create” and Chapter 34, *XML Schema-based configuration*.) Why do definitions of beans scoped at the `request`, `session`, `globalSession` and custom-scope levels require the `<aop:scoped-proxy/>` element ? Let's examine the following singleton bean definition and contrast it with what you need to define for the aforementioned scopes. (The following `userPreferences` bean definition as it stands is *incomplete.)*

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="session"/>

<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>
```

In the preceding example, the singleton bean `userManager` is injected with a reference to the HTTP `Session`-scoped bean `userPreferences`. The salient point here is that the `userManager` bean is a singleton: it will be instantiated *exactly once* per container, and its dependencies (in this case only one, the `userPreferences` bean) are also injected only once. This means that the `userManager` bean will only operate on the exact same `userPreferences` object, that is, the one that it was originally injected with.

This is *not* the behavior you want when injecting a shorter-lived scoped bean into a longer-lived scoped bean, for example injecting an HTTP `Session`-scoped collaborating bean as a dependency into singleton bean. Rather, you need a single `userManager` object, and for the lifetime of an HTTP `Session`, you need a `userPreferences` object that is specific to said HTTP `Session`. Thus the container creates an object that exposes the exact same public interface as the `UserPreferences` class (ideally an object that *is a* `UserPreferences` instance) which can fetch the real `UserPreferences` object from the scoping mechanism (HTTP request, `Session`, etc.). The container injects this proxy object into the `userManager` bean, which is unaware that this `UserPreferences` reference is a proxy. In this example, when a `UserManager` instance invokes a method on the dependency-injected `UserPreferences` object, it actually is invoking a method on the proxy. The proxy then fetches the real `UserPreferences` object from (in this case) the HTTP `Session`, and delegates the method invocation onto the retrieved real `UserPreferences` object.

Thus you need the following, correct and complete, configuration when injecting `request-`, `session-`, and `globalSession-scoped` beans into collaborating objects:

```
<bean id="userPreferences" class="com.foo.UserPreferences" scope="session">
    <aop:scoped-proxy/>
</bean>
<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>
```

Choosing the type of proxy to create

By default, when the Spring container creates a proxy for a bean that is marked up with the `<aop:scoped-proxy/>` element, *a CGLIB-based class proxy is created*.

> **Note**
>
> CGLIB proxies only intercept public method calls! Do not call non-public methods on such a proxy; they will not be delegated to the actual scoped target object.

Alternatively, you can configure the Spring container to create standard JDK interface-based proxies for such scoped beans, by specifying `false` for the value of the `proxy-target-class` attribute of

the <aop:scoped-proxy/> element. Using JDK interface-based proxies means that you do not need additional libraries in your application classpath to effect such proxying. However, it also means that the class of the scoped bean must implement at least one interface, and *that all* collaborators into which the scoped bean is injected must reference the bean through one of its interfaces.

```
<!-- DefaultUserPreferences implements the UserPreferences interface -->
<bean id="userPreferences" class="com.foo.DefaultUserPreferences" scope="session">
    <aop:scoped-proxy proxy-target-class="false"/>
</bean>
<bean id="userManager" class="com.foo.UserManager">
    <property name="userPreferences" ref="userPreferences"/>
</bean>
```

For more detailed information about choosing class-based or interface-based proxying, see Section 9.6, “Proxying mechanisms”.

Custom scopes

The bean scoping mechanism is extensible; You can define your own scopes, or even redefine existing scopes, although the latter is considered bad practice and you *cannot* override the built-in `singleton` and `prototype` scopes.

Creating a custom scope

To integrate your custom scope(s) into the Spring container, you need to implement the `org.springframework.beans.factory.config.Scope` interface, which is described in this section. For an idea of how to implement your own scopes, see the `Scope` implementations that are supplied with the Spring Framework itself and the Scope javadocs, which explains the methods you need to implement in more detail.

The `Scope` interface has four methods to get objects from the scope, remove them from the scope, and allow them to be destroyed.

The following method returns the object from the underlying scope. The session scope implementation, for example, returns the session-scoped bean (and if it does not exist, the method returns a new instance of the bean, after having bound it to the session for future reference).

```
Object get(String name, ObjectFactory objectFactory)
```

The following method removes the object from the underlying scope. The session scope implementation for example, removes the session-scoped bean from the underlying session. The object should be returned, but you can return null if the object with the specified name is not found.

```
Object remove(String name)
```

The following method registers the callbacks the scope should execute when it is destroyed or when the specified object in the scope is destroyed. Refer to the javadocs or a Spring scope implementation for more information on destruction callbacks.

```
void registerDestructionCallback(String name, Runnable destructionCallback)
```

The following method obtains the conversation identifier for the underlying scope. This identifier is different for each scope. For a session scoped implementation, this identifier can be the session identifier.

```
String getConversationId()
```

Using a custom scope

After you write and test one or more custom `Scope` implementations, you need to make the Spring container aware of your new scope(s). The following method is the central method to register a new `Scope` with the Spring container:

```
void registerScope(String scopeName, Scope scope);
```

This method is declared on the `ConfigurableBeanFactory` interface, which is available on most of the concrete `ApplicationContext` implementations that ship with Spring via the BeanFactory property.

The first argument to the `registerScope(..)` method is the unique name associated with a scope; examples of such names in the Spring container itself are `singleton` and `prototype`. The second argument to the `registerScope(..)` method is an actual instance of the custom `Scope` implementation that you wish to register and use.

Suppose that you write your custom `Scope` implementation, and then register it as below.

> **Note**
>
> The example below uses `SimpleThreadScope` which is included with Spring, but not registered by default. The instructions would be the same for your own custom `Scope` implementations.

```
Scope threadScope = new SimpleThreadScope();
beanFactory.registerScope("thread", threadScope);
```

You then create bean definitions that adhere to the scoping rules of your custom `Scope`:

```
<bean id="..." class="..." scope="thread">
```

With a custom `Scope` implementation, you are not limited to programmatic registration of the scope. You can also do the `Scope` registration declaratively, using the `CustomScopeConfigurer` class:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean class="org.springframework.beans.factory.config.CustomScopeConfigurer">
        <property name="scopes">
            <map>
                <entry key="thread">
                    <bean class="org.springframework.context.support.SimpleThreadScope"/>
                </entry>
            </map>
        </property>
    </bean>

    <bean id="bar" class="x.y.Bar" scope="thread">
        <property name="name" value="Rick"/>
        <aop:scoped-proxy/>
    </bean>

    <bean id="foo" class="x.y.Foo">
        <property name="bar" ref="bar"/>
    </bean>

</beans>
```

Note

When you place `<aop:scoped-proxy/>` in a `FactoryBean` implementation, it is the factory bean itself that is scoped, not the object returned from `getObject()`.

5.6 Customizing the nature of a bean

Lifecycle callbacks

To interact with the container's management of the bean lifecycle, you can implement the Spring `InitializingBean` and `DisposableBean` interfaces. The container calls `afterPropertiesSet()` for the former and `destroy()` for the latter to allow the bean to perform certain actions upon initialization and destruction of your beans.

Tip

The JSR-250 `@PostConstruct` and `@PreDestroy` annotations are generally considered best practice for receiving lifecycle callbacks in a modern Spring application. Using these annotations means that your beans are not coupled to Spring specific interfaces. For details see the section called "@PostConstruct and @PreDestroy".

If you don't want to use the JSR-250 annotations but you are still looking to remove coupling consider the use of init-method and destroy-method object definition metadata.

Internally, the Spring Framework uses `BeanPostProcessor` implementations to process any callback interfaces it can find and call the appropriate methods. If you need custom features or other lifecycle behavior Spring does not offer out-of-the-box, you can implement a `BeanPostProcessor` yourself. For more information, see Section 5.8, "Container Extension Points".

In addition to the initialization and destruction callbacks, Spring-managed objects may also implement the `Lifecycle` interface so that those objects can participate in the startup and shutdown process as driven by the container's own lifecycle.

The lifecycle callback interfaces are described in this section.

Initialization callbacks

The `org.springframework.beans.factory.InitializingBean` interface allows a bean to perform initialization work after all necessary properties on the bean have been set by the container. The `InitializingBean` interface specifies a single method:

```
void afterPropertiesSet() throws Exception;
```

It is recommended that you do not use the `InitializingBean` interface because it unnecessarily couples the code to Spring. Alternatively, use the `@PostConstruct` annotation or specify a POJO initialization method. In the case of XML-based configuration metadata, you use the `init-method` attribute to specify the name of the method that has a void no-argument signature. For example, the following definition:

```
<bean id="exampleInitBean" class="examples.ExampleBean" init-method="init"/>
```

```
public class ExampleBean {

    public void init() {
        // do some initialization work
    }

}
```

…is exactly the same as…

```
<bean id="exampleInitBean" class="examples.AnotherExampleBean"/>
```

```
public class AnotherExampleBean implements InitializingBean {

    public void afterPropertiesSet() {
        // do some initialization work
    }

}
```

but does not couple the code to Spring.

Destruction callbacks

Implementing the `org.springframework.beans.factory.DisposableBean` interface allows a bean to get a callback when the container containing it is destroyed. The `DisposableBean` interface specifies a single method:

```
void destroy() throws Exception;
```

It is recommended that you do not use the `DisposableBean` callback interface because it unnecessarily couples the code to Spring. Alternatively, use the `@PreDestroy` annotation or specify a generic method that is supported by bean definitions. With XML-based configuration metadata, you use the `destroy-method` attribute on the `<bean/>`. For example, the following definition:

```
<bean id="exampleInitBean" class="examples.ExampleBean" destroy-method="cleanup"/>
```

```
public class ExampleBean {

    public void cleanup() {
        // do some destruction work (like releasing pooled connections)
    }

}
```

is exactly the same as:

```
<bean id="exampleInitBean" class="examples.AnotherExampleBean"/>
```

```
public class AnotherExampleBean implements DisposableBean {

    public void destroy() {
        // do some destruction work (like releasing pooled connections)
    }

}
```

but does not couple the code to Spring.

Default initialization and destroy methods

When you write initialization and destroy method callbacks that do not use the Spring-specific `InitializingBean` and `DisposableBean` callback interfaces, you typically write methods with names such as `init()`, `initialize()`, `dispose()`, and so on. Ideally, the names of such lifecycle callback methods are standardized across a project so that all developers use the same method names and ensure consistency.

You can configure the Spring container to `look` for named initialization and destroy callback method names on *every* bean. This means that you, as an application developer, can write your application classes and use an initialization callback called `init()`, without having to configure an `init-method="init"` attribute with each bean definition. The Spring IoC container calls that method when the bean is created (and in accordance with the standard lifecycle callback contract described previously). This feature also enforces a consistent naming convention for initialization and destroy method callbacks.

Suppose that your initialization callback methods are named `init()` and destroy callback methods are named `destroy()`. Your class will resemble the class in the following example.

```
public class DefaultBlogService implements BlogService {

    private BlogDao blogDao;

    public void setBlogDao(BlogDao blogDao) {
        this.blogDao = blogDao;
    }

    // this is (unsurprisingly) the initialization callback method
    public void init() {
        if (this.blogDao == null) {
            throw new IllegalStateException("The [blogDao] property must be set.");
        }
    }

}
```

```
<beans default-init-method="init">

    <bean id="blogService" class="com.foo.DefaultBlogService">
        <property name="blogDao" ref="blogDao" />
    </bean>

</beans>
```

The presence of the `default-init-method` attribute on the top-level `<beans/>` element attribute causes the Spring IoC container to recognize a method called `init` on beans as the initialization method callback. When a bean is created and assembled, if the bean class has such a method, it is invoked at the appropriate time.

You configure destroy method callbacks similarly (in XML, that is) by using the `default-destroy-method` attribute on the top-level `<beans/>` element.

Where existing bean classes already have callback methods that are named at variance with the convention, you can override the default by specifying (in XML, that is) the method name using the `init-method` and `destroy-method` attributes of the <bean/> itself.

The Spring container guarantees that a configured initialization callback is called immediately after a bean is supplied with all dependencies. Thus the initialization callback is called on the raw bean reference, which means that AOP interceptors and so forth are not yet applied to the bean. A target bean is fully created *first*, *then* an AOP proxy (for example) with its interceptor chain is applied. If the target bean and the proxy are defined separately, your code can even interact with the raw target bean, bypassing the proxy. Hence, it would be inconsistent to apply the interceptors to the init method, because doing so would couple the lifecycle of the target bean with its proxy/interceptors and leave strange semantics when your code interacts directly to the raw target bean.

Combining lifecycle mechanisms

As of Spring 2.5, you have three options for controlling bean lifecycle behavior: the `InitializingBean` and `DisposableBean` callback interfaces; custom `init()` and `destroy()` methods; and the `@PostConstruct and @PreDestroy annotations`. You can combine these mechanisms to control a given bean.

> **Note**
>
> If multiple lifecycle mechanisms are configured for a bean, and each mechanism is configured with a different method name, then each configured method is executed in the order listed below. However, if the same method name is configured - for example, `init()` for an initialization method - for more than one of these lifecycle mechanisms, that method is executed once, as explained in the preceding section.

Multiple lifecycle mechanisms configured for the same bean, with different initialization methods, are called as follows:

- Methods annotated with `@PostConstruct`
- `afterPropertiesSet()` as defined by the `InitializingBean` callback interface
- A custom configured `init()` method

Destroy methods are called in the same order:

- Methods annotated with `@PreDestroy`
- `destroy()` as defined by the `DisposableBean` callback interface
- A custom configured `destroy()` method

Startup and shutdown callbacks

The `Lifecycle` interface defines the essential methods for any object that has its own lifecycle requirements (e.g. starts and stops some background process):

```
public interface Lifecycle {

    void start();

    void stop();

    boolean isRunning();

}
```

Any Spring-managed object may implement that interface. Then, when the `ApplicationContext` itself starts and stops, it will cascade those calls to all `Lifecycle` implementations defined within that context. It does this by delegating to a `LifecycleProcessor`:

```
public interface LifecycleProcessor extends Lifecycle {

    void onRefresh();

    void onClose();

}
```

Notice that the `LifecycleProcessor` is itself an extension of the `Lifecycle` interface. It also adds two other methods for reacting to the context being refreshed and closed.

The order of startup and shutdown invocations can be important. If a "depends-on" relationship exists between any two objects, the dependent side will start *after* its dependency, and it will stop *before* its dependency. However, at times the direct dependencies are unknown. You may only know that objects of a certain type should start prior to objects of another type. In those cases, the `SmartLifecycle` interface defines another option, namely the `getPhase()` method as defined on its super-interface, `Phased`.

```
public interface Phased {

    int getPhase();

}
```

```
public interface SmartLifecycle extends Lifecycle, Phased {

    boolean isAutoStartup();

    void stop(Runnable callback);

}
```

When starting, the objects with the lowest phase start first, and when stopping, the reverse order is followed. Therefore, an object that implements `SmartLifecycle` and whose `getPhase()` method returns `Integer.MIN_VALUE` would be among the first to start and the last to stop. At the other end of

the spectrum, a phase value of `Integer.MAX_VALUE` would indicate that the object should be started last and stopped first (likely because it depends on other processes to be running). When considering the phase value, it's also important to know that the default phase for any "normal" `Lifecycle` object that does not implement `SmartLifecycle` would be 0. Therefore, any negative phase value would indicate that an object should start before those standard components (and stop after them), and vice versa for any positive phase value.

As you can see the stop method defined by `SmartLifecycle` accepts a callback. Any implementation *must* invoke that callback's `run()` method after that implementation's shutdown process is complete. That enables asynchronous shutdown where necessary since the default implementation of the `LifecycleProcessor` interface, `DefaultLifecycleProcessor`, will wait up to its timeout value for the group of objects within each phase to invoke that callback. The default per-phase timeout is 30 seconds. You can override the default lifecycle processor instance by defining a bean named "lifecycleProcessor" within the context. If you only want to modify the timeout, then defining the following would be sufficient:

```
<bean id="lifecycleProcessor" class="org.springframework.context.support.DefaultLifecycleProcessor">
    <!-- timeout value in milliseconds -->
    <property name="timeoutPerShutdownPhase" value="10000"/>
</bean>
```

As mentioned, the `LifecycleProcessor` interface defines callback methods for the refreshing and closing of the context as well. The latter will simply drive the shutdown process as if `stop()` had been called explicitly, but it will happen when the context is closing. The *refresh* callback on the other hand enables another feature of `SmartLifecycle` beans. When the context is refreshed (after all objects have been instantiated and initialized), that callback will be invoked, and at that point the default lifecycle processor will check the boolean value returned by each `SmartLifecycle` object's `isAutoStartup()` method. If "true", then that object will be started at that point rather than waiting for an explicit invocation of the context's or its own `start()` method (unlike the context refresh, the context start does not happen automatically for a standard context implementation). The "phase" value as well as any "depends-on" relationships will determine the startup order in the same way as described above.

Shutting down the Spring IoC container gracefully in non-web applications

> **Note**
>
> This section applies only to non-web applications. Spring's web-based `ApplicationContext` implementations already have code in place to shut down the Spring IoC container gracefully when the relevant web application is shut down.

If you are using Spring's IoC container in a non-web application environment; for example, in a rich client desktop environment; you register a shutdown hook with the JVM. Doing so ensures a graceful shutdown and calls the relevant destroy methods on your singleton beans so that all resources are released. Of course, you must still configure and implement these destroy callbacks correctly.

To register a shutdown hook, you call the `registerShutdownHook()` method that is declared on the `AbstractApplicationContext` class:

```
import org.springframework.context.support.AbstractApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Boot {

    public static void main(final String[] args) throws Exception {

        AbstractApplicationContext ctx = new ClassPathXmlApplicationContext(
                new String []{"beans.xml"});

        // add a shutdown hook for the above context...
        ctx.registerShutdownHook();

        // app runs here...

        // main method exits, hook is called prior to the app shutting down...

    }
}
```

ApplicationContextAware and BeanNameAware

When an `ApplicationContext` creates an object instance that implements the `org.springframework.context.ApplicationContextAware` interface, the instance is provided with a reference to that `ApplicationContext`.

```
public interface ApplicationContextAware {

    void setApplicationContext(ApplicationContext applicationContext) throws BeansException;

}
```

Thus beans can manipulate programmatically the `ApplicationContext` that created them, through the `ApplicationContext` interface, or by casting the reference to a known subclass of this interface, such as `ConfigurableApplicationContext`, which exposes additional functionality. One use would be the programmatic retrieval of other beans. Sometimes this capability is useful; however, in general you should avoid it, because it couples the code to Spring and does not follow the Inversion of Control style, where collaborators are provided to beans as properties. Other methods of the `ApplicationContext` provide access to file resources, publishing application events, and accessing a `MessageSource`. These additional features are described in Section 5.15, “Additional Capabilities of the ApplicationContext”

As of Spring 2.5, autowiring is another alternative to obtain reference to the `ApplicationContext`. The "traditional" `constructor` and `byType` autowiring modes (as described in the section called “Autowiring collaborators”) can provide a dependency of type `ApplicationContext` for a constructor argument or setter method parameter, respectively. For more flexibility, including the ability to autowire fields and multiple parameter methods, use the new annotation-based autowiring features. If you do, the `ApplicationContext` is autowired into a field, constructor argument, or method parameter that is expecting the `ApplicationContext` type if the field, constructor, or method in question carries the `@Autowired` annotation. For more information, see the section called “@Autowired”.

When an `ApplicationContext` creates a class that implements the `org.springframework.beans.factory.BeanNameAware` interface, the class is provided with a reference to the name defined in its associated object definition.

```
public interface BeanNameAware {

    void setBeanName(string name) throws BeansException;

}
```

The callback is invoked after population of normal bean properties but before an initialization callback such as `InitializingBean` *afterPropertiesSet* or a custom init-method.

Other Aware interfaces

Besides `ApplicationContextAware` and `BeanNameAware` discussed above, Spring offers a range of `Aware` interfaces that allow beans to indicate to the container that they require a certain *infrastructure* dependency. The most important `Aware` interfaces are summarized below - as a general rule, the name is a good indication of the dependency type:

Table 5.4. Aware interfaces

Name	Injected Dependency	Explained in…
`ApplicationContextAware`	Declaring `ApplicationContext`	the section called “ApplicationContextAware and BeanNameAware”
`ApplicationEventPublisherAware`	Event publisher of the enclosing `ApplicationContext`	Section 5.15, “Additional Capabilities of the ApplicationContext”
`BeanClassLoaderAware`	Class loader used to load the bean classes.	the section called “Instantiating beans”
`BeanFactoryAware`	Declaring `BeanFactory`	the section called “ApplicationContextAware and BeanNameAware”
`BeanNameAware`	Name of the declaring bean	the section called “ApplicationContextAware and BeanNameAware”
`BootstrapContextAware`	Resource adapter `BootstrapContext` the container runs in. Typically available only in JCA aware `ApplicationContexts`	Chapter 26, *JCA CCI*
`LoadTimeWeaverAware`	Defined *weaver* for processing class definition at load time	the section called “Load-time weaving with AspectJ in the Spring Framework”
`MessageSourceAware`	Configured strategy for resolving messages (with support for parametrization and internationalization)	Section 5.15, “Additional Capabilities of the ApplicationContext”
`NotificationPublisherAware`	Spring JMX notification publisher	Section 25.7, “Notifications”
`PortletConfigAware`	Current `PortletConfig` the container runs in. Valid only in a web-aware Spring `ApplicationContext`	Chapter 20, *Portlet MVC Framework*

Name	Injected Dependency	Explained in…
`PortletContextAware`	Current `PortletContext` the container runs in. Valid only in a web-aware Spring `ApplicationContext`	Chapter 20, *Portlet MVC Framework*
`ResourceLoaderAware`	Configured loader for low-level access to resources	Chapter 6, *Resources*
`ServletConfigAware`	Current `ServletConfig` the container runs in. Valid only in a web-aware Spring `ApplicationContext`	Chapter 17, *Web MVC framework*
`ServletContextAware`	Current `ServletContext` the container runs in. Valid only in a web-aware Spring `ApplicationContext`	Chapter 17, *Web MVC framework*

Note again that usage of these interfaces ties your code to the Spring API and does not follow the Inversion of Control style. As such, they are recommended for infrastructure beans that require programmatic access to the container.

5.7 Bean definition inheritance

A bean definition can contain a lot of configuration information, including constructor arguments, property values, and container-specific information such as initialization method, static factory method name, and so on. A child bean definition inherits configuration data from a parent definition. The child definition can override some values, or add others, as needed. Using parent and child bean definitions can save a lot of typing. Effectively, this is a form of templating.

If you work with an `ApplicationContext` interface programmatically, child bean definitions are represented by the `ChildBeanDefinition` class. Most users do not work with them on this level, instead configuring bean definitions declaratively in something like the `ClassPathXmlApplicationContext`. When you use XML-based configuration metadata, you indicate a child bean definition by using the `parent` attribute, specifying the parent bean as the value of this attribute.

```
<bean id="inheritedTestBean" abstract="true"
        class="org.springframework.beans.TestBean">
    <property name="name" value="parent"/>
    <property name="age" value="1"/>
</bean>

<bean id="inheritsWithDifferentClass"
        class="org.springframework.beans.DerivedTestBean"
        parent="inheritedTestBean" init-method="initialize">
    <property name="name" value="override"/>
    <!-- the age property value of 1 will be inherited from parent -->
</bean>
```

A child bean definition uses the bean class from the parent definition if none is specified, but can also override it. In the latter case, the child bean class must be compatible with the parent, that is, it must accept the parent's property values.

A child bean definition inherits constructor argument values, property values, and method overrides from the parent, with the option to add new values. Any initialization method, destroy method, and/or `static` factory method settings that you specify will override the corresponding parent settings.

The remaining settings are *always* taken from the child definition: *depends on*, *autowire mode*, *dependency check*, *singleton*, *scope*, *lazy init*.

The preceding example explicitly marks the parent bean definition as abstract by using the `abstract` attribute. If the parent definition does not specify a class, explicitly marking the parent bean definition as `abstract` is required, as follows:

```
<bean id="inheritedTestBeanWithoutClass" abstract="true">
    <property name="name" value="parent"/>
    <property name="age" value="1"/>
</bean>

<bean id="inheritsWithClass" class="org.springframework.beans.DerivedTestBean"
        parent="inheritedTestBeanWithoutClass" init-method="initialize">
    <property name="name" value="override"/>
    <!-- age will inherit the value of 1 from the parent bean definition-->
</bean>
```

The parent bean cannot be instantiated on its own because it is incomplete, and it is also explicitly marked as `abstract`. When a definition is `abstract` like this, it is usable only as a pure template bean definition that serves as a parent definition for child definitions. Trying to use such an `abstract` parent bean on its own, by referring to it as a ref property of another bean or doing an explicit `getBean()` call with the parent bean id, returns an error. Similarly, the container's internal `preInstantiateSingletons()` method ignores bean definitions that are defined as abstract.

> **Note**
>
> `ApplicationContext` pre-instantiates all singletons by default. Therefore, it is important (at least for singleton beans) that if you have a (parent) bean definition which you intend to use only as a template, and this definition specifies a class, you must make sure to set the *abstract* attribute to *true*, otherwise the application context will actually (attempt to) pre-instantiate the `abstract` bean.

5.8 Container Extension Points

Typically, an application developer does not need to subclass `ApplicationContext` implementation classes. Instead, the Spring IoC container can be extended by plugging in implementations of special integration interfaces. The next few sections describe these integration interfaces.

Customizing beans using a BeanPostProcessor

The `BeanPostProcessor` interface defines *callback methods* that you can implement to provide your own (or override the container's default) instantiation logic, dependency-resolution logic, and so forth. If you want to implement some custom logic after the Spring container finishes instantiating, configuring, and initializing a bean, you can plug in one or more `BeanPostProcessor` implementations.

You can configure multiple `BeanPostProcessor` instances, and you can control the order in which these `BeanPostProcessors` execute by setting the `order` property. You can set this property only if the `BeanPostProcessor` implements the `Ordered` interface; if you write your own `BeanPostProcessor` you should consider implementing the `Ordered` interface too. For further

details, consult the javadocs of the `BeanPostProcessor` and `Ordered` interfaces. See also the note below on programmatic registration of `BeanPostProcessors`

> **Note**
>
> `BeanPostProcessors` operate on bean (or object) *instances*; that is to say, the Spring IoC container instantiates a bean instance and *then* `BeanPostProcessors` do their work.
>
> `BeanPostProcessors` are scoped *per-container*. This is only relevant if you are using container hierarchies. If you define a `BeanPostProcessor` in one container, it will *only* post-process the beans in that container. In other words, beans that are defined in one container are not post-processed by a `BeanPostProcessor` defined in another container, even if both containers are part of the same hierarchy.
>
> To change the actual bean definition (i.e., the *blueprint* that defines the bean), you instead need to use a `BeanFactoryPostProcessor` as described in the section called “Customizing configuration metadata with a BeanFactoryPostProcessor”.

The `org.springframework.beans.factory.config.BeanPostProcessor` interface consists of exactly two callback methods. When such a class is registered as a post-processor with the container, for each bean instance that is created by the container, the post-processor gets a callback from the container both *before* container initialization methods (such as InitializingBean’s *afterPropertiesSet()* and any declared init method) are called as well as *after* any bean initialization callbacks. The post-processor can take any action with the bean instance, including ignoring the callback completely. A bean post-processor typically checks for callback interfaces or may wrap a bean with a proxy. Some Spring AOP infrastructure classes are implemented as bean post-processors in order to provide proxy-wrapping logic.

An `ApplicationContext` *automatically detects* any beans that are defined in the configuration metadata which implement the `BeanPostProcessor` interface. The `ApplicationContext` registers these beans as post-processors so that they can be called later upon bean creation. Bean post-processors can be deployed in the container just like any other beans.

Note that when declaring a `BeanPostProcessor` using an `@Bean` factory method on a configuration class, the return type of the factory method should be the implementation class itself or at least the `org.springframework.beans.factory.config.BeanPostProcessor` interface, clearly indicating the post-processor nature of that bean. Otherwise, the `ApplicationContext` won’t be able to autodetect it by type before fully creating it. Since a `BeanPostProcessor` needs to be instantiated early in order to apply to the initialization of other beans in the context, this early type detection is critical.

> **Note**
>
> **Programmatically registering BeanPostProcessors**
>
> While the recommended approach for `BeanPostProcessor` registration is through `ApplicationContext` auto-detection (as described above), it is also possible to register them *programmatically* against a `ConfigurableBeanFactory` using the `addBeanPostProcessor` method. This can be useful when needing to evaluate conditional logic before registration, or even for copying bean post processors across contexts in a hierarchy. Note however that `BeanPostProcessors` added programmatically *do not respect the `Ordered` interface*. Here it is the *order of registration* that dictates the order of execution. Note also that

> `BeanPostProcessors` registered programmatically are always processed before those registered through auto-detection, regardless of any explicit ordering.

> **Note**
>
> **BeanPostProcessors and AOP auto-proxying**
>
> Classes that implement the `BeanPostProcessor` interface are *special* and are treated differently by the container. All `BeanPostProcessors` *and beans that they reference directly* are instantiated on startup, as part of the special startup phase of the `ApplicationContext`. Next, all `BeanPostProcessors` are registered in a sorted fashion and applied to all further beans in the container. Because AOP auto-proxying is implemented as a `BeanPostProcessor` itself, neither `BeanPostProcessors` nor the beans they reference directly are eligible for auto-proxying, and thus do not have aspects woven into them.
>
> For any such bean, you should see an informational log message: "*Bean foo is not eligible for getting processed by all BeanPostProcessor interfaces (for example: not eligible for auto-proxying)*".
>
> Note that if you have beans wired into your `BeanPostProcessor` using autowiring or `@Resource` (which may fall back to autowiring), Spring might access unexpected beans when searching for type-matching dependency candidates, and therefore make them ineligible for auto-proxying or other kinds of bean post-processing. For example, if you have a dependency annotated with `@Resource` where the field/setter name does not directly correspond to the declared name of a bean and no name attribute is used, then Spring will access other beans for matching them by type.

The following examples show how to write, register, and use `BeanPostProcessors` in an `ApplicationContext`.

Example: Hello World, BeanPostProcessor-style

This first example illustrates basic usage. The example shows a custom `BeanPostProcessor` implementation that invokes the `toString()` method of each bean as it is created by the container and prints the resulting string to the system console.

Find below the custom `BeanPostProcessor` implementation class definition:

```
package scripting;

import org.springframework.beans.factory.config.BeanPostProcessor;
import org.springframework.beans.BeansException;

public class InstantiationTracingBeanPostProcessor implements BeanPostProcessor {

    // simply return the instantiated bean as-is
    public Object postProcessBeforeInitialization(Object bean,
            String beanName) throws BeansException {
        return bean; // we could potentially return any object reference here...
    }

    public Object postProcessAfterInitialization(Object bean,
            String beanName) throws BeansException {
        System.out.println("Bean '" + beanName + "' created : " + bean.toString());
        return bean;
    }

}
```

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:lang="http://www.springframework.org/schema/lang"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/lang
        http://www.springframework.org/schema/lang/spring-lang.xsd">

    <lang:groovy id="messenger"
            script-source="classpath:org/springframework/scripting/groovy/Messenger.groovy">
        <lang:property name="message" value="Fiona Apple Is Just So Dreamy."/>
    </lang:groovy>

    <!--
    when the above bean (messenger) is instantiated, this custom
    BeanPostProcessor implementation will output the fact to the system console
    -->
    <bean class="scripting.InstantiationTracingBeanPostProcessor"/>

</beans>
```

Notice how the `InstantiationTracingBeanPostProcessor` is simply defined. It does not even have a name, and because it is a bean it can be dependency-injected just like any other bean. (The preceding configuration also defines a bean that is backed by a Groovy script. The Spring dynamic language support is detailed in the chapter entitled Chapter 29, *Dynamic language support*.)

The following simple Java application executes the preceding code and configuration:

```
import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import org.springframework.scripting.Messenger;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        ApplicationContext ctx = new ClassPathXmlApplicationContext("scripting/beans.xml");
        Messenger messenger = (Messenger) ctx.getBean("messenger");
        System.out.println(messenger);
    }

}
```

The output of the preceding application resembles the following:

```
Bean 'messenger' created : org.springframework.scripting.groovy.GroovyMessenger@272961
org.springframework.scripting.groovy.GroovyMessenger@272961
```

Example: The RequiredAnnotationBeanPostProcessor

Using callback interfaces or annotations in conjunction with a custom `BeanPostProcessor` implementation is a common means of extending the Spring IoC container. An example is Spring's `RequiredAnnotationBeanPostProcessor` - a `BeanPostProcessor` implementation that ships with the Spring distribution which ensures that JavaBean properties on beans that are marked with an (arbitrary) annotation are actually (configured to be) dependency-injected with a value.

Customizing configuration metadata with a BeanFactoryPostProcessor

The next extension point that we will look at is the `org.springframework.beans.factory.config.BeanFactoryPostProcessor`. The semantics of this interface are similar to those of the `BeanPostProcessor`, with one major difference: `BeanFactoryPostProcessor` operates on the *bean configuration metadata*; that is, the Spring IoC

container allows a `BeanFactoryPostProcessor` to read the configuration metadata and potentially change it *before* the container instantiates any beans other than `BeanFactoryPostProcessors`.

You can configure multiple `BeanFactoryPostProcessors`, and you can control the order in which these `BeanFactoryPostProcessors` execute by setting the `order` property. However, you can only set this property if the `BeanFactoryPostProcessor` implements the `Ordered` interface. If you write your own `BeanFactoryPostProcessor`, you should consider implementing the `Ordered` interface too. Consult the javadocs of the `BeanFactoryPostProcessor` and `Ordered` interfaces for more details.

> **Note**
>
> If you want to change the actual bean *instances* (i.e., the objects that are created from the configuration metadata), then you instead need to use a `BeanPostProcessor` (described above in the section called “Customizing beans using a BeanPostProcessor”). While it is technically possible to work with bean instances within a `BeanFactoryPostProcessor` (e.g., using `BeanFactory.getBean()`), doing so causes premature bean instantiation, violating the standard container lifecycle. This may cause negative side effects such as bypassing bean post processing.
>
> Also, `BeanFactoryPostProcessors` are scoped *per-container*. This is only relevant if you are using container hierarchies. If you define a `BeanFactoryPostProcessor` in one container, it will *only* be applied to the bean definitions in that container. Bean definitions in one container will not be post-processed by `BeanFactoryPostProcessors` in another container, even if both containers are part of the same hierarchy.

A bean factory post-processor is executed automatically when it is declared inside an `ApplicationContext`, in order to apply changes to the configuration metadata that define the container. Spring includes a number of predefined bean factory post-processors, such as `PropertyOverrideConfigurer` and `PropertyPlaceholderConfigurer`. A custom `BeanFactoryPostProcessor` can also be used, for example, to register custom property editors.

An `ApplicationContext` automatically detects any beans that are deployed into it that implement the `BeanFactoryPostProcessor` interface. It uses these beans as bean factory post-processors, at the appropriate time. You can deploy these post-processor beans as you would any other bean.

> **Note**
>
> As with `BeanPostProcessors` , you typically do not want to configure `BeanFactoryPostProcessors` for lazy initialization. If no other bean references a `Bean(Factory)PostProcessor`, that post-processor will not get instantiated at all. Thus, marking it for lazy initialization will be ignored, and the `Bean(Factory)PostProcessor` will be instantiated eagerly even if you set the `default-lazy-init` attribute to `true` on the declaration of your `<beans />` element.

Example: the Class name substitution PropertyPlaceholderConfigurer

You use the `PropertyPlaceholderConfigurer` to externalize property values from a bean definition in a separate file using the standard Java `Properties` format. Doing so enables the person deploying an application to customize environment-specific properties such as database URLs and passwords, without the complexity or risk of modifying the main XML definition file or files for the container.

Consider the following XML-based configuration metadata fragment, where a `DataSource` with placeholder values is defined. The example shows properties configured from an external `Properties` file. At runtime, a `PropertyPlaceholderConfigurer` is applied to the metadata that will replace some properties of the DataSource. The values to replace are specified as *placeholders* of the form `${property-name}` which follows the Ant / log4j / JSP EL style.

```
<bean class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">
    <property name="locations" value="classpath:com/foo/jdbc.properties"/>
</bean>

<bean id="dataSource" destroy-method="close"
        class="org.apache.commons.dbcp.BasicDataSource">
    <property name="driverClassName" value="${jdbc.driverClassName}"/>
    <property name="url" value="${jdbc.url}"/>
    <property name="username" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
</bean>
```

The actual values come from another file in the standard Java `Properties` format:

```
jdbc.driverClassName=org.hsqldb.jdbcDriver
jdbc.url=jdbc:hsqldb:hsql://production:9002
jdbc.username=sa
jdbc.password=root
```

Therefore, the string `${jdbc.username}` is replaced at runtime with the value *sa*, and the same applies for other placeholder values that match keys in the properties file. The `PropertyPlaceholderConfigurer` checks for placeholders in most properties and attributes of a bean definition. Furthermore, the placeholder prefix and suffix can be customized.

With the `context` namespace introduced in Spring 2.5, it is possible to configure property placeholders with a dedicated configuration element. One or more locations can be provided as a comma-separated list in the `location` attribute.

```
<context:property-placeholder location="classpath:com/foo/jdbc.properties"/>
```

The `PropertyPlaceholderConfigurer` not only looks for properties in the `Properties` file you specify. By default it also checks against the Java `System` properties if it cannot find a property in the specified properties files. You can customize this behavior by setting the `systemPropertiesMode` property of the configurer with one of the following three supported integer values:

- *never* (0): Never check system properties
- *fallback* (1): Check system properties if not resolvable in the specified properties files. This is the default.
- *override* (2): Check system properties first, before trying the specified properties files. This allows system properties to override any other property source.

Consult the `PropertyPlaceholderConfigurer` javadocs for more information.

> **Tip**
>
> You can use the `PropertyPlaceholderConfigurer` to substitute class names, which is sometimes useful when you have to pick a particular implementation class at runtime. For example:

```
<bean class="org.springframework.beans.factory.config.PropertyPlaceholderConfigurer">
    <property name="locations">
        <value>classpath:com/foo/strategy.properties</value>
    </property>
    <property name="properties">
        <value>custom.strategy.class=com.foo.DefaultStrategy</value>
    </property>
</bean>

<bean id="serviceStrategy" class="${custom.strategy.class}"/>
```

If the class cannot be resolved at runtime to a valid class, resolution of the bean fails when it is about to be created, which is during the `preInstantiateSingletons()` phase of an `ApplicationContext` for a non-lazy-init bean.

Example: the PropertyOverrideConfigurer

The `PropertyOverrideConfigurer`, another bean factory post-processor, resembles the `PropertyPlaceholderConfigurer`, but unlike the latter, the original definitions can have default values or no values at all for bean properties. If an overriding `Properties` file does not have an entry for a certain bean property, the default context definition is used.

Note that the bean definition is *not* aware of being overridden, so it is not immediately obvious from the XML definition file that the override configurer is being used. In case of multiple `PropertyOverrideConfigurer` instances that define different values for the same bean property, the last one wins, due to the overriding mechanism.

Properties file configuration lines take this format:

```
beanName.property=value
```

For example:

```
dataSource.driverClassName=com.mysql.jdbc.Driver
dataSource.url=jdbc:mysql:mydb
```

This example file can be used with a container definition that contains a bean called *dataSource*, which has *driver* and *url* properties.

Compound property names are also supported, as long as every component of the path except the final property being overridden is already non-null (presumably initialized by the constructors). In this example…

```
foo.fred.bob.sammy=123
```

i. the `sammy` property of the `bob` property of the `fred` property of the `foo` bean is set to the scalar value `123`.

> **Note**
>
> Specified override values are always *literal* values; they are not translated into bean references. This convention also applies when the original value in the XML bean definition specifies a bean reference.

With the `context` namespace introduced in Spring 2.5, it is possible to configure property overriding with a dedicated configuration element:

```
<context:property-override location="classpath:override.properties"/>
```

Customizing instantiation logic with a FactoryBean

Implement the `org.springframework.beans.factory.FactoryBean` interface for objects that *are themselves factories*.

The `FactoryBean` interface is a point of pluggability into the Spring IoC container's instantiation logic. If you have complex initialization code that is better expressed in Java as opposed to a (potentially) verbose amount of XML, you can create your own `FactoryBean`, write the complex initialization inside that class, and then plug your custom `FactoryBean` into the container.

The `FactoryBean` interface provides three methods:

- `Object getObject()`: returns an instance of the object this factory creates. The instance can possibly be shared, depending on whether this factory returns singletons or prototypes.
- `boolean isSingleton()`: returns `true` if this `FactoryBean` returns singletons, `false` otherwise.
- `Class getObjectType()`: returns the object type returned by the `getObject()` method or `null` if the type is not known in advance.

The `FactoryBean` concept and interface is used in a number of places within the Spring Framework; more than 50 implementations of the `FactoryBean` interface ship with Spring itself.

When you need to ask a container for an actual `FactoryBean` instance itself instead of the bean it produces, preface the bean's id with the ampersand symbol (`&`) when calling the `getBean()` method of the `ApplicationContext`. So for a given `FactoryBean` with an id of `myBean`, invoking `getBean("myBean")` on the container returns the product of the `FactoryBean`; whereas, invoking `getBean("&myBean")` returns the `FactoryBean` instance itself.

5.9 Annotation-based container configuration

Are annotations better than XML for configuring Spring?

The introduction of annotation-based configurations raised the question of whether this approach is *better* than XML. The short answer is *it depends*. The long answer is that each approach has its pros and cons, and usually it is up to the developer to decide which strategy suits them better. Due to the way they are defined, annotations provide a lot of context in their declaration, leading to shorter and more concise configuration. However, XML excels at wiring up components without touching their source code or recompiling them. Some developers prefer having the wiring close to the source while others argue that annotated classes are no longer POJOs and, furthermore, that the configuration becomes decentralized and harder to control.

No matter the choice, Spring can accommodate both styles and even mix them together. It's worth pointing out that through its JavaConfig option, Spring allows annotations to be used in a non-invasive way, without touching the target components source code and that in terms of tooling, all configuration styles are supported by the Spring Tool Suite.

An alternative to XML setups is provided by annotation-based configuration which rely on the bytecode metadata for wiring up components instead of angle-bracket declarations. Instead of using XML to

describe a bean wiring, the developer moves the configuration into the component class itself by using annotations on the relevant class, method, or field declaration. As mentioned in the section called "Example: The RequiredAnnotationBeanPostProcessor", using a `BeanPostProcessor` in conjunction with annotations is a common means of extending the Spring IoC container. For example, Spring 2.0 introduced the possibility of enforcing required properties with the @Required annotation. Spring 2.5 made it possible to follow that same general approach to drive Spring's dependency injection. Essentially, the `@Autowired` annotation provides the same capabilities as described in the section called "Autowiring collaborators" but with more fine-grained control and wider applicability. Spring 2.5 also added support for JSR-250 annotations such as `@PostConstruct`, and `@PreDestroy`. Spring 3.0 added support for JSR-330 (Dependency Injection for Java) annotations contained in the javax.inject package such as `@Inject` and `@Named`. Details about those annotations can be found in the relevant section.

> **Note**
>
> Annotation injection is performed *before* XML injection, thus the latter configuration will override the former for properties wired through both approaches.

As always, you can register them as individual bean definitions, but they can also be implicitly registered by including the following tag in an XML-based Spring configuration (notice the inclusion of the `context` namespace):

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

</beans>
```

(The implicitly registered post-processors include `AutowiredAnnotationBeanPostProcessor`, `CommonAnnotationBeanPostProcessor`, `PersistenceAnnotationBeanPostProcessor`, as well as the aforementioned `RequiredAnnotationBeanPostProcessor`.)

> **Note**
>
> `<context:annotation-config/>` only looks for annotations on beans in the same application context in which it is defined. This means that, if you put `<context:annotation-config/>` in a `WebApplicationContext` for a `DispatcherServlet`, it only checks for `@Autowired` beans in your controllers, and not your services. See Section 17.2, "The DispatcherServlet" for more information.

@Required

The `@Required` annotation applies to bean property setter methods, as in the following example:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Required
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

This annotation simply indicates that the affected bean property must be populated at configuration time, through an explicit property value in a bean definition or through autowiring. The container throws an exception if the affected bean property has not been populated; this allows for eager and explicit failure, avoiding `NullPointerExceptions` or the like later on. It is still recommended that you put assertions into the bean class itself, for example, into an init method. Doing so enforces those required references and values even when you use the class outside of a container.

@Autowired

As expected, you can apply the `@Autowired` annotation to "traditional" setter methods:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Autowired
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

> **Note**
>
> JSR 330's @Inject annotation can be used in place of Spring's `@Autowired` annotation in the examples below. See here for more details

You can also apply the annotation to methods with arbitrary names and/or multiple arguments:

```
public class MovieRecommender {

    private MovieCatalog movieCatalog;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public void prepare(MovieCatalog movieCatalog,
            CustomerPreferenceDao customerPreferenceDao) {
        this.movieCatalog = movieCatalog;
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...

}
```

You can apply `@Autowired` to constructors and fields:

```
public class MovieRecommender {

    @Autowired
    private MovieCatalog movieCatalog;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public MovieRecommender(CustomerPreferenceDao customerPreferenceDao) {
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...

}
```

It is also possible to provide *all* beans of a particular type from the `ApplicationContext` by adding the annotation to a field or method that expects an array of that type:

```
public class MovieRecommender {

    @Autowired
    private MovieCatalog[] movieCatalogs;

    // ...

}
```

The same applies for typed collections:

```
public class MovieRecommender {

    private Set<MovieCatalog> movieCatalogs;

    @Autowired
    public void setMovieCatalogs(Set<MovieCatalog> movieCatalogs) {
        this.movieCatalogs = movieCatalogs;
    }

    // ...

}
```

> **Tip**
>
> Your beans can implement the `org.springframework.core.Ordered` interface or either use the `@Order` or standard `@Priority` annotation if you want items in the array or list to be sorted into a specific order.

Even typed Maps can be autowired as long as the expected key type is `String`. The Map values will contain all beans of the expected type, and the keys will contain the corresponding bean names:

```
public class MovieRecommender {

    private Map<String, MovieCatalog> movieCatalogs;

    @Autowired
    public void setMovieCatalogs(Map<String, MovieCatalog> movieCatalogs) {
        this.movieCatalogs = movieCatalogs;
    }

    // ...

}
```

By default, the autowiring fails whenever *zero* candidate beans are available; the default behavior is to treat annotated methods, constructors, and fields as indicating *required* dependencies. This behavior can be changed as demonstrated below.

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Autowired(required=false)
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

Note

Only *one annotated constructor per-class* can be marked as *required*, but multiple non-required constructors can be annotated. In that case, each is considered among the candidates and Spring uses the *greediest* constructor whose dependencies can be satisfied, that is the constructor that has the largest number of arguments.

`@Autowired`'s *required* attribute is recommended over the `@Required` annotation. The *required* attribute indicates that the property is not required for autowiring purposes, the property is ignored if it cannot be autowired. `@Required`, on the other hand, is stronger in that it enforces the property that was set by any means supported by the container. If no value is injected, a corresponding exception is raised.

You can also use `@Autowired` for interfaces that are well-known resolvable dependencies: `BeanFactory`, `ApplicationContext`, `Environment`, `ResourceLoader`, `ApplicationEventPublisher`, and `MessageSource`. These interfaces and their extended interfaces, such as `ConfigurableApplicationContext` or `ResourcePatternResolver`, are automatically resolved, with no special setup necessary.

```
public class MovieRecommender {

    @Autowired
    private ApplicationContext context;

    public MovieRecommender() {
    }

    // ...

}
```

Note

`@Autowired`, `@Inject`, `@Resource`, and `@Value` annotations are handled by a Spring `BeanPostProcessor` implementations which in turn means that you *cannot* apply these annotations within your own `BeanPostProcessor` or `BeanFactoryPostProcessor` types (if any). These types must be *wired up* explicitly via XML or using a Spring `@Bean` method.

Fine-tuning annotation-based autowiring with qualifiers

Because autowiring by type may lead to multiple candidates, it is often necessary to have more control over the selection process. One way to accomplish this is with Spring's `@Qualifier` annotation. You can associate qualifier values with specific arguments, narrowing the set of type matches so that a specific bean is chosen for each argument. In the simplest case, this can be a plain descriptive value:

```
public class MovieRecommender {

    @Autowired
    @Qualifier("main")
    private MovieCatalog movieCatalog;

    // ...

}
```

The `@Qualifier` annotation can also be specified on individual constructor arguments or method parameters:

```
public class MovieRecommender {

    private MovieCatalog movieCatalog;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public void prepare(@Qualifier("main")MovieCatalog movieCatalog,
            CustomerPreferenceDao customerPreferenceDao) {
        this.movieCatalog = movieCatalog;
        this.customerPreferenceDao = customerPreferenceDao;
    }

    // ...

}
```

The corresponding bean definitions appear as follows. The bean with qualifier value "main" is wired with the constructor argument that is qualified with the same value.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <qualifier value="main"/>

        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <qualifier value="action"/>

        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean id="movieRecommender" class="example.MovieRecommender"/>

</beans>
```

For a fallback match, the bean name is considered a default qualifier value. Thus you can define the bean with an id "main" instead of the nested qualifier element, leading to the same matching result. However, although you can use this convention to refer to specific beans by name, `@Autowired` is fundamentally about type-driven injection with optional semantic qualifiers. This means that qualifier values, even with the bean name fallback, always have narrowing semantics within the set of type matches; they do not semantically express a reference to a unique bean id. Good qualifier values are "main" or "EMEA" or "persistent", expressing characteristics of a specific component that are independent from the bean id, which may be auto-generated in case of an anonymous bean definition like the one in the preceding example.

Qualifiers also apply to typed collections, as discussed above, for example, to `Set<MovieCatalog>`. In this case, all matching beans according to the declared qualifiers are injected as a collection. This implies that qualifiers do not have to be unique; they rather simply constitute filtering criteria. For example, you can define multiple `MovieCatalog` beans with the same qualifier value "action"; all of which would be injected into a `Set<MovieCatalog>` annotated with `@Qualifier("action")`.

> **Tip**
>
> If you intend to express annotation-driven injection by name, do not primarily use `@Autowired`, even if is technically capable of referring to a bean name through `@Qualifier` values. Instead, use the JSR-250 `@Resource` annotation, which is semantically defined to identify a specific target component by its unique name, with the declared type being irrelevant for the matching process.
>
> As a specific consequence of this semantic difference, beans that are themselves defined as a collection or map type cannot be injected through `@Autowired`, because type matching is not properly applicable to them. Use `@Resource` for such beans, referring to the specific collection or map bean by unique name.
>
> `@Autowired` applies to fields, constructors, and multi-argument methods, allowing for narrowing through qualifier annotations at the parameter level. By contrast, `@Resource` is supported only for fields and bean property setter methods with a single argument. As a consequence, stick with qualifiers if your injection target is a constructor or a multi-argument method.

You can create your own custom qualifier annotations. Simply define an annotation and provide the `@Qualifier` annotation within your definition:

```
@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
@Qualifier
public @interface Genre {

    String value();
}
```

Then you can provide the custom qualifier on autowired fields and parameters:

```
public class MovieRecommender {

    @Autowired
    @Genre("Action")
    private MovieCatalog actionCatalog;
    private MovieCatalog comedyCatalog;

    @Autowired
    public void setComedyCatalog(@Genre("Comedy") MovieCatalog comedyCatalog) {
        this.comedyCatalog = comedyCatalog;
    }

    // ...

}
```

Next, provide the information for the candidate bean definitions. You can add `<qualifier/>` tags as sub-elements of the `<bean/>` tag and then specify the `type` and `value` to match your custom qualifier annotations. The type is matched against the fully-qualified class name of the annotation. Or, as a convenience if no risk of conflicting names exists, you can use the short class name. Both approaches are demonstrated in the following example.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <qualifier type="Genre" value="Action"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        _<qualifier type="example.Genre" value="Comedy"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean id="movieRecommender" class="example.MovieRecommender"/>

</beans>
```

In Section 5.10, “Classpath scanning and managed components”, you will see an annotation-based alternative to providing the qualifier metadata in XML. Specifically, see the section called “Providing qualifier metadata with annotations”.

In some cases, it may be sufficient to use an annotation without a value. This may be useful when the annotation serves a more generic purpose and can be applied across several different types of dependencies. For example, you may provide an *offline* catalog that would be searched when no Internet connection is available. First define the simple annotation:

```
@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
@Qualifier
public @interface Offline {

}
```

Then add the annotation to the field or property to be autowired:

```
public class MovieRecommender {

    @Autowired
    @Offline
    private MovieCatalog offlineCatalog;

    // ...

}
```

Now the bean definition only needs a qualifier `type`:

```
<bean class="example.SimpleMovieCatalog">
    <qualifier type="Offline"/>
    <!-- inject any dependencies required by this bean -->
</bean>
```

You can also define custom qualifier annotations that accept named attributes in addition to or instead of the simple `value` attribute. If multiple attribute values are then specified on a field or parameter to be autowired, a bean definition must match *all* such attribute values to be considered an autowire candidate. As an example, consider the following annotation definition:

```
@Target({ElementType.FIELD, ElementType.PARAMETER})
@Retention(RetentionPolicy.RUNTIME)
@Qualifier
public @interface MovieQualifier {

    String genre();

    Format format();

}
```

In this case `Format` is an enum:

```
public enum Format {
    VHS, DVD, BLURAY
}
```

The fields to be autowired are annotated with the custom qualifier and include values for both attributes: `genre` and `format`.

```
public class MovieRecommender {

    @Autowired
    @MovieQualifier(format=Format.VHS, genre="Action")
    private MovieCatalog actionVhsCatalog;

    @Autowired
    @MovieQualifier(format=Format.VHS, genre="Comedy")
    private MovieCatalog comedyVhsCatalog;

    @Autowired
    @MovieQualifier(format=Format.DVD, genre="Action")
    private MovieCatalog actionDvdCatalog;

    @Autowired
    @MovieQualifier(format=Format.BLURAY, genre="Comedy")
    private MovieCatalog comedyBluRayCatalog;

    // ...

}
```

Finally, the bean definitions should contain matching qualifier values. This example also demonstrates that bean *meta* attributes may be used instead of the `<qualifier/>` sub-elements. If available, the `<qualifier/>` and its attributes take precedence, but the autowiring mechanism falls back on the values provided within the `<meta/>` tags if no such qualifier is present, as in the last two bean definitions in the following example.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:annotation-config/>

    <bean class="example.SimpleMovieCatalog">
        <qualifier type="MovieQualifier">
            <attribute key="format" value="VHS"/>
            <attribute key="genre" value="Action"/>
        </qualifier>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <qualifier type="MovieQualifier">
            <attribute key="format" value="VHS"/>
            <attribute key="genre" value="Comedy"/>
        </qualifier>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <meta key="format" value="DVD"/>
        <meta key="genre" value="Action"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

    <bean class="example.SimpleMovieCatalog">
        <meta key="format" value="BLURAY"/>
        <meta key="genre" value="Comedy"/>
        <!-- inject any dependencies required by this bean -->
    </bean>

</beans>
```

Using generics as autowiring qualifiers

In addition to the `@Qualifier` annotation, it is also possible to use Java generic types as an implicit form of qualification. For example, suppose you have the following configuration:

```
@Configuration
public class MyConfiguration {

    @Bean
    public StringStore stringStore() {
        return new StringStore();
    }

    @Bean
    public IntegerStore integerStore() {
        return new IntegerStore();
    }

}
```

Assuming that beans above implement a generic interface, i.e. `Store<String>` and `Store<Integer>`, you can `@Autowire` the `Store` interface and the *generic* will be used as a qualifier:

```
@Autowired
private Store<String> s1; // <String> qualifier, injects the stringStore bean

@Autowired
private Store<Integer> s2; // <Integer> qualifier, injects the integerStore bean
```

Generic qualifiers also apply when autowiring Lists, Maps and Arrays:

```
// Inject all Store beans as long as they have an <Integer> generic
// Store<String> beans will not appear in this list
@Autowired
private List<Store<Integer>> s;
```

CustomAutowireConfigurer

The `CustomAutowireConfigurer` is a `BeanFactoryPostProcessor` that enables you to register your own custom qualifier annotation types even if they are not annotated with Spring's `@Qualifier` annotation.

```
<bean id="customAutowireConfigurer"
        class="org.springframework.beans.factory.annotation.CustomAutowireConfigurer">
    <property name="customQualifierTypes">
        <set>
            <value>example.CustomQualifier</value>
        </set>
    </property>
</bean>
```

The `AutowireCandidateResolver` determines autowire candidates by:

- the `autowire-candidate` value of each bean definition
- any `default-autowire-candidates` pattern(s) available on the `<beans/>` element
- the presence of `@Qualifier` annotations and any custom annotations registered with the `CustomAutowireConfigurer`

When multiple beans qualify as autowire candidates, the determination of a "primary" is the following: if exactly one bean definition among the candidates has a `primary` attribute set to `true`, it will be selected.

@Resource

Spring also supports injection using the JSR-250 `@Resource` annotation on fields or bean property setter methods. This is a common pattern in Java EE 5 and 6, for example in JSF 1.2 managed beans or JAX-WS 2.0 endpoints. Spring supports this pattern for Spring-managed objects as well.

`@Resource` takes a name attribute, and by default Spring interprets that value as the bean name to be injected. In other words, it follows *by-name* semantics, as demonstrated in this example:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Resource(name="myMovieFinder")
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

}
```

If no name is specified explicitly, the default name is derived from the field name or setter method. In case of a field, it takes the field name; in case of a setter method, it takes the bean property name. So the following example is going to have the bean with name "movieFinder" injected into its setter method:

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Resource
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

}
```

> **Note**
>
> The name provided with the annotation is resolved as a bean name by the `ApplicationContext` of which the `CommonAnnotationBeanPostProcessor` is aware. The names can be resolved through JNDI if you configure Spring's `SimpleJndiBeanFactory` explicitly. However, it is recommended that you rely on the default behavior and simply use Spring's JNDI lookup capabilities to preserve the level of indirection.

In the exclusive case of `@Resource` usage with no explicit name specified, and similar to `@Autowired`, `@Resource` finds a primary type match instead of a specific named bean and resolves well-known resolvable dependencies: the `BeanFactory`, `ApplicationContext`, `ResourceLoader`, `ApplicationEventPublisher`, and `MessageSource` interfaces.

Thus in the following example, the `customerPreferenceDao` field first looks for a bean named customerPreferenceDao, then falls back to a primary type match for the type `CustomerPreferenceDao`. The "context" field is injected based on the known resolvable dependency type `ApplicationContext`.

```
public class MovieRecommender {

    @Resource
    private CustomerPreferenceDao customerPreferenceDao;

    @Resource
    private ApplicationContext context;

    public MovieRecommender() {
    }

    // ...

}
```

@PostConstruct and @PreDestroy

The `CommonAnnotationBeanPostProcessor` not only recognizes the `@Resource` annotation but also the JSR-250 *lifecycle* annotations. Introduced in Spring 2.5, the support for these annotations offers yet another alternative to those described in initialization callbacks and destruction callbacks. Provided that the `CommonAnnotationBeanPostProcessor` is registered within the Spring `ApplicationContext`, a method carrying one of these annotations is invoked at the same point in the lifecycle as the corresponding Spring lifecycle interface method or explicitly declared callback method. In the example below, the cache will be pre-populated upon initialization and cleared upon destruction.

```
public class CachingMovieLister {

    @PostConstruct
    public void populateMovieCache() {
        // populates the movie cache upon initialization...
    }

    @PreDestroy
    public void clearMovieCache() {
        // clears the movie cache upon destruction...
    }

}
```

> **Note**
>
> For details about the effects of combining various lifecycle mechanisms, see the section called “Combining lifecycle mechanisms”.

5.10 Classpath scanning and managed components

Most examples in this chapter use XML to specify the configuration metadata that produces each `BeanDefinition` within the Spring container. The previous section (Section 5.9, “Annotation-based container configuration”) demonstrates how to provide a lot of the configuration metadata through source-level annotations. Even in those examples, however, the "base" bean definitions are explicitly defined in the XML file, while the annotations only drive the dependency injection. This section describes an option for implicitly detecting the *candidate components* by scanning the classpath. Candidate components are classes that match against a filter criteria and have a corresponding bean definition registered with the container. This removes the need to use XML to perform bean registration, instead you can use annotations (for example @Component), AspectJ type expressions, or your own custom filter criteria to select which classes will have bean definitions registered with the container.

> **Note**
>
> Starting with Spring 3.0, many features provided by the Spring JavaConfig project are part of the core Spring Framework. This allows you to define beans using Java rather than using the traditional XML files. Take a look at the `@Configuration`, `@Bean`, `@Import`, and `@DependsOn` annotations for examples of how to use these new features.

@Component and further stereotype annotations

The `@Repository` annotation is a marker for any class that fulfills the role or *stereotype* (also known as Data Access Object or DAO) of a repository. Among the uses of this marker is the automatic translation of exceptions as described in the section called “Exception translation”.

Spring provides further stereotype annotations: `@Component`, `@Service`, and `@Controller`. `@Component` is a generic stereotype for any Spring-managed component. `@Repository`, `@Service`, and `@Controller` are specializations of `@Component` for more specific use cases, for example, in the persistence, service, and presentation layers, respectively. Therefore, you can annotate your component classes with `@Component`, but by annotating them with `@Repository`, `@Service`, or `@Controller` instead, your classes are more properly suited for processing by tools or associating with aspects. For example, these stereotype annotations make ideal targets for pointcuts. It is also possible that `@Repository`, `@Service`, and `@Controller` may carry additional semantics in future releases of the Spring Framework. Thus, if you are choosing between using `@Component` or `@Service` for your service layer, `@Service` is clearly the better choice. Similarly, as stated above, `@Repository` is already supported as a marker for automatic exception translation in your persistence layer.

Meta-annotations

Many of the annotations provided by Spring can be used as "meta-annotations" in your own code. A meta-annotation is simply an annotation, that can be applied to another annotation. For example, The `@Service` annotation mentioned above is meta-annotated with with `@Component`:

```
@Target({ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Documented
@Component // Spring will see this and treat @Service in the same way as @Component
public @interface Service {

    // ....

}
```

Meta-annotations can also be combined together to create *composed annotations*. For example, the `@RestController` annotation from Spring MVC is *composed* of `@Controller` and `@ResponseBody`.

With the exception of `value()`, meta-annotated types may redeclare attributes from the source annotation to allow user customization. This can be particularly useful when you want to only expose a subset of the source annotation attributes. For example, here is a custom `@Scope` annotation that defines `session` scope, but still allows customization of the `proxyMode`.

```
@Target({ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Documented
@Scope("session")
public @interface SessionScope {

    ScopedProxyMode proxyMode() default ScopedProxyMode.DEFAULT

}
```

Automatically detecting classes and registering bean definitions

Spring can automatically detect stereotyped classes and register corresponding `BeanDefinitions` with the `ApplicationContext`. For example, the following two classes are eligible for such autodetection:

```
@Service
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Autowired
    public SimpleMovieLister(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

}
```

```
@Repository
public class JpaMovieFinder implements MovieFinder {
    // implementation elided for clarity
}
```

To autodetect these classes and register the corresponding beans, you need to add `@ComponentScan` to your `@Configuration` class, where the `basePackages` attribute is a common parent package for the two classes. (Alternatively, you can specify a comma-separated list that includes the parent package of each class.)

```
@Configuration
@ComponentScan(basePackages = "org.example")
public class AppConfig  {
    ...
}
```

> **Note**
>
> for concision, the above may have used the `value` attribute of the annotation, i.e. `ComponentScan("org.example")`

The following is an alternative using XML

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:component-scan base-package="org.example"/>

</beans>
```

> **Tip**
>
> The use of `<context:component-scan>` implicitly enables the functionality of `<context:annotation-config>`. There is usually no need to include the `<context:annotation-config>` element when using `<context:component-scan>`.

> **Note**
>
> The scanning of classpath packages requires the presence of corresponding directory entries in the classpath. When you build JARs with Ant, make sure that you do *not* activate the files-only switch of the JAR task. Also, classpath directories may not get exposed based on security policies in some environments, e.g. standalone apps on JDK 1.7.0_45 and higher (which requires *Trusted-*

> *Library* setup in your manifests; see http://stackoverflow.com/questions/19394570/java-jre-7u45-breaks-classloader-getresources).

Furthermore, the `AutowiredAnnotationBeanPostProcessor` and `CommonAnnotationBeanPostProcessor` are both included implicitly when you use the component-scan element. That means that the two components are autodetected *and* wired together - all without any bean configuration metadata provided in XML.

> **Note**
>
> You can disable the registration of `AutowiredAnnotationBeanPostProcessor` and `CommonAnnotationBeanPostProcessor` by including the *annotation-config* attribute with a value of false.

Using filters to customize scanning

By default, classes annotated with `@Component`, `@Repository`, `@Service`, `@Controller`, or a custom annotation that itself is annotated with `@Component` are the only detected candidate components. However, you can modify and extend this behavior simply by applying custom filters. Add them as *includeFilters* or *excludeFilters* parameters of the `@ComponentScan` annotation (or as *include-filter* or *exclude-filter* sub-elements of the `component-scan` element). Each filter element requires the `type` and `expression` attributes. The following table describes the filtering options.

Table 5.5. Filter Types

Filter Type	Example Expression	Description
annotation (default)	`org.example.SomeAnnotation`	An annotation to be present at the type level in target components.
assignable	`org.example.SomeClass`	A class (or interface) that the target components are assignable to (extend/ implement).
aspectj	`org.example..*Service+`	An AspectJ type expression to be matched by the target components.
regex	`org\.example\.Default.*`	A regex expression to be matched by the target components class names.
custom	`org.example.MyTypeFilter`	A custom implementation of the `org.springframework.core.type .TypeF` interface.

The following example shows the configuration ignoring all `@Repository` annotations and using "stub" repositories instead.

```
@Configuration
@ComponentScan(basePackages = "org.example",
        includeFilters = @Filter(type = FilterType.REGEX, pattern = ".*Stub.*Repository"),
        excludeFilters = @Filter(Repository.class))
public class AppConfig {
    ...
}
```

and the equivalent using XML

```
<beans>
    <context:component-scan base-package="org.example">
        <context:include-filter type="regex"
                expression=".*Stub.*Repository"/>
        <context:exclude-filter type="annotation"
                expression="org.springframework.stereotype.Repository"/>
    </context:component-scan>
</beans>
```

> **Note**
>
> You can also disable the default filters by setting `useDefaultFilters=false` on the annotation or providing `use-default-filters="false"` as an attribute of the <component-scan/> element. This will in effect disable automatic detection of classes annotated with `@Component`, `@Repository`, `@Service`, or `@Controller`.

Defining bean metadata within components

Spring components can also contribute bean definition metadata to the container. You do this with the same `@Bean` annotation used to define bean metadata within `@Configuration` annotated classes. Here is a simple example:

```
@Component
public class FactoryMethodComponent {

    @Bean
    @Qualifier("public")
    public TestBean publicInstance() {
        return new TestBean("publicInstance");
    }

    public void doWork() {
        // Component method implementation omitted
    }

}
```

This class is a Spring component that has application-specific code contained in its `doWork()` method. However, it also contributes a bean definition that has a factory method referring to the method `publicInstance()`. The `@Bean` annotation identifies the factory method and other bean definition properties, such as a qualifier value through the `@Qualifier` annotation. Other method level annotations that can be specified are `@Scope`, `@Lazy`, and custom qualifier annotations.

> **Tip**
>
> In addition to its role for component initialization, the `@Lazy` annotation may also be placed on injection points marked with `@Autowired` or `@Inject`. In this context, it leads to the injection of a lazy-resolution proxy.

Autowired fields and methods are supported as previously discussed, with additional support for autowiring of `@Bean` methods:

```
@Component
public class FactoryMethodComponent {

    private static int i;

    @Bean
    @Qualifier("public")
    public TestBean publicInstance() {
        return new TestBean("publicInstance");
    }

    // use of a custom qualifier and autowiring of method parameters

    @Bean
    protected TestBean protectedInstance(
            @Qualifier("public") TestBean spouse,
            @Value("#{privateInstance.age}") String country) {
        TestBean tb = new TestBean("protectedInstance", 1);
        tb.setSpouse(spouse);
        tb.setCountry(country);
        return tb;
    }

    @Bean
    @Scope(BeanDefinition.SCOPE_SINGLETON)
    private TestBean privateInstance() {
        return new TestBean("privateInstance", i++);
    }

    @Bean
    @Scope(value = WebApplicationContext.SCOPE_SESSION, proxyMode = ScopedProxyMode.TARGET_CLASS)
    public TestBean requestScopedInstance() {
        return new TestBean("requestScopedInstance", 3);
    }

}
```

The example autowires the `String` method parameter `country` to the value of the `Age` property on another bean named `privateInstance`. A Spring Expression Language element defines the value of the property through the notation `#{ <expression> }`. For `@Value` annotations, an expression resolver is preconfigured to look for bean names when resolving expression text.

The `@Bean` methods in a Spring component are processed differently than their counterparts inside a Spring `@Configuration` class. The difference is that `@Component` classes are not enhanced with CGLIB to intercept the invocation of methods and fields. CGLIB proxying is the means by which invoking methods or fields within `@Bean` methods in `@Configuration` classes creates bean metadata references to collaborating objects; such methods are *not* invoked with normal Java semantics. In contrast, invoking a method or field in an `@Bean` method within a `@Component` class *has* standard Java semantics.

Naming autodetected components

When a component is autodetected as part of the scanning process, its bean name is generated by the `BeanNameGenerator` strategy known to that scanner. By default, any Spring stereotype annotation (`@Component`, `@Repository`, `@Service`, and `@Controller`) that contains a `name` value will thereby provide that name to the corresponding bean definition.

If such an annotation contains no `name` value or for any other detected component (such as those discovered by custom filters), the default bean name generator returns the uncapitalized non-qualified

class name. For example, if the following two components were detected, the names would be myMovieLister and movieFinderImpl:

```
@Service("myMovieLister")
public class SimpleMovieLister {
    // ...
}
```

```
@Repository
public class MovieFinderImpl implements MovieFinder {
    // ...
}
```

Note

If you do not want to rely on the default bean-naming strategy, you can provide a custom bean-naming strategy. First, implement the `BeanNameGenerator` interface, and be sure to include a default no-arg constructor. Then, provide the fully-qualified class name when configuring the scanner:

```
@Configuration
@ComponentScan(basePackages = "org.example", nameGenerator = MyNameGenerator.class)
public class AppConfig {
    ...
}
```

```
<beans>
    <context:component-scan base-package="org.example"
        name-generator="org.example.MyNameGenerator" />
</beans>
```

As a general rule, consider specifying the name with the annotation whenever other components may be making explicit references to it. On the other hand, the auto-generated names are adequate whenever the container is responsible for wiring.

Providing a scope for autodetected components

As with Spring-managed components in general, the default and most common scope for autodetected components is singleton. However, sometimes you need other scopes, which Spring 2.5 provides with a new `@Scope` annotation. Simply provide the name of the scope within the annotation:

```
@Scope("prototype")
@Repository
public class MovieFinderImpl implements MovieFinder {
    // ...
}
```

Note

To provide a custom strategy for scope resolution rather than relying on the annotation-based approach, implement the `ScopeMetadataResolver` interface, and be sure to include a default no-arg constructor. Then, provide the fully-qualified class name when configuring the scanner:

```
@Configuration
@ComponentScan(basePackages = "org.example", scopeResolver = MyScopeResolver.class)
public class AppConfig {
    ...
}
```

```
<beans>
    <context:component-scan base-package="org.example"
            scope-resolver="org.example.MyScopeResolver" />
</beans>
```

When using certain non-singleton scopes, it may be necessary to generate proxies for the scoped objects. The reasoning is described in the section called “Scoped beans as dependencies”. For this purpose, a *scoped-proxy* attribute is available on the component-scan element. The three possible values are: no, interfaces, and targetClass. For example, the following configuration will result in standard JDK dynamic proxies:

```
@Configuration
@ComponentScan(basePackages = "org.example", scopedProxy = ScopedProxyMode.INTERFACES)
public class AppConfig {
    ...
}
```

```
<beans>
    <context:component-scan base-package="org.example"
        scoped-proxy="interfaces" />
</beans>
```

Providing qualifier metadata with annotations

The `@Qualifier` annotation is discussed in the section called “Fine-tuning annotation-based autowiring with qualifiers”. The examples in that section demonstrate the use of the `@Qualifier` annotation and custom qualifier annotations to provide fine-grained control when you resolve autowire candidates. Because those examples were based on XML bean definitions, the qualifier metadata was provided on the candidate bean definitions using the `qualifier` or `meta` sub-elements of the `bean` element in the XML. When relying upon classpath scanning for autodetection of components, you provide the qualifier metadata with type-level annotations on the candidate class. The following three examples demonstrate this technique:

```
@Component
@Qualifier("Action")
public class ActionMovieCatalog implements MovieCatalog {
    // ...
}
```

```
@Component
@Genre("Action")
public class ActionMovieCatalog implements MovieCatalog {
    // ...
}
```

```
@Component
@Offline
public class CachingMovieCatalog implements MovieCatalog {
    // ...
}
```

> **Note**
>
> As with most annotation-based alternatives, keep in mind that the annotation metadata is bound to the class definition itself, while the use of XML allows for multiple beans *of the same type* to provide variations in their qualifier metadata, because that metadata is provided per-instance rather than per-class.

5.11 Using JSR 330 Standard Annotations

Starting with Spring 3.0, Spring offers support for JSR-330 standard annotations (Dependency Injection). Those annotations are scanned in the same way as the Spring annotations. You just need to have the relevant jars in your classpath.

> **Note**
>
> If you are using Maven, the `javax.inject` artifact is available in the standard Maven repository (http://repo1.maven.org/maven2/javax/inject/javax.inject/1/). You can add the following dependency to your file pom.xml:

```
<dependency>
    <groupId>javax.inject</groupId>
    <artifactId>javax.inject</artifactId>
    <version>1</version>
</dependency>
```

Dependency Injection with @Inject and @Named

Instead of `@Autowired`, `@javax.inject.Inject` may be used as follows:

```
import javax.inject.Inject;

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

As with `@Autowired`, it is possible to use `@Inject` at the class-level, field-level, method-level and constructor-argument level. If you would like to use a qualified name for the dependency that should be injected, you should use the `@Named` annotation as follows:

```
import javax.inject.Inject;
import javax.inject.Named;

public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(@Named("main") MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

@Named: a standard equivalent to the @Component annotation

Instead of `@Component`, `@javax.inject.Named` may be used as follows:

```
import javax.inject.Inject;
import javax.inject.Named;

@Named("movieListener")
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

It is very common to use `@Component` without specifying a name for the component. `@Named` can be used in a similar fashion:

```
import javax.inject.Inject;
import javax.inject.Named;

@Named
public class SimpleMovieLister {

    private MovieFinder movieFinder;

    @Inject
    public void setMovieFinder(MovieFinder movieFinder) {
        this.movieFinder = movieFinder;
    }

    // ...

}
```

When using `@Named`, it is possible to use component-scanning in the exact same way as when using Spring annotations:

```
@Configuration
@ComponentScan(basePackages = "org.example")
public class AppConfig  {
    ...
}
```

Limitations of the standard approach

When working with standard annotations, it is important to know that some significant features are not available as shown in the table below:

Table 5.6. Spring annotations vs. standard annotations

Spring	**javax.inject.***	**javax.inject restrictions / comments**
@Autowired	@Inject	@Inject has no *required* attribute
@Component	@Named	-
@Scope("singleton")	@Singleton	The JSR-330 default scope is like Spring's `prototype`.

Spring	javax.inject.*	javax.inject restrictions / comments
		However, in order to keep it consistent with Spring's general defaults, a JSR-330 bean declared in the Spring container is a `singleton` by default. In order to use a scope other than `singleton`, you should use Spring's `@Scope` annotation. `javax.inject` also provides a @Scope annotation. Nevertheless, this one is only intended to be used for creating your own annotations.
@Qualifier	@Named	-
@Value	-	no equivalent
@Required	-	no equivalent
@Lazy	-	no equivalent

5.12 Java-based container configuration

Basic concepts: @Bean and @Configuration

The central artifacts in Spring's new Java-configuration support are `@Configuration`-annotated classes and `@Bean`-annotated methods.

The `@Bean` annotation is used to indicate that a method instantiates, configures and initializes a new object to be managed by the Spring IoC container. For those familiar with Spring's `<beans/>` XML configuration the `@Bean` annotation plays the same role as the `<bean/>` element. You can use `@Bean` annotated methods with any Spring `@Component`, however, they are most often used with `@Configuration` beans.

Annotating a class with `@Configuration` indicates that its primary purpose is as a source of bean definitions. Furthermore, `@Configuration` classes allow inter-bean dependencies to be defined by simply calling other `@Bean` methods in the same class. The simplest possible `@Configuration` class would read as follows:

```
@Configuration
public class AppConfig {

    @Bean
    public MyService myService() {
        return new MyServiceImpl();
    }

}
```

The `AppConfig` class above would be equivalent to the following Spring `<beans/>` XML:

```
<beans>
    <bean id="myService" class="com.acme.services.MyServiceImpl"/>
</beans>
```

The @Bean and @Configuration annotations will be discussed in depth in the sections below. First, however, we'll cover the various ways of creating a spring container using Java-based configuration.

Full @Configuration vs *lite* @Beans mode?

When @Bean methods are declared within classes that are *not* annotated with @Configuration they are referred to as being processed in a *lite* mode. For example, bean methods declared in a @Component or even in a *plain old class* will be considered *lite*.

Unlike full @Configuration, lite @Bean methods cannot easily declare inter-bean dependencies. Usually one @Bean method should not invoke another @Bean method when operating in *lite* mode.

Only using @Bean methods within @Configuration classes is a recommended approach of ensuring that *full* mode is always used. This will prevent the same @Bean method from accidentally being invoked multiple times and helps to reduce subtle bugs that can be hard to track down when operating in *lite* mode.

Instantiating the Spring container using AnnotationConfigApplicationContext

The sections below document Spring's AnnotationConfigApplicationContext, new in Spring 3.0. This versatile ApplicationContext implementation is capable of accepting not only @Configuration classes as input, but also plain @Component classes and classes annotated with JSR-330 metadata.

When @Configuration classes are provided as input, the @Configuration class itself is registered as a bean definition, and all declared @Bean methods within the class are also registered as bean definitions.

When @Component and JSR-330 classes are provided, they are registered as bean definitions, and it is assumed that DI metadata such as @Autowired or @Inject are used within those classes where necessary.

Simple construction

In much the same way that Spring XML files are used as input when instantiating a ClassPathXmlApplicationContext, @Configuration classes may be used as input when instantiating an AnnotationConfigApplicationContext. This allows for completely XML-free usage of the Spring container:

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(AppConfig.class);
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

As mentioned above, AnnotationConfigApplicationContext is not limited to working only with @Configuration classes. Any @Component or JSR-330 annotated class may be supplied as input to the constructor. For example:

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(MyServiceImpl.class,
 Dependency1.class, Dependency2.class);
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

The above assumes that `MyServiceImpl`, `Dependency1` and `Dependency2` use Spring dependency injection annotations such as `@Autowired`.

Building the container programmatically using register(Class<?>...)

An `AnnotationConfigApplicationContext` may be instantiated using a no-arg constructor and then configured using the `register()` method. This approach is particularly useful when programmatically building an `AnnotationConfigApplicationContext`.

```
public static void main(String[] args) {
    AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
    ctx.register(AppConfig.class, OtherConfig.class);
    ctx.register(AdditionalConfig.class);
    ctx.refresh();
    MyService myService = ctx.getBean(MyService.class);
    myService.doStuff();
}
```

Enabling component scanning with scan(String…)

To enable component scanning, just annotate your `@Configuration` class as follows:

```
@Configuration
@ComponentScan(basePackages = "com.acme")
public class AppConfig  {
    ...
}
```

> **Tip**
>
> Experienced Spring users will be familiar with the XML declaration equivalent from Spring's `context:` namespace
>
> ```
> <beans>
>     <context:component-scan base-package="com.acme"/>
> </beans>
> ```

In the example above, the `com.acme` package will be scanned, looking for any `@Component`-annotated classes, and those classes will be registered as Spring bean definitions within the container. `AnnotationConfigApplicationContext` exposes the `scan(String...)` method to allow for the same component-scanning functionality:

```
public static void main(String[] args) {
    AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
    ctx.scan("com.acme");
    ctx.refresh();
    MyService myService = ctx.getBean(MyService.class);
}
```

> **Note**
>
> Remember that `@Configuration` classes are meta-annotated with `@Component`, so they are candidates for component-scanning! In the example above, assuming that `AppConfig` is

> declared within the `com.acme` package (or any package underneath), it will be picked up during the call to `scan()`, and upon `refresh()` all its `@Bean` methods will be processed and registered as bean definitions within the container.

Support for web applications with AnnotationConfigWebApplicationContext

A `WebApplicationContext` variant of `AnnotationConfigApplicationContext` is available with `AnnotationConfigWebApplicationContext`. This implementation may be used when configuring the Spring `ContextLoaderListener` servlet listener, Spring MVC `DispatcherServlet`, etc. What follows is a `web.xml` snippet that configures a typical Spring MVC web application. Note the use of the `contextClass` context-param and init-param:

```
<web-app>
    <!-- Configure ContextLoaderListener to use AnnotationConfigWebApplicationContext
        instead of the default XmlWebApplicationContext -->
    <context-param>
        <param-name>contextClass</param-name>
        <param-value>
            org.springframework.web.context.support.AnnotationConfigWebApplicationContext
        </param-value>
    </context-param>

    <!-- Configuration locations must consist of one or more comma- or space-delimited
        fully-qualified @Configuration classes. Fully-qualified packages may also be
        specified for component-scanning -->
    <context-param>
        <param-name>contextConfigLocation</param-name>
        <param-value>com.acme.AppConfig</param-value>
    </context-param>

    <!-- Bootstrap the root application context as usual using ContextLoaderListener -->
    <listener>
        <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
    </listener>

    <!-- Declare a Spring MVC DispatcherServlet as usual -->
    <servlet>
        <servlet-name>dispatcher</servlet-name>
        <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
        <!-- Configure DispatcherServlet to use AnnotationConfigWebApplicationContext
            instead of the default XmlWebApplicationContext -->
        <init-param>
            <param-name>contextClass</param-name>
            <param-value>
                org.springframework.web.context.support.AnnotationConfigWebApplicationContext
            </param-value>
        </init-param>
        <!-- Again, config locations must consist of one or more comma- or space-delimited
            and fully-qualified @Configuration classes -->
        <init-param>
            <param-name>contextConfigLocation</param-name>
            <param-value>com.acme.web.MvcConfig</param-value>
        </init-param>
    </servlet>

    <!-- map all requests for /app/* to the dispatcher servlet -->
    <servlet-mapping>
        <servlet-name>dispatcher</servlet-name>
        <url-pattern>/app/*</url-pattern>
    </servlet-mapping>
</web-app>
```

Using the @Bean annotation

`@Bean` is a method-level annotation and a direct analog of the XML `<bean/>` element. The annotation supports some of the attributes offered by `<bean/>`, such as: init-method, destroy-method, autowiring and `name`.

You can use the `@Bean` annotation in a `@Configuration`-annotated or in a `@Component`-annotated class.

Declaring a bean

To declare a bean, simply annotate a method with the `@Bean` annotation. You use this method to register a bean definition within an `ApplicationContext` of the type specified as the method's return value. By default, the bean name will be the same as the method name. The following is a simple example of a `@Bean` method declaration:

```
@Configuration
public class AppConfig {

    @Bean
    public TransferService transferService() {
        return new TransferServiceImpl();
    }

}
```

The preceding configuration is exactly equivalent to the following Spring XML:

```
<beans>
    <bean id="transferService" class="com.acme.TransferServiceImpl"/>
</beans>
```

Both declarations make a bean named `transferService` available in the `ApplicationContext`, bound to an object instance of type `TransferServiceImpl`:

```
transferService -> com.acme.TransferServiceImpl
```

Receiving lifecycle callbacks

Any classes defined with the `@Bean` annotation support the regular lifecycle callbacks and can use the `@PostConstruct` and `@PreDestroy` annotations from JSR-250, see JSR-250 annotations for further details.

The regular Spring lifecycle callbacks are fully supported as well. If a bean implements `InitializingBean`, `DisposableBean`, or `Lifecycle`, their respective methods are called by the container.

The standard set of `*Aware` interfaces such as BeanFactoryAware, BeanNameAware, MessageSourceAware, ApplicationContextAware, and so on are also fully supported.

The `@Bean` annotation supports specifying arbitrary initialization and destruction callback methods, much like Spring XML's `init-method` and `destroy-method` attributes on the `bean` element:

```
public class Foo {
    public void init() {
        // initialization logic
    }
}

public class Bar {
    public void cleanup() {
        // destruction logic
    }
}

@Configuration
public class AppConfig {

    @Bean(initMethod = "init")
    public Foo foo() {
        return new Foo();
    }

    @Bean(destroyMethod = "cleanup")
    public Bar bar() {
        return new Bar();
    }

}
```

Of course, in the case of `Foo` above, it would be equally as valid to call the `init()` method directly during construction:

```
@Configuration
public class AppConfig {
    @Bean
    public Foo foo() {
        Foo foo = new Foo();
        foo.init();
    return foo;
    }

    // ...

}
```

> **Tip**
>
> When you work directly in Java, you can do anything you like with your objects and do not always need to rely on the container lifecycle!

Specifying bean scope

Using the @Scope annotation

You can specify that your beans defined with the `@Bean` annotation should have a specific scope. You can use any of the standard scopes specified in the Bean Scopes section.

The default scope is `singleton`, but you can override this with the `@Scope` annotation:

```
@Configuration
public class MyConfiguration {

    @Bean
    @Scope("prototype")
    public Encryptor encryptor() {
        // ...
    }

}
```

@Scope and scoped-proxy

Spring offers a convenient way of working with scoped dependencies through scoped proxies. The easiest way to create such a proxy when using the XML configuration is the `<aop:scoped-proxy/>` element. Configuring your beans in Java with a @Scope annotation offers equivalent support with the proxyMode attribute. The default is no proxy (`ScopedProxyMode.NO`), but you can specify `ScopedProxyMode.TARGET_CLASS` or `ScopedProxyMode.INTERFACES`.

If you port the scoped proxy example from the XML reference documentation (see preceding link) to our `@Bean` using Java, it would look like the following:

```
// an HTTP Session-scoped bean exposed as a proxy
@Bean
@Scope(value = "session", proxyMode = ScopedProxyMode.TARGET_CLASS)
public UserPreferences userPreferences() {
    return new UserPreferences();
}

@Bean
public Service userService() {
    UserService service = new SimpleUserService();
    // a reference to the proxied userPreferences bean
    service.setUserPreferences(userPreferences());
    return service;
}
```

Customizing bean naming

By default, configuration classes use a `@Bean` method's name as the name of the resulting bean. This functionality can be overridden, however, with the `name` attribute.

```
@Configuration
public class AppConfig {

    @Bean(name = "myFoo")
    public Foo foo() {
        return new Foo();
    }

}
```

Bean aliasing

As discussed in the section called "Naming beans", it is sometimes desirable to give a single bean multiple names, otherwise known as*bean aliasing*. The `name` attribute of the `@Bean` annotation accepts a String array for this purpose.

```
@Configuration
public class AppConfig {

    @Bean(name = { "dataSource", "subsystemA-dataSource", "subsystemB-dataSource" })
    public DataSource dataSource() {
        // instantiate, configure and return DataSource bean...
    }

}
```

Bean description

Sometimes it is helpful to provide a more detailed textual description of a bean. This can be particularly useful when beans are exposed (perhaps via JMX) for monitoring purposes.

To add a description to a `@Bean` the `@Description` annotation can be used:

```
@Configuration
public class AppConfig {

    @Bean
    @Desciption("Provides a basic example of a bean")
    public Foo foo() {
        return new Foo();
    }

}
```

Using the @Configuration annotation

`@Configuration` is a class-level annotation indicating that an object is a source of bean definitions. `@Configuration` classes declare beans via public `@Bean` annotated methods. Calls to `@Bean` methods on `@Configuration` classes can also be used to define inter-bean dependencies. See the section called “Basic concepts: @Bean and @Configuration” for a general introduction.

Injecting inter-bean dependencies

When `@Beans` have dependencies on one another, expressing that dependency is as simple as having one bean method call another:

```
@Configuration
public class AppConfig {

    @Bean
    public Foo foo() {
        return new Foo(bar());
    }

    @Bean
    public Bar bar() {
        return new Bar();
    }

}
```

In the example above, the `foo` bean receives a reference to `bar` via constructor injection.

> **Note**
>
> This method of declaring inter-bean dependencies only works when the `@Bean` method is declared within a `@Configuration` class. You cannot declare inter-bean dependencies using plain `@Component` classes.

Lookup method injection

As noted earlier, lookup method injection is an advanced feature that you should use rarely. It is useful in cases where a singleton-scoped bean has a dependency on a prototype-scoped bean. Using Java for this type of configuration provides a natural means for implementing this pattern.

```
public abstract class CommandManager {
    public Object process(Object commandState) {
        // grab a new instance of the appropriate Command interface
        Command command = createCommand();

        // set the state on the (hopefully brand new) Command instance
        command.setState(commandState);
    return command.execute();
    }

    // okay... but where is the implementation of this method?
    protected abstract Command createCommand();
}
```

Using Java-configuration support , you can create a subclass of `CommandManager` where the abstract `createCommand()` method is overridden in such a way that it looks up a new (prototype) command object:

```
@Bean
@Scope("prototype")
public AsyncCommand asyncCommand() {
    AsyncCommand command = new AsyncCommand();
    // inject dependencies here as required
    return command;
}

@Bean
public CommandManager commandManager() {
    // return new anonymous implementation of CommandManager with command() overridden
    // to return a new prototype Command object
    return new CommandManager() {
        protected Command createCommand() {
            return asyncCommand();
        }
    }
}
```

Further information about how Java-based configuration works internally

The following example shows a `@Bean` annotated method being called twice:

```
@Configuration
public class AppConfig {

    @Bean
    public ClientService clientService1() {
        ClientServiceImpl clientService = new ClientServiceImpl();
        clientService.setClientDao(clientDao());
        return clientService;
    }

    @Bean
    public ClientService clientService2() {
        ClientServiceImpl clientService = new ClientServiceImpl();
        clientService.setClientDao(clientDao());
        return clientService;
    }

    @Bean
    public ClientDao clientDao() {
        return new ClientDaoImpl();
    }

}
```

`clientDao()` has been called once in `clientService1()` and once in `clientService2()`. Since this method creates a new instance of `ClientDaoImpl` and returns it, you would normally expect having 2 instances (one for each service). That definitely would be problematic: in Spring, instantiated beans have a `singleton` scope by default. This is where the magic comes in: All `@Configuration` classes are subclassed at startup-time with `CGLIB`. In the subclass, the child method checks the container first for any cached (scoped) beans before it calls the parent method and creates a new instance. Note that as of Spring 3.2, it is no longer necessary to add CGLIB to your classpath because CGLIB classes have been repackaged under org.springframework and included directly within the spring-core JAR.

> **Note**
>
> The behavior could be different according to the scope of your bean. We are talking about singletons here.

> **Note**
>
> There are a few restrictions due to the fact that CGLIB dynamically adds features at startup-time:
>
> - Configuration classes should not be final
> - They should have a constructor with no arguments

Composing Java-based configurations

Using the @Import annotation

Much as the `<import/>` element is used within Spring XML files to aid in modularizing configurations, the `@Import` annotation allows for loading `@Bean` definitions from another configuration class:

```
@Configuration
public class ConfigA {

     @Bean
    public A a() {
        return new A();
    }

}

@Configuration
@Import(ConfigA.class)
public class ConfigB {

    @Bean
    public B b() {
        return new B();
    }

}
```

Now, rather than needing to specify both `ConfigA.class` and `ConfigB.class` when instantiating the context, only `ConfigB` needs to be supplied explicitly:

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(ConfigB.class);

    // now both beans A and B will be available...
    A a = ctx.getBean(A.class);
    B b = ctx.getBean(B.class);
}
```

This approach simplifies container instantiation, as only one class needs to be dealt with, rather than requiring the developer to remember a potentially large number of `@Configuration` classes during construction.

Injecting dependencies on imported @Bean definitions

The example above works, but is simplistic. In most practical scenarios, beans will have dependencies on one another across configuration classes. When using XML, this is not an issue, per se, because there is no compiler involved, and one can simply declare `ref="someBean"` and trust that Spring will work it out during container initialization. Of course, when using `@Configuration` classes, the Java compiler places constraints on the configuration model, in that references to other beans must be valid Java syntax.

Fortunately, solving this problem is simple. Remember that `@Configuration` classes are ultimately just another bean in the container - this means that they can take advantage of `@Autowired` injection metadata just like any other bean!

Let's consider a more real-world scenario with several `@Configuration` classes, each depending on beans declared in the others:

```
@Configuration
public class ServiceConfig {

    @Autowired
    private AccountRepository accountRepository;

    @Bean
    public TransferService transferService() {
        return new TransferServiceImpl(accountRepository);
    }

}

@Configuration
public class RepositoryConfig {

    @Autowired
    private DataSource dataSource;

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(dataSource);
    }

}

@Configuration
@Import({ServiceConfig.class, RepositoryConfig.class})
public class SystemTestConfig {

    @Bean
    public DataSource dataSource() {
        // return new DataSource
    }

}

public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(SystemTestConfig.class);
    // everything wires up across configuration classes...
    TransferService transferService = ctx.getBean(TransferService.class);
    transferService.transfer(100.00, "A123", "C456");
}
```

In the scenario above, using `@Autowired` works well and provides the desired modularity, but determining exactly where the autowired bean definitions are declared is still somewhat ambiguous. For example, as a developer looking at `ServiceConfig`, how do you know exactly where the `@Autowired` `AccountRepository` bean is declared? It's not explicit in the code, and this may be just fine. Remember that the Spring Tool Suite provides tooling that can render graphs showing how everything is wired up - that may be all you need. Also, your Java IDE can easily find all declarations and uses of the `AccountRepository` type, and will quickly show you the location of `@Bean` methods that return that type.

In cases where this ambiguity is not acceptable and you wish to have direct navigation from within your IDE from one `@Configuration` class to another, consider autowiring the configuration classes themselves:

```
@Configuration
public class ServiceConfig {

    @Autowired
    private RepositoryConfig repositoryConfig;

    @Bean
    public TransferService transferService() {
        // navigate through the config class to the @Bean method!
        return new TransferServiceImpl(repositoryConfig.accountRepository());
    }

}
```

In the situation above, it is completely explicit where `AccountRepository` is defined. However, `ServiceConfig` is now tightly coupled to `RepositoryConfig`; that's the tradeoff. This tight coupling can be somewhat mitigated by using interface-based or abstract class-based `@Configuration` classes. Consider the following:

```
@Configuration
public class ServiceConfig {

    @Autowired
    private RepositoryConfig repositoryConfig;

    @Bean
    public TransferService transferService() {
        return new TransferServiceImpl(repositoryConfig.accountRepository());
    }
}

@Configuration
public interface RepositoryConfig {

    @Bean
    AccountRepository accountRepository();

}

@Configuration
public class DefaultRepositoryConfig implements RepositoryConfig {

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(...);
    }

}

@Configuration
@Import({ServiceConfig.class, DefaultRepositoryConfig.class}) // import the concrete config!
public class SystemTestConfig {

    @Bean
    public DataSource dataSource() {
        // return DataSource
    }

}

public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(SystemTestConfig.class);
    TransferService transferService = ctx.getBean(TransferService.class);
    transferService.transfer(100.00, "A123", "C456");
}
```

Now `ServiceConfig` is loosely coupled with respect to the concrete `DefaultRepositoryConfig`, and built-in IDE tooling is still useful: it will be easy for the developer to get a type hierarchy of

`RepositoryConfig` implementations. In this way, navigating `@Configuration` classes and their dependencies becomes no different than the usual process of navigating interface-based code.

Conditionally including @Configuration classes or @Beans

It is often useful to conditionally enable to disable a complete `@Configuration` class, or even individual `@Bean` methods, based on some arbitrary system state. One common example of this it to use the `@Profile` annotation to active beans only when a specific profile has been enabled in the Spring `Environment` (see the section called “Bean definition profiles” for details).

The `@Profile` annotation is actually implemented using a much more flexible annotation called `@Conditional`. The `@Conditional` annotation indicates specific `org.springframework.context.annotation.Condition` implementations that should be consulted before a `@Bean` is registered.

Implementations of the `Condition` interface simply provide a `matches(...)` method that returns `true` or `false`. For example, here is the actual `Condition` implementation used for `@Profile`:

```
@Override
public boolean matches(ConditionContext context, AnnotatedTypeMetadata metadata) {
    if (context.getEnvironment() != null) {
        // Read the @Profile annotation attributes
        MultiValueMap<String, Object> attrs =
 metadata.getAllAnnotationAttributes(Profile.class.getName());
        if (attrs != null) {
            for (Object value : attrs.get("value")) {
                if (context.getEnvironment().acceptsProfiles(((String[]) value))) {
                    return true;
                }
            }
            return false;
        }
    }
    return true;
}
```

See the `@Conditional` javadocs for more detail.

Combining Java and XML configuration

Spring’s `@Configuration` class support does not aim to be a 100% complete replacement for Spring XML. Some facilities such as Spring XML namespaces remain an ideal way to configure the container. In cases where XML is convenient or necessary, you have a choice: either instantiate the container in an "XML-centric" way using, for example, `ClassPathXmlApplicationContext`, or in a "Java-centric" fashion using `AnnotationConfigApplicationContext` and the `@ImportResource` annotation to import XML as needed.

XML-centric use of @Configuration classes

It may be preferable to bootstrap the Spring container from XML and include `@Configuration` classes in an ad-hoc fashion. For example, in a large existing codebase that uses Spring XML, it will be easier to create `@Configuration` classes on an as-needed basis and include them from the existing XML files. Below you’ll find the options for using `@Configuration` classes in this kind of "XML-centric" situation.

Remember that `@Configuration` classes are ultimately just bean definitions in the container. In this example, we create a `@Configuration` class named `AppConfig` and include it within `system-test-config.xml` as a `<bean/>` definition. Because `<context:annotation-config/>` is switched

on, the container will recognize the `@Configuration` annotation, and process the `@Bean` methods declared in `AppConfig` properly.

```
@Configuration
public class AppConfig {

    @Autowired
    private DataSource dataSource;

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(dataSource);
    }

    @Bean
    public TransferService transferService() {
        return new TransferService(accountRepository());
    }

}
```

```
system-test-config.xml
<beans>
    <!-- enable processing of annotations such as @Autowired and @Configuration -->
    <context:annotation-config/>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>

    <bean class="com.acme.AppConfig"/>

    <bean class="org.springframework.jdbc.datasource.DriverManagerDataSource">
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>
</beans>
```

```
jdbc.properties
jdbc.url=jdbc:hsqldb:hsql://localhost/xdb
jdbc.username=sa
jdbc.password=
```

```
public static void main(String[] args) {
    ApplicationContext ctx = new ClassPathXmlApplicationContext("classpath:/com/acme/system-test-
config.xml");
    TransferService transferService = ctx.getBean(TransferService.class);
    // ...
}
```

> **Note**
>
> In `system-test-config.xml` above, the `AppConfig<bean/>` does not declare an `id` element. While it would be acceptable to do so, it is unnecessary given that no other bean will ever refer to it, and it is unlikely that it will be explicitly fetched from the container by name. Likewise with the `DataSource` bean - it is only ever autowired by type, so an explicit bean id is not strictly required.

Because `@Configuration` is meta-annotated with `@Component`, `@Configuration`-annotated classes are automatically candidates for component scanning. Using the same scenario as above, we can redefine `system-test-config.xml` to take advantage of component-scanning. Note that in this case, we don't need to explicitly declare `<context:annotation-config/>`, because `<context:component-scan/>` enables all the same functionality.

```
system-test-config.xml
<beans>
    <!-- picks up and registers AppConfig as a bean definition -->
    <context:component-scan base-package="com.acme"/>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>

    <bean class="org.springframework.jdbc.datasource.DriverManagerDataSource">
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>
</beans>
```

@Configuration class-centric use of XML with @ImportResource

In applications where `@Configuration` classes are the primary mechanism for configuring the container, it will still likely be necessary to use at least some XML. In these scenarios, simply use `@ImportResource` and define only as much XML as is needed. Doing so achieves a "Java-centric" approach to configuring the container and keeps XML to a bare minimum.

```
@Configuration
@ImportResource("classpath:/com/acme/properties-config.xml")
public class AppConfig {

    @Value("${jdbc.url}")
    private String url;

    @Value("${jdbc.username}")
    private String username;

    @Value("${jdbc.password}")
    private String password;

    @Bean
    public DataSource dataSource() {
        return new DriverManagerDataSource(url, username, password);
    }

}
```

```
properties-config.xml
<beans>
    <context:property-placeholder location="classpath:/com/acme/jdbc.properties"/>
</beans>
```

```
jdbc.properties
jdbc.url=jdbc:hsqldb:hsql://localhost/xdb
jdbc.username=sa
jdbc.password=
```

```
public static void main(String[] args) {
    ApplicationContext ctx = new AnnotationConfigApplicationContext(AppConfig.class);
    TransferService transferService = ctx.getBean(TransferService.class);
    // ...
}
```

5.13 Environment abstraction

The `Environment` is an abstraction integrated in the container that models two key aspects of the application environment: *profiles* and *properties*.

A *profile* is a named, logical group of bean definitions to be registered with the container only if the given profile is active. Beans may be assigned to a profile whether defined in XML or via annotations. The role

of the `Environment` object with relation to profiles is in determining which profiles (if any) are currently active, and which profiles (if any) should be active by default.

Properties play an important role in almost all applications, and may originate from a variety of sources: properties files, JVM system properties, system environment variables, JNDI, servlet context parameters, ad-hoc Properties objects, Maps, and so on. The role of the `Environment` object with relation to properties is to provide the user with a convenient service interface for configuring property sources and resolving properties from them.

Bean definition profiles

Bean definition profiles is a mechanism in the core container that allows for registration of different beans in different environments. The word *environment* can mean different things to different users and this feature can help with many use cases, including:

- working against an in-memory datasource in development vs looking up that same datasource from JNDI when in QA or production
- registering monitoring infrastructure only when deploying an application into a performance environment
- registering customized implementations of beans for customer A vs. customer B deployments

Let's consider the first use case in a practical application that requires a `DataSource`. In a test environment, the configuration may look like this:

```
@Bean
public DataSource dataSource() {
    return new EmbeddedDatabaseBuilder()
        .setType(EmbeddedDatabaseType.HSQL)
        .addScript("my-schema.sql")
        .addScript("my-test-data.sql")
        .build();
}
```

Let's now consider how this application will be deployed into a QA or production environment, assuming that the datasource for the application will be registered with the production application server's JNDI directory. Our `dataSource` bean now looks like this:

```
@Bean
public DataSource dataSource() throws Exception {
    Context ctx = new InitialContext();
    return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
}
```

The problem is how to switch between using these two variations based on the current environment. Over time, Spring users have devised a number of ways to get this done, usually relying on a combination of system environment variables and XML `<import/>` statements containing `${placeholder}` tokens that resolve to the correct configuration file path depending on the value of an environment variable. Bean definition profiles is a core container feature that provides a solution to this problem.

If we generalize the example use case above of environment-specific bean definitions, we end up with the need to register certain bean definitions in certain contexts, while not in others. You could say that you want to register a certain profile of bean definitions in situation A, and a different profile in situation B. Let's first see how we can update our configuration to reflect this need.

@Profile

The `@Profile` annotation allows to indicate that a component is eligible for registration when one or more specified profiles are active. Using our example above, we can rewrite the *dataSource* configuration as follows:

```
@Configuration
@Profile("dev")
public class StandaloneDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .addScript("classpath:com/bank/config/sql/test-data.sql")
            .build();
    }
}
```

```
@Configuration
@Profile("production")
public class JndiDataConfig {

    @Bean
    public DataSource dataSource() throws Exception {
        Context ctx = new InitialContext();
        return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
    }
}
```

`@Profile` can be used as a meta-annotation, for the purpose of composing custom stereotype annotations. The following example defines a `@Production` custom annotation that can be used as a drop-in replacement of `@Profile("production")`:

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
@Profile("production")
public @interface Production {
}
```

`@Profile` can also be specified at method-level to include only one particular bean of a configuration class:

```
@Configuration
public class AppConfig {

    @Bean
    @Profile("dev")
    public DataSource devDataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .addScript("classpath:com/bank/config/sql/test-data.sql")
            .build();
    }

    @Bean
    @Profile("production")
    public DataSource productionDataSource() throws Exception {
        Context ctx = new InitialContext();
        return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
    }
}
```

> **Tip**
>
> If a `@Configuration` class is marked with `@Profile`, all of the `@Bean` methods and `@Import` annotations associated with that class will be bypassed unless one or more of the specified profiles are active. If a `@Component` or `@Configuration` class is marked with `@Profile({"p1", "p2"})`, that class will not be registered/ processed unless profiles *p1* and/or *p2* have been activated. If a given profile is prefixed with the NOT operator (`!`), the annotated element will be registered if the profile is **not** active. e.g., for `@Profile({"p1", "!p2"})`, registration will occur if profile *p1* is active or if profile *p2* is not active.

XML Bean definition profiles

The XML counterpart is an update of the `beans` element that accepts a `profile` attribute. Our sample configuration above can be rewritten in two XML files as follows:

```
<beans profile="dev"
    xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/jdbc"
    xsi:schemaLocation="...">

    <jdbc:embedded-database id="dataSource">
        <jdbc:script location="classpath:com/bank/config/sql/schema.sql"/>
        <jdbc:script location="classpath:com/bank/config/sql/test-data.sql"/>
    </jdbc:embedded-database>
</beans>
```

```
<beans profile="production"
    xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jee="http://www.springframework.org/schema/jee"
    xsi:schemaLocation="...">

    <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource"/>
</beans>
```

It is also possible to avoid that split and nest `<beans/>` elements within the same file:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/jdbc"
    xmlns:jee="http://www.springframework.org/schema/jee"
    xsi:schemaLocation="...">

    <!-- other bean definitions -->

    <beans profile="dev">
        <jdbc:embedded-database id="dataSource">
            <jdbc:script location="classpath:com/bank/config/sql/schema.sql"/>
            <jdbc:script location="classpath:com/bank/config/sql/test-data.sql"/>
        </jdbc:embedded-database>
    </beans>

    <beans profile="production">
        <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource"/>
    </beans>
</beans>
```

The `spring-bean.xsd` has been constrained to allow such elements only as the last ones in the file. This should help provide flexibility without incurring clutter in the XML files.

Enabling a profile

Now that we have updated our configuration, we still need to instruct which profile is active. If we started our sample application right now, we would see a `NoSuchBeanDefinitionException` thrown, because the container could not find the Spring bean named `dataSource`.

Activating a profile can be done in several ways, but the most straightforward is to do it programmatically against the `ApplicationContext` API:

```
AnnotationConfigApplicationContext ctx = new AnnotationConfigApplicationContext();
ctx.getEnvironment().setActiveProfiles("dev");
ctx.register(SomeConfig.class, StandaloneDataConfig.class, JndiDataConfig.class);
ctx.refresh();
```

In addition, profiles may also be activated declaratively through the `spring.profiles.active` property which may be specified through system environment variables, JVM system properties, servlet context parameters in `web.xml` or even as an entry in JNDI (see the section called “PropertySource Abstraction”).

Note that profiles are not an "either-or" proposition; it is possible to activate multiple profiles at once. Programmatically, simply provide multiple profile names to the `setActiveProfiles()` method, which accepts `String...` varargs:

```
ctx.getEnvironment().setActiveProfiles("profile1", "profile2");
```

Declaratively, `spring.profiles.active` may accept a comma-separated list of profile names:

```
-Dspring.profiles.active="profile1,profile2"
```

Default profile

The *default* profile represents the profile that is enabled by default. Consider the following:

```
@Configuration
@Profile("default")
public class DefaultDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .build();
    }
}
```

If no profile is active, the `dataSource` above will be created; this can be seen as a way to provide a *default* definition for one or more beans. If any profile is enabled, the *default* profile will not apply.

The name of that default profile can be changed using `setDefaultProfiles` on the `Environment` or declaratively using the `spring.profiles.default` property.

PropertySource Abstraction

Spring’s Environment abstraction provides search operations over a configurable hierarchy of property sources. To explain fully, consider the following:

```
ApplicationContext ctx = new GenericApplicationContext();
Environment env = ctx.getEnvironment();
boolean containsFoo = env.containsProperty("foo");
System.out.println("Does my environment contain the 'foo' property? " + containsFoo);
```

In the snippet above, we see a high-level way of asking Spring whether the `foo` property is defined for the current environment. To answer this question, the `Environment` object performs a search over a set of `PropertySource` objects. A `PropertySource` is a simple abstraction over any source of key-value pairs, and Spring's `StandardEnvironment` is configured with two PropertySource objects — one representing the set of JVM system properties (*a la* `System.getProperties()`) and one representing the set of system environment variables (*a la* `System.getenv()`).

> **Note**
>
> These default property sources are present for `StandardEnvironment`, for use in standalone applications. `StandardServletEnvironment` is populated with additional default property sources including servlet config and servlet context parameters. `StandardPortletEnvironment` similarly has access to portlet config and portlet context parameters as property sources. Both can optionally enable a `JndiPropertySource`. See Javadoc for details.

Concretely, when using the `StandardEnvironment`, the call to `env.containsProperty("foo")` will return true if a `foo` system property or `foo` environment variable is present at runtime.

> **Tip**
>
> The search performed is hierarchical. By default, system properties have precedence over environment variables, so if the `foo` property happens to be set in both places during a call to `env.getProperty("foo")`, the system property value will *win* and be returned preferentially over the environment variable.

Most importantly, the entire mechanism is configurable. Perhaps you have a custom source of properties that you'd like to integrate into this search. No problem — simply implement and instantiate your own `PropertySource` and add it to the set of `PropertySources` for the current `Environment`:

```
ConfigurableApplicationContext ctx = new GenericApplicationContext();
MutablePropertySources sources = ctx.getEnvironment().getPropertySources();
sources.addFirst(new MyPropertySource());
```

In the code above, `MyPropertySource` has been added with highest precedence in the search. If it contains a `foo` property, it will be detected and returned ahead of any `foo` property in any other `PropertySource`. The `MutablePropertySources` API exposes a number of methods that allow for precise manipulation of the set of property sources.

@PropertySource

The `@PropertySource` annotation provides a convenient and declarative mechanism for adding a `PropertySource` to Spring's `Environment`.

Given a file "app.properties" containing the key/value pair `testbean.name=myTestBean`, the following `@Configuration` class uses `@PropertySource` in such a way that a call to `testBean.getName()` will return "myTestBean".

```
@Configuration
@PropertySource("classpath:/com/myco/app.properties")
public class AppConfig {
    @Autowired
    Environment env;

    @Bean
    public TestBean testBean() {
        TestBean testBean = new TestBean();
        testBean.setName(env.getProperty("testbean.name"));
        return testBean;
    }
}
```

Any `${...}` placeholders present in a `@PropertySource` resource location will be resolved against the set of property sources already registered against the environment. For example:

```
@Configuration
@PropertySource("classpath:/com/${my.placeholder:default/path}/app.properties")
public class AppConfig {
    @Autowired
    Environment env;

    @Bean
    public TestBean testBean() {
        TestBean testBean = new TestBean();
        testBean.setName(env.getProperty("testbean.name"));
        return testBean;
    }
}
```

Assuming that "my.placeholder" is present in one of the property sources already registered, e.g. system properties or environment variables, the placeholder will be resolved to the corresponding value. If not, then "default/path" will be used as a default. If no default is specified and a property cannot be resolved, an `IllegalArgumentException` will be thrown.

Placeholder resolution in statements

Historically, the value of placeholders in elements could be resolved only against JVM system properties or environment variables. No longer is this the case. Because the Environment abstraction is integrated throughout the container, it's easy to route resolution of placeholders through it. This means that you may configure the resolution process in any way you like: change the precedence of searching through system properties and environment variables, or remove them entirely; add your own property sources to the mix as appropriate.

Concretely, the following statement works regardless of where the `customer` property is defined, as long as it is available in the `Environment`:

```
<beans>
    <import resource="com/bank/service/${customer}-config.xml"/>
</beans>
```

5.14 Registering a LoadTimeWeaver

The `LoadTimeWeaver` is used by Spring to dynamically transform classes as they are loaded into the Java virtual machine (JVM).

To enable load-time weaving add the `@EnableLoadTimeWeaving` to one of your `@Configuration` classes:

```
@Configuration
@EnableLoadTimeWeaving
public class AppConfig {

}
```

Alternatively for XML configuration use the `context:load-time-weaver` element:

```
<beans>
    <context:load-time-weaver/>
</beans>
```

Once configured for the `ApplicationContext`. Any bean within that `ApplicationContext` may implement `LoadTimeWeaverAware`, thereby receiving a reference to the load-time weaver instance. This is particularly useful in combination with Spring's JPA support where load-time weaving may be necessary for JPA class transformation. Consult the `LocalContainerEntityManagerFactoryBean` javadocs for more detail. For more on AspectJ load-time weaving, see the section called "Load-time weaving with AspectJ in the Spring Framework".

5.15 Additional Capabilities of the ApplicationContext

As was discussed in the chapter introduction, the `org.springframework.beans.factory` package provides basic functionality for managing and manipulating beans, including in a programmatic way. The `org.springframework.context` package adds the `ApplicationContext` interface, which extends the `BeanFactory` interface, in addition to extending other interfaces to provide additional functionality in a more *application framework-oriented style*. Many people use the `ApplicationContext` in a completely declarative fashion, not even creating it programmatically, but instead relying on support classes such as `ContextLoader` to automatically instantiate an `ApplicationContext` as part of the normal startup process of a Java EE web application.

To enhance `BeanFactory` functionality in a more framework-oriented style the context package also provides the following functionality:

- *Access to messages in i18n-style*, through the `MessageSource` interface.
- *Access to resources*, such as URLs and files, through the `ResourceLoader` interface.
- *Event publication* to beans implementing the `ApplicationListener` interface, through the use of the `ApplicationEventPublisher` interface.
- *Loading of multiple (hierarchical) contexts*, allowing each to be focused on one particular layer, such as the web layer of an application, through the `HierarchicalBeanFactory` interface.

Internationalization using MessageSource

The `ApplicationContext` interface extends an interface called `MessageSource`, and therefore provides internationalization (i18n) functionality. Spring also provides the interface `HierarchicalMessageSource`, which can resolve messages hierarchically. Together these interfaces provide the foundation upon which Spring effects message resolution. The methods defined on these interfaces include:

- `String getMessage(String code, Object[] args, String default, Locale loc)`: The basic method used to retrieve a message from the `MessageSource`. When no message is found for the specified locale, the default message is used. Any arguments passed in become replacement values, using the `MessageFormat` functionality provided by the standard library.

- `String getMessage(String code, Object[] args, Locale loc)`: Essentially the same as the previous method, but with one difference: no default message can be specified; if the message cannot be found, a `NoSuchMessageException` is thrown.
- `String getMessage(MessageSourceResolvable resolvable, Locale locale)`: All properties used in the preceding methods are also wrapped in a class named `MessageSourceResolvable`, which you can use with this method.

When an `ApplicationContext` is loaded, it automatically searches for a `MessageSource` bean defined in the context. The bean must have the name `messageSource`. If such a bean is found, all calls to the preceding methods are delegated to the message source. If no message source is found, the `ApplicationContext` attempts to find a parent containing a bean with the same name. If it does, it uses that bean as the `MessageSource`. If the `ApplicationContext` cannot find any source for messages, an empty `DelegatingMessageSource` is instantiated in order to be able to accept calls to the methods defined above.

Spring provides two `MessageSource` implementations, `ResourceBundleMessageSource` and `StaticMessageSource`. Both implement `HierarchicalMessageSource` in order to do nested messaging. The `StaticMessageSource` is rarely used but provides programmatic ways to add messages to the source. The `ResourceBundleMessageSource` is shown in the following example:

```
<beans>
    <bean id="messageSource"
            class="org.springframework.context.support.ResourceBundleMessageSource">
        <property name="basenames">
            <list>
                <value>format</value>
                <value>exceptions</value>
                <value>windows</value>
            </list>
        </property>
    </bean>
</beans>
```

In the example it is assumed you have three resource bundles defined in your classpath called `format`, `exceptions` and `windows`. Any request to resolve a message will be handled in the JDK standard way of resolving messages through ResourceBundles. For the purposes of the example, assume the contents of two of the above resource bundle files are…

```
# in format.properties
message=Alligators rock!
```

```
# in exceptions.properties
argument.required=The {0} argument is required.
```

A program to execute the `MessageSource` functionality is shown in the next example. Remember that all `ApplicationContext` implementations are also `MessageSource` implementations and so can be cast to the `MessageSource` interface.

```
public static void main(String[] args) {
    MessageSource resources = new ClassPathXmlApplicationContext("beans.xml");
    String message = resources.getMessage("message", null, "Default", null);
    System.out.println(message);
}
```

The resulting output from the above program will be…

```
Alligators rock!
```

So to summarize, the `MessageSource` is defined in a file called `beans.xml`, which exists at the root of your classpath. The `messageSource` bean definition refers to a number of resource bundles through its `basenames` property. The three files that are passed in the list to the `basenames` property exist as files at the root of your classpath and are called `format.properties`, `exceptions.properties`, and `windows.properties` respectively.

The next example shows arguments passed to the message lookup; these arguments will be converted into Strings and inserted into placeholders in the lookup message.

```
<beans>

    <!-- this MessageSource is being used in a web application -->
    <bean id="messageSource" class="org.springframework.context.support.ResourceBundleMessageSource">
        <property name="basename" value="exceptions"/>
    </bean>

    <!-- lets inject the above MessageSource into this POJO -->
    <bean id="example" class="com.foo.Example">
        <property name="messages" ref="messageSource"/>
    </bean>

</beans>
```

```
public class Example {

    private MessageSource messages;

    public void setMessages(MessageSource messages) {
        this.messages = messages;
    }

    public void execute() {
        String message = this.messages.getMessage("argument.required",
            new Object [] {"userDao"}, "Required", null);
        System.out.println(message);
    }

}
```

The resulting output from the invocation of the `execute()` method will be…

```
The userDao argument is required.
```

With regard to internationalization (i18n), Spring's various `MessageResource` implementations follow the same locale resolution and fallback rules as the standard JDK `ResourceBundle`. In short, and continuing with the example `messageSource` defined previously, if you want to resolve messages against the British (`en-GB`) locale, you would create files called `format_en_GB.properties`, `exceptions_en_GB.properties`, and `windows_en_GB.properties` respectively.

Typically, locale resolution is managed by the surrounding environment of the application. In this example, the locale against which (British) messages will be resolved is specified manually.

```
# in exceptions_en_GB.properties
argument.required=Ebagum lad, the {0} argument is required, I say, required.
```

```
public static void main(final String[] args) {
    MessageSource resources = new ClassPathXmlApplicationContext("beans.xml");
    String message = resources.getMessage("argument.required",
        new Object [] {"userDao"}, "Required", Locale.UK);
    System.out.println(message);
}
```

The resulting output from the running of the above program will be…

```
Ebagum lad, the userDao argument is required, I say, required.
```

You can also use the `MessageSourceAware` interface to acquire a reference to any `MessageSource` that has been defined. Any bean that is defined in an `ApplicationContext` that implements the `MessageSourceAware` interface is injected with the application context's `MessageSource` when the bean is created and configured.

> **Note**
>
> *As an alternative to `ResourceBundleMessageSource`, Spring provides a `ReloadableResourceBundleMessageSource` class. This variant supports the same bundle file format but is more flexible than the standard JDK based `ResourceBundleMessageSource` implementation.* In particular, it allows for reading files from any Spring resource location (not just from the classpath) and supports hot reloading of bundle property files (while efficiently caching them in between). Check out the `ReloadableResourceBundleMessageSource` javadocs for details.

Standard and Custom Events

Event handling in the `ApplicationContext` is provided through the `ApplicationEvent` class and `ApplicationListener` interface. If a bean that implements the `ApplicationListener` interface is deployed into the context, every time an `ApplicationEvent` gets published to the `ApplicationContext`, that bean is notified. Essentially, this is the standard *Observer* design pattern. Spring provides the following standard events:

Table 5.7. Built-in Events

Event	Explanation
`ContextRefreshedEvent`	Published when the `ApplicationContext` is initialized or refreshed, for example, using the `refresh()` method on the `ConfigurableApplicationContext` interface. "Initialized" here means that all beans are loaded, post-processor beans are detected and activated, singletons are pre-instantiated, and the `ApplicationContext` object is ready for use. As long as the context has not been closed, a refresh can be triggered multiple times, provided that the chosen `ApplicationContext` actually supports such "hot" refreshes. For example, `XmlWebApplicationContext` supports hot refreshes, but `GenericApplicationContext` does not.
`ContextStartedEvent`	Published when the `ApplicationContext` is started, using the `start()` method on the `ConfigurableApplicationContext` interface. "Started" here means that all `Lifecycle` beans receive an explicit start

Event	Explanation
	signal. Typically this signal is used to restart beans after an explicit stop, but it may also be used to start components that have not been configured for autostart , for example, components that have not already started on initialization.
`ContextStoppedEvent`	Published when the `ApplicationContext` is stopped, using the `stop()` method on the `ConfigurableApplicationContext` interface. "Stopped" here means that all `Lifecycle` beans receive an explicit stop signal. A stopped context may be restarted through a `start()` call.
`ContextClosedEvent`	Published when the `ApplicationContext` is closed, using the `close()` method on the `ConfigurableApplicationContext` interface. "Closed" here means that all singleton beans are destroyed. A closed context reaches its end of life; it cannot be refreshed or restarted.
`RequestHandledEvent`	A web-specific event telling all beans that an HTTP request has been serviced. This event is published *after* the request is complete. This event is only applicable to web applications using Spring's `DispatcherServlet`.

You can also create and publish your own custom events. This example demonstrates a simple class that extends Spring's `ApplicationEvent` base class:

```
public class BlackListEvent extends ApplicationEvent {

    private final String address;
    private final String test;

    public BlackListEvent(Object source, String address, String test) {
        super(source);
        this.address = address;
        this.test = test;
    }

    // accessor and other methods...

}
```

To publish a custom `ApplicationEvent`, call the `publishEvent()` method on an `ApplicationEventPublisher`. Typically this is done by creating a class that implements `ApplicationEventPublisherAware` and registering it as a Spring bean. The following example demonstrates such a class:

```
public class EmailService implements ApplicationEventPublisherAware {

    private List<String> blackList;
    private ApplicationEventPublisher publisher;

    public void setBlackList(List<String> blackList) {
        this.blackList = blackList;
    }

    public void setApplicationEventPublisher(ApplicationEventPublisher publisher) {
        this.publisher = publisher;
    }

    public void sendEmail(String address, String text) {
        if (blackList.contains(address)) {
            BlackListEvent event = new BlackListEvent(this, address, text);
            publisher.publishEvent(event);
            return;
        }
        // send email...
    }

}
```

At configuration time, the Spring container will detect that `EmailService` implements `ApplicationEventPublisherAware` and will automatically call `setApplicationEventPublisher()`. In reality, the parameter passed in will be the Spring container itself; you're simply interacting with the application context via its `ApplicationEventPublisher` interface.

To receive the custom `ApplicationEvent`, create a class that implements `ApplicationListener` and register it as a Spring bean. The following example demonstrates such a class:

```
public class BlackListNotifier implements ApplicationListener<BlackListEvent> {

    private String notificationAddress;

    public void setNotificationAddress(String notificationAddress) {
        this.notificationAddress = notificationAddress;
    }

    public void onApplicationEvent(BlackListEvent event) {
        // notify appropriate parties via notificationAddress...
    }

}
```

Notice that `ApplicationListener` is generically parameterized with the type of your custom event, `BlackListEvent`. This means that the `onApplicationEvent()` method can remain type-safe, avoiding any need for downcasting. You may register as many event listeners as you wish, but note that by default event listeners receive events synchronously. This means the `publishEvent()` method blocks until all listeners have finished processing the event. One advantage of this synchronous and single-threaded approach is that when a listener receives an event, it operates inside the transaction context of the publisher if a transaction context is available. If another strategy for event publication becomes necessary, refer to the JavaDoc for Spring's `ApplicationEventMulticaster` interface.

The following example shows the bean definitions used to register and configure each of the classes above:

```
<bean id="emailService" class="example.EmailService">
    <property name="blackList">
        <list>
            <value>known.spammer@example.org</value>
            <value>known.hacker@example.org</value>
            <value>john.doe@example.org</value>
        </list>
    </property>
</bean>

<bean id="blackListNotifier" class="example.BlackListNotifier">
    <property name="notificationAddress" value="blacklist@example.org"/>
</bean>
```

Putting it all together, when the `sendEmail()` method of the `emailService` bean is called, if there are any emails that should be blacklisted, a custom event of type `BlackListEvent` is published. The `blackListNotifier` bean is registered as an `ApplicationListener` and thus receives the `BlackListEvent`, at which point it can notify appropriate parties.

> **Note**
>
> Spring's eventing mechanism is designed for simple communication between Spring beans within the same application context. However, for more sophisticated enterprise integration needs, the separately-maintained Spring Integration project provides complete support for building lightweight, pattern-oriented, event-driven architectures that build upon the well-known Spring programming model.

Convenient access to low-level resources

For optimal usage and understanding of application contexts, users should generally familiarize themselves with Spring's `Resource` abstraction, as described in the chapter Chapter 6, *Resources*.

An application context is a `ResourceLoader`, which can be used to load `Resources`. A `Resource` is essentially a more feature rich version of the JDK class `java.net.URL`, in fact, the implementations of the `Resource` wrap an instance of `java.net.URL` where appropriate. A `Resource` can obtain low-level resources from almost any location in a transparent fashion, including from the classpath, a filesystem location, anywhere describable with a standard URL, and some other variations. If the resource location string is a simple path without any special prefixes, where those resources come from is specific and appropriate to the actual application context type.

You can configure a bean deployed into the application context to implement the special callback interface, `ResourceLoaderAware`, to be automatically called back at initialization time with the application context itself passed in as the `ResourceLoader`. You can also expose properties of type `Resource`, to be used to access static resources; they will be injected into it like any other properties. You can specify those `Resource` properties as simple String paths, and rely on a special JavaBean `PropertyEditor` that is automatically registered by the context, to convert those text strings to actual `Resource` objects when the bean is deployed.

The location path or paths supplied to an `ApplicationContext` constructor are actually resource strings, and in simple form are treated appropriately to the specific context implementation. `ClassPathXmlApplicationContext` treats a simple location path as a classpath location. You can also use location paths (resource strings) with special prefixes to force loading of definitions from the classpath or a URL, regardless of the actual context type.

Convenient ApplicationContext instantiation for web applications

You can create `ApplicationContext` instances declaratively by using, for example, a `ContextLoader`. Of course you can also create `ApplicationContext` instances programmatically by using one of the `ApplicationContext` implementations.

You can register an `ApplicationContext` using the `ContextLoaderListener` as follows:

```
<context-param>
    <param-name>contextConfigLocation</param-name>
    <param-value>/WEB-INF/daoContext.xml /WEB-INF/applicationContext.xml</param-value>
</context-param>

<listener>
    <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
</listener>
```

The listener inspects the `contextConfigLocation` parameter. If the parameter does not exist, the listener uses `/WEB-INF/applicationContext.xml` as a default. When the parameter *does* exist, the listener separates the String by using predefined delimiters (comma, semicolon and whitespace) and uses the values as locations where application contexts will be searched. Ant-style path patterns are supported as well. Examples are `/WEB-INF/*Context.xml` for all files with names ending with "Context.xml", residing in the "WEB-INF" directory, and `/WEB-INF/**/*Context.xml`, for all such files in any subdirectory of "WEB-INF".

Deploying a Spring ApplicationContext as a Java EE RAR file

It is possible to deploy a Spring ApplicationContext as a RAR file, encapsulating the context and all of its required bean classes and library JARs in a Java EE RAR deployment unit. This is the equivalent of bootstrapping a standalone ApplicationContext, just hosted in Java EE environment, being able to access the Java EE servers facilities. RAR deployment is more natural alternative to scenario of deploying a headless WAR file, in effect, a WAR file without any HTTP entry points that is used only for bootstrapping a Spring ApplicationContext in a Java EE environment.

RAR deployment is ideal for application contexts that do not need HTTP entry points but rather consist only of message endpoints and scheduled jobs. Beans in such a context can use application server resources such as the JTA transaction manager and JNDI-bound JDBC DataSources and JMS ConnectionFactory instances, and may also register with the platform's JMX server - all through Spring's standard transaction management and JNDI and JMX support facilities. Application components can also interact with the application server's JCA WorkManager through Spring's `TaskExecutor` abstraction.

Check out the JavaDoc of the `SpringContextResourceAdapter` class for the configuration details involved in RAR deployment.

For a simple deployment of a Spring ApplicationContext as a Java EE RAR file: package all application classes into a RAR file, which is a standard JAR file with a different file extension. Add all required library JARs into the root of the RAR archive. Add a "META-INF/ra.xml" deployment descriptor (as shown in `SpringContextResourceAdapter`'s JavaDoc) and the corresponding Spring XML bean definition file(s) (typically "META-INF/applicationContext.xml"), and drop the resulting RAR file into your application server's deployment directory.

> **Note**
>
> Such RAR deployment units are usually self-contained; they do not expose components to the outside world, not even to other modules of the same application. Interaction with a RAR-based ApplicationContext usually occurs through JMS destinations that it shares with other modules. A RAR-based ApplicationContext may also, for example, schedule some jobs, reacting to new files in the file system (or the like). If it needs to allow synchronous access from the outside, it could for example export RMI endpoints, which of course may be used by other application modules on the same machine.

5.16 The BeanFactory

The `BeanFactory` provides the underlying basis for Spring's IoC functionality but it is only used directly in integration with other third-party frameworks and is now largely historical in nature for most users of Spring. The `BeanFactory` and related interfaces, such as `BeanFactoryAware`, `InitializingBean`, `DisposableBean`, are still present in Spring for the purposes of backward compatibility with the large number of third-party frameworks that integrate with Spring. Often third-party components that can not use more modern equivalents such as `@PostConstruct` or `@PreDestroy` in order to remain compatible with JDK 1.4 or to avoid a dependency on JSR-250.

This section provides additional background into the differences between the `BeanFactory` and `ApplicationContext` and how one might access the IoC container directly through a classic singleton lookup.

BeanFactory or ApplicationContext?

Use an `ApplicationContext` unless you have a good reason for not doing so.

Because the `ApplicationContext` includes all functionality of the `BeanFactory`, it is generally recommended over the `BeanFactory`, except for a few situations such as in an `Applet` where memory consumption might be critical and a few extra kilobytes might make a difference. However, for most typical enterprise applications and systems, the `ApplicationContext` is what you will want to use. Spring makes *heavy* use of the `BeanPostProcessor` extension point (to effect proxying and so on). If you use only a plain `BeanFactory`, a fair amount of support such as transactions and AOP will not take effect, at least not without some extra steps on your part. This situation could be confusing because nothing is actually wrong with the configuration.

The following table lists features provided by the `BeanFactory` and `ApplicationContext` interfaces and implementations.

Table 5.8. Feature Matrix

Feature	**`BeanFactory`**	**`ApplicationContext`**
Bean instantiation/wiring	Yes	Yes
Automatic `BeanPostProcessor` registration	No	Yes
Automatic `BeanFactoryPostProcessor` registration	No	Yes

Feature	`BeanFactory`	`ApplicationContext`
Convenient `MessageSource` access (for i18n)	No	Yes
`ApplicationEvent` publication	No	Yes

To explicitly register a bean post-processor with a `BeanFactory` implementation, you must write code like this:

```
ConfigurableBeanFactory factory = new XmlBeanFactory(...);

// now register any needed BeanPostProcessor instances
MyBeanPostProcessor postProcessor = new MyBeanPostProcessor();
factory.addBeanPostProcessor(postProcessor);

// now start using the factory
```

To explicitly register a `BeanFactoryPostProcessor` when using a `BeanFactory` implementation, you must write code like this:

```
XmlBeanFactory factory = new XmlBeanFactory(new FileSystemResource("beans.xml"));

// bring in some property values from a Properties file
PropertyPlaceholderConfigurer cfg = new PropertyPlaceholderConfigurer();
cfg.setLocation(new FileSystemResource("jdbc.properties"));

// now actually do the replacement
cfg.postProcessBeanFactory(factory);
```

In both cases, the explicit registration step is inconvenient, which is one reason why the various `ApplicationContext` implementations are preferred above plain `BeanFactory` implementations in the vast majority of Spring-backed applications, especially when using `BeanFactoryPostProcessors` and `BeanPostProcessors`. These mechanisms implement important functionality such as property placeholder replacement and AOP.

Glue code and the evil singleton

It is best to write most application code in a dependency-injection (DI) style, where that code is served out of a Spring IoC container, has its own dependencies supplied by the container when it is created, and is completely unaware of the container. However, for the small glue layers of code that are sometimes needed to tie other code together, you sometimes need a singleton (or quasi-singleton) style access to a Spring IoC container. For example, third-party code may try to construct new objects directly (`Class.forName()` style), without the ability to get these objects out of a Spring IoC container.If the object constructed by the third-party code is a small stub or proxy, which then uses a singleton style access to a Spring IoC container to get a real object to delegate to, then inversion of control has still been achieved for the majority of the code (the object coming out of the container). Thus most code is still unaware of the container or how it is accessed, and remains decoupled from other code, with all ensuing benefits. EJBs may also use this stub/proxy approach to delegate to a plain Java implementation object, retrieved from a Spring IoC container. While the Spring IoC container itself ideally does not have to be a singleton, it may be unrealistic in terms of memory usage or initialization times (when using beans in the Spring IoC container such as a Hibernate `SessionFactory`) for each bean to use its own, non-singleton Spring IoC container.

Looking up the application context in a service locator style is sometimes the only option for accessing shared Spring-managed components, such as in an EJB 2.1 environment, or when you want to share

a single ApplicationContext as a parent to WebApplicationContexts across WAR files. In this case you should look into using the utility class `ContextSingletonBeanFactoryLocator` locator that is described in this Spring team blog entry.

6. Resources

6.1 Introduction

Java's standard `java.net.URL` class and standard handlers for various URL prefixes unfortunately are not quite adequate enough for all access to low-level resources. For example, there is no standardized URL implementation that may be used to access a resource that needs to be obtained from the classpath, or relative to a `ServletContext`. While it is possible to register new handlers for specialized URL prefixes (similar to existing handlers for prefixes such as `http:`), this is generally quite complicated, and the URL interface still lacks some desirable functionality, such as a method to check for the existence of the resource being pointed to.

6.2 The Resource interface

Spring's `Resource` interface is meant to be a more capable interface for abstracting access to low-level resources.

```
public interface Resource extends InputStreamSource {

    boolean exists();

    boolean isOpen();

    URL getURL() throws IOException;

    File getFile() throws IOException;

    Resource createRelative(String relativePath) throws IOException;

    String getFilename();

    String getDescription();

}
```

```
public interface InputStreamSource {

    InputStream getInputStream() throws IOException;

}
```

Some of the most important methods from the `Resource` interface are:

- `getInputStream()`: locates and opens the resource, returning an `InputStream` for reading from the resource. It is expected that each invocation returns a fresh `InputStream`. It is the responsibility of the caller to close the stream.
- `exists()`: returns a `boolean` indicating whether this resource actually exists in physical form.
- `isOpen()`: returns a `boolean` indicating whether this resource represents a handle with an open stream. If `true`, the `InputStream` cannot be read multiple times, and must be read once only and then closed to avoid resource leaks. Will be `false` for all usual resource implementations, with the exception of `InputStreamResource`.
- `getDescription()`: returns a description for this resource, to be used for error output when working with the resource. This is often the fully qualified file name or the actual URL of the resource.

Other methods allow you to obtain an actual URL or `File` object representing the resource (if the underlying implementation is compatible, and supports that functionality).

The `Resource` abstraction is used extensively in Spring itself, as an argument type in many method signatures when a resource is needed. Other methods in some Spring APIs (such as the constructors to various `ApplicationContext` implementations), take a `String` which in unadorned or simple form is used to create a `Resource` appropriate to that context implementation, or via special prefixes on the `String` path, allow the caller to specify that a specific `Resource` implementation must be created and used.

While the `Resource` interface is used a lot with Spring and by Spring, it's actually very useful to use as a general utility class by itself in your own code, for access to resources, even when your code doesn't know or care about any other parts of Spring. While this couples your code to Spring, it really only couples it to this small set of utility classes, which are serving as a more capable replacement for `URL`, and can be considered equivalent to any other library you would use for this purpose.

It is important to note that the `Resource` abstraction does not replace functionality: it wraps it where possible. For example, a `UrlResource` wraps a URL, and uses the wrapped `URL` to do its work.

6.3 Built-in Resource implementations

There are a number of `Resource` implementations that come supplied straight out of the box in Spring:

UrlResource

The `UrlResource` wraps a `java.net.URL`, and may be used to access any object that is normally accessible via a URL, such as files, an HTTP target, an FTP target, etc. All URLs have a standardized `String` representation, such that appropriate standardized prefixes are used to indicate one URL type from another. This includes `file:` for accessing filesystem paths, `http:` for accessing resources via the HTTP protocol, `ftp:` for accessing resources via FTP, etc.

A `UrlResource` is created by Java code explicitly using the `UrlResource` constructor, but will often be created implicitly when you call an API method which takes a `String` argument which is meant to represent a path. For the latter case, a JavaBeans `PropertyEditor` will ultimately decide which type of `Resource` to create. If the path string contains a few well-known (to it, that is) prefixes such as `classpath:`, it will create an appropriate specialized `Resource` for that prefix. However, if it doesn't recognize the prefix, it will assume the this is just a standard URL string, and will create a `UrlResource`.

ClassPathResource

This class represents a resource which should be obtained from the classpath. This uses either the thread context class loader, a given class loader, or a given class for loading resources.

This `Resource` implementation supports resolution as `java.io.File` if the class path resource resides in the file system, but not for classpath resources which reside in a jar and have not been expanded (by the servlet engine, or whatever the environment is) to the filesystem. To address this the various `Resource` implementations always support resolution as a `java.net.URL`.

A `ClassPathResource` is created by Java code explicitly using the `ClassPathResource` constructor, but will often be created implicitly when you call an API method which takes a `String` argument which is meant to represent a path. For the latter case, a JavaBeans `PropertyEditor` will recognize the special prefix `classpath:` on the string path, and create a `ClassPathResource` in that case.

FileSystemResource

This is a `Resource` implementation for `java.io.File` handles. It obviously supports resolution as a `File`, and as a `URL`.

ServletContextResource

This is a `Resource` implementation for `ServletContext` resources, interpreting relative paths within the relevant web application's root directory.

This always supports stream access and URL access, but only allows `java.io.File` access when the web application archive is expanded and the resource is physically on the filesystem. Whether or not it's expanded and on the filesystem like this, or accessed directly from the JAR or somewhere else like a DB (it's conceivable) is actually dependent on the Servlet container.

InputStreamResource

A `Resource` implementation for a given `InputStream`. This should only be used if no specific `Resource` implementation is applicable. In particular, prefer `ByteArrayResource` or any of the file-based `Resource` implementations where possible.

In contrast to other `Resource` implementations, this is a descriptor for an *already* opened resource - therefore returning `true` from `isOpen()`. Do not use it if you need to keep the resource descriptor somewhere, or if you need to read a stream multiple times.

ByteArrayResource

This is a `Resource` implementation for a given byte array. It creates a `ByteArrayInputStream` for the given byte array.

It's useful for loading content from any given byte array, without having to resort to a single-use `InputStreamResource`.

6.4 The ResourceLoader

The `ResourceLoader` interface is meant to be implemented by objects that can return (i.e. load) `Resource` instances.

```
public interface ResourceLoader {

    Resource getResource(String location);

}
```

All application contexts implement the `ResourceLoader` interface, and therefore all application contexts may be used to obtain `Resource` instances.

When you call `getResource()` on a specific application context, and the location path specified doesn't have a specific prefix, you will get back a `Resource` type that is appropriate to that particular application context. For example, assume the following snippet of code was executed against a `ClassPathXmlApplicationContext` instance:

```
Resource template = ctx.getResource("some/resource/path/myTemplate.txt");
```

What would be returned would be a `ClassPathResource`; if the same method was executed against a `FileSystemXmlApplicationContext` instance, you'd get back a `FileSystemResource`. For a `WebApplicationContext`, you'd get back a `ServletContextResource`, and so on.

As such, you can load resources in a fashion appropriate to the particular application context.

On the other hand, you may also force `ClassPathResource` to be used, regardless of the application context type, by specifying the special `classpath:` prefix:

```
Resource template = ctx.getResource("classpath:some/resource/path/myTemplate.txt");
```

Similarly, one can force a `UrlResource` to be used by specifying any of the standard `java.net.URL` prefixes:

```
Resource template = ctx.getResource("file:///some/resource/path/myTemplate.txt");
```

```
Resource template = ctx.getResource("http://myhost.com/resource/path/myTemplate.txt");
```

The following table summarizes the strategy for converting `Strings` to `Resources`:

Table 6.1. Resource strings

Prefix	Example	Explanation
classpath:	`classpath:com/myapp/config.xml`	Loaded from the classpath.
file:	`file:///data/config.xml`	Loaded as a `URL`, from the filesystem. [1]
http:	`http://myserver/logo.png`	Loaded as a `URL`.
(none)	`/data/config.xml`	Depends on the underlying `ApplicationContext`.

[1] But see also the section called "FileSystemResource caveats".

6.5 The ResourceLoaderAware interface

The `ResourceLoaderAware` interface is a special marker interface, identifying objects that expect to be provided with a `ResourceLoader` reference.

```
public interface ResourceLoaderAware {

    void setResourceLoader(ResourceLoader resourceLoader);
}
```

When a class implements `ResourceLoaderAware` and is deployed into an application context (as a Spring-managed bean), it is recognized as `ResourceLoaderAware` by the application context. The application context will then invoke the `setResourceLoader(ResourceLoader)`, supplying itself as the argument (remember, all application contexts in Spring implement the `ResourceLoader` interface).

Of course, since an `ApplicationContext` is a `ResourceLoader`, the bean could also implement the `ApplicationContextAware` interface and use the supplied application context directly to load resources, but in general, it's better to use the specialized `ResourceLoader` interface if that's all that's needed. The code would just be coupled to the resource loading interface, which can be considered a utility interface, and not the whole Spring `ApplicationContext` interface.

As of Spring 2.5, you can rely upon autowiring of the `ResourceLoader` as an alternative to implementing the `ResourceLoaderAware` interface. The "traditional" `constructor` and `byType` autowiring modes (as described in the section called “Autowiring collaborators”) are now capable of providing a dependency of type `ResourceLoader` for either a constructor argument or setter method parameter respectively. For more flexibility (including the ability to autowire fields and multiple parameter methods), consider using the new annotation-based autowiring features. In that case, the `ResourceLoader` will be autowired into a field, constructor argument, or method parameter that is expecting the `ResourceLoader` type as long as the field, constructor, or method in question carries the `@Autowired` annotation. For more information, see the section called “@Autowired”.

6.6 Resources as dependencies

If the bean itself is going to determine and supply the resource path through some sort of dynamic process, it probably makes sense for the bean to use the `ResourceLoader` interface to load resources. Consider as an example the loading of a template of some sort, where the specific resource that is needed depends on the role of the user. If the resources are static, it makes sense to eliminate the use of the `ResourceLoader` interface completely, and just have the bean expose the `Resource` properties it needs, and expect that they will be injected into it.

What makes it trivial to then inject these properties, is that all application contexts register and use a special JavaBeans `PropertyEditor` which can convert `String` paths to `Resource` objects. So if `myBean` has a template property of type `Resource`, it can be configured with a simple string for that resource, as follows:

```
<bean id="myBean" class="...">
    <property name="template" value="some/resource/path/myTemplate.txt"/>
</bean>
```

Note that the resource path has no prefix, so because the application context itself is going to be used as the `ResourceLoader`, the resource itself will be loaded via a `ClassPathResource`, `FileSystemResource`, or `ServletContextResource` (as appropriate) depending on the exact type of the context.

If there is a need to force a specific `Resource` type to be used, then a prefix may be used. The following two examples show how to force a `ClassPathResource` and a `UrlResource` (the latter being used to access a filesystem file).

```
<property name="template" value="classpath:some/resource/path/myTemplate.txt">
```

```
<property name="template" value="file:///some/resource/path/myTemplate.txt"/>
```

6.7 Application contexts and Resource paths

Constructing application contexts

An application context constructor (for a specific application context type) generally takes a string or array of strings as the location path(s) of the resource(s) such as XML files that make up the definition of the context.

When such a location path doesn’t have a prefix, the specific `Resource` type built from that path and used to load the bean definitions, depends on and is appropriate to the specific application context. For example, if you create a `ClassPathXmlApplicationContext` as follows:

```
ApplicationContext ctx = new ClassPathXmlApplicationContext("conf/appContext.xml");
```

The bean definitions will be loaded from the classpath, as a `ClassPathResource` will be used. But if you create a `FileSystemXmlApplicationContext` as follows:

```
ApplicationContext ctx =
    new FileSystemXmlApplicationContext("conf/appContext.xml");
```

The bean definition will be loaded from a filesystem location, in this case relative to the current working directory.

Note that the use of the special classpath prefix or a standard URL prefix on the location path will override the default type of `Resource` created to load the definition. So this `FileSystemXmlApplicationContext`...

```
ApplicationContext ctx =
    new FileSystemXmlApplicationContext("classpath:conf/appContext.xml");
```

i. will actually load its bean definitions from the classpath. However, it is still a `FileSystemXmlApplicationContext`. If it is subsequently used as a `ResourceLoader`, any unprefixed paths will still be treated as filesystem paths.

Constructing ClassPathXmlApplicationContext instances - shortcuts

The `ClassPathXmlApplicationContext` exposes a number of constructors to enable convenient instantiation. The basic idea is that one supplies merely a string array containing just the filenames of the XML files themselves (without the leading path information), and one *also* supplies a `Class`; the `ClassPathXmlApplicationContext` will derive the path information from the supplied class.

An example will hopefully make this clear. Consider a directory layout that looks like this:

```
com/
  foo/
 services.xml
 daos.xml
    MessengerService.class
```

A `ClassPathXmlApplicationContext` instance composed of the beans defined in the `'services.xml'` and `'daos.xml'` could be instantiated like so...

```
ApplicationContext ctx = new ClassPathXmlApplicationContext(
    new String[] {"services.xml", "daos.xml"}, MessengerService.class);
```

Please do consult the `ClassPathXmlApplicationContext` javadocs for details on the various constructors.

Wildcards in application context constructor resource paths

The resource paths in application context constructor values may be a simple path (as shown above) which has a one-to-one mapping to a target Resource, or alternately may contain the special "classpath*:" prefix and/or internal Ant-style regular expressions (matched using Spring's `PathMatcher` utility). Both of the latter are effectively wildcards

One use for this mechanism is when doing component-style application assembly. All components can *publish* context definition fragments to a well-known location path, and when the final application context is created using the same path prefixed via `classpath*:`, all component fragments will be picked up automatically.

Note that this wildcarding is specific to use of resource paths in application context constructors (or when using the `PathMatcher` utility class hierarchy directly), and is resolved at construction time. It has nothing to do with the `Resource` type itself. It's not possible to use the `classpath*:` prefix to construct an actual `Resource`, as a resource points to just one resource at a time.

Ant-style Patterns

When the path location contains an Ant-style pattern, for example:

```
/WEB-INF/-context.xml
  com/mycompany//applicationContext.xml
  file:C:/some/path/-context.xml
  classpath:com/mycompany//applicationContext.xml
```

i. the resolver follows a more complex but defined procedure to try to resolve the wildcard. It produces a Resource for the path up to the last non-wildcard segment and obtains a URL from it. If this URL is not a "jar:" URL or container-specific variant (e.g. " `zip:`" in WebLogic, " `wsjar`" in WebSphere, etc.), then a `java.io.File` is obtained from it and used to resolve the wildcard by traversing the filesystem. In the case of a jar URL, the resolver either gets a `java.net.JarURLConnection` from it or manually parses the jar URL and then traverses the contents of the jar file to resolve the wildcards.

Implications on portability

If the specified path is already a file URL (either explicitly, or implicitly because the base `ResourceLoader` is a filesystem one, then wildcarding is guaranteed to work in a completely portable fashion.

If the specified path is a classpath location, then the resolver must obtain the last non-wildcard path segment URL via a `Classloader.getResource()` call. Since this is just a node of the path (not the file at the end) it is actually undefined (in the `ClassLoader` javadocs) exactly what sort of a URL is returned in this case. In practice, it is always a `java.io.File` representing the directory, where the classpath resource resolves to a filesystem location, or a jar URL of some sort, where the classpath resource resolves to a jar location. Still, there is a portability concern on this operation.

If a jar URL is obtained for the last non-wildcard segment, the resolver must be able to get a `java.net.JarURLConnection` from it, or manually parse the jar URL, to be able to walk the contents of the jar, and resolve the wildcard. This will work in most environments, but will fail in others, and it is strongly recommended that the wildcard resolution of resources coming from jars be thoroughly tested in your specific environment before you rely on it.

The Classpath*: portability classpath*: prefix

When constructing an XML-based application context, a location string may use the special `classpath*:` prefix:

```
ApplicationContext ctx =
    new ClassPathXmlApplicationContext("classpath*:conf/appContext.xml");
```

This special prefix specifies that all classpath resources that match the given name must be obtained (internally, this essentially happens via a `ClassLoader.getResources(...)` call), and then merged to form the final application context definition.

> **Note**
>
> The wildcard classpath relies on the `getResources()` method of the underlying classloader. As most application servers nowadays supply their own classloader implementation, the

> behavior might differ especially when dealing with jar files. A simple test to check if `classpath*` works is to use the classloader to load a file from within a jar on the classpath: `getClass().getClassLoader().getResources("<someFileInsideTheJar>")`. Try this test with files that have the same name but are placed inside two different locations. In case an inappropriate result is returned, check the application server documentation for settings that might affect the classloader behavior.

The "`classpath*:`" prefix can also be combined with a `PathMatcher` pattern in the rest of the location path, for example "`classpath*:META-INF/*-beans.xml`". In this case, the resolution strategy is fairly simple: a ClassLoader.getResources() call is used on the last non-wildcard path segment to get all the matching resources in the class loader hierarchy, and then off each resource the same PathMatcher resolution strategy described above is used for the wildcard subpath.

Other notes relating to wildcards

Please note that "`classpath*:`" when combined with Ant-style patterns will only work reliably with at least one root directory before the pattern starts, unless the actual target files reside in the file system. This means that a pattern like "`classpath*:*.xml`" will not retrieve files from the root of jar files but rather only from the root of expanded directories. This originates from a limitation in the JDK's `ClassLoader.getResources()` method which only returns file system locations for a passed-in empty string (indicating potential roots to search).

Ant-style patterns with "`classpath:`" resources are not guaranteed to find matching resources if the root package to search is available in multiple class path locations. This is because a resource such as

```
com/mycompany/package1/service-context.xml
```

may be in only one location, but when a path such as

```
classpath:com/mycompany/**/service-context.xml
```

is used to try to resolve it, the resolver will work off the (first) URL returned by `getResource("com/mycompany");`. If this base package node exists in multiple classloader locations, the actual end resource may not be underneath. Therefore, preferably, use "`classpath*:`" with the same Ant-style pattern in such a case, which will search all class path locations that contain the root package.

FileSystemResource caveats

A `FileSystemResource` that is not attached to a `FileSystemApplicationContext` (that is, a `FileSystemApplicationContext` is not the actual `ResourceLoader`) will treat absolute vs. relative paths as you would expect. Relative paths are relative to the current working directory, while absolute paths are relative to the root of the filesystem.

For backwards compatibility (historical) reasons however, this changes when the `FileSystemApplicationContext` is the `ResourceLoader`. The `FileSystemApplicationContext` simply forces all attached `FileSystemResource` instances to treat all location paths as relative, whether they start with a leading slash or not. In practice, this means the following are equivalent:

```
ApplicationContext ctx =
    new FileSystemXmlApplicationContext("conf/context.xml");
```

```
ApplicationContext ctx =
    new FileSystemXmlApplicationContext("/conf/context.xml");
```

As are the following: (Even though it would make sense for them to be different, as one case is relative and the other absolute.)

```
FileSystemXmlApplicationContext ctx = ...;
ctx.getResource("some/resource/path/myTemplate.txt");
```

```
FileSystemXmlApplicationContext ctx = ...;
ctx.getResource("/some/resource/path/myTemplate.txt");
```

In practice, if true absolute filesystem paths are needed, it is better to forgo the use of absolute paths with `FileSystemResource` / `FileSystemXmlApplicationContext`, and just force the use of a `UrlResource`, by using the `file:` URL prefix.

```
// actual context type doesn't matter, the Resource will always be UrlResource
ctx.getResource("file:///some/resource/path/myTemplate.txt");
```

```
// force this FileSystemXmlApplicationContext to load its definition via a UrlResource
ApplicationContext ctx =
    new FileSystemXmlApplicationContext("file:///conf/context.xml");
```

7. Validation, Data Binding, and Type Conversion

7.1 Introduction

JSR-303/JSR-349 Bean Validation

Spring Framework 4.0 supports Bean Validation 1.0 (JSR-303) and Bean Validation 1.1 (JSR-349) in terms of setup support, also adapting it to Spring's `Validator` interface.

An application can choose to enable Bean Validation once globally, as described in Section 7.8, "Spring Validation", and use it exclusively for all validation needs.

An application can also register additional Spring `Validator` instances per `DataBinder` instance, as described in the section called "Configuring a DataBinder". This may be useful for plugging in validation logic without the use of annotations.

There are pros and cons for considering validation as business logic, and Spring offers a design for validation (and data binding) that does not exclude either one of them. Specifically validation should not be tied to the web tier, should be easy to localize and it should be possible to plug in any validator available. Considering the above, Spring has come up with a `Validator` interface that is both basic ands eminently usable in every layer of an application.

Data binding is useful for allowing user input to be dynamically bound to the domain model of an application (or whatever objects you use to process user input). Spring provides the so-called `DataBinder` to do exactly that. The `Validator` and the `DataBinder` make up the `validation` package, which is primarily used in but not limited to the MVC framework.

The `BeanWrapper` is a fundamental concept in the Spring Framework and is used in a lot of places. However, you probably will not have the need to use the `BeanWrapper` directly. Because this is reference documentation however, we felt that some explanation might be in order. We will explain the `BeanWrapper` in this chapter since, if you were going to use it at all, you would most likely do so when trying to bind data to objects.

Spring's DataBinder and the lower-level BeanWrapper both use PropertyEditors to parse and format property values. The `PropertyEditor` concept is part of the JavaBeans specification, and is also explained in this chapter. Spring 3 introduces a "core.convert" package that provides a general type conversion facility, as well as a higher-level "format" package for formatting UI field values. These new packages may be used as simpler alternatives to PropertyEditors, and will also be discussed in this chapter.

7.2 Validation using Spring's Validator interface

Spring features a `Validator` interface that you can use to validate objects. The `Validator` interface works using an `Errors` object so that while validating, validators can report validation failures to the `Errors` object.

Let's consider a small data object:

```
public class Person {

    private String name;
    private int age;

    // the usual getters and setters...
}
```

We're going to provide validation behavior for the `Person` class by implementing the following two methods of the `org.springframework.validation.Validator` interface:

- `supports(Class)` - Can this `Validator` validate instances of the supplied `Class`?
- `validate(Object, org.springframework.validation.Errors)` - validates the given object and in case of validation errors, registers those with the given `Errors` object

Implementing a `Validator` is fairly straightforward, especially when you know of the `ValidationUtils` helper class that the Spring Framework also provides.

```
public class PersonValidator implements Validator {

    /*
     * This Validator validates *just* Person instances
     */
    public boolean supports(Class clazz) {
        return Person.class.equals(clazz);
    }

    public void validate(Object obj, Errors e) {
        ValidationUtils.rejectIfEmpty(e, "name", "name.empty");
        Person p = (Person) obj;
        if (p.getAge() < 0) {
            e.rejectValue("age", "negativevalue");
        } else if (p.getAge() > 110) {
            e.rejectValue("age", "too.darn.old");
        }
    }
}
```

As you can see, the `static rejectIfEmpty(..)` method on the `ValidationUtils` class is used to reject the `'name'` property if it is `null` or the empty string. Have a look at the `ValidationUtils` javadocs to see what functionality it provides besides the example shown previously.

While it is certainly possible to implement a single `Validator` class to validate each of the nested objects in a rich object, it may be better to encapsulate the validation logic for each nested class of object in its own `Validator` implementation. A simple example of a *'rich'* object would be a `Customer` that is composed of two `String` properties (a first and second name) and a complex `Address` object. `Address` objects may be used independently of `Customer` objects, and so a distinct `AddressValidator` has been implemented. If you want your `CustomerValidator` to reuse the logic contained within the `AddressValidator` class without resorting to copy-and-paste, you can dependency-inject or instantiate an `AddressValidator` within your `CustomerValidator`, and use it like so:

```
public class CustomerValidator implements Validator {

    private final Validator addressValidator;

    public CustomerValidator(Validator addressValidator) {
        if (addressValidator == null) {
            throw new IllegalArgumentException("The supplied [Validator] is " +
                "required and must not be null.");
        }
        if (!addressValidator.supports(Address.class)) {
            throw new IllegalArgumentException("The supplied [Validator] must " +
                support the validation of [Address] instances.");
        }
        this.addressValidator = addressValidator;
    }

    /**
     * This Validator validates Customer instances, and any subclasses of Customer too
     */
    public boolean supports(Class clazz) {
        return Customer.class.isAssignableFrom(clazz);
    }

    public void validate(Object target, Errors errors) {
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "firstName", "field.required");
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "surname", "field.required");
        Customer customer = (Customer) target;
        try {
            errors.pushNestedPath("address");
            ValidationUtils.invokeValidator(this.addressValidator, customer.getAddress(), errors);
        } finally {
            errors.popNestedPath();
        }
    }
}
```

Validation errors are reported to the `Errors` object passed to the validator. In case of Spring Web MVC you can use `<spring:bind/>` tag to inspect the error messages, but of course you can also inspect the errors object yourself. More information about the methods it offers can be found in the javadocs.

7.3 Resolving codes to error messages

We've talked about databinding and validation. Outputting messages corresponding to validation errors is the last thing we need to discuss. In the example we've shown above, we rejected the `name` and the `age` field. If we're going to output the error messages by using a `MessageSource`, we will do so using the error code we've given when rejecting the field (*name* and *age* in this case). When you call (either directly, or indirectly, using for example the `ValidationUtils` class) `rejectValue` or one of the other `reject` methods from the `Errors` interface, the underlying implementation will not only register the code you've passed in, but also a number of additional error codes. What error codes it registers is determined by the `MessageCodesResolver` that is used. By default, the `DefaultMessageCodesResolver` is used, which for example not only registers a message with the code you gave, but also messages that include the field name you passed to the reject method. So in case you reject a field using `rejectValue("age", "too.darn.old")`, apart from the `too.darn.old` code, Spring will also register `too.darn.old.age` and `too.darn.old.age.int` (so the first will include the field name and the second will include the type of the field); this is done as a convenience to aid developers in targeting error messages and suchlike.

More information on the `MessageCodesResolver` and the default strategy can be found online in the javadocs of `MessageCodesResolver` and `DefaultMessageCodesResolver`, respectively.

7.4 Bean manipulation and the BeanWrapper

The `org.springframework.beans` package adheres to the JavaBeans standard provided by Oracle. A JavaBean is simply a class with a default no-argument constructor, which follows a naming convention where (by way of an example) a property named `bingoMadness` would have a setter method `setBingoMadness(..)` and a getter method `getBingoMadness()`. For more information about JavaBeans and the specification, please refer to Oracle's website (javabeans).

One quite important class in the beans package is the `BeanWrapper` interface and its corresponding implementation (`BeanWrapperImpl`). As quoted from the javadocs, the `BeanWrapper` offers functionality to set and get property values (individually or in bulk), get property descriptors, and to query properties to determine if they are readable or writable. Also, the `BeanWrapper` offers support for nested properties, enabling the setting of properties on sub-properties to an unlimited depth. Then, the `BeanWrapper` supports the ability to add standard JavaBeans `PropertyChangeListeners` and `VetoableChangeListeners`, without the need for supporting code in the target class. Last but not least, the `BeanWrapper` provides support for the setting of indexed properties. The `BeanWrapper` usually isn't used by application code directly, but by the `DataBinder` and the `BeanFactory`.

The way the `BeanWrapper` works is partly indicated by its name: *it wraps a bean* to perform actions on that bean, like setting and retrieving properties.

Setting and getting basic and nested properties

Setting and getting properties is done using the `setPropertyValue(s)` and `getPropertyValue(s)` methods that both come with a couple of overloaded variants. They're all described in more detail in the javadocs Spring comes with. What's important to know is that there are a couple of conventions for indicating properties of an object. A couple of examples:

Table 7.1. Examples of properties

Expression	Explanation
`name`	Indicates the property `name` corresponding to the methods `getName()` or `isName()` and `setName(..)`
`account.name`	Indicates the nested property `name` of the property `account` corresponding e.g. to the methods `getAccount().setName()` or `getAccount().getName()`
`account[2]`	Indicates the *third* element of the indexed property `account`. Indexed properties can be of type `array`, `list` or other *naturally ordered* collection
`account[COMPANYNAME]`	Indicates the value of the map entry indexed by the key *COMPANYNAME* of the Map property `account`

Below you'll find some examples of working with the `BeanWrapper` to get and set properties.

(This next section is not vitally important to you if you're not planning to work with the `BeanWrapper` directly. If you're just using the `DataBinder` and the `BeanFactory` and their out-of-the-box implementation, you should skip ahead to the section about `PropertyEditors`.)

Consider the following two classes:

```
public class Company {

    private String name;
    private Employee managingDirector;

    public String getName() {
        return this.name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public Employee getManagingDirector() {
        return this.managingDirector;
    }

    public void setManagingDirector(Employee managingDirector) {
        this.managingDirector = managingDirector;
    }
}
```

```
public class Employee {

    private String name;

    private float salary;

    public String getName() {
        return this.name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public float getSalary() {
        return salary;
    }

    public void setSalary(float salary) {
        this.salary = salary;
    }
}
```

The following code snippets show some examples of how to retrieve and manipulate some of the properties of instantiated `Companies` and `Employees`:

```
BeanWrapper company = BeanWrapperImpl(new Company());
// setting the company name..
company.setPropertyValue("name", "Some Company Inc.");
// ... can also be done like this:
PropertyValue value = new PropertyValue("name", "Some Company Inc.");
company.setPropertyValue(value);

// ok, let's create the director and tie it to the company:
BeanWrapper jim = BeanWrapperImpl(new Employee());
jim.setPropertyValue("name", "Jim Stravinsky");
company.setPropertyValue("managingDirector", jim.getWrappedInstance());

// retrieving the salary of the managingDirector through the company
Float salary = (Float) company.getPropertyValue("managingDirector.salary");
```

Built-in PropertyEditor implementations

Spring uses the concept of `PropertyEditors` to effect the conversion between an `Object` and a `String`. If you think about it, it sometimes might be handy to be able to represent properties in a different way than the object itself. For example, a `Date` can be represented in a human readable way (as the `String` '`2007-14-09`'), while we're still able to convert the human readable form back to the original date (or even better: convert any date entered in a human readable form, back to `Date` objects). This behavior can be achieved by *registering custom editors*, of type `java.beans.PropertyEditor`. Registering custom editors on a `BeanWrapper` or alternately in a specific IoC container as mentioned in the previous chapter, gives it the knowledge of how to convert properties to the desired type. Read more about `PropertyEditors` in the javadocs of the `java.beans` package provided by Oracle.

A couple of examples where property editing is used in Spring:

- *setting properties on beans* is done using `PropertyEditors`. When mentioning `java.lang.String` as the value of a property of some bean you're declaring in XML file, Spring will (if the setter of the corresponding property has a `Class`-parameter) use the `ClassEditor` to try to resolve the parameter to a `Class` object.
- *parsing HTTP request parameters* in Spring's MVC framework is done using all kinds of `PropertyEditors` that you can manually bind in all subclasses of the `CommandController`.

Spring has a number of built-in `PropertyEditors` to make life easy. Each of those is listed below and they are all located in the `org.springframework.beans.propertyeditors` package. Most, but not all (as indicated below), are registered by default by `BeanWrapperImpl`. Where the property editor is configurable in some fashion, you can of course still register your own variant to override the default one:

Table 7.2. Built-in PropertyEditors

Class	Explanation
`ByteArrayPropertyEditor`	Editor for byte arrays. Strings will simply be converted to their corresponding byte representations. Registered by default by `BeanWrapperImpl`.
`ClassEditor`	Parses Strings representing classes to actual classes and the other way around. When a class is not found, an `IllegalArgumentException` is thrown. Registered by default by `BeanWrapperImpl`.

Class	Explanation
`CustomBooleanEditor`	Customizable property editor for `Boolean` properties. Registered by default by `BeanWrapperImpl`, but, can be overridden by registering custom instance of it as custom editor.
`CustomCollectionEditor`	Property editor for Collections, converting any source `Collection` to a given target `Collection` type.
`CustomDateEditor`	Customizable property editor for java.util.Date, supporting a custom DateFormat. NOT registered by default. Must be user registered as needed with appropriate format.
`CustomNumberEditor`	Customizable property editor for any Number subclass like `Integer`, `Long`, `Float`, `Double`. Registered by default by `BeanWrapperImpl`, but can be overridden by registering custom instance of it as a custom editor.
`FileEditor`	Capable of resolving Strings to `java.io.File` objects. Registered by default by `BeanWrapperImpl`.
`InputStreamEditor`	One-way property editor, capable of taking a text string and producing (via an intermediate `ResourceEditor` and `Resource`) an `InputStream`, so `InputStream` properties may be directly set as Strings. Note that the default usage will not close the `InputStream` for you! Registered by default by `BeanWrapperImpl`.
`LocaleEditor`	Capable of resolving Strings to `Locale` objects and vice versa (the String format is *[country]*[variant], which is the same thing the toString() method of Locale provides). Registered by default by `BeanWrapperImpl`.
`PatternEditor`	Capable of resolving Strings to `java.util.regex.Pattern` objects and vice versa.
`PropertiesEditor`	Capable of converting Strings (formatted using the format as defined in the javadocs of the `java.util.Properties` class) to `Properties` objects. Registered by default by `BeanWrapperImpl`.

Class	Explanation
`StringTrimmerEditor`	Property editor that trims Strings. Optionally allows transforming an empty string into a `null` value. NOT registered by default; must be user registered as needed.
`URLEditor`	Capable of resolving a String representation of a URL to an actual `URL` object. Registered by default by `BeanWrapperImpl`.

Spring uses the `java.beans.PropertyEditorManager` to set the search path for property editors that might be needed. The search path also includes `sun.bean.editors`, which includes `PropertyEditor` implementations for types such as `Font`, `Color`, and most of the primitive types. Note also that the standard JavaBeans infrastructure will automatically discover `PropertyEditor` classes (without you having to register them explicitly) if they are in the same package as the class they handle, and have the same name as that class, with `'Editor'` appended; for example, one could have the following class and package structure, which would be sufficient for the `FooEditor` class to be recognized and used as the `PropertyEditor` for `Foo`-typed properties.

```
com
  chank
    pop
      Foo
      FooEditor // the PropertyEditor for the Foo class
```

Note that you can also use the standard `BeanInfo` JavaBeans mechanism here as well (described in not-amazing-detail here). Find below an example of using the `BeanInfo` mechanism for explicitly registering one or more `PropertyEditor` instances with the properties of an associated class.

```
com
  chank
    pop
      Foo
      FooBeanInfo // the BeanInfo for the Foo class
```

Here is the Java source code for the referenced `FooBeanInfo` class. This would associate a `CustomNumberEditor` with the `age` property of the `Foo` class.

```
public class FooBeanInfo extends SimpleBeanInfo {

    public PropertyDescriptor[] getPropertyDescriptors() {
        try {
            final PropertyEditor numberPE = new CustomNumberEditor(Integer.class, true);
            PropertyDescriptor ageDescriptor = new PropertyDescriptor("age", Foo.class) {
                public PropertyEditor createPropertyEditor(Object bean) {
                    return numberPE;
                };
            };
            return new PropertyDescriptor[] { ageDescriptor };
        }
        catch (IntrospectionException ex) {
            throw new Error(ex.toString());
        }
    }
}
```

Registering additional custom PropertyEditors

When setting bean properties as a string value, a Spring IoC container ultimately uses standard JavaBeans `PropertyEditors` to convert these Strings to the complex type of the property. Spring pre-registers a number of custom `PropertyEditors` (for example, to convert a classname expressed as a string into a real `Class` object). Additionally, Java's standard JavaBeans `PropertyEditor` lookup mechanism allows a `PropertyEditor` for a class simply to be named appropriately and placed in the same package as the class it provides support for, to be found automatically.

If there is a need to register other custom `PropertyEditors`, there are several mechanisms available. The most manual approach, which is not normally convenient or recommended, is to simply use the `registerCustomEditor()` method of the `ConfigurableBeanFactory` interface, assuming you have a `BeanFactory` reference. Another, slightly more convenient, mechanism is to use a special bean factory post-processor called `CustomEditorConfigurer`. Although bean factory post-processors can be used with `BeanFactory` implementations, the `CustomEditorConfigurer` has a nested property setup, so it is strongly recommended that it is used with the `ApplicationContext`, where it may be deployed in similar fashion to any other bean, and automatically detected and applied.

Note that all bean factories and application contexts automatically use a number of built-in property editors, through their use of something called a `BeanWrapper` to handle property conversions. The standard property editors that the `BeanWrapper` registers are listed in the previous section. Additionally, `ApplicationContexts` also override or add an additional number of editors to handle resource lookups in a manner appropriate to the specific application context type.

Standard JavaBeans `PropertyEditor` instances are used to convert property values expressed as strings to the actual complex type of the property. `CustomEditorConfigurer`, a bean factory post-processor, may be used to conveniently add support for additional `PropertyEditor` instances to an `ApplicationContext`.

Consider a user class `ExoticType`, and another class `DependsOnExoticType` which needs `ExoticType` set as a property:

```
package example;

public class ExoticType {

    private String name;

    public ExoticType(String name) {
        this.name = name;
    }
}

public class DependsOnExoticType {

    private ExoticType type;

    public void setType(ExoticType type) {
        this.type = type;
    }
}
```

When things are properly set up, we want to be able to assign the type property as a string, which a `PropertyEditor` will behind the scenes convert into an actual `ExoticType` instance:

```
<bean id="sample" class="example.DependsOnExoticType">
    <property name="type" value="aNameForExoticType"/>
</bean>
```

The `PropertyEditor` implementation could look similar to this:

```
// converts string representation to ExoticType object
package example;

public class ExoticTypeEditor extends PropertyEditorSupport {

    public void setAsText(String text) {
        setValue(new ExoticType(text.toUpperCase()));
    }
}
```

Finally, we use `CustomEditorConfigurer` to register the new `PropertyEditor` with the `ApplicationContext`, which will then be able to use it as needed:

```
<bean class="org.springframework.beans.factory.config.CustomEditorConfigurer">
    <property name="customEditors">
        <map>
            <entry key="example.ExoticType" value="example.ExoticTypeEditor"/>
        </map>
    </property>
</bean>
```

Using PropertyEditorRegistrars

Another mechanism for registering property editors with the Spring container is to create and use a `PropertyEditorRegistrar`. This interface is particularly useful when you need to use the same set of property editors in several different situations: write a corresponding registrar and reuse that in each case. `PropertyEditorRegistrars` work in conjunction with an interface called `PropertyEditorRegistry`, an interface that is implemented by the Spring `BeanWrapper` (and `DataBinder`). `PropertyEditorRegistrars` are particularly convenient when used in conjunction with the `CustomEditorConfigurer` (introduced here), which exposes a property called `setPropertyEditorRegistrars(..)`: `PropertyEditorRegistrars` added to a `CustomEditorConfigurer` in this fashion can easily be shared with `DataBinder` and Spring MVC `Controllers`. Furthermore, it avoids the need for synchronization on custom editors: a `PropertyEditorRegistrar` is expected to create fresh `PropertyEditor` instances for each bean creation attempt.

Using a `PropertyEditorRegistrar` is perhaps best illustrated with an example. First off, you need to create your own `PropertyEditorRegistrar` implementation:

```
package com.foo.editors.spring;

public final class CustomPropertyEditorRegistrar implements PropertyEditorRegistrar {

    public void registerCustomEditors(PropertyEditorRegistry registry) {

        // it is expected that new PropertyEditor instances are created
        registry.registerCustomEditor(ExoticType.class, new ExoticTypeEditor());

        // you could register as many custom property editors as are required here...
    }
}
```

See also the `org.springframework.beans.support.ResourceEditorRegistrar` for an example `PropertyEditorRegistrar` implementation. Notice how in its implementation of the `registerCustomEditors(..)` method it creates new instances of each property editor.

Next we configure a `CustomEditorConfigurer` and inject an instance of our `CustomPropertyEditorRegistrar` into it:

```
<bean class="org.springframework.beans.factory.config.CustomEditorConfigurer">
    <property name="propertyEditorRegistrars">
        <list>
            <ref bean="customPropertyEditorRegistrar"/>
        </list>
    </property>
</bean>

<bean id="customPropertyEditorRegistrar"
    class="com.foo.editors.spring.CustomPropertyEditorRegistrar"/>
```

Finally, and in a bit of a departure from the focus of this chapter, for those of you using Spring's MVC web framework, using `PropertyEditorRegistrars` in conjunction with data-binding `Controllers` (such as `SimpleFormController`) can be very convenient. Find below an example of using a `PropertyEditorRegistrar` in the implementation of an `initBinder(..)` method:

```
public final class RegisterUserController extends SimpleFormController {

    private final PropertyEditorRegistrar customPropertyEditorRegistrar;

    public RegisterUserController(PropertyEditorRegistrar propertyEditorRegistrar) {
        this.customPropertyEditorRegistrar = propertyEditorRegistrar;
    }

    protected void initBinder(HttpServletRequest request,
            ServletRequestDataBinder binder) throws Exception {
        this.customPropertyEditorRegistrar.registerCustomEditors(binder);
    }

    // other methods to do with registering a User
}
```

This style of `PropertyEditor` registration can lead to concise code (the implementation of `initBinder(..)` is just one line long!), and allows common `PropertyEditor` registration code to be encapsulated in a class and then shared amongst as many `Controllers` as needed.

7.5 Spring Type Conversion

Spring 3 introduces a `core.convert` package that provides a general type conversion system. The system defines an SPI to implement type conversion logic, as well as an API to execute type conversions at runtime. Within a Spring container, this system can be used as an alternative to PropertyEditors to convert externalized bean property value strings to required property types. The public API may also be used anywhere in your application where type conversion is needed.

Converter SPI

The SPI to implement type conversion logic is simple and strongly typed:

```
package org.springframework.core.convert.converter;

public interface Converter<S, T> {

    T convert(S source);

}
```

To create your own converter, simply implement the interface above. Parameterize `S` as the type you are converting from, and `T` as the type you are converting to. Such a converter can also be applied transparently if a collection or array of `S` needs to be converted to an array or collection of `T`, provided that a delegating array/collection converter has been registered as well (which `DefaultConversionService` does by default).

For each call to `convert(S)`, the source argument is guaranteed to be NOT null. Your Converter may throw any unchecked exception if conversion fails; specifically, an `IllegalArgumentException` should be thrown to report an invalid source value. Take care to ensure that your `Converter` implementation is thread-safe.

Several converter implementations are provided in the `core.convert.support` package as a convenience. These include converters from Strings to Numbers and other common types. Consider `StringToInteger` as an example for a typical `Converter` implementation:

```
package org.springframework.core.convert.support;

final class StringToInteger implements Converter<String, Integer> {

    public Integer convert(String source) {
        return Integer.valueOf(source);
    }

}
```

ConverterFactory

When you need to centralize the conversion logic for an entire class hierarchy, for example, when converting from String to java.lang.Enum objects, implement `ConverterFactory`:

```
package org.springframework.core.convert.converter;

public interface ConverterFactory<S, R> {

    <T extends R> Converter<S, T> getConverter(Class<T> targetType);

}
```

Parameterize S to be the type you are converting from and R to be the base type defining the *range* of classes you can convert to. Then implement getConverter(Class<T>), where T is a subclass of R.

Consider the `StringToEnum` ConverterFactory as an example:

```
package org.springframework.core.convert.support;

final class StringToEnumConverterFactory implements ConverterFactory<String, Enum> {

    public <T extends Enum> Converter<String, T> getConverter(Class<T> targetType) {
        return new StringToEnumConverter(targetType);
    }

    private final class StringToEnumConverter<T extends Enum> implements Converter<String, T> {

        private Class<T> enumType;

        public StringToEnumConverter(Class<T> enumType) {
            this.enumType = enumType;
        }

        public T convert(String source) {
            return (T) Enum.valueOf(this.enumType, source.trim());
        }
    }
}
```

GenericConverter

When you require a sophisticated Converter implementation, consider the GenericConverter interface. With a more flexible but less strongly typed signature, a GenericConverter supports converting between

multiple source and target types. In addition, a GenericConverter makes available source and target field context you can use when implementing your conversion logic. Such context allows a type conversion to be driven by a field annotation, or generic information declared on a field signature.

```
package org.springframework.core.convert.converter;

public interface GenericConverter {

    public Set<ConvertiblePair> getConvertibleTypes();

    Object convert(Object source, TypeDescriptor sourceType, TypeDescriptor targetType);

}
```

To implement a GenericConverter, have getConvertibleTypes() return the supported source#target type pairs. Then implement convert(Object, TypeDescriptor, TypeDescriptor) to implement your conversion logic. The source TypeDescriptor provides access to the source field holding the value being converted. The target TypeDescriptor provides access to the target field where the converted value will be set.

A good example of a GenericConverter is a converter that converts between a Java Array and a Collection. Such an ArrayToCollectionConverter introspects the field that declares the target Collection type to resolve the Collection's element type. This allows each element in the source array to be converted to the Collection element type before the Collection is set on the target field.

> **Note**
>
> Because GenericConverter is a more complex SPI interface, only use it when you need it. Favor Converter or ConverterFactory for basic type conversion needs.

ConditionalGenericConverter

Sometimes you only want a Converter to execute if a specific condition holds true. For example, you might only want to execute a Converter if a specific annotation is present on the target field. Or you might only want to execute a Converter if a specific method, such as static valueOf method, is defined on the target class. ConditionalGenericConverter is an subinterface of GenericConverter that allows you to define such custom matching criteria:

```
public interface ConditionalGenericConverter extends GenericConverter {

    boolean matches(TypeDescriptor sourceType, TypeDescriptor targetType);

}
```

A good example of a ConditionalGenericConverter is an EntityConverter that converts between an persistent entity identifier and an entity reference. Such a EntityConverter might only match if the target entity type declares a static finder method e.g. findAccount(Long). You would perform such a finder method check in the implementation of matches(TypeDescriptor, TypeDescriptor).

ConversionService API

The ConversionService defines a unified API for executing type conversion logic at runtime. Converters are often executed behind this facade interface:

```
package org.springframework.core.convert;

public interface ConversionService {

    boolean canConvert(Class<?> sourceType, Class<?> targetType);

    <T> T convert(Object source, Class<T> targetType);

    boolean canConvert(TypeDescriptor sourceType, TypeDescriptor targetType);

    Object convert(Object source, TypeDescriptor sourceType, TypeDescriptor targetType);

}
```

Most ConversionService implementations also implement `ConverterRegistry`, which provides an SPI for registering converters. Internally, a ConversionService implementation delegates to its registered converters to carry out type conversion logic.

A robust ConversionService implementation is provided in the `core.convert.support` package. `GenericConversionService` is the general-purpose implementation suitable for use in most environments. `ConversionServiceFactory` provides a convenient factory for creating common ConversionService configurations.

Configuring a ConversionService

A ConversionService is a stateless object designed to be instantiated at application startup, then shared between multiple threads. In a Spring application, you typically configure a ConversionService instance per Spring container (or ApplicationContext). That ConversionService will be picked up by Spring and then used whenever a type conversion needs to be performed by the framework. You may also inject this ConversionService into any of your beans and invoke it directly.

> **Note**
>
> If no ConversionService is registered with Spring, the original PropertyEditor-based system is used.

To register a default ConversionService with Spring, add the following bean definition with id `conversionService`:

```
<bean id="conversionService"
    class="org.springframework.context.support.ConversionServiceFactoryBean"/>
```

A default ConversionService can convert between strings, numbers, enums, collections, maps, and other common types. To supplement or override the default converters with your own custom converter(s), set the `converters` property. Property values may implement either of the Converter, ConverterFactory, or GenericConverter interfaces.

```
<bean id="conversionService"
        class="org.springframework.context.support.ConversionServiceFactoryBean">
    <property name="converters">
        <set>
            <bean class="example.MyCustomConverter"/>
        </set>
    </property>
</bean>
```

It is also common to use a ConversionService within a Spring MVC application. See the section called “Configuring Formatting in Spring MVC” for details on use with `<mvc:annotation-driven/>`.

In certain situations you may wish to apply formatting during conversion. See the section called “FormatterRegistry SPI” for details on using `FormattingConversionServiceFactoryBean`.

Using a ConversionService programmatically

To work with a ConversionService instance programmatically, simply inject a reference to it like you would for any other bean:

```
@Service
public class MyService {

    @Autowired
    public MyService(ConversionService conversionService) {
        this.conversionService = conversionService;
    }

    public void doIt() {
        this.conversionService.convert(...)
    }
}
```

For most use cases, the `convert` method specifying the *targetType* can be used but it will not work with more complex types such as a collection of a parameterized element. If you want to convert a `List` of `Integer` to a `List` of `String` programmatically, for instance, you need to provide a formal definition of the source and target types.

Fortunately, `TypeDescriptor` provides various options to make that straightforward:

```
DefaultConversionService cs = new DefaultConversionService();

List<Integer> input = ....
cs.convert(input,
    TypeDescriptor.forObject(input), // List<Integer> type descriptor
    TypeDescriptor.collection(List.class, TypeDescriptor.valueOf(String.class)));
```

Note that `DefaultConversionService` registers converters automatically which are appropriate for most environments. This includes collection converters, scalar converters, and also basic `Object` to `String` converters. The same converters can be registered with any `ConverterRegistry` using the *static* `addDefaultConverters` method on the `DefaultConversionService` class.

Converters for value types will be reused for arrays and collections, so there is no need to create a specific converter to convert from a `Collection` of `S` to a `Collection` of `T`, assuming that standard collection handling is appropriate.

7.6 Spring Field Formatting

As discussed in the previous section, `core.convert` is a general-purpose type conversion system. It provides a unified ConversionService API as well as a strongly-typed Converter SPI for implementing conversion logic from one type to another. A Spring Container uses this system to bind bean property values. In addition, both the Spring Expression Language (SpEL) and DataBinder use this system to bind field values. For example, when SpEL needs to coerce a `Short` to a `Long` to complete an `expression.setValue(Object bean, Object value)` attempt, the core.convert system performs the coercion.

Now consider the type conversion requirements of a typical client environment such as a web or desktop application. In such environments, you typically convert *from String* to support the client postback

process, as well as back *to String* to support the view rendering process. In addition, you often need to localize String values. The more general *core.convert* Converter SPI does not address such *formatting* requirements directly. To directly address them, Spring 3 introduces a convenient Formatter SPI that provides a simple and robust alternative to PropertyEditors for client environments.

In general, use the Converter SPI when you need to implement general-purpose type conversion logic; for example, for converting between a java.util.Date and and java.lang.Long. Use the Formatter SPI when you're working in a client environment, such as a web application, and need to parse and print localized field values. The ConversionService provides a unified type conversion API for both SPIs.

Formatter SPI

The Formatter SPI to implement field formatting logic is simple and strongly typed:

```
package org.springframework.format;

public interface Formatter<T> extends Printer<T>, Parser<T> {
}
```

Where Formatter extends from the Printer and Parser building-block interfaces:

```
public interface Printer<T> {
    String print(T fieldValue, Locale locale);
}
```

```
import java.text.ParseException;

public interface Parser<T> {
    T parse(String clientValue, Locale locale) throws ParseException;
}
```

To create your own Formatter, simply implement the Formatter interface above. Parameterize T to be the type of object you wish to format, for example, `java.util.Date`. Implement the `print()` operation to print an instance of T for display in the client locale. Implement the `parse()` operation to parse an instance of T from the formatted representation returned from the client locale. Your Formatter should throw a ParseException or IllegalArgumentException if a parse attempt fails. Take care to ensure your Formatter implementation is thread-safe.

Several Formatter implementations are provided in `format` subpackages as a convenience. The `number` package provides a `NumberFormatter`, `CurrencyFormatter`, and `PercentFormatter` to format `java.lang.Number` objects using a `java.text.NumberFormat`. The `datetime` package provides a `DateFormatter` to format `java.util.Date` objects with a `java.text.DateFormat`. The `datetime.joda` package provides comprehensive datetime formatting support based on the Joda Time library.

Consider `DateFormatter` as an example `Formatter` implementation:

```
package org.springframework.format.datetime;

public final class DateFormatter implements Formatter<Date> {

    private String pattern;

    public DateFormatter(String pattern) {
        this.pattern = pattern;
    }

    public String print(Date date, Locale locale) {
        if (date == null) {
            return "";
        }
        return getDateFormat(locale).format(date);
    }

    public Date parse(String formatted, Locale locale) throws ParseException {
        if (formatted.length() == 0) {
            return null;
        }
        return getDateFormat(locale).parse(formatted);
    }

    protected DateFormat getDateFormat(Locale locale) {
        DateFormat dateFormat = new SimpleDateFormat(this.pattern, locale);
        dateFormat.setLenient(false);
        return dateFormat;
    }

}
```

The Spring team welcomes community-driven `Formatter` contributions; see jira.spring.io to contribute.

Annotation-driven Formatting

As you will see, field formatting can be configured by field type or annotation. To bind an Annotation to a formatter, implement AnnotationFormatterFactory:

```
package org.springframework.format;

public interface AnnotationFormatterFactory<A extends Annotation> {

    Set<Class<?>> getFieldTypes();

    Printer<?> getPrinter(A annotation, Class<?> fieldType);

    Parser<?> getParser(A annotation, Class<?> fieldType);

}
```

Parameterize A to be the field annotationType you wish to associate formatting logic with, for example `org.springframework.format.annotation.DateTimeFormat`. Have `getFieldTypes()` return the types of fields the annotation may be used on. Have `getPrinter()` return a Printer to print the value of an annotated field. Have `getParser()` return a Parser to parse a clientValue for an annotated field.

The example AnnotationFormatterFactory implementation below binds the @NumberFormat Annotation to a formatter. This annotation allows either a number style or pattern to be specified:

```
public final class NumberFormatAnnotationFormatterFactory
        implements AnnotationFormatterFactory<NumberFormat> {

    public Set<Class<?>> getFieldTypes() {
        return new HashSet<Class<?>>(asList(new Class<?>[] {
            Short.class, Integer.class, Long.class, Float.class,
            Double.class, BigDecimal.class, BigInteger.class }));
    }

    public Printer<Number> getPrinter(NumberFormat annotation, Class<?> fieldType) {
        return configureFormatterFrom(annotation, fieldType);
    }

    public Parser<Number> getParser(NumberFormat annotation, Class<?> fieldType) {
        return configureFormatterFrom(annotation, fieldType);
    }

    private Formatter<Number> configureFormatterFrom(NumberFormat annotation,
            Class<?> fieldType) {
        if (!annotation.pattern().isEmpty()) {
            return new NumberFormatter(annotation.pattern());
        } else {
            Style style = annotation.style();
            if (style == Style.PERCENT) {
                return new PercentFormatter();
            } else if (style == Style.CURRENCY) {
                return new CurrencyFormatter();
            } else {
                return new NumberFormatter();
            }
        }
    }
}
```

To trigger formatting, simply annotate fields with @NumberFormat:

```
public class MyModel {

    @NumberFormat(style=Style.CURRENCY)
    private BigDecimal decimal;

}
```

Format Annotation API

A portable format annotation API exists in the `org.springframework.format.annotation` package. Use @NumberFormat to format java.lang.Number fields. Use @DateTimeFormat to format java.util.Date, java.util.Calendar, java.util.Long, or Joda Time fields.

The example below uses @DateTimeFormat to format a java.util.Date as a ISO Date (yyyy-MM-dd):

```
public class MyModel {

    @DateTimeFormat(iso=ISO.DATE)
    private Date date;

}
```

FormatterRegistry SPI

The FormatterRegistry is an SPI for registering formatters and converters. `FormattingConversionService` is an implementation of FormatterRegistry suitable for most environments. This implementation may be configured programmatically or declaratively as a Spring bean using `FormattingConversionServiceFactoryBean`. Because this implementation also

implements `ConversionService`, it can be directly configured for use with Spring's DataBinder and the Spring Expression Language (SpEL).

Review the FormatterRegistry SPI below:

```
package org.springframework.format;

public interface FormatterRegistry extends ConverterRegistry {

    void addFormatterForFieldType(Class<?> fieldType, Printer<?> printer, Parser<?> parser);

    void addFormatterForFieldType(Class<?> fieldType, Formatter<?> formatter);

    void addFormatterForFieldType(Formatter<?> formatter);

    void addFormatterForAnnotation(AnnotationFormatterFactory<?, ?> factory);

}
```

As shown above, Formatters can be registered by fieldType or annotation.

The FormatterRegistry SPI allows you to configure Formatting rules centrally, instead of duplicating such configuration across your Controllers. For example, you might want to enforce that all Date fields are formatted a certain way, or fields with a specific annotation are formatted in a certain way. With a shared FormatterRegistry, you define these rules once and they are applied whenever formatting is needed.

FormatterRegistrar SPI

The FormatterRegistrar is an SPI for registering formatters and converters through the FormatterRegistry:

```
package org.springframework.format;

public interface FormatterRegistrar {

    void registerFormatters(FormatterRegistry registry);

}
```

A FormatterRegistrar is useful when registering multiple related converters and formatters for a given formatting category, such as Date formatting. It can also be useful where declarative registration is insufficient. For example when a formatter needs to be indexed under a specific field type different from its own <T> or when registering a Printer/Parser pair. The next section provides more information on converter and formatter registration.

Configuring Formatting in Spring MVC

In a Spring MVC application, you may configure a custom ConversionService instance explicitly as an attribute of the `annotation-driven` element of the MVC namespace. This ConversionService will then be used anytime a type conversion is required during Controller model binding. If not configured explicitly, Spring MVC will automatically register default formatters and converters for common types such as numbers and dates.

To rely on default formatting rules, no custom configuration is required in your Spring MVC config XML:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <mvc:annotation-driven/>

</beans>
```

With this one-line of configuration, default formatters for Numbers and Date types will be installed, including support for the @NumberFormat and @DateTimeFormat annotations. Full support for the Joda Time formatting library is also installed if Joda Time is present on the classpath.

To inject a ConversionService instance with custom formatters and converters registered, set the conversion-service attribute and then specify custom converters, formatters, or FormatterRegistrars as properties of the FormattingConversionServiceFactoryBean:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <mvc:annotation-driven conversion-service="conversionService"/>

    <bean id="conversionService"
            class="org.springframework.format.support.FormattingConversionServiceFactoryBean">
        <property name="converters">
            <set>
                <bean class="org.example.MyConverter"/>
            </set>
        </property>
        <property name="formatters">
            <set>
                <bean class="org.example.MyFormatter"/>
                <bean class="org.example.MyAnnotationFormatterFactory"/>
            </set>
        </property>
        <property name="formatterRegistrars">
            <set>
                <bean class="org.example.MyFormatterRegistrar"/>
            </set>
        </property>
    </bean>

</beans>
```

> **Note**
>
> See the section called “FormatterRegistrar SPI” and the `FormattingConversionServiceFactoryBean` for more information on when to use FormatterRegistrars.

7.7 Configuring a global date & time format

By default, date and time fields that are not annotated with `@DateTimeFormat` are converted from strings using the the `DateFormat.SHORT` style. If you prefer, you can change this by defining your own global format.

You will need to ensure that Spring does not register default formatters, and instead you should register all formatters manually. Use the `org.springframework.format.datetime.joda.JodaTimeFormatterRegistrar` or `org.springframework.format.datetime.DateFormatterRegistrar` class depending on whether you use the Joda Time library.

For example, the following Java configuration will register a global ' `yyyyMMdd`' format. This example does not depend on the Joda Time library:

```
@Configuration
public class AppConfig {

    @Bean
    public FormattingConversionService conversionService() {

        // Use the DefaultFormattingConversionService but do not register defaults
        DefaultFormattingConversionService conversionService = new
 DefaultFormattingConversionService(false);

        // Ensure @NumberFormat is still supported
        conversionService.addFormatterForFieldAnnotation(new NumberFormatAnnotationFormatterFactory());

        // Register date conversion with a specific global format
        DateFormatterRegistrar registrar = new DateFormatterRegistrar();
        registrar.setFormatter(new DateFormatter("yyyyMMdd"));
        registrar.registerFormatters(conversionService);

        return conversionService;
    }
}
```

If you prefer XML based configuration you can use a `FormattingConversionServiceFactoryBean`. Here is the same example, this time using Joda Time:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd>

    <bean
 id="conversionService" class="org.springframework.format.support.FormattingConversionServiceFactoryBean">
        <property name="registerDefaultFormatters" value="false" />
        <property name="formatters">
            <set>
                <bean class="org.springframework.format.number.NumberFormatAnnotationFormatterFactory" /
>
            </set>
        </property>
        <property name="formatterRegistrars">
            <set>
                <bean class="org.springframework.format.datetime.joda.JodaTimeFormatterRegistrar">
                    <property name="dateFormatter">

  <bean class="org.springframework.format.datetime.joda.DateTimeFormatterFactoryBean">
                            <property name="pattern" value="yyyyMMdd"/>
                        </bean>
                    </property>
                </bean>
            </set>
        </property>
    </bean>
</beans>
```

> **Note**
>
> Joda Time provides separate distinct types to represent `date`, `time` and `date-time` values. The `dateFormatter`, `timeFormatter` and `dateTimeFormatter` properties of the `JodaTimeFormatterRegistrar` should be used to configure the different formats for each type. The `DateTimeFormatterFactoryBean` provides a convenient way to create formatters.

If you are using Spring MVC remember to explicitly configure the conversion service that is used. For Java based `@Configuration` this means extending the `WebMvcConfigurationSupport` class and overriding the `mvcConversionService()` method. For XML you should use the `'conversion-service'` attribute of the `mvc:annotation-driven` element. See the section called “Configuring Formatting in Spring MVC” for details.

7.8 Spring Validation

Spring 3 introduces several enhancements to its validation support. First, the JSR-303 Bean Validation API is now fully supported. Second, when used programmatically, Spring’s DataBinder can now validate objects as well as bind to them. Third, Spring MVC now has support for declaratively validating `@Controller` inputs.

Overview of the JSR-303 Bean Validation API

JSR-303 standardizes validation constraint declaration and metadata for the Java platform. Using this API, you annotate domain model properties with declarative validation constraints and the runtime enforces them. There are a number of built-in constraints you can take advantage of. You may also define your own custom constraints.

To illustrate, consider a simple PersonForm model with two properties:

```
public class PersonForm {
    private String name;
    private int age;
}
```

JSR-303 allows you to define declarative validation constraints against such properties:

```
public class PersonForm {

    @NotNull
    @Size(max=64)
    private String name;

    @Min(0)
    private int age;

}
```

When an instance of this class is validated by a JSR-303 Validator, these constraints will be enforced.

For general information on JSR-303/JSR-349, see the Bean Validation website. For information on the specific capabilities of the default reference implementation, see the Hibernate Validator documentation. To learn how to setup a Bean Validation provider as a Spring bean, keep reading.

Configuring a Bean Validation Provider

Spring provides full support for the Bean Validation API. This includes convenient support for bootstrapping a JSR-303/JSR-349 Bean Validation provider as a Spring bean. This allows for a `javax.validation.ValidatorFactory` or `javax.validation.Validator` to be injected wherever validation is needed in your application.

Use the `LocalValidatorFactoryBean` to configure a default Validator as a Spring bean:

```
<bean id="validator"
    class="org.springframework.validation.beanvalidation.LocalValidatorFactoryBean"/>
```

The basic configuration above will trigger Bean Validation to initialize using its default bootstrap mechanism. A JSR-303/JSR-349 provider, such as Hibernate Validator, is expected to be present in the classpath and will be detected automatically.

Injecting a Validator

`LocalValidatorFactoryBean` implements both `javax.validation.ValidatorFactory` and `javax.validation.Validator`, as well as Spring's `org.springframework.validation.Validator`. You may inject a reference to either of these interfaces into beans that need to invoke validation logic.

Inject a reference to `javax.validation.Validator` if you prefer to work with the Bean Validation API directly:

```
import javax.validation.Validator;

@Service
public class MyService {

    @Autowired
    private Validator validator;
```

Inject a reference to `org.springframework.validation.Validator` if your bean requires the Spring Validation API:

```
import org.springframework.validation.Validator;

@Service
public class MyService {

    @Autowired
    private Validator validator;

}
```

Configuring Custom Constraints

Each Bean Validation constraint consists of two parts. First, a `@Constraint` annotation that declares the constraint and its configurable properties. Second, an implementation of the `javax.validation.ConstraintValidator` interface that implements the constraint's behavior. To associate a declaration with an implementation, each `@Constraint` annotation references a corresponding ValidationConstraint implementation class. At runtime, a `ConstraintValidatorFactory` instantiates the referenced implementation when the constraint annotation is encountered in your domain model.

By default, the `LocalValidatorFactoryBean` configures a `SpringConstraintValidatorFactory` that uses Spring to create ConstraintValidator instances. This allows your custom ConstraintValidators to benefit from dependency injection like any other Spring bean.

Shown below is an example of a custom `@Constraint` declaration, followed by an associated `ConstraintValidator` implementation that uses Spring for dependency injection:

```
@Target({ElementType.METHOD, ElementType.FIELD})
@Retention(RetentionPolicy.RUNTIME)
@Constraint(validatedBy=MyConstraintValidator.class)
public @interface MyConstraint {
}
```

```
import javax.validation.ConstraintValidator;

public class MyConstraintValidator implements ConstraintValidator {

    @Autowired;
    private Foo aDependency;

    ...
}
```

As you can see, a ConstraintValidator implementation may have its dependencies @Autowired like any other Spring bean.

Spring-driven Method Validation

The method validation feature supported by Bean Validation 1.1, and as a custom extension also by Hibernate Validator 4.3, can be integrated into a Spring context through a `MethodValidationPostProcessor` bean definition:

```
<bean class="org.springframework.validation.beanvalidation.MethodValidationPostProcessor"/>
```

In order to be eligible for Spring-driven method validation, all target classes need to be annotated with Spring's `@Validated` annotation, optionally declaring the validation groups to use. Check out the `MethodValidationPostProcessor` javadocs for setup details with Hibernate Validator and Bean Validation 1.1 providers.

Additional Configuration Options

The default `LocalValidatorFactoryBean` configuration should prove sufficient for most cases. There are a number of configuration options for various Bean Validation constructs, from message interpolation to traversal resolution. See the `LocalValidatorFactoryBean` javadocs for more information on these options.

Configuring a DataBinder

Since Spring 3, a DataBinder instance can be configured with a Validator. Once configured, the Validator may be invoked by calling `binder.validate()`. Any validation Errors are automatically added to the binder's BindingResult.

When working with the DataBinder programmatically, this can be used to invoke validation logic after binding to a target object:

```
Foo target = new Foo();
DataBinder binder = new DataBinder(target);
binder.setValidator(new FooValidator());

// bind to the target object
binder.bind(propertyValues);

// validate the target object
binder.validate();

// get BindingResult that includes any validation errors
BindingResult results = binder.getBindingResult();
```

A DataBinder can also be configured with multiple `Validator` instances via `dataBinder.addValidators` and `dataBinder.replaceValidators`. This is useful when combining globally configured Bean Validation with a Spring `Validator` configured locally on a DataBinder instance. See the section called "Configuring a Validator for use by Spring MVC".

Spring MVC 3 Validation

Beginning with Spring 3, Spring MVC has the ability to automatically validate `@Controller` inputs. In previous versions it was up to the developer to manually invoke validation logic.

Triggering @Controller Input Validation

To trigger validation of a `@Controller` input, simply annotate the input argument as `@Valid`:

```
@Controller
public class MyController {

    @RequestMapping("/foo", method=RequestMethod.POST)
    public void processFoo(@Valid Foo foo) { /* ... */ }
```

Spring MVC will validate a @Valid object after binding so-long as an appropriate Validator has been configured.

> **Note**
>
> The @Valid annotation is part of the standard JSR-303 Bean Validation API, and is not a Spring-specific construct.

Configuring a Validator for use by Spring MVC

The `Validator` instance invoked when a `@Valid` method argument is encountered may be configured in two ways. First, you may call `binder.setValidator(Validator)` within a `@Controller`'s `@InitBinder` callback. This allows you to configure a `Validator` instance per `@Controller` class:

```
@Controller
public class MyController {

    @InitBinder
    protected void initBinder(WebDataBinder binder) {
        binder.setValidator(new FooValidator());
    }

    @RequestMapping("/foo", method=RequestMethod.POST)
    public void processFoo(@Valid Foo foo) { ... }

}
```

Second, you may call `setValidator(Validator)` on the global `WebBindingInitializer`. This allows you to configure a `Validator` instance across all `@Controller` classes. This can be achieved easily by using the Spring MVC namespace:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <mvc:annotation-driven validator="globalValidator"/>

</beans>
```

To combine a global and a local validator, configure the global validator as shown above and then add a local validator:

```
@Controller
public class MyController {

    @InitBinder
    protected void initBinder(WebDataBinder binder) {
        binder.addValidators(new FooValidator());
    }

}
```

Configuring a JSR-303/JSR-349 Validator for use by Spring MVC

With Bean Validation, a single `javax.validation.Validator` instance typically validates *all* model objects that declare validation constraints. To configure such a JSR-303 backed Validator with Spring MVC, simply add a Bean Validation provider, such as Hibernate Validator, to your classpath. Spring MVC will detect it and automatically enable Bean Validation support across all Controllers.

The Spring MVC configuration required to enable Bean Validation support is shown below:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <!-- JSR-303/JSR-349 support will be detected on classpath and enabled automatically -->
    <mvc:annotation-driven/>

</beans>
```

With this minimal configuration, anytime a `@Valid` `@Controller` input is encountered, it will be validated by the Bean Validation provider. That provider, in turn, will enforce any constraints declared against the input. Any `ConstraintViolations` will automatically be exposed as errors in the `BindingResult` renderable by standard Spring MVC form tags.

8. Spring Expression Language (SpEL)

8.1 Introduction

The Spring Expression Language (SpEL for short) is a powerful expression language that supports querying and manipulating an object graph at runtime. The language syntax is similar to Unified EL but offers additional features, most notably method invocation and basic string templating functionality.

While there are several other Java expression languages available, OGNL, MVEL, and JBoss EL, to name a few, the Spring Expression Language was created to provide the Spring community with a single well supported expression language that can be used across all the products in the Spring portfolio. Its language features are driven by the requirements of the projects in the Spring portfolio, including tooling requirements for code completion support within the eclipse based Spring Tool Suite. That said, SpEL is based on a technology agnostic API allowing other expression language implementations to be integrated should the need arise.

While SpEL serves as the foundation for expression evaluation within the Spring portfolio, it is not directly tied to Spring and can be used independently. In order to be self contained, many of the examples in this chapter use SpEL as if it were an independent expression language. This requires creating a few bootstrapping infrastructure classes such as the parser. Most Spring users will not need to deal with this infrastructure and will instead only author expression strings for evaluation. An example of this typical use is the integration of SpEL into creating XML or annotated based bean definitions as shown in the section Expression support for defining bean definitions.

This chapter covers the features of the expression language, its API, and its language syntax. In several places an Inventor and Inventor's Society class are used as the target objects for expression evaluation. These class declarations and the data used to populate them are listed at the end of the chapter.

8.2 Feature Overview

The expression language supports the following functionality

- Literal expressions
- Boolean and relational operators
- Regular expressions
- Class expressions
- Accessing properties, arrays, lists, maps
- Method invocation
- Relational operators
- Assignment
- Calling constructors
- Bean references
- Array construction

- Inline lists
- Inline maps
- Ternary operator
- Variables
- User defined functions
- Collection projection
- Collection selection
- Templated expressions

8.3 Expression Evaluation using Spring's Expression Interface

This section introduces the simple use of SpEL interfaces and its expression language. The complete language reference can be found in the section Language Reference.

The following code introduces the SpEL API to evaluate the literal string expression *Hello World*.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("'Hello World'");
String message = (String) exp.getValue();
```

The value of the message variable is simply *Hello World*.

The SpEL classes and interfaces you are most likely to use are located in the packages `org.springframework.expression` and its sub packages and `spel.support`.

The interface `ExpressionParser` is responsible for parsing an expression string. In this example the expression string is a string literal denoted by the surrounding single quotes. The interface `Expression` is responsible for evaluating the previously defined expression string. There are two exceptions that can be thrown, `ParseException` and `EvaluationException` when calling *`parser.parseExpression`* and *`exp.getValue`* respectively.

SpEL supports a wide range of features, such as calling methods, accessing properties, and calling constructors.

As an example of method invocation, we call the *concat* method on the string literal.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("'Hello World'.concat('!')");
String message = (String) exp.getValue();
```

The value of message is now *Hello World!*.

As an example of calling a JavaBean property, the String property *Bytes* can be called as shown below.

```
ExpressionParser parser = new SpelExpressionParser();

// invokes getBytes()
Expression exp = parser.parseExpression("'Hello World'.bytes");
byte[] bytes = (byte[]) exp.getValue();
```

SpEL also supports nested properties using standard *dot* notation, i.e. prop1.prop2.prop3 and the setting of property values

Public fields may also be accessed.

```
ExpressionParser parser = new SpelExpressionParser();

// invokes getBytes().length
Expression exp = parser.parseExpression("'Hello World'.bytes.length");
int length = (Integer) exp.getValue();
```

The String's constructor can be called instead of using a string literal.

```
ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("new String('hello world').toUpperCase()");
String message = exp.getValue(String.class);
```

Note the use of the generic method `public <T> T getValue(Class<T> desiredResultType)`. Using this method removes the need to cast the value of the expression to the desired result type. An `EvaluationException` will be thrown if the value cannot be cast to the type `T` or converted using the registered type converter.

The more common usage of SpEL is to provide an expression string that is evaluated against a specific object instance (called the root object). There are two options here and which to choose depends on whether the object against which the expression is being evaluated will be changing with each call to evaluate the expression. In the following example we retrieve the `name` property from an instance of the Inventor class.

```
// Create and set a calendar
GregorianCalendar c = new GregorianCalendar();
c.set(1856, 7, 9);

// The constructor arguments are name, birthday, and nationality.
Inventor tesla = new Inventor("Nikola Tesla", c.getTime(), "Serbian");

ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("name");

EvaluationContext context = new StandardEvaluationContext(tesla);
String name = (String) exp.getValue(context);
```

In the last line, the value of the string variable *name* will be set to "Nikola Tesla". The class StandardEvaluationContext is where you can specify which object the "name" property will be evaluated against. This is the mechanism to use if the root object is unlikely to change, it can simply be set once in the evaluation context. If the root object is likely to change repeatedly, it can be supplied on each call to `getValue`, as this next example shows:

```
/ Create and set a calendar
GregorianCalendar c = new GregorianCalendar();
c.set(1856, 7, 9);

// The constructor arguments are name, birthday, and nationality.
Inventor tesla = new Inventor("Nikola Tesla", c.getTime(), "Serbian");

ExpressionParser parser = new SpelExpressionParser();
Expression exp = parser.parseExpression("name");
String name = (String) exp.getValue(tesla);
```

In this case the inventor `tesla` has been supplied directly to `getValue` and the expression evaluation infrastructure creates and manages a default evaluation context internally - it did not require one to be supplied.

The StandardEvaluationContext is relatively expensive to construct and during repeated usage it builds up cached state that enables subsequent expression evaluations to be performed more quickly. For this reason it is better to cache and reuse them where possible, rather than construct a new one for each expression evaluation.

In some cases it can be desirable to use a configured evaluation context and yet still supply a different root object on each call to `getValue`. `getValue` allows both to be specified on the same call. In these situations the root object passed on the call is considered to override any (which maybe null) specified on the evaluation context.

> **Note**
>
> In standalone usage of SpEL there is a need to create the parser, parse expressions and perhaps provide evaluation contexts and a root context object. However, more common usage is to provide only the SpEL expression string as part of a configuration file, for example for Spring bean or Spring Web Flow definitions. In this case, the parser, evaluation context, root object and any predefined variables are all set up implicitly, requiring the user to specify nothing other than the expressions.

As a final introductory example, the use of a boolean operator is shown using the Inventor object in the previous example.

```
Expression exp = parser.parseExpression("name == 'Nikola Tesla'");
boolean result = exp.getValue(context, Boolean.class); // evaluates to true
```

The EvaluationContext interface

The interface `EvaluationContext` is used when evaluating an expression to resolve properties, methods, fields, and to help perform type conversion. The out-of-the-box implementation, `StandardEvaluationContext`, uses reflection to manipulate the object, caching `java.lang.reflect`'s `Method`, `Field`, and `Constructor` instances for increased performance.

The `StandardEvaluationContext` is where you may specify the root object to evaluate against via the method `setRootObject()` or passing the root object into the constructor. You can also specify variables and functions that will be used in the expression using the methods `setVariable()` and `registerFunction()`. The use of variables and functions are described in the language reference sections Variables and Functions. The `StandardEvaluationContext` is also where you can register custom `ConstructorResolvers`, `MethodResolvers`, and `PropertyAccessors` to extend how SpEL evaluates expressions. Please refer to the JavaDoc of these classes for more details.

Type Conversion

By default SpEL uses the conversion service available in Spring core (`org.springframework.core.convert.ConversionService`). This conversion service comes with many converters built in for common conversions but is also fully extensible so custom conversions between types can be added. Additionally it has the key capability that it is generics aware. This means that when working with generic types in expressions, SpEL will attempt conversions to maintain type correctness for any objects it encounters.

What does this mean in practice? Suppose assignment, using `setValue()`, is being used to set a `List` property. The type of the property is actually `List<Boolean>`. SpEL will recognize that the elements of the list need to be converted to `Boolean` before being placed in it. A simple example:

```
class Simple {
    public List<Boolean> booleanList = new ArrayList<Boolean>();
}

Simple simple = new Simple();

simple.booleanList.add(true);

StandardEvaluationContext simpleContext = new StandardEvaluationContext(simple);

// false is passed in here as a string. SpEL and the conversion service will
// correctly recognize that it needs to be a Boolean and convert it
parser.parseExpression("booleanList[0]").setValue(simpleContext, "false");

// b will be false
Boolean b = simple.booleanList.get(0);
```

Parser configuration

It is possible to configure the SpEL expression parser using a parser configuration object (`org.springframework.expression.spel.SpelParserConfiguration`). The configuration object controls the behaviour of some of the expression components. For example, if indexing into an array or collection and the element at the specified index is `null` it is possible to automatically create the element. This is useful when using expressions made up of a chain of property references. If indexing into an array or list and specifying an index that is beyond the end of the current size of the array or list it is possible to automatically grow the array or list to accommodate that index.

```
class Demo {
    public List<String> list;
}

// Turn on:
// - auto null reference initialization
// - auto collection growing
SpelParserConfiguration config = new SpelParserConfiguration(true,true);

ExpressionParser parser = new SpelExpressionParser(config);

Expression expression = parser.parseExpression("list[3]");

Demo demo = new Demo();

Object o = expression.getValue(demo);

// demo.list will now be a real collection of 4 entries
// Each entry is a new empty String
```

It is also possible to configure the behaviour of the SpEL expression compiler.

SpEL compilation

Spring Framework 4.1 includes a basic expression compiler. Expressions are usually interpreted which provides a lot of dynamic flexibility during evaluation but does not provide the optimum performance. For occasional expression usage this is fine, but when used by other components like Spring Integration, performance can be very important and there is no real need for the dynamism.

The new SpEL compiler is intended to address this need. The compiler will generate a real Java class on the fly during evaluation that embodies the expression behaviour and use that to achieve much faster expression evaluation. Due to the lack of typing around expressions the compiler uses information gathered during the interpreted evaluations of an expression when performing compilation. For example, it does not know the type of a property reference purely from the expression but during the

first interpreted evaluation it will find out what it is. Of course, basing the compilation on this information could cause trouble later if the types of the various expression elements change over time. For this reason compilation is best suited to expressions whose type information is not going to change on repeated evaluations.

For a basic expression like this:

`someArray[0].someProperty.someOtherProperty < 0.1`

which involves array access, some property derefencing and numeric operations, the performance gain can be very noticeable. In an example microbenchmark run of 50000 iterations, it was taking 75ms to evaluate using only the interpreter and just 3ms using the compiled version of the expression.

Compiler configuration

The compiler is not turned on by default, but there are two ways to turn it on. It can be turned on using the parser configuration process discussed earlier or via a system property when SpEL usage is embedded inside another component. This section discusses both of these options.

Is is important to understand that there are a few modes the compiler can operate in, captured in an enum (`org.springframework.expression.spel.SpelCompilerMode`). The modes are as follows:

- `OFF` - The compiler is switched off; this is the default.
- `IMMEDIATE` - In immediate mode the expressions are compiled as soon as possible. This is typically after the first interpreted evaluation. If the compiled expression fails (typically due to a type changing, as described above) then the caller of the expression evaluation will receive an exception.
- `MIXED` - In mixed mode the expressions silently switch between interpreted and compiled mode over time. After some number of interpreted runs they will switch to compiled form and if something goes wrong with the compiled form (like a type changing, as described above) then the expression will automatically switch back to interpreted form again. Sometime later it may generate another compiled form and switch to it. Basically the exception that the user gets in `IMMEDIATE` mode is instead handled internally.

`IMMEDIATE` mode exists because `MIXED` mode could cause issues for expressions that have side effects. If a compiled expression blows up after partially succeeding it may have already done something that has affected the state of the system. If this has happened the caller may not want it to silently re-run in interpreted mode since part of the expression may be running twice.

After selecting a mode, use the `SpelParserConfiguration` to configure the parser:

```
SpelParserConfiguration config = new SpelParserConfiguration(SpelCompilerMode.IMMEDIATE,
    this.getClass().getClassLoader());

SpelExpressionParser parser = new SpelExpressionParser(config);

Expression expr = parser.parseExpression("payload");

MyMessage message = new MyMessage();

Object payload = expr.getValue(message);
```

When specifying the compiler mode it is also possible to specify a classloader (passing null is allowed). Compiled expressions will be defined in a child classloader created under any that is supplied. It is important to ensure if a classloader is specified it can see all the types involved in the expression evaluation process. If none is specified then a default classloader will be used (typically the context classloader for the thread that is running during expression evaluation).

The second way to configure the compiler is for use when SpEL is embedded inside some other component and it may not be possible to configure via a configuration object. In these cases it is possible to use a system property. The property `spring.expression.compiler.mode` can be set to one of the `SpelCompilerMode` enum values (`off`, `immediate` or `mixed`).

Compiler limitations

With Spring Framework 4.1 the basic compilation framework is in place. However, the framework does not yet support compiling every kind of expression. The initial focus has been on the common expressions that are likely to be used in performance critical contexts. These kinds of expression cannot be compiled at the moment:

- expressions involving assignment
- expressions relying on the conversion service
- expressions using custom resolvers or accessors
- expressions using selection or projection

More and more types of expression will be compilable in the future.

8.4 Expression support for defining bean definitions

SpEL expressions can be used with XML or annotation-based configuration metadata for defining `BeanDefinitions`. In both cases the syntax to define the expression is of the form `#{ <expression string> }`.

XML based configuration

A property or constructor-arg value can be set using expressions as shown below.

```
<bean id="numberGuess" class="org.spring.samples.NumberGuess">
    <property name="randomNumber" value="#{ T(java.lang.Math).random() * 100.0 }"/>

    <!-- other properties -->
</bean>
```

The variable `systemProperties` is predefined, so you can use it in your expressions as shown below. Note that you do not have to prefix the predefined variable with the # symbol in this context.

```
<bean id="taxCalculator" class="org.spring.samples.TaxCalculator">
    <property name="defaultLocale" value="#{ systemProperties['user.region'] }"/>

    <!-- other properties -->
</bean>
```

You can also refer to other bean properties by name, for example.

```
<bean id="numberGuess" class="org.spring.samples.NumberGuess">
    <property name="randomNumber" value="{ T(java.lang.Math).random() * 100.0 }"/>

    <!-- other properties -->
</bean>

<bean id="shapeGuess" class="org.spring.samples.ShapeGuess">
    <property name="initialShapeSeed" value="{ numberGuess.randomNumber }"/>

    <!-- other properties -->
</bean>
```

Annotation-based configuration

The `@Value` annotation can be placed on fields, methods and method/constructor parameters to specify a default value.

Here is an example to set the default value of a field variable.

```
public static class FieldValueTestBean

    @Value("#{ systemProperties['user.region'] }")
    private String defaultLocale;

    public void setDefaultLocale(String defaultLocale) {
        this.defaultLocale = defaultLocale;
    }

    public String getDefaultLocale() {
        return this.defaultLocale;
    }

}
```

The equivalent but on a property setter method is shown below.

```
public static class PropertyValueTestBean

    private String defaultLocale;

    @Value("#{ systemProperties['user.region'] }")
    public void setDefaultLocale(String defaultLocale) {
        this.defaultLocale = defaultLocale;
    }

    public String getDefaultLocale() {
        return this.defaultLocale;
    }

}
```

Autowired methods and constructors can also use the `@Value` annotation.

```
public class SimpleMovieLister {

    private MovieFinder movieFinder;
    private String defaultLocale;

    @Autowired
    public void configure(MovieFinder movieFinder,
            @Value("#{ systemProperties['user.region'] }") String defaultLocale) {
        this.movieFinder = movieFinder;
        this.defaultLocale = defaultLocale;
    }

    // ...
}
```

```
public class MovieRecommender {

    private String defaultLocale;

    private CustomerPreferenceDao customerPreferenceDao;

    @Autowired
    public MovieRecommender(CustomerPreferenceDao customerPreferenceDao,
            @Value("#{systemProperties['user.country']}") String defaultLocale) {
        this.customerPreferenceDao = customerPreferenceDao;
        this.defaultLocale = defaultLocale;
    }

    // ...
}
```

8.5 Language Reference

Literal expressions

The types of literal expressions supported are strings, dates, numeric values (int, real, and hex), boolean and null. Strings are delimited by single quotes. To put a single quote itself in a string use two single quote characters. The following listing shows simple usage of literals. Typically they would not be used in isolation like this, but as part of a more complex expression, for example using a literal on one side of a logical comparison operator.

```
ExpressionParser parser = new SpelExpressionParser();

// evals to "Hello World"
String helloWorld = (String) parser.parseExpression("'Hello World'").getValue();

double avogadrosNumber = (Double) parser.parseExpression("6.0221415E+23").getValue();

// evals to 2147483647
int maxValue = (Integer) parser.parseExpression("0x7FFFFFFF").getValue();

boolean trueValue = (Boolean) parser.parseExpression("true").getValue();

Object nullValue = parser.parseExpression("null").getValue();
```

Numbers support the use of the negative sign, exponential notation, and decimal points. By default real numbers are parsed using Double.parseDouble().

Properties, Arrays, Lists, Maps, Indexers

Navigating with property references is easy: just use a period to indicate a nested property value. The instances of the `Inventor` class, pupin, and tesla, were populated with data listed in the section Classes used in the examples. To navigate "down" and get Tesla's year of birth and Pupin's city of birth the following expressions are used.

```
// evals to 1856
int year = (Integer) parser.parseExpression("Birthdate.Year + 1900").getValue(context);

String city = (String) parser.parseExpression("placeOfBirth.City").getValue(context);
```

Case insensitivity is allowed for the first letter of property names. The contents of arrays and lists are obtained using square bracket notation.

```
ExpressionParser parser = new SpelExpressionParser();

// Inventions Array
StandardEvaluationContext teslaContext = new StandardEvaluationContext(tesla);

// evaluates to "Induction motor"
String invention = parser.parseExpression("inventions[3]").getValue(
        teslaContext, String.class);

// Members List
StandardEvaluationContext societyContext = new StandardEvaluationContext(ieee);

// evaluates to "Nikola Tesla"
String name = parser.parseExpression("Members[0].Name").getValue(
        societyContext, String.class);

// List and Array navigation
// evaluates to "Wireless communication"
String invention = parser.parseExpression("Members[0].Inventions[6]").getValue(
        societyContext, String.class);
```

The contents of maps are obtained by specifying the literal key value within the brackets. In this case, because keys for the Officers map are strings, we can specify string literals.

```
// Officer's Dictionary

Inventor pupin = parser.parseExpression("Officers['president']").getValue(
        societyContext, Inventor.class);

// evaluates to "Idvor"
String city = parser.parseExpression("Officers['president'].PlaceOfBirth.City").getValue(
        societyContext, String.class);

// setting values
parser.parseExpression("Officers['advisors'][0].PlaceOfBirth.Country").setValue(
        societyContext, "Croatia");
```

Inline lists

Lists can be expressed directly in an expression using `{}` notation.

```
// evaluates to a Java list containing the four numbers
List numbers = (List) parser.parseExpression("{1,2,3,4}").getValue(context);

List listOfLists = (List) parser.parseExpression("{{'a','b'},{'x','y'}}").getValue(context);
```

`{}` by itself means an empty list. For performance reasons, if the list is itself entirely composed of fixed literals then a constant list is created to represent the expression, rather than building a new list on each evaluation.

Inline Maps

Maps can also be expressed directly in an expression using `{key:value}` notation.

```
// evaluates to a Java map containing the two entries
Map inventorInfo = (Map) parser.parseExpression("{name:'Nikola',dob:'10-July-1856'}").getValue(context);

Map mapOfMaps = (Map) parser.parseExpression("{name:{first:'Nikola',last:'Tesla'},dob:
{day:10,month:'July',year:1856}}").getValue(context);
```

`{:}` by itself means an empty map. For performance reasons, if the map is itself composed of fixed literals or other nested constant structures (lists or maps) then a constant map is created to represent the expression, rather than building a new map on each evaluation. Quoting of the map keys is optional, the examples above are not using quoted keys.

Array construction

Arrays can be built using the familiar Java syntax, optionally supplying an initializer to have the array populated at construction time.

```
int[] numbers1 = (int[]) parser.parseExpression("new int[4]").getValue(context);

// Array with initializer
int[] numbers2 = (int[]) parser.parseExpression("new int[]{1,2,3}").getValue(context);

// Multi dimensional array
int[][] numbers3 = (int[][]) parser.parseExpression("new int[4][5]").getValue(context);
```

It is not currently allowed to supply an initializer when constructing a multi-dimensional array.

Methods

Methods are invoked using typical Java programming syntax. You may also invoke methods on literals. Varargs are also supported.

```
// string literal, evaluates to "bc"
String c = parser.parseExpression("'abc'.substring(2, 3)").getValue(String.class);

// evaluates to true
boolean isMember = parser.parseExpression("isMember('Mihajlo Pupin')").getValue(
        societyContext, Boolean.class);
```

Operators

Relational operators

The relational operators; equal, not equal, less than, less than or equal, greater than, and greater than or equal are supported using standard operator notation.

```
// evaluates to true
boolean trueValue = parser.parseExpression("2 == 2").getValue(Boolean.class);

// evaluates to false
boolean falseValue = parser.parseExpression("2 < -5.0").getValue(Boolean.class);

// evaluates to true
boolean trueValue = parser.parseExpression("'black' < 'block'").getValue(Boolean.class);
```

In addition to standard relational operators SpEL supports the `instanceof` and regular expression based `matches` operator.

```
// evaluates to false
boolean falseValue = parser.parseExpression(
        "'xyz' instanceof T(int)").getValue(Boolean.class);

// evaluates to true
boolean trueValue = parser.parseExpression(
        "'5.00' matches '^-?\\d+(\\.\\d{2})?$'").getValue(Boolean.class);

//evaluates to false
boolean falseValue = parser.parseExpression(
        "'5.0067' matches '\^-?\\d+(\\.\\d{2})?$'").getValue(Boolean.class);
```

Each symbolic operator can also be specified as a purely alphabetic equivalent. This avoids problems where the symbols used have special meaning for the document type in which the expression is embedded (eg. an XML document). The textual equivalents are shown here: `lt` (<), `gt` (>), `le` (<=), `ge` (>=), `eq` (==), `ne` (!=), `div` (/), `mod` (%), `not` (!). These are case insensitive.

Logical operators

The logical operators that are supported are and, or, and not. Their use is demonstrated below.

```
// -- AND --

// evaluates to false
boolean falseValue = parser.parseExpression("true and false").getValue(Boolean.class);

// evaluates to true
String expression = "isMember('Nikola Tesla') and isMember('Mihajlo Pupin')";
boolean trueValue = parser.parseExpression(expression).getValue(societyContext, Boolean.class);

// -- OR --

// evaluates to true
boolean trueValue = parser.parseExpression("true or false").getValue(Boolean.class);

// evaluates to true
String expression = "isMember('Nikola Tesla') or isMember('Albert Einstein')";
boolean trueValue = parser.parseExpression(expression).getValue(societyContext, Boolean.class);

// -- NOT --

// evaluates to false
boolean falseValue = parser.parseExpression("!true").getValue(Boolean.class);

// -- AND and NOT --
String expression = "isMember('Nikola Tesla') and !isMember('Mihajlo Pupin')";
boolean falseValue = parser.parseExpression(expression).getValue(societyContext, Boolean.class);
```

Mathematical operators

The addition operator can be used on both numbers and strings. Subtraction, multiplication and division can be used only on numbers. Other mathematical operators supported are modulus (%) and exponential power (^). Standard operator precedence is enforced. These operators are demonstrated below.

```
// Addition
int two = parser.parseExpression("1 + 1").getValue(Integer.class); // 2

String testString = parser.parseExpression(
        "'test' + ' ' + 'string'").getValue(String.class); // test string

// Subtraction
int four = parser.parseExpression("1 - -3").getValue(Integer.class); // 4

double d = parser.parseExpression("1000.00 - 1e4").getValue(Double.class); // -9000

// Multiplication
int six = parser.parseExpression("-2 * -3").getValue(Integer.class); // 6

double twentyFour = parser.parseExpression("2.0 * 3e0 * 4").getValue(Double.class); // 24.0

// Division
int minusTwo = parser.parseExpression("6 / -3").getValue(Integer.class); // -2

double one = parser.parseExpression("8.0 / 4e0 / 2").getValue(Double.class); // 1.0

// Modulus
int three = parser.parseExpression("7 % 4").getValue(Integer.class); // 3

int one = parser.parseExpression("8 / 5 % 2").getValue(Integer.class); // 1

// Operator precedence
int minusTwentyOne = parser.parseExpression("1+2-3*8").getValue(Integer.class); // -21
```

Assignment

Setting of a property is done by using the assignment operator. This would typically be done within a call to `setValue` but can also be done inside a call to `getValue`.

```
Inventor inventor = new Inventor();
StandardEvaluationContext inventorContext = new StandardEvaluationContext(inventor);

parser.parseExpression("Name").setValue(inventorContext, "Alexander Seovic2");

// alternatively

String aleks = parser.parseExpression(
        "Name = 'Alexandar Seovic'").getValue(inventorContext, String.class);
```

Types

The special `T` operator can be used to specify an instance of java.lang.Class (the *type*). Static methods are invoked using this operator as well. The `StandardEvaluationContext` uses a `TypeLocator` to find types and the `StandardTypeLocator` (which can be replaced) is built with an understanding of the java.lang package. This means T() references to types within java.lang do not need to be fully qualified, but all other type references must be.

```
Class dateClass = parser.parseExpression("T(java.util.Date)").getValue(Class.class);

Class stringClass = parser.parseExpression("T(String)").getValue(Class.class);

boolean trueValue = parser.parseExpression(
        "T(java.math.RoundingMode).CEILING < T(java.math.RoundingMode).FLOOR")
        .getValue(Boolean.class);
```

Constructors

Constructors can be invoked using the new operator. The fully qualified class name should be used for all but the primitive type and String (where int, float, etc, can be used).

```
Inventor einstein = p.parseExpression(
        "new org.spring.samples.spel.inventor.Inventor('Albert Einstein', 'German')")
        .getValue(Inventor.class);

//create new inventor instance within add method of List
p.parseExpression(
        "Members.add(new org.spring.samples.spel.inventor.Inventor(
            'Albert Einstein', 'German'))").getValue(societyContext);
```

Variables

Variables can be referenced in the expression using the syntax `#variableName`. Variables are set using the method setVariable on the `StandardEvaluationContext`.

```
Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
StandardEvaluationContext context = new StandardEvaluationContext(tesla);
context.setVariable("newName", "Mike Tesla");

parser.parseExpression("Name = #newName").getValue(context);

System.out.println(tesla.getName()) // "Mike Tesla"
```

The #this and #root variables

The variable #this is always defined and refers to the current evaluation object (against which unqualified references are resolved). The variable #root is always defined and refers to the root context object. Although #this may vary as components of an expression are evaluated, #root always refers to the root.

```
// create an array of integers
List<Integer> primes = new ArrayList<Integer>();
primes.addAll(Arrays.asList(2,3,5,7,11,13,17));

// create parser and set variable primes as the array of integers
ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();
context.setVariable("primes",primes);

// all prime numbers > 10 from the list (using selection ?{...})
// evaluates to [11, 13, 17]
List<Integer> primesGreaterThanTen = (List<Integer>) parser.parseExpression(
        "#primes.?[#this>10]").getValue(context);
```

Functions

You can extend SpEL by registering user defined functions that can be called within the expression string. The function is registered with the `StandardEvaluationContext` using the method.

```
public void registerFunction(String name, Method m)
```

A reference to a Java Method provides the implementation of the function. For example, a utility method to reverse a string is shown below.

```
public abstract class StringUtils {

    public static String reverseString(String input) {
        StringBuilder backwards = new StringBuilder();
        for (int i = 0; i < input.length(); i++)
            backwards.append(input.charAt(input.length() - 1 - i));
        }
        return backwards.toString();
    }
}
```

This method is then registered with the evaluation context and can be used within an expression string.

```
ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();

context.registerFunction("reverseString",
    StringUtils.class.getDeclaredMethod("reverseString", new Class[] { String.class }));

String helloWorldReversed = parser.parseExpression(
    "#reverseString('hello')").getValue(context, String.class);
```

Bean references

If the evaluation context has been configured with a bean resolver it is possible to lookup beans from an expression using the (@) symbol.

```
ExpressionParser parser = new SpelExpressionParser();
StandardEvaluationContext context = new StandardEvaluationContext();
context.setBeanResolver(new MyBeanResolver());

// This will end up calling resolve(context,"foo") on MyBeanResolver during evaluation
Object bean = parser.parseExpression("@foo").getValue(context);
```

Ternary Operator (If-Then-Else)

You can use the ternary operator for performing if-then-else conditional logic inside the expression. A minimal example is:

```
String falseString = parser.parseExpression(
        "false ? 'trueExp' : 'falseExp'").getValue(String.class);
```

In this case, the boolean false results in returning the string value *falseExp*. A more realistic example is shown below.

```
parser.parseExpression("Name").setValue(societyContext, "IEEE");
societyContext.setVariable("queryName", "Nikola Tesla");

expression = "isMember(#queryName)? #queryName + ' is a member of the ' " +
        "+ Name + ' Society' : #queryName + ' is not a member of the ' + Name + ' Society'";

String queryResultString = parser.parseExpression(expression)
        .getValue(societyContext, String.class);
// queryResultString = "Nikola Tesla is a member of the IEEE Society"
```

Also see the next section on the Elvis operator for an even shorter syntax for the ternary operator.

The Elvis Operator

The Elvis operator is a shortening of the ternary operator syntax and is used in the Groovy language. With the ternary operator syntax you usually have to repeat a variable twice, for example:

```
String name = "Elvis Presley";
String displayName = name != null ? name : "Unknown";
```

Instead you can use the Elvis operator, named for the resemblance to Elvis' hair style.

```
ExpressionParser parser = new SpelExpressionParser();

String name = parser.parseExpression("null?:'Unknown'").getValue(String.class);

System.out.println(name); // Unknown
```

Here is a more complex example.

```
ExpressionParser parser = new SpelExpressionParser();

Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
StandardEvaluationContext context = new StandardEvaluationContext(tesla);

String name = parser.parseExpression("Name?:'Elvis Presley'").getValue(context, String.class);

System.out.println(name); // Nikola Tesla

tesla.setName(null);

name = parser.parseExpression("Name?:'Elvis Presley'").getValue(context, String.class);

System.out.println(name); // Elvis Presley
```

Safe Navigation operator

The Safe Navigation operator is used to avoid a `NullPointerException` and comes from the Groovy language. Typically when you have a reference to an object you might need to verify that it is not null before accessing methods or properties of the object. To avoid this, the safe navigation operator will simply return null instead of throwing an exception.

```
ExpressionParser parser = new SpelExpressionParser();

Inventor tesla = new Inventor("Nikola Tesla", "Serbian");
tesla.setPlaceOfBirth(new PlaceOfBirth("Smiljan"));

StandardEvaluationContext context = new StandardEvaluationContext(tesla);

String city = parser.parseExpression("PlaceOfBirth?.City").getValue(context, String.class);
System.out.println(city); // Smiljan

tesla.setPlaceOfBirth(null);

city = parser.parseExpression("PlaceOfBirth?.City").getValue(context, String.class);

System.out.println(city); // null - does not throw NullPointerException!!!
```

Note

The Elvis operator can be used to apply default values in expressions, e.g. in an `@Value` expression:

```
@Value("#{systemProperties['pop3.port'] ?: 25}")
```

This will inject a system property `pop3.port` if it is defined or 25 if not.

Collection Selection

Selection is a powerful expression language feature that allows you to transform some source collection into another by selecting from its entries.

Selection uses the syntax `?[selectionExpression]`. This will filter the collection and return a new collection containing a subset of the original elements. For example, selection would allow us to easily get a list of Serbian inventors:

```
List<Inventor> list = (List<Inventor>) parser.parseExpression(
        "Members.?[Nationality == 'Serbian']").getValue(societyContext);
```

Selection is possible upon both lists and maps. In the former case the selection criteria is evaluated against each individual list element whilst against a map the selection criteria is evaluated against each map entry (objects of the Java type `Map.Entry`). Map entries have their key and value accessible as properties for use in the selection.

This expression will return a new map consisting of those elements of the original map where the entry value is less than 27.

```
Map newMap = parser.parseExpression("map.?[value<27]").getValue();
```

In addition to returning all the selected elements, it is possible to retrieve just the first or the last value. To obtain the first entry matching the selection the syntax is `^[...]` whilst to obtain the last matching selection the syntax is `$[...]`.

Collection Projection

Projection allows a collection to drive the evaluation of a sub-expression and the result is a new collection. The syntax for projection is `![projectionExpression]`. Most easily understood by example, suppose we have a list of inventors but want the list of cities where they were born. Effectively we want to evaluate *placeOfBirth.city* for every entry in the inventor list. Using projection:

```
// returns [Smiljan, Idvor ]
List placesOfBirth = (List)parser.parseExpression("Members.![placeOfBirth.city]");
```

A map can also be used to drive projection and in this case the projection expression is evaluated against each entry in the map (represented as a Java `Map.Entry`). The result of a projection across a map is a list consisting of the evaluation of the projection expression against each map entry.

Expression templating

Expression templates allow a mixing of literal text with one or more evaluation blocks. Each evaluation block is delimited with prefix and suffix characters that you can define, a common choice is to use `#{ }` as the delimiters. For example,

```
String randomPhrase = parser.parseExpression(
        "random number is #{T(java.lang.Math).random()}",
        new TemplateParserContext()).getValue(String.class);

// evaluates to "random number is 0.7038186818312008"
```

The string is evaluated by concatenating the literal text 'random number is ' with the result of evaluating the expression inside the #{} delimiter, in this case the result of calling that random() method. The second argument to the method `parseExpression()` is of the type `ParserContext`. The `ParserContext` interface is used to influence how the expression is parsed in order to support the expression templating functionality. The definition of `TemplateParserContext` is shown below.

```
public class TemplateParserContext implements ParserContext {

    public String getExpressionPrefix() {
        return "#{";
    }

    public String getExpressionSuffix() {
        return "}";
    }

    public boolean isTemplate() {
        return true;
    }
}
```

8.6 Classes used in the examples

Inventor.java

```
package org.spring.samples.spel.inventor;

import java.util.Date;
import java.util.GregorianCalendar;

public class Inventor {

    private String name;
    private String nationality;
    private String[] inventions;
    private Date birthdate;
    private PlaceOfBirth placeOfBirth;

    public Inventor(String name, String nationality) {
        GregorianCalendar c= new GregorianCalendar();
        this.name = name;
        this.nationality = nationality;
        this.birthdate = c.getTime();
    }

    public Inventor(String name, Date birthdate, String nationality) {
        this.name = name;
        this.nationality = nationality;
        this.birthdate = birthdate;
    }

    public Inventor() {
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public String getNationality() {
        return nationality;
    }

    public void setNationality(String nationality) {
        this.nationality = nationality;
    }

    public Date getBirthdate() {
        return birthdate;
    }

    public void setBirthdate(Date birthdate) {
        this.birthdate = birthdate;
    }

    public PlaceOfBirth getPlaceOfBirth() {
        return placeOfBirth;
    }

    public void setPlaceOfBirth(PlaceOfBirth placeOfBirth) {
        this.placeOfBirth = placeOfBirth;
    }

    public void setInventions(String[] inventions) {
        this.inventions = inventions;
    }

    public String[] getInventions() {
        return inventions;
    }
}
```

PlaceOfBirth.java

```
package org.spring.samples.spel.inventor;

public class PlaceOfBirth {

    private String city;
    private String country;

    public PlaceOfBirth(String city) {
        this.city=city;
    }

    public PlaceOfBirth(String city, String country) {
        this(city);
        this.country = country;
    }

    public String getCity() {
        return city;
    }

    public void setCity(String s) {
        this.city = s;
    }

    public String getCountry() {
        return country;
    }

    public void setCountry(String country) {
        this.country = country;
    }

}
```

Society.java

```
package org.spring.samples.spel.inventor;

import java.util.*;

public class Society {

    private String name;

    public static String Advisors = "advisors";
    public static String President = "president";

    private List<Inventor> members = new ArrayList<Inventor>();
    private Map officers = new HashMap();

    public List getMembers() {
        return members;
    }

    public Map getOfficers() {
        return officers;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public boolean isMember(String name) {
        for (Inventor inventor : members) {
            if (inventor.getName().equals(name)) {
                return true;
            }
        }
        return false;
    }

}
```

9. Aspect Oriented Programming with Spring

9.1 Introduction

Aspect-Oriented Programming (AOP) complements Object-Oriented Programming (OOP) by providing another way of thinking about program structure. The key unit of modularity in OOP is the class, whereas in AOP the unit of modularity is the *aspect*. Aspects enable the modularization of concerns such as transaction management that cut across multiple types and objects. (Such concerns are often termed *crosscutting* concerns in AOP literature.)

One of the key components of Spring is the *AOP framework*. While the Spring IoC container does not depend on AOP, meaning you do not need to use AOP if you don't want to, AOP complements Spring IoC to provide a very capable middleware solution.

Spring 2.0 AOP

Spring 2.0 introduces a simpler and more powerful way of writing custom aspects using either a schema-based approach or the @AspectJ annotation style. Both of these styles offer fully typed advice and use of the AspectJ pointcut language, while still using Spring AOP for weaving.

The Spring 2.0 schema- and @AspectJ-based AOP support is discussed in this chapter. Spring 2.0 AOP remains fully backwards compatible with Spring 1.2 AOP, and the lower-level AOP support offered by the Spring 1.2 APIs is discussed in the following chapter.

AOP is used in the Spring Framework to…

- … provide declarative enterprise services, especially as a replacement for EJB declarative services. The most important such service is *declarative transaction management*.
- … allow users to implement custom aspects, complementing their use of OOP with AOP.

> **Note**
>
> If you are interested only in generic declarative services or other pre-packaged declarative middleware services such as pooling, you do not need to work directly with Spring AOP, and can skip most of this chapter.

AOP concepts

Let us begin by defining some central AOP concepts and terminology. These terms are not Spring-specific… unfortunately, AOP terminology is not particularly intuitive; however, it would be even more confusing if Spring used its own terminology.

- *Aspect*: a modularization of a concern that cuts across multiple classes. Transaction management is a good example of a crosscutting concern in enterprise Java applications. In Spring AOP, aspects are implemented using regular classes (the schema-based approach) or regular classes annotated with the `@Aspect` annotation (the `@AspectJ` style).
- *Join point*: a point during the execution of a program, such as the execution of a method or the handling of an exception. In Spring AOP, a join point *always* represents a method execution.

- *Advice*: action taken by an aspect at a particular join point. Different types of advice include "around," "before" and "after" advice. (Advice types are discussed below.) Many AOP frameworks, including Spring, model an advice as an *interceptor*, maintaining a chain of interceptors *around* the join point.
- *Pointcut*: a predicate that matches join points. Advice is associated with a pointcut expression and runs at any join point matched by the pointcut (for example, the execution of a method with a certain name). The concept of join points as matched by pointcut expressions is central to AOP, and Spring uses the AspectJ pointcut expression language by default.
- *Introduction*: declaring additional methods or fields on behalf of a type. Spring AOP allows you to introduce new interfaces (and a corresponding implementation) to any advised object. For example, you could use an introduction to make a bean implement an `IsModified` interface, to simplify caching. (An introduction is known as an inter-type declaration in the AspectJ community.)
- *Target object*: object being advised by one or more aspects. Also referred to as the *advised* object. Since Spring AOP is implemented using runtime proxies, this object will always be a *proxied* object.
- *AOP proxy*: an object created by the AOP framework in order to implement the aspect contracts (advise method executions and so on). In the Spring Framework, an AOP proxy will be a JDK dynamic proxy or a CGLIB proxy.
- *Weaving*: linking aspects with other application types or objects to create an advised object. This can be done at compile time (using the AspectJ compiler, for example), load time, or at runtime. Spring AOP, like other pure Java AOP frameworks, performs weaving at runtime.

Types of advice:

- *Before advice*: Advice that executes before a join point, but which does not have the ability to prevent execution flow proceeding to the join point (unless it throws an exception).
- *After returning advice*: Advice to be executed after a join point completes normally: for example, if a method returns without throwing an exception.
- *After throwing advice*: Advice to be executed if a method exits by throwing an exception.
- *After (finally) advice*: Advice to be executed regardless of the means by which a join point exits (normal or exceptional return).
- *Around advice*: Advice that surrounds a join point such as a method invocation. This is the most powerful kind of advice. Around advice can perform custom behavior before and after the method invocation. It is also responsible for choosing whether to proceed to the join point or to shortcut the advised method execution by returning its own return value or throwing an exception.

Around advice is the most general kind of advice. Since Spring AOP, like AspectJ, provides a full range of advice types, we recommend that you use the least powerful advice type that can implement the required behavior. For example, if you need only to update a cache with the return value of a method, you are better off implementing an after returning advice than an around advice, although an around advice can accomplish the same thing. Using the most specific advice type provides a simpler programming model with less potential for errors. For example, you do not need to invoke the `proceed()` method on the `JoinPoint` used for around advice, and hence cannot fail to invoke it.

In Spring 2.0, all advice parameters are statically typed, so that you work with advice parameters of the appropriate type (the type of the return value from a method execution for example) rather than `Object` arrays.

The concept of join points, matched by pointcuts, is the key to AOP which distinguishes it from older technologies offering only interception. Pointcuts enable advice to be targeted independently of the Object-Oriented hierarchy. For example, an around advice providing declarative transaction management can be applied to a set of methods spanning multiple objects (such as all business operations in the service layer).

Spring AOP capabilities and goals

Spring AOP is implemented in pure Java. There is no need for a special compilation process. Spring AOP does not need to control the class loader hierarchy, and is thus suitable for use in a Servlet container or application server.

Spring AOP currently supports only method execution join points (advising the execution of methods on Spring beans). Field interception is not implemented, although support for field interception could be added without breaking the core Spring AOP APIs. If you need to advise field access and update join points, consider a language such as AspectJ.

Spring AOP's approach to AOP differs from that of most other AOP frameworks. The aim is not to provide the most complete AOP implementation (although Spring AOP is quite capable); it is rather to provide a close integration between AOP implementation and Spring IoC to help solve common problems in enterprise applications.

Thus, for example, the Spring Framework's AOP functionality is normally used in conjunction with the Spring IoC container. Aspects are configured using normal bean definition syntax (although this allows powerful "autoproxying" capabilities): this is a crucial difference from other AOP implementations. There are some things you cannot do easily or efficiently with Spring AOP, such as advise very fine-grained objects (such as domain objects typically): AspectJ is the best choice in such cases. However, our experience is that Spring AOP provides an excellent solution to most problems in enterprise Java applications that are amenable to AOP.

Spring AOP will never strive to compete with AspectJ to provide a comprehensive AOP solution. We believe that both proxy-based frameworks like Spring AOP and full-blown frameworks such as AspectJ are valuable, and that they are complementary, rather than in competition. Spring seamlessly integrates Spring AOP and IoC with AspectJ, to enable all uses of AOP to be catered for within a consistent Spring-based application architecture. This integration does not affect the Spring AOP API or the AOP Alliance API: Spring AOP remains backward-compatible. See the following chapter for a discussion of the Spring AOP APIs.

> **Note**
>
> One of the central tenets of the Spring Framework is that of *non-invasiveness*; this is the idea that you should not be forced to introduce framework-specific classes and interfaces into your business/domain model. However, in some places the Spring Framework does give you the option to introduce Spring Framework-specific dependencies into your codebase: the rationale in giving you such options is because in certain scenarios it might be just plain easier to read or code some specific piece of functionality in such a way. The Spring Framework (almost) always offers you the choice though: you have the freedom to make an informed decision as to which option best suits your particular use case or scenario.
>
> One such choice that is relevant to this chapter is that of which AOP framework (and which AOP style) to choose. You have the choice of AspectJ and/or Spring AOP, and you also have the choice of either the @AspectJ annotation-style approach or the Spring XML configuration-style approach.

> The fact that this chapter chooses to introduce the @AspectJ-style approach first should not be taken as an indication that the Spring team favors the @AspectJ annotation-style approach over the Spring XML configuration-style.
>
> See Section 9.4, “Choosing which AOP declaration style to use” for a more complete discussion of the whys and wherefores of each style.

AOP Proxies

Spring AOP defaults to using standard JDK *dynamic proxies* for AOP proxies. This enables any interface (or set of interfaces) to be proxied.

Spring AOP can also use CGLIB proxies. This is necessary to proxy classes, rather than interfaces. CGLIB is used by default if a business object does not implement an interface. As it is good practice to program to interfaces rather than classes, business classes normally will implement one or more business interfaces. It is possible to force the use of CGLIB, in those (hopefully rare) cases where you need to advise a method that is not declared on an interface, or where you need to pass a proxied object to a method as a concrete type.

It is important to grasp the fact that Spring AOP is *proxy-based*. See the section called “Understanding AOP proxies” for a thorough examination of exactly what this implementation detail actually means.

9.2 @AspectJ support

@AspectJ refers to a style of declaring aspects as regular Java classes annotated with annotations. The @AspectJ style was introduced by the AspectJ project as part of the AspectJ 5 release. Spring interprets the same annotations as AspectJ 5, using a library supplied by AspectJ for pointcut parsing and matching. The AOP runtime is still pure Spring AOP though, and there is no dependency on the AspectJ compiler or weaver.

> **Note**
>
> Using the AspectJ compiler and weaver enables use of the full AspectJ language, and is discussed in Section 9.8, “Using AspectJ with Spring applications”.

Enabling @AspectJ Support

To use @AspectJ aspects in a Spring configuration you need to enable Spring support for configuring Spring AOP based on @AspectJ aspects, and *autoproxying* beans based on whether or not they are advised by those aspects. By autoproxying we mean that if Spring determines that a bean is advised by one or more aspects, it will automatically generate a proxy for that bean to intercept method invocations and ensure that advice is executed as needed.

The @AspectJ support can be enabled with XML or Java style configuration. In either case you will also need to ensure that AspectJ’s `aspectjweaver.jar` library is on the classpath of your application (version 1.6.8 or later). This library is available in the `'lib'` directory of an AspectJ distribution or via the Maven Central repository.

Enabling @AspectJ Support with Java configuration

To enable @AspectJ support with Java `@Configuration` add the `@EnableAspectJAutoProxy` annotation:

```
@Configuration
@EnableAspectJAutoProxy
public class AppConfig {

}
```

Enabling @AspectJ Support with XML configuration

To enable @AspectJ support with XML based configuration use the `aop:aspectj-autoproxy` element:

```
<aop:aspectj-autoproxy/>
```

This assumes that you are using schema support as described in Chapter 34, *XML Schema-based configuration*. See the section called “the aop schema” for how to import the tags in the aop namespace.

Declaring an aspect

With the @AspectJ support enabled, any bean defined in your application context with a class that is an @AspectJ aspect (has the `@Aspect` annotation) will be automatically detected by Spring and used to configure Spring AOP. The following example shows the minimal definition required for a not-very-useful aspect:

A regular bean definition in the application context, pointing to a bean class that has the `@Aspect` annotation:

```
<bean id="myAspect" class="org.xyz.NotVeryUsefulAspect">
    <!-- configure properties of aspect here as normal -->
</bean>
```

And the `NotVeryUsefulAspect` class definition, annotated with `org.aspectj.lang.annotation.Aspect` annotation;

```
package org.xyz;
import org.aspectj.lang.annotation.Aspect;

@Aspect
public class NotVeryUsefulAspect {

}
```

Aspects (classes annotated with `@Aspect`) may have methods and fields just like any other class. They may also contain pointcut, advice, and introduction (inter-type) declarations.

> **Autodetecting aspects through component scanning**
>
> You may register aspect classes as regular beans in your Spring XML configuration, or autodetect them through classpath scanning - just like any other Spring-managed bean. However, note that the *@Aspect* annotation is *not* sufficient for autodetection in the classpath: For that purpose, you need to add a separate *@Component* annotation (or alternatively a custom stereotype annotation that qualifies, as per the rules of Spring’s component scanner).

> **Advising aspects with other aspects?**
>
> In Spring AOP, it is *not* possible to have aspects themselves be the target of advice from other aspects. The *@Aspect* annotation on a class marks it as an aspect, and hence excludes it from auto-proxying.

Declaring a pointcut

Recall that pointcuts determine join points of interest, and thus enable us to control when advice executes. *Spring AOP only supports method execution join points for Spring beans*, so you can think of a pointcut as matching the execution of methods on Spring beans. A pointcut declaration has two parts: a signature comprising a name and any parameters, and a pointcut expression that determines *exactly* which method executions we are interested in. In the @AspectJ annotation-style of AOP, a pointcut signature is provided by a regular method definition, and the pointcut expression is indicated using the `@Pointcut` annotation (the method serving as the pointcut signature *must* have a `void` return type).

An example will help make this distinction between a pointcut signature and a pointcut expression clear. The following example defines a pointcut named `'anyOldTransfer'` that will match the execution of any method named `'transfer'`:

```
@Pointcut("execution(* transfer(..))")// the pointcut expression
private void anyOldTransfer() {}// the pointcut signature
```

The pointcut expression that forms the value of the `@Pointcut` annotation is a regular AspectJ 5 pointcut expression. For a full discussion of AspectJ's pointcut language, see the AspectJ Programming Guide (and for extensions, the AspectJ 5 Developers Notebook) or one of the books on AspectJ such as "Eclipse AspectJ" by Colyer et. al. or "AspectJ in Action" by Ramnivas Laddad.

Supported Pointcut Designators

Spring AOP supports the following AspectJ pointcut designators (PCD) for use in pointcut expressions:

Other pointcut types

The full AspectJ pointcut language supports additional pointcut designators that are not supported in Spring. These are: `call`, `get`, `set`, `preinitialization`, `staticinitialization`, `initialization`, `handler`, `adviceexecution`, `withincode`, `cflow`, `cflowbelow`, `if`, `@this`, and `@withincode`. Use of these pointcut designators in pointcut expressions interpreted by Spring AOP will result in an `IllegalArgumentException` being thrown.

The set of pointcut designators supported by Spring AOP may be extended in future releases to support more of the AspectJ pointcut designators.

- *execution* - for matching method execution join points, this is the primary pointcut designator you will use when working with Spring AOP
- *within* - limits matching to join points within certain types (simply the execution of a method declared within a matching type when using Spring AOP)
- *this* - limits matching to join points (the execution of methods when using Spring AOP) where the bean reference (Spring AOP proxy) is an instance of the given type
- *target* - limits matching to join points (the execution of methods when using Spring AOP) where the target object (application object being proxied) is an instance of the given type
- *args* - limits matching to join points (the execution of methods when using Spring AOP) where the arguments are instances of the given types

- *@target* - limits matching to join points (the execution of methods when using Spring AOP) where the class of the executing object has an annotation of the given type
- *@args* - limits matching to join points (the execution of methods when using Spring AOP) where the runtime type of the actual arguments passed have annotations of the given type(s)
- *@within* - limits matching to join points within types that have the given annotation (the execution of methods declared in types with the given annotation when using Spring AOP)
- *@annotation* - limits matching to join points where the subject of the join point (method being executed in Spring AOP) has the given annotation

Because Spring AOP limits matching to only method execution join points, the discussion of the pointcut designators above gives a narrower definition than you will find in the AspectJ programming guide. In addition, AspectJ itself has type-based semantics and at an execution join point both `this` and `target` refer to the same object - the object executing the method. Spring AOP is a proxy-based system and differentiates between the proxy object itself (bound to `this`) and the target object behind the proxy (bound to `target`).

> **Note**
>
> Due to the proxy-based nature of Spring's AOP framework, protected methods are by definition *not* intercepted, neither for JDK proxies (where this isn't applicable) nor for CGLIB proxies (where this is technically possible but not recommendable for AOP purposes). As a consequence, any given pointcut will be matched against *public methods only*!
>
> If your interception needs include protected/private methods or even constructors, consider the use of Spring-driven native AspectJ weaving instead of Spring's proxy-based AOP framework. This constitutes a different mode of AOP usage with different characteristics, so be sure to make yourself familiar with weaving first before making a decision.

Spring AOP also supports an additional PCD named *bean*. This PCD allows you to limit the matching of join points to a particular named Spring bean, or to a set of named Spring beans (when using wildcards). The *bean* PCD has the following form:

```
bean(idOrNameOfBean)
```

The *idOrNameOfBean* token can be the name of any Spring bean: limited wildcard support using the * character is provided, so if you establish some naming conventions for your Spring beans you can quite easily write a *bean* PCD expression to pick them out. As is the case with other pointcut designators, the *bean* PCD can be &&'ed, ||'ed, and ! (negated) too.

> **Note**
>
> Please note that the *bean* PCD is *only* supported in Spring AOP - and *not* in native AspectJ weaving. It is a Spring-specific extension to the standard PCDs that AspectJ defines.
>
> The *bean* PCD operates at the *instance* level (building on the Spring bean name concept) rather than at the type level only (which is what weaving-based AOP is limited to). Instance-based pointcut designators are a special capability of Spring's proxy-based AOP framework and its close integration with the Spring bean factory, where it is natural and straightforward to identify specific beans by name.

Combining pointcut expressions

Pointcut expressions can be combined using *&&*, || and *!*. It is also possible to refer to pointcut expressions by name. The following example shows three pointcut expressions: `anyPublicOperation` (which matches if a method execution join point represents the execution of any public method); `inTrading` (which matches if a method execution is in the trading module), and `tradingOperation` (which matches if a method execution represents any public method in the trading module).

```
@Pointcut("execution(public * (..))")
    private void anyPublicOperation() {}

    @Pointcut("within(com.xyz.someapp.trading..)")
    private void inTrading() {}

    @Pointcut("anyPublicOperation() && inTrading()")
    private void tradingOperation() {}
```

It is a best practice to build more complex pointcut expressions out of smaller named components as shown above. When referring to pointcuts by name, normal Java visibility rules apply (you can see private pointcuts in the same type, protected pointcuts in the hierarchy, public pointcuts anywhere and so on). Visibility does not affect pointcut *matching*.

Sharing common pointcut definitions

When working with enterprise applications, you often want to refer to modules of the application and particular sets of operations from within several aspects. We recommend defining a "SystemArchitecture" aspect that captures common pointcut expressions for this purpose. A typical such aspect would look as follows:

```
package com.xyz.someapp;

import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Pointcut;

@Aspect
public class SystemArchitecture {

    /
     * A join point is in the web layer if the method is defined
     * in a type in the com.xyz.someapp.web package or any sub-package
     * under that.
     /
    @Pointcut("within(com.xyz.someapp.web..)")
    public void inWebLayer() {}

    /
     * A join point is in the service layer if the method is defined
     * in a type in the com.xyz.someapp.service package or any sub-package
     * under that.
     /
    @Pointcut("within(com.xyz.someapp.service..)")
    public void inServiceLayer() {}

    /
     * A join point is in the data access layer if the method is defined
     * in a type in the com.xyz.someapp.dao package or any sub-package
     * under that.
     /
    @Pointcut("within(com.xyz.someapp.dao..)")
    public void inDataAccessLayer() {}

    /
     * A business service is the execution of any method defined on a service
     * interface. This definition assumes that interfaces are placed in the
     * "service" package, and that implementation types are in sub-packages.
     *
     * If you group service interfaces by functional area (for example,
     * in packages com.xyz.someapp.abc.service and com.xyz.someapp.def.service) then
     * the pointcut expression "execution(* com.xyz.someapp..service.*(..))"
     * could be used instead.
     *
     * Alternatively, you can write the expression using the bean
     * PCD, like so "bean(Service)". (This assumes that you have
     * named your Spring service beans in a consistent fashion.)
     */
    @Pointcut("execution( com.xyz.someapp..service..(..))")
    public void businessService() {}

    /*
     * A data access operation is the execution of any method defined on a
     * dao interface. This definition assumes that interfaces are placed in the
     * "dao" package, and that implementation types are in sub-packages.
     */
    @Pointcut("execution( com.xyz.someapp.dao..(..))")
    public void dataAccessOperation() {}

}
```

The pointcuts defined in such an aspect can be referred to anywhere that you need a pointcut expression. For example, to make the service layer transactional, you could write:

```
<aop:config>
    <aop:advisor
        pointcut="com.xyz.someapp.SystemArchitecture.businessService()"
        advice-ref="tx-advice"/>
</aop:config>

<tx:advice id="tx-advice">
    <tx:attributes>
        <tx:method name="*" propagation="REQUIRED"/>
    </tx:attributes>
</tx:advice>
```

The `<aop:config>` and `<aop:advisor>` elements are discussed in Section 9.3, “Schema-based AOP support”. The transaction elements are discussed in Chapter 12, *Transaction Management*.

Examples

Spring AOP users are likely to use the `execution` pointcut designator the most often. The format of an execution expression is:

```
execution(modifiers-pattern? ret-type-pattern declaring-type-pattern? name-pattern(param-pattern)
            throws-pattern?)
```

All parts except the returning type pattern (ret-type-pattern in the snippet above), name pattern, and parameters pattern are optional. The returning type pattern determines what the return type of the method must be in order for a join point to be matched. Most frequently you will use `*` as the returning type pattern, which matches any return type. A fully-qualified type name will match only when the method returns the given type. The name pattern matches the method name. You can use the `*` wildcard as all or part of a name pattern. The parameters pattern is slightly more complex: `()` matches a method that takes no parameters, whereas `(..)` matches any number of parameters (zero or more). The pattern `(*)` matches a method taking one parameter of any type, `(*,String)` matches a method taking two parameters, the first can be of any type, the second must be a String. Consult the Language Semantics section of the AspectJ Programming Guide for more information.

Some examples of common pointcut expressions are given below.

- the execution of any public method:

```
execution(public * *(..))
```

- the execution of any method with a name beginning with "set":

```
execution(* set*(..))
```

- the execution of any method defined by the `AccountService` interface:

```
execution(* com.xyz.service.AccountService.*(..))
```

- the execution of any method defined in the service package:

```
execution(* com.xyz.service..(..))
```

- the execution of any method defined in the service package or a sub-package:

```
execution(* com.xyz.service...(..))
```

- any join point (method execution only in Spring AOP) within the service package:

```
within(com.xyz.service.*)
```

- any join point (method execution only in Spring AOP) within the service package or a sub-package:

```
within(com.xyz.service..*)
```

- any join point (method execution only in Spring AOP) where the proxy implements the `AccountService` interface:

```
this(com.xyz.service.AccountService)
```

> **Note**
>
> *this* is more commonly used in a binding form :- see the following section on advice for how to make the proxy object available in the advice body.

- any join point (method execution only in Spring AOP) where the target object implements the `AccountService` interface:

```
target(com.xyz.service.AccountService)
```

> **Note**
>
> *target* is more commonly used in a binding form :- see the following section on advice for how to make the target object available in the advice body.

- any join point (method execution only in Spring AOP) which takes a single parameter, and where the argument passed at runtime is `Serializable`:

```
args(java.io.Serializable)
```

> **Note**
>
> *args* is more commonly used in a binding form :- see the following section on advice for how to make the method arguments available in the advice body.

Note that the pointcut given in this example is different to `execution(* *(java.io.Serializable))`: the args version matches if the argument passed at runtime is Serializable, the execution version matches if the method signature declares a single parameter of type `Serializable`.

- any join point (method execution only in Spring AOP) where the target object has an `@Transactional` annotation:

```
@target(org.springframework.transaction.annotation.Transactional)
```

> **Note**
>
> *@target* can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) where the declared type of the target object has an `@Transactional` annotation:

```
@within(org.springframework.transaction.annotation.Transactional)
```

> **Note**
>
> *@within* can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) where the executing method has an `@Transactional` annotation:

```
@annotation(org.springframework.transaction.annotation.Transactional)
```

> **Note**
>
> *@annotation* can also be used in a binding form :- see the following section on advice for how to make the annotation object available in the advice body.

- any join point (method execution only in Spring AOP) which takes a single parameter, and where the runtime type of the argument passed has the `@Classified` annotation:

```
@args(com.xyz.security.Classified)
```

> **Note**
>
> *@args* can also be used in a binding form :- see the following section on advice for how to make the annotation object(s) available in the advice body.

- any join point (method execution only in Spring AOP) on a Spring bean named *`tradeService`*:

```
bean(tradeService)
```

- any join point (method execution only in Spring AOP) on Spring beans having names that match the wildcard expression *`*Service`*:

```
bean(*Service)
```

Writing good pointcuts

During compilation, AspectJ processes pointcuts in order to try and optimize matching performance. Examining code and determining if each join point matches (statically or dynamically) a given pointcut is a costly process. (A dynamic match means the match cannot be fully determined from static analysis and a test will be placed in the code to determine if there is an actual match when the code is running). On first encountering a pointcut declaration, AspectJ will rewrite it into an optimal form for the matching process. What does this mean? Basically pointcuts are rewritten in DNF (Disjunctive Normal Form) and the components of the pointcut are sorted such that those components that are cheaper to evaluate are checked first. This means you do not have to worry about understanding the performance of various pointcut designators and may supply them in any order in a pointcut declaration.

However, AspectJ can only work with what it is told, and for optimal performance of matching you should think about what they are trying to achieve and narrow the search space for matches as much as possible in the definition. The existing designators naturally fall into one of three groups: kinded, scoping and context:

- Kinded designators are those which select a particular kind of join point. For example: execution, get, set, call, handler
- Scoping designators are those which select a group of join points of interest (of probably many kinds). For example: within, withincode
- Contextual designators are those that match (and optionally bind) based on context. For example: this, target, @annotation

A well written pointcut should try and include at least the first two types (kinded and scoping), whilst the contextual designators may be included if wishing to match based on join point context, or bind that context for use in the advice. Supplying either just a kinded designator or just a contextual designator will work but could affect weaving performance (time and memory used) due to all the extra processing and analysis. Scoping designators are very fast to match and their usage means AspectJ can very quickly dismiss groups of join points that should not be further processed - that is why a good pointcut should always include one if possible.

Declaring advice

Advice is associated with a pointcut expression, and runs before, after, or around method executions matched by the pointcut. The pointcut expression may be either a simple reference to a named pointcut, or a pointcut expression declared in place.

Before advice

Before advice is declared in an aspect using the `@Before` annotation:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Before;

@Aspect
public class BeforeExample {

    @Before("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doAccessCheck() {
        // ...
    }

}
```

If using an in-place pointcut expression we could rewrite the above example as:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Before;

@Aspect
public class BeforeExample {

    @Before("execution(* com.xyz.myapp.dao..(..))")
    public void doAccessCheck() {
        // ...
    }

}
```

After returning advice

After returning advice runs when a matched method execution returns normally. It is declared using the `@AfterReturning` annotation:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterReturning;

@Aspect
public class AfterReturningExample {

    @AfterReturning("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doAccessCheck() {
        // ...
    }

}
```

> **Note**
>
> Note: it is of course possible to have multiple advice declarations, and other members as well, all inside the same aspect. We're just showing a single advice declaration in these examples to focus on the issue under discussion at the time.

Sometimes you need access in the advice body to the actual value that was returned. You can use the form of `@AfterReturning` that binds the return value for this:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterReturning;

@Aspect
public class AfterReturningExample {

    @AfterReturning(
        pointcut="com.xyz.myapp.SystemArchitecture.dataAccessOperation()",
        returning="retVal")
    public void doAccessCheck(Object retVal) {
        // ...
    }

}
```

The name used in the `returning` attribute must correspond to the name of a parameter in the advice method. When a method execution returns, the return value will be passed to the advice method as the corresponding argument value. A `returning` clause also restricts matching to only those method executions that return a value of the specified type (`Object` in this case, which will match any return value).

Please note that it is *not* possible to return a totally different reference when using after-returning advice.

After throwing advice

After throwing advice runs when a matched method execution exits by throwing an exception. It is declared using the `@AfterThrowing` annotation:

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterThrowing;

@Aspect
public class AfterThrowingExample {

    @AfterThrowing("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doRecoveryActions() {
        // ...
    }

}
```

Often you want the advice to run only when exceptions of a given type are thrown, and you also often need access to the thrown exception in the advice body. Use the `throwing` attribute to both restrict matching (if desired, use `Throwable` as the exception type otherwise) and bind the thrown exception to an advice parameter.

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.AfterThrowing;

@Aspect
public class AfterThrowingExample {

    @AfterThrowing(
        pointcut="com.xyz.myapp.SystemArchitecture.dataAccessOperation()",
        throwing="ex")
    public void doRecoveryActions(DataAccessException ex) {
        // ...
    }

}
```

The name used in the `throwing` attribute must correspond to the name of a parameter in the advice method. When a method execution exits by throwing an exception, the exception will be passed to the advice method as the corresponding argument value. A `throwing` clause also restricts matching to only those method executions that throw an exception of the specified type (`DataAccessException` in this case).

After (finally) advice

After (finally) advice runs however a matched method execution exits. It is declared using the `@After` annotation. After advice must be prepared to handle both normal and exception return conditions. It is typically used for releasing resources, etc.

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.After;

@Aspect
public class AfterFinallyExample {

    @After("com.xyz.myapp.SystemArchitecture.dataAccessOperation()")
    public void doReleaseLock() {
        // ...
    }

}
```

Around advice

The final kind of advice is around advice. Around advice runs "around" a matched method execution. It has the opportunity to do work both before and after the method executes, and to determine when, how, and even if, the method actually gets to execute at all. Around advice is often used if you need to share state before and after a method execution in a thread-safe manner (starting and stopping a timer for example). Always use the least powerful form of advice that meets your requirements (i.e. don't use around advice if simple before advice would do).

Around advice is declared using the `@Around` annotation. The first parameter of the advice method must be of type `ProceedingJoinPoint`. Within the body of the advice, calling `proceed()` on the `ProceedingJoinPoint` causes the underlying method to execute. The `proceed` method may also be called passing in an `Object[]` - the values in the array will be used as the arguments to the method execution when it proceeds.

> **Note**
>
> The behavior of proceed when called with an Object[] is a little different than the behavior of proceed for around advice compiled by the AspectJ compiler. For around advice written using the traditional AspectJ language, the number of arguments passed to proceed must match the number of arguments passed to the around advice (not the number of arguments taken by the underlying join point), and the value passed to proceed in a given argument position supplants the original value at the join point for the entity the value was bound to (Don't worry if this doesn't make sense right now!). The approach taken by Spring is simpler and a better match to its proxy-based, execution only semantics. You only need to be aware of this difference if you are compiling @AspectJ aspects written for Spring and using proceed with arguments with the AspectJ compiler and weaver. There is a way to write such aspects that is 100% compatible across both Spring AOP and AspectJ, and this is discussed in the following section on advice parameters.

```
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Around;
import org.aspectj.lang.ProceedingJoinPoint;

@Aspect
public class AroundExample {

    @Around("com.xyz.myapp.SystemArchitecture.businessService()")
    public Object doBasicProfiling(ProceedingJoinPoint pjp) throws Throwable {
        // start stopwatch
        Object retVal = pjp.proceed();
        // stop stopwatch
        return retVal;
    }

}
```

The value returned by the around advice will be the return value seen by the caller of the method. A simple caching aspect for example could return a value from a cache if it has one, and invoke proceed() if it does not. Note that proceed may be invoked once, many times, or not at all within the body of the around advice, all of these are quite legal.

Advice parameters

Spring offers fully typed advice - meaning that you declare the parameters you need in the advice signature (as we saw for the returning and throwing examples above) rather than work with `Object[]` arrays all the time. We'll see how to make argument and other contextual values available to the advice body in a moment. First let's take a look at how to write generic advice that can find out about the method the advice is currently advising.

Access to the current JoinPoint

Any advice method may declare as its first parameter, a parameter of type `org.aspectj.lang.JoinPoint` (please note that around advice is *required* to declare a first parameter of type `ProceedingJoinPoint`, which is a subclass of `JoinPoint`. The `JoinPoint` interface provides a number of useful methods such as `getArgs()` (returns the method arguments), `getThis()` (returns the proxy object), `getTarget()` (returns the target object), `getSignature()` (returns a description of the method that is being advised) and `toString()` (prints a useful description of the method being advised). Please do consult the javadocs for full details.

Passing parameters to advice

We've already seen how to bind the returned value or exception value (using after returning and after throwing advice). To make argument values available to the advice body, you can use the binding form of `args`. If a parameter name is used in place of a type name in an args expression, then the value of the corresponding argument will be passed as the parameter value when the advice is invoked. An example should make this clearer. Suppose you want to advise the execution of dao operations that take an Account object as the first parameter, and you need access to the account in the advice body. You could write the following:

```
@Before("com.xyz.myapp.SystemArchitecture.dataAccessOperation() && args(account,..)")
public void validateAccount(Account account) {
    // ...
}
```

The `args(account,..)` part of the pointcut expression serves two purposes: firstly, it restricts matching to only those method executions where the method takes at least one parameter, and the argument passed to that parameter is an instance of `Account`; secondly, it makes the actual `Account` object available to the advice via the `account` parameter.

Another way of writing this is to declare a pointcut that "provides" the `Account` object value when it matches a join point, and then just refer to the named pointcut from the advice. This would look as follows:

```
@Pointcut("com.xyz.myapp.SystemArchitecture.dataAccessOperation() && args(account,..)")
private void accountDataAccessOperation(Account account) {}

@Before("accountDataAccessOperation(account)")
public void validateAccount(Account account) {
    // ...
}
```

The interested reader is once more referred to the AspectJ programming guide for more details.

The proxy object (`this`), target object (`target`), and annotations (`@within`, `@target`, `@annotation`, `@args`) can all be bound in a similar fashion. The following example shows how you could match the execution of methods annotated with an `@Auditable` annotation, and extract the audit code.

First the definition of the `@Auditable` annotation:

```
@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.METHOD)
public @interface Auditable {
    AuditCode value();
}
```

And then the advice that matches the execution of `@Auditable` methods:

```
@Before("com.xyz.lib.Pointcuts.anyPublicMethod() && @annotation(auditable)")
public void audit(Auditable auditable) {
    AuditCode code = auditable.value();
    // ...
}
```

Advice parameters and generics

Spring AOP can handle generics used in class declarations and method parameters. Suppose you have a generic type like this:

```
public interface Sample<T> {
    void sampleGenericMethod(T param);
    void sampleGenericCollectionMethod(Collection>T> param);
}
```

You can restrict interception of method types to certain parameter types by simply typing the advice parameter to the parameter type you want to intercept the method for:

```
@Before("execution(* ..Sample+.sampleGenericMethod(*)) && args(param)")
public void beforeSampleMethod(MyType param) {
    // Advice implementation
}
```

That this works is pretty obvious as we already discussed above. However, it's worth pointing out that this won't work for generic collections. So you cannot define a pointcut like this:

```
@Before("execution(* ..Sample+.sampleGenericCollectionMethod(*)) && args(param)")
public void beforeSampleMethod(Collection<MyType> param) {
    // Advice implementation
}
```

To make this work we would have to inspect every element of the collection, which is not reasonable as we also cannot decide how to treat `null` values in general. To achieve something similar to this you have to type the parameter to `Collection<?>` and manually check the type of the elements.

Determining argument names

The parameter binding in advice invocations relies on matching names used in pointcut expressions to declared parameter names in (advice and pointcut) method signatures. Parameter names are *not* available through Java reflection, so Spring AOP uses the following strategies to determine parameter names:

- If the parameter names have been specified by the user explicitly, then the specified parameter names are used: both the advice and the pointcut annotations have an optional "argNames" attribute which can be used to specify the argument names of the annotated method - these argument names *are* available at runtime. For example:

```
@Before(value="com.xyz.lib.Pointcuts.anyPublicMethod() && target(bean) && @annotation(auditable)",
        argNames="bean,auditable")
public void audit(Object bean, Auditable auditable) {
    AuditCode code = auditable.value();
    // ... use code and bean
}
```

If the first parameter is of the `JoinPoint`, `ProceedingJoinPoint`, or `JoinPoint.StaticPart` type, you may leave out the name of the parameter from the value of the "argNames" attribute. For example, if you modify the preceding advice to receive the join point object, the "argNames" attribute need not include it:

```
@Before(value="com.xyz.lib.Pointcuts.anyPublicMethod() && target(bean) && @annotation(auditable)",
        argNames="bean,auditable")
public void audit(JoinPoint jp, Object bean, Auditable auditable) {
    AuditCode code = auditable.value();
    // ... use code, bean, and jp
}
```

The special treatment given to the first parameter of the `JoinPoint`, `ProceedingJoinPoint`, and `JoinPoint.StaticPart` types is particularly convenient for advice that do not collect any other join

point context. In such situations, you may simply omit the "argNames" attribute. For example, the following advice need not declare the "argNames" attribute:

```
@Before("com.xyz.lib.Pointcuts.anyPublicMethod()")
public void audit(JoinPoint jp) {
    // ... use jp
}
```

- Using the `'argNames'` attribute is a little clumsy, so if the `'argNames'` attribute has not been specified, then Spring AOP will look at the debug information for the class and try to determine the parameter names from the local variable table. This information will be present as long as the classes have been compiled with debug information (`'-g:vars'` at a minimum). The consequences of compiling with this flag on are: (1) your code will be slightly easier to understand (reverse engineer), (2) the class file sizes will be very slightly bigger (typically inconsequential), (3) the optimization to remove unused local variables will not be applied by your compiler. In other words, you should encounter no difficulties building with this flag on.

> **Note**
>
> If an @AspectJ aspect has been compiled by the AspectJ compiler (ajc) even without the debug information then there is no need to add the argNames attribute as the compiler will retain the needed information.

- If the code has been compiled without the necessary debug information, then Spring AOP will attempt to deduce the pairing of binding variables to parameters (for example, if only one variable is bound in the pointcut expression, and the advice method only takes one parameter, the pairing is obvious!). If the binding of variables is ambiguous given the available information, then an `AmbiguousBindingException` will be thrown.
- If all of the above strategies fail then an `IllegalArgumentException` will be thrown.

Proceeding with arguments

We remarked earlier that we would describe how to write a proceed call *with arguments* that works consistently across Spring AOP and AspectJ. The solution is simply to ensure that the advice signature binds each of the method parameters in order. For example:

```
@Around("execution(List<Account> find*(..)) && " +
        "com.xyz.myapp.SystemArchitecture.inDataAccessLayer() && " +
        "args(accountHolderNamePattern)")
public Object preProcessQueryPattern(ProceedingJoinPoint pjp,
        String accountHolderNamePattern) throws Throwable {
    String newPattern = preProcess(accountHolderNamePattern);
    return pjp.proceed(new Object[] {newPattern});
}
```

In many cases you will be doing this binding anyway (as in the example above).

Advice ordering

What happens when multiple pieces of advice all want to run at the same join point? Spring AOP follows the same precedence rules as AspectJ to determine the order of advice execution. The highest precedence advice runs first "on the way in" (so given two pieces of before advice, the one with highest precedence runs first). "On the way out" from a join point, the highest precedence advice runs last (so given two pieces of after advice, the one with the highest precedence will run second).

When two pieces of advice defined in *different* aspects both need to run at the same join point, unless you specify otherwise the order of execution is undefined. You can control the order of execution by specifying precedence. This is done in the normal Spring way by either implementing the `org.springframework.core.Ordered` interface in the aspect class or annotating it with the `Order` annotation. Given two aspects, the aspect returning the lower value from `Ordered.getValue()` (or the annotation value) has the higher precedence.

When two pieces of advice defined in *the same* aspect both need to run at the same join point, the ordering is undefined (since there is no way to retrieve the declaration order via reflection for javac-compiled classes). Consider collapsing such advice methods into one advice method per join point in each aspect class, or refactor the pieces of advice into separate aspect classes - which can be ordered at the aspect level.

Introductions

Introductions (known as inter-type declarations in AspectJ) enable an aspect to declare that advised objects implement a given interface, and to provide an implementation of that interface on behalf of those objects.

An introduction is made using the `@DeclareParents` annotation. This annotation is used to declare that matching types have a new parent (hence the name). For example, given an interface `UsageTracked`, and an implementation of that interface `DefaultUsageTracked`, the following aspect declares that all implementors of service interfaces also implement the `UsageTracked` interface. (In order to expose statistics via JMX for example.)

```
@Aspect
public class UsageTracking {

    @DeclareParents(value="com.xzy.myapp.service.*+", defaultImpl=DefaultUsageTracked.class)
    public static UsageTracked mixin;

    @Before("com.xyz.myapp.SystemArchitecture.businessService() && this(usageTracked)")
    public void recordUsage(UsageTracked usageTracked) {
        usageTracked.incrementUseCount();
    }

}
```

The interface to be implemented is determined by the type of the annotated field. The `value` attribute of the `@DeclareParents` annotation is an AspectJ type pattern :- any bean of a matching type will implement the UsageTracked interface. Note that in the before advice of the above example, service beans can be directly used as implementations of the `UsageTracked` interface. If accessing a bean programmatically you would write the following:

```
UsageTracked usageTracked = (UsageTracked) context.getBean("myService");
```

Aspect instantiation models

> **Note**
>
> (This is an advanced topic, so if you are just starting out with AOP you can safely skip it until later.)

By default there will be a single instance of each aspect within the application context. AspectJ calls this the singleton instantiation model. It is possible to define aspects with alternate lifecycles :- Spring supports AspectJ's `perthis` and `pertarget` instantiation models (`percflow`, `percflowbelow`, and `pertypewithin` are not currently supported).

A "perthis" aspect is declared by specifying a `perthis` clause in the `@Aspect` annotation. Let's look at an example, and then we'll explain how it works.

```
@Aspect("perthis(com.xyz.myapp.SystemArchitecture.businessService())")
public class MyAspect {

    private int someState;

    @Before(com.xyz.myapp.SystemArchitecture.businessService())
    public void recordServiceUsage() {
        // ...
    }

}
```

The effect of the `'perthis'` clause is that one aspect instance will be created for each unique service object executing a business service (each unique object bound to *this* at join points matched by the pointcut expression). The aspect instance is created the first time that a method is invoked on the service object. The aspect goes out of scope when the service object goes out of scope. Before the aspect instance is created, none of the advice within it executes. As soon as the aspect instance has been created, the advice declared within it will execute at matched join points, but only when the service object is the one this aspect is associated with. See the AspectJ programming guide for more information on per-clauses.

The `'pertarget'` instantiation model works in exactly the same way as perthis, but creates one aspect instance for each unique target object at matched join points.

Example

Now that you have seen how all the constituent parts work, let's put them together to do something useful!

The execution of business services can sometimes fail due to concurrency issues (for example, deadlock loser). If the operation is retried, it is quite likely to succeed next time round. For business services where it is appropriate to retry in such conditions (idempotent operations that don't need to go back to the user for conflict resolution), we'd like to transparently retry the operation to avoid the client seeing a `PessimisticLockingFailureException`. This is a requirement that clearly cuts across multiple services in the service layer, and hence is ideal for implementing via an aspect.

Because we want to retry the operation, we will need to use around advice so that we can call proceed multiple times. Here's how the basic aspect implementation looks:

```
@Aspect
public class ConcurrentOperationExecutor implements Ordered {

    private static final int DEFAULT_MAX_RETRIES = 2;

    private int maxRetries = DEFAULT_MAX_RETRIES;
    private int order = 1;

    public void setMaxRetries(int maxRetries) {
        this.maxRetries = maxRetries;
    }

    public int getOrder() {
        return this.order;
    }

    public void setOrder(int order) {
        this.order = order;
    }

    @Around("com.xyz.myapp.SystemArchitecture.businessService()")
    public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
        int numAttempts = 0;
        PessimisticLockingFailureException lockFailureException;
        do {
            numAttempts++;
            try {
                return pjp.proceed();
            }
            catch(PessimisticLockingFailureException ex) {
                lockFailureException = ex;
            }
        } while(numAttempts <= this.maxRetries);
        throw lockFailureException;
    }

}
```

Note that the aspect implements the `Ordered` interface so we can set the precedence of the aspect higher than the transaction advice (we want a fresh transaction each time we retry). The `maxRetries` and `order` properties will both be configured by Spring. The main action happens in the `doConcurrentOperation` around advice. Notice that for the moment we're applying the retry logic to all `businessService()`s. We try to proceed, and if we fail with an `PessimisticLockingFailureException` we simply try again unless we have exhausted all of our retry attempts.

The corresponding Spring configuration is:

```
<aop:aspectj-autoproxy/>

<bean id="concurrentOperationExecutor" class="com.xyz.myapp.service.impl.ConcurrentOperationExecutor">
    <property name="maxRetries" value="3"/>
    <property name="order" value="100"/>
</bean>
```

To refine the aspect so that it only retries idempotent operations, we might define an `Idempotent` annotation:

```
@Retention(RetentionPolicy.RUNTIME)
public @interface Idempotent {
    // marker annotation
}
```

and use the annotation to annotate the implementation of service operations. The change to the aspect to only retry idempotent operations simply involves refining the pointcut expression so that only `@Idempotent` operations match:

```
@Around("com.xyz.myapp.SystemArchitecture.businessService() && " +
        "@annotation(com.xyz.myapp.service.Idempotent)")
public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
    ...
}
```

9.3 Schema-based AOP support

If you prefer an XML-based format, then Spring also offers support for defining aspects using the new "aop" namespace tags. The exact same pointcut expressions and advice kinds are supported as when using the @AspectJ style, hence in this section we will focus on the new *syntax* and refer the reader to the discussion in the previous section (Section 9.2, “@AspectJ support”) for an understanding of writing pointcut expressions and the binding of advice parameters.

To use the aop namespace tags described in this section, you need to import the spring-aop schema as described in Chapter 34, *XML Schema-based configuration*. See the section called “the aop schema” for how to import the tags in the aop namespace.

Within your Spring configurations, all aspect and advisor elements must be placed within an `<aop:config>` element (you can have more than one `<aop:config>` element in an application context configuration). An `<aop:config>` element can contain pointcut, advisor, and aspect elements (note these must be declared in that order).

> **Warning**
>
> The `<aop:config>` style of configuration makes heavy use of Spring’s auto-proxying mechanism. This can cause issues (such as advice not being woven) if you are already using explicit auto-proxying via the use of `BeanNameAutoProxyCreator` or suchlike. The recommended usage pattern is to use either just the `<aop:config>` style, or just the `AutoProxyCreator` style.

Declaring an aspect

Using the schema support, an aspect is simply a regular Java object defined as a bean in your Spring application context. The state and behavior is captured in the fields and methods of the object, and the pointcut and advice information is captured in the XML.

An aspect is declared using the <aop:aspect> element, and the backing bean is referenced using the `ref` attribute:

```
<aop:config>
    <aop:aspect id="myAspect" ref="aBean">
        ...
    </aop:aspect>
</aop:config>

<bean id="aBean" class="...">
    ...
</bean>
```

The bean backing the aspect (" `aBean`" in this case) can of course be configured and dependency injected just like any other Spring bean.

Declaring a pointcut

A named pointcut can be declared inside an <aop:config> element, enabling the pointcut definition to be shared across several aspects and advisors.

A pointcut representing the execution of any business service in the service layer could be defined as follows:

```
<aop:config>

    <aop:pointcut id="businessService"
        expression="execution(* com.xyz.myapp.service..(..))"/>

</aop:config>
```

Note that the pointcut expression itself is using the same AspectJ pointcut expression language as described in Section 9.2, “@AspectJ support”. If you are using the schema based declaration style, you can refer to named pointcuts defined in types (@Aspects) within the pointcut expression. Another way of defining the above pointcut would be:

```
<aop:config>

    <aop:pointcut id="businessService"
        expression="com.xyz.myapp.SystemArchitecture.businessService()"/>

</aop:config>
```

Assuming you have a `SystemArchitecture` aspect as described in the section called “Sharing common pointcut definitions”.

Declaring a pointcut inside an aspect is very similar to declaring a top-level pointcut:

```
<aop:config>

    <aop:aspect id="myAspect" ref="aBean">

        <aop:pointcut id="businessService"
            expression="execution(* com.xyz.myapp.service..(..))"/>

        ...

    </aop:aspect>

</aop:config>
```

Much the same way in an @AspectJ aspect, pointcuts declared using the schema based definition style may collect join point context. For example, the following pointcut collects the *this* object as the join point context and passes it to advice:

```
<aop:config>

    <aop:aspect id="myAspect" ref="aBean">

        <aop:pointcut id="businessService"
            expression="execution(* com.xyz.myapp.service..(..)) &amp;amp;&amp;amp; this(service)"/>

        <aop:before pointcut-ref="businessService" method="monitor"/>

        ...

    </aop:aspect>

</aop:config>
```

The advice must be declared to receive the collected join point context by including parameters of the matching names:

```
public void monitor(Object service) {
    ...
}
```

When combining pointcut sub-expressions, *&&* is awkward within an XML document, and so the keywords *and*, *or* and *not* can be used in place of *&&*, || and *!* respectively. For example, the previous pointcut may be better written as:

```
<aop:config>

    <aop:aspect id="myAspect" ref="aBean">

        <aop:pointcut id="businessService"
            expression="execution(* com.xyz.myapp.service..(..)) and this(service)"/>

        <aop:before pointcut-ref="businessService" method="monitor"/>

        ...
    </aop:aspect>
</aop:config>
```

Note that pointcuts defined in this way are referred to by their XML id and cannot be used as named pointcuts to form composite pointcuts. The named pointcut support in the schema based definition style is thus more limited than that offered by the @AspectJ style.

Declaring advice

The same five advice kinds are supported as for the @AspectJ style, and they have exactly the same semantics.

Before advice

Before advice runs before a matched method execution. It is declared inside an `<aop:aspect>` using the <aop:before> element.

```
<aop:aspect id="beforeExample" ref="aBean">

    <aop:before
        pointcut-ref="dataAccessOperation"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

Here `dataAccessOperation` is the id of a pointcut defined at the top (`<aop:config>`) level. To define the pointcut inline instead, replace the `pointcut-ref` attribute with a `pointcut` attribute:

```
<aop:aspect id="beforeExample" ref="aBean">

    <aop:before
        pointcut="execution(* com.xyz.myapp.dao..(..))"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

As we noted in the discussion of the @AspectJ style, using named pointcuts can significantly improve the readability of your code.

The method attribute identifies a method (`doAccessCheck`) that provides the body of the advice. This method must be defined for the bean referenced by the aspect element containing the advice. Before a data access operation is executed (a method execution join point matched by the pointcut expression), the "doAccessCheck" method on the aspect bean will be invoked.

After returning advice

After returning advice runs when a matched method execution completes normally. It is declared inside an `<aop:aspect>` in the same way as before advice. For example:

```
<aop:aspect id="afterReturningExample" ref="aBean">

    <aop:after-returning
        pointcut-ref="dataAccessOperation"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

Just as in the @AspectJ style, it is possible to get hold of the return value within the advice body. Use the returning attribute to specify the name of the parameter to which the return value should be passed:

```
<aop:aspect id="afterReturningExample" ref="aBean">

    <aop:after-returning
        pointcut-ref="dataAccessOperation"
        returning="retVal"
        method="doAccessCheck"/>

    ...

</aop:aspect>
```

The doAccessCheck method must declare a parameter named `retVal`. The type of this parameter constrains matching in the same way as described for @AfterReturning. For example, the method signature may be declared as:

```
public void doAccessCheck(Object retVal) {...
```

After throwing advice

After throwing advice executes when a matched method execution exits by throwing an exception. It is declared inside an `<aop:aspect>` using the after-throwing element:

```
<aop:aspect id="afterThrowingExample" ref="aBean">

    <aop:after-throwing
        pointcut-ref="dataAccessOperation"
        method="doRecoveryActions"/>

    ...

</aop:aspect>
```

Just as in the @AspectJ style, it is possible to get hold of the thrown exception within the advice body. Use the throwing attribute to specify the name of the parameter to which the exception should be passed:

```
<aop:aspect id="afterThrowingExample" ref="aBean">

    <aop:after-throwing
        pointcut-ref="dataAccessOperation"
        throwing="dataAccessEx"
        method="doRecoveryActions"/>

    ...

</aop:aspect>
```

The doRecoveryActions method must declare a parameter named `dataAccessEx`. The type of this parameter constrains matching in the same way as described for @AfterThrowing. For example, the method signature may be declared as:

```
public void doRecoveryActions(DataAccessException dataAccessEx) {...
```

After (finally) advice

After (finally) advice runs however a matched method execution exits. It is declared using the `after` element:

```
<aop:aspect id="afterFinallyExample" ref="aBean">

    <aop:after
        pointcut-ref="dataAccessOperation"
        method="doReleaseLock"/>

    ...

</aop:aspect>
```

Around advice

The final kind of advice is around advice. Around advice runs "around" a matched method execution. It has the opportunity to do work both before and after the method executes, and to determine when, how, and even if, the method actually gets to execute at all. Around advice is often used if you need to share state before and after a method execution in a thread-safe manner (starting and stopping a timer for example). Always use the least powerful form of advice that meets your requirements; don't use around advice if simple before advice would do.

Around advice is declared using the `aop:around` element. The first parameter of the advice method must be of type `ProceedingJoinPoint`. Within the body of the advice, calling `proceed()` on the `ProceedingJoinPoint` causes the underlying method to execute. The `proceed` method may also be calling passing in an `Object[]` - the values in the array will be used as the arguments to the method execution when it proceeds. See the section called "Around advice" for notes on calling proceed with an `Object[]`.

```
<aop:aspect id="aroundExample" ref="aBean">

    <aop:around
        pointcut-ref="businessService"
        method="doBasicProfiling"/>

    ...

</aop:aspect>
```

The implementation of the `doBasicProfiling` advice would be exactly the same as in the @AspectJ example (minus the annotation of course):

```
public Object doBasicProfiling(ProceedingJoinPoint pjp) throws Throwable {
    // start stopwatch
    Object retVal = pjp.proceed();
    // stop stopwatch
    return retVal;
}
```

Advice parameters

The schema based declaration style supports fully typed advice in the same way as described for the @AspectJ support - by matching pointcut parameters by name against advice method parameters. See the section called “Advice parameters” for details. If you wish to explicitly specify argument names for the advice methods (not relying on the detection strategies previously described) then this is done using the `arg-names` attribute of the advice element, which is treated in the same manner to the "argNames" attribute in an advice annotation as described in the section called “Determining argument names”. For example:

```
<aop:before
    pointcut="com.xyz.lib.Pointcuts.anyPublicMethod() and @annotation(auditable)"
    method="audit"
    arg-names="auditable"/>
```

The `arg-names` attribute accepts a comma-delimited list of parameter names.

Find below a slightly more involved example of the XSD-based approach that illustrates some around advice used in conjunction with a number of strongly typed parameters.

```
package x.y.service;

public interface FooService {

    Foo getFoo(String fooName, int age);
}

public class DefaultFooService implements FooService {

    public Foo getFoo(String name, int age) {
        return new Foo(name, age);
    }
}
```

Next up is the aspect. Notice the fact that the `profile(..)` method accepts a number of strongly-typed parameters, the first of which happens to be the join point used to proceed with the method call: the presence of this parameter is an indication that the `profile(..)` is to be used as `around` advice:

```
package x.y;

import org.aspectj.lang.ProceedingJoinPoint;
import org.springframework.util.StopWatch;

public class SimpleProfiler {

    public Object profile(ProceedingJoinPoint call, String name, int age) throws Throwable {
        StopWatch clock = new StopWatch("Profiling for '" + name + "' and '" + age + "'");
        try {
            clock.start(call.toShortString());
            return call.proceed();
        } finally {
            clock.stop();
            System.out.println(clock.prettyPrint());
        }
    }
}
```

Finally, here is the XML configuration that is required to effect the execution of the above advice for a particular join point:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/aop http://www.springframework.org/schema/aop/spring-
aop.xsd">

    <!-- this is the object that will be proxied by Spring's AOP infrastructure -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- this is the actual advice itself -->
    <bean id="profiler" class="x.y.SimpleProfiler"/>

    <aop:config>
        <aop:aspect ref="profiler">

            <aop:pointcut id="theExecutionOfSomeFooServiceMethod"
                expression="execution(* x.y.service.FooService.getFoo(String,int))
                and args(name, age)"/>

            <aop:around pointcut-ref="theExecutionOfSomeFooServiceMethod"
                method="profile"/>

        </aop:aspect>
    </aop:config>

</beans>
```

If we had the following driver script, we would get output something like this on standard output:

```
import org.springframework.beans.factory.BeanFactory;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import x.y.service.FooService;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        BeanFactory ctx = new ClassPathXmlApplicationContext("x/y/plain.xml");
        FooService foo = (FooService) ctx.getBean("fooService");
        foo.getFoo("Pengo", 12);
    }
}
```

```
StopWatch 'Profiling for 'Pengo and 12': running time (millis) = 0
-----------------------------------------
ms     %     Task name
-----------------------------------------
00000  ?  execution(getFoo)
```

Advice ordering

When multiple advice needs to execute at the same join point (executing method) the ordering rules are as described in the section called “Advice ordering”. The precedence between aspects is determined by either adding the `Order` annotation to the bean backing the aspect or by having the bean implement the `Ordered` interface.

Introductions

Introductions (known as inter-type declarations in AspectJ) enable an aspect to declare that advised objects implement a given interface, and to provide an implementation of that interface on behalf of those objects.

An introduction is made using the `aop:declare-parents` element inside an `aop:aspect` This element is used to declare that matching types have a new parent (hence the name). For example, given an interface `UsageTracked`, and an implementation of that interface `DefaultUsageTracked`, the following aspect declares that all implementors of service interfaces also implement the `UsageTracked` interface. (In order to expose statistics via JMX for example.)

```
<aop:aspect id="usageTrackerAspect" ref="usageTracking">

    <aop:declare-parents
        types-matching="com.xzy.myapp.service.*+"
        implement-interface="com.xyz.myapp.service.tracking.UsageTracked"
        default-impl="com.xyz.myapp.service.tracking.DefaultUsageTracked"/>

    <aop:before
        pointcut="com.xyz.myapp.SystemArchitecture.businessService()
            and this(usageTracked)"
            method="recordUsage"/>

</aop:aspect>
```

The class backing the `usageTracking` bean would contain the method:

```
public void recordUsage(UsageTracked usageTracked) {
    usageTracked.incrementUseCount();
}
```

The interface to be implemented is determined by `implement-interface` attribute. The value of the `types-matching` attribute is an AspectJ type pattern :- any bean of a matching type will implement the `UsageTracked` interface. Note that in the before advice of the above example, service beans can be directly used as implementations of the `UsageTracked` interface. If accessing a bean programmatically you would write the following:

```
UsageTracked usageTracked = (UsageTracked) context.getBean("myService");
```

Aspect instantiation models

The only supported instantiation model for schema-defined aspects is the singleton model. Other instantiation models may be supported in future releases.

Advisors

The concept of "advisors" is brought forward from the AOP support defined in Spring 1.2 and does not have a direct equivalent in AspectJ. An advisor is like a small self-contained aspect that has a single piece of advice. The advice itself is represented by a bean, and must implement one of the advice interfaces described in the section called “Advice types in Spring”. Advisors can take advantage of AspectJ pointcut expressions though.

Spring supports the advisor concept with the `<aop:advisor>` element. You will most commonly see it used in conjunction with transactional advice, which also has its own namespace support in Spring. Here’s how it looks:

```
<aop:config>

    <aop:pointcut id="businessService"
        expression="execution(* com.xyz.myapp.service..(..))"/>

    <aop:advisor
        pointcut-ref="businessService"
        advice-ref="tx-advice"/>

</aop:config>

<tx:advice id="tx-advice">
    <tx:attributes>
        <tx:method name="*" propagation="REQUIRED"/>
    </tx:attributes>
</tx:advice>
```

As well as the `pointcut-ref` attribute used in the above example, you can also use the `pointcut` attribute to define a pointcut expression inline.

To define the precedence of an advisor so that the advice can participate in ordering, use the `order` attribute to define the `Ordered` value of the advisor.

Example

Let's see how the concurrent locking failure retry example from the section called "Example" looks when rewritten using the schema support.

The execution of business services can sometimes fail due to concurrency issues (for example, deadlock loser). If the operation is retried, it is quite likely it will succeed next time round. For business services where it is appropriate to retry in such conditions (idempotent operations that don't need to go back to the user for conflict resolution), we'd like to transparently retry the operation to avoid the client seeing a `PessimisticLockingFailureException`. This is a requirement that clearly cuts across multiple services in the service layer, and hence is ideal for implementing via an aspect.

Because we want to retry the operation, we'll need to use around advice so that we can call proceed multiple times. Here's how the basic aspect implementation looks (it's just a regular Java class using the schema support):

```
public class ConcurrentOperationExecutor implements Ordered {

    private static final int DEFAULT_MAX_RETRIES = 2;

    private int maxRetries = DEFAULT_MAX_RETRIES;
    private int order = 1;

    public void setMaxRetries(int maxRetries) {
        this.maxRetries = maxRetries;
    }

    public int getOrder() {
        return this.order;
    }

    public void setOrder(int order) {
        this.order = order;
    }

    public Object doConcurrentOperation(ProceedingJoinPoint pjp) throws Throwable {
        int numAttempts = 0;
        PessimisticLockingFailureException lockFailureException;
        do {
            numAttempts++;
            try {
                return pjp.proceed();
            }
            catch(PessimisticLockingFailureException ex) {
                lockFailureException = ex;
            }
        } while(numAttempts <= this.maxRetries);
        throw lockFailureException;
    }

}
```

Note that the aspect implements the `Ordered` interface so we can set the precedence of the aspect higher than the transaction advice (we want a fresh transaction each time we retry). The `maxRetries` and `order` properties will both be configured by Spring. The main action happens in the `doConcurrentOperation` around advice method. We try to proceed, and if we fail with a `PessimisticLockingFailureException` we simply try again unless we have exhausted all of our retry attempts.

> **Note**
>
> This class is identical to the one used in the @AspectJ example, but with the annotations removed.

The corresponding Spring configuration is:

```
<aop:config>

    <aop:aspect id="concurrentOperationRetry" ref="concurrentOperationExecutor">

        <aop:pointcut id="idempotentOperation"
            expression="execution(* com.xyz.myapp.service..(..))"/>

        <aop:around
            pointcut-ref="idempotentOperation"
            method="doConcurrentOperation"/>

    </aop:aspect>

</aop:config>

<bean id="concurrentOperationExecutor"
    class="com.xyz.myapp.service.impl.ConcurrentOperationExecutor">
        <property name="maxRetries" value="3"/>
        <property name="order" value="100"/>
</bean>
```

Notice that for the time being we assume that all business services are idempotent. If this is not the case we can refine the aspect so that it only retries genuinely idempotent operations, by introducing an `Idempotent` annotation:

```
@Retention(RetentionPolicy.RUNTIME)
public @interface Idempotent {
    // marker annotation
}
```

and using the annotation to annotate the implementation of service operations. The change to the aspect to retry only idempotent operations simply involves refining the pointcut expression so that only `@Idempotent` operations match:

```
<aop:pointcut id="idempotentOperation"
        expression="execution(* com.xyz.myapp.service..(..)) and
        @annotation(com.xyz.myapp.service.Idempotent)"/>
```

9.4 Choosing which AOP declaration style to use

Once you have decided that an aspect is the best approach for implementing a given requirement, how do you decide between using Spring AOP or AspectJ, and between the Aspect language (code) style, @AspectJ annotation style, or the Spring XML style? These decisions are influenced by a number of factors including application requirements, development tools, and team familiarity with AOP.

Spring AOP or full AspectJ?

Use the simplest thing that can work. Spring AOP is simpler than using full AspectJ as there is no requirement to introduce the AspectJ compiler / weaver into your development and build processes. If you only need to advise the execution of operations on Spring beans, then Spring AOP is the right choice. If you need to advise objects not managed by the Spring container (such as domain objects typically), then you will need to use AspectJ. You will also need to use AspectJ if you wish to advise join points other than simple method executions (for example, field get or set join points, and so on).

When using AspectJ, you have the choice of the AspectJ language syntax (also known as the "code style") or the @AspectJ annotation style. Clearly, if you are not using Java 5+ then the choice has been made for you… use the code style. If aspects play a large role in your design, and you are able to use the AspectJ Development Tools (AJDT) plugin for Eclipse, then the AspectJ language syntax is the preferred option: it is cleaner and simpler because the language was purposefully designed for writing

aspects. If you are not using Eclipse, or have only a few aspects that do not play a major role in your application, then you may want to consider using the @AspectJ style and sticking with a regular Java compilation in your IDE, and adding an aspect weaving phase to your build script.

@AspectJ or XML for Spring AOP?

If you have chosen to use Spring AOP, then you have a choice of @AspectJ or XML style. There are various tradeoffs to consider.

The XML style will be most familiar to existing Spring users and it is backed by genuine POJOs. When using AOP as a tool to configure enterprise services then XML can be a good choice (a good test is whether you consider the pointcut expression to be a part of your configuration you might want to change independently). With the XML style arguably it is clearer from your configuration what aspects are present in the system.

The XML style has two disadvantages. Firstly it does not fully encapsulate the implementation of the requirement it addresses in a single place. The DRY principle says that there should be a single, unambiguous, authoritative representation of any piece of knowledge within a system. When using the XML style, the knowledge of *how* a requirement is implemented is split across the declaration of the backing bean class, and the XML in the configuration file. When using the @AspectJ style there is a single module - the aspect - in which this information is encapsulated. Secondly, the XML style is slightly more limited in what it can express than the @AspectJ style: only the "singleton" aspect instantiation model is supported, and it is not possible to combine named pointcuts declared in XML. For example, in the @AspectJ style you can write something like:

```
@Pointcut(execution(* get*()))
    public void propertyAccess() {}

    @Pointcut(execution(org.xyz.Account+ *(..))
    public void operationReturningAnAccount() {}

    @Pointcut(propertyAccess() && operationReturningAnAccount())
    public void accountPropertyAccess() {}
```

In the XML style I can declare the first two pointcuts:

```
<aop:pointcut id="propertyAccess"
        expression="execution(* get*())"/>

<aop:pointcut id="operationReturningAnAccount"
        expression="execution(org.xyz.Account+ *(..))"/>
```

The downside of the XML approach is that you cannot define the `accountPropertyAccess` pointcut by combining these definitions.

The @AspectJ style supports additional instantiation models, and richer pointcut composition. It has the advantage of keeping the aspect as a modular unit. It also has the advantage the @AspectJ aspects can be understood (and thus consumed) both by Spring AOP and by AspectJ - so if you later decide you need the capabilities of AspectJ to implement additional requirements then it is very easy to migrate to an AspectJ-based approach. On balance the Spring team prefer the @AspectJ style whenever you have aspects that do more than simple "configuration" of enterprise services.

9.5 Mixing aspect types

It is perfectly possible to mix @AspectJ style aspects using the autoproxying support, schema-defined `<aop:aspect>` aspects, `<aop:advisor>` declared advisors and even proxies and interceptors

defined using the Spring 1.2 style in the same configuration. All of these are implemented using the same underlying support mechanism and will co-exist without any difficulty.

9.6 Proxying mechanisms

Spring AOP uses either JDK dynamic proxies or CGLIB to create the proxy for a given target object. (JDK dynamic proxies are preferred whenever you have a choice).

If the target object to be proxied implements at least one interface then a JDK dynamic proxy will be used. All of the interfaces implemented by the target type will be proxied. If the target object does not implement any interfaces then a CGLIB proxy will be created.

If you want to force the use of CGLIB proxying (for example, to proxy every method defined for the target object, not just those implemented by its interfaces) you can do so. However, there are some issues to consider:

- `final` methods cannot be advised, as they cannot be overridden.
- As of Spring 3.2, it is no longer necessary to add CGLIB to your project classpath, as CGLIB classes are repackaged under org.springframework and included directly in the spring-core JAR. This means that CGLIB-based proxy support *just works* in the same way that JDK dynamic proxies always have.
- The constructor of your proxied object will be called twice. This is a natural consequence of the CGLIB proxy model whereby a subclass is generated for each proxied object. For each proxied instance, two objects are created: the actual proxied object and an instance of the subclass that implements the advice. This behavior is not exhibited when using JDK proxies. Usually, calling the constructor of the proxied type twice, is not an issue, as there are usually only assignments taking place and no real logic is implemented in the constructor.

To force the use of CGLIB proxies set the value of the `proxy-target-class` attribute of the `<aop:config>` element to true:

```
<aop:config proxy-target-class="true">
    <!-- other beans defined here... -->
</aop:config>
```

To force CGLIB proxying when using the @AspectJ autoproxy support, set the `'proxy-target-class'` attribute of the `<aop:aspectj-autoproxy>` element to `true`:

```
<aop:aspectj-autoproxy proxy-target-class="true"/>
```

> **Note**
>
> Multiple `<aop:config/>` sections are collapsed into a single unified auto-proxy creator at runtime, which applies the *strongest* proxy settings that any of the `<aop:config/>` sections (typically from different XML bean definition files) specified. This also applies to the `<tx:annotation-driven/>` and `<aop:aspectj-autoproxy/>` elements.
>
> To be clear: using *`proxy-target-class="true"`* on `<tx:annotation-driven/>`, `<aop:aspectj-autoproxy/>` or `<aop:config/>` elements will force the use of CGLIB proxies *for all three of them*.

Understanding AOP proxies

Spring AOP is *proxy-based*. It is vitally important that you grasp the semantics of what that last statement actually means before you write your own aspects or use any of the Spring AOP-based aspects supplied with the Spring Framework.

Consider first the scenario where you have a plain-vanilla, un-proxied, nothing-special-about-it, straight object reference, as illustrated by the following code snippet.

```
public class SimplePojo implements Pojo {

    public void foo() {
        // this next method invocation is a direct call on the this reference
        this.bar();
    }

    public void bar() {
        // some logic...
    }
}
```

If you invoke a method on an object reference, the method is invoked *directly* on that object reference, as can be seen below.

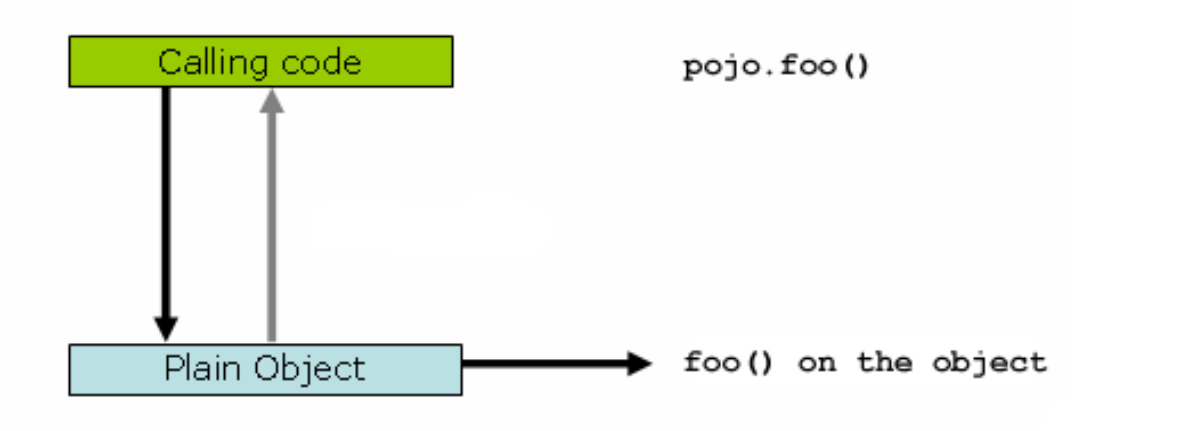


Figure 9.1.

```
public class Main {

    public static void main(String[] args) {

        Pojo pojo = new SimplePojo();

        // this is a direct method call on the pojo reference
        pojo.foo();
    }
}
```

Things change slightly when the reference that client code has is a proxy. Consider the following diagram and code snippet.

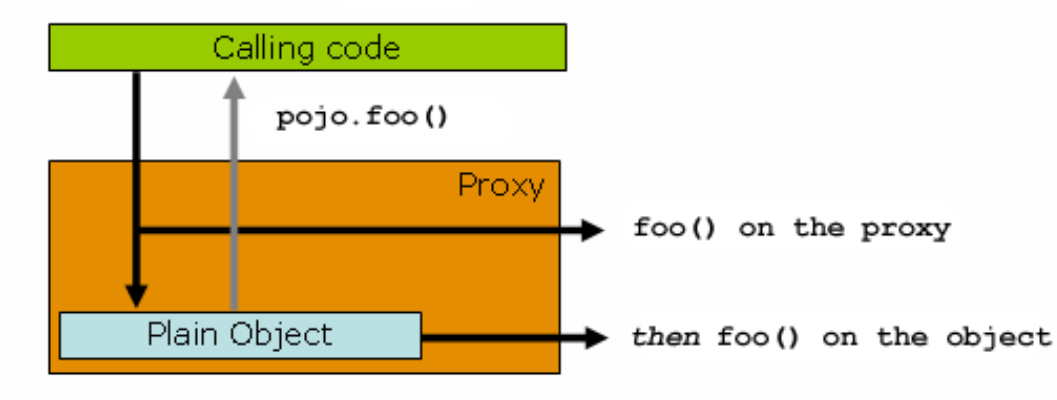


Figure 9.2.

```
public class Main {

    public static void main(String[] args) {

        ProxyFactory factory = new ProxyFactory(new SimplePojo());
        factory.addInterface(Pojo.class);
        factory.addAdvice(new RetryAdvice());

        Pojo pojo = (Pojo) factory.getProxy();

        // this is a method call on the proxy!
        pojo.foo();
    }
}
```

The key thing to understand here is that the client code inside the `main(..)` of the `Main` class *has a reference to the proxy*. This means that method calls on that object reference will be calls on the proxy, and as such the proxy will be able to delegate to all of the interceptors (advice) that are relevant to that particular method call. However, once the call has finally reached the target object, the `SimplePojo` reference in this case, any method calls that it may make on itself, such as `this.bar()` or `this.foo()`, are going to be invoked against the *this* reference, and *not* the proxy. This has important implications. It means that self-invocation is *not* going to result in the advice associated with a method invocation getting a chance to execute.

Okay, so what is to be done about this? The best approach (the term best is used loosely here) is to refactor your code such that the self-invocation does not happen. For sure, this does entail some work on your part, but it is the best, least-invasive approach. The next approach is absolutely horrendous, and I am almost reticent to point it out precisely because it is so horrendous. You can (choke!) totally tie the logic within your class to Spring AOP by doing this:

```
public class SimplePojo implements Pojo {

    public void foo() {
        // this works, but... gah!
        ((Pojo) AopContext.currentProxy()).bar();
    }

    public void bar() {
        // some logic...
    }
}
```

This totally couples your code to Spring AOP, *and* it makes the class itself aware of the fact that it is being used in an AOP context, which flies in the face of AOP. It also requires some additional configuration when the proxy is being created:

```
public class Main {

    public static void main(String[] args) {

        ProxyFactory factory = new ProxyFactory(new SimplePojo());
        factory.adddInterface(Pojo.class);
        factory.addAdvice(new RetryAdvice());
        factory.setExposeProxy(true);

        Pojo pojo = (Pojo) factory.getProxy();

        // this is a method call on the proxy!
        pojo.foo();
    }
}
```

Finally, it must be noted that AspectJ does not have this self-invocation issue because it is not a proxy-based AOP framework.

9.7 Programmatic creation of @AspectJ Proxies

In addition to declaring aspects in your configuration using either `<aop:config>` or `<aop:aspectj-autoproxy>`, it is also possible programmatically to create proxies that advise target objects. For the full details of Spring's AOP API, see the next chapter. Here we want to focus on the ability to automatically create proxies using @AspectJ aspects.

The class `org.springframework.aop.aspectj.annotation.AspectJProxyFactory` can be used to create a proxy for a target object that is advised by one or more @AspectJ aspects. Basic usage for this class is very simple, as illustrated below. See the javadocs for full information.

```
// create a factory that can generate a proxy for the given target object
AspectJProxyFactory factory = new AspectJProxyFactory(targetObject);

// add an aspect, the class must be an @AspectJ aspect
// you can call this as many times as you need with different aspects
factory.addAspect(SecurityManager.class);

// you can also add existing aspect instances, the type of the object supplied must be an @AspectJ
 aspect
factory.addAspect(usageTracker);

// now get the proxy object...
MyInterfaceType proxy = factory.getProxy();
```

9.8 Using AspectJ with Spring applications

Everything we've covered so far in this chapter is pure Spring AOP. In this section, we're going to look at how you can use the AspectJ compiler/weaver instead of, or in addition to, Spring AOP if your needs go beyond the facilities offered by Spring AOP alone.

Spring ships with a small AspectJ aspect library, which is available standalone in your distribution as `spring-aspects.jar`; you'll need to add this to your classpath in order to use the aspects in it. the section called "Using AspectJ to dependency inject domain objects with Spring" and the section called "Other Spring aspects for AspectJ" discuss the content of this library and how you can use it. the section called "Configuring AspectJ aspects using Spring IoC" discusses how to dependency inject AspectJ aspects that are woven using the AspectJ compiler. Finally, the section called "Load-time weaving with AspectJ in the Spring Framework" provides an introduction to load-time weaving for Spring applications using AspectJ.

Using AspectJ to dependency inject domain objects with Spring

The Spring container instantiates and configures beans defined in your application context. It is also possible to ask a bean factory to configure a *pre-existing* object given the name of a bean definition containing the configuration to be applied. The `spring-aspects.jar` contains an annotation-driven aspect that exploits this capability to allow dependency injection of *any object*. The support is intended to be used for objects created *outside of the control of any container*. Domain objects often fall into this category because they are often created programmatically using the `new` operator, or by an ORM tool as a result of a database query.

The `@Configurable` annotation marks a class as eligible for Spring-driven configuration. In the simplest case it can be used just as a marker annotation:

```
package com.xyz.myapp.domain;

import org.springframework.beans.factory.annotation.Configurable;

@Configurable
public class Account {
    // ...
}
```

When used as a marker interface in this way, Spring will configure new instances of the annotated type (`Account` in this case) using a bean definition (typically prototype-scoped) with the same name as the fully-qualified type name (`com.xyz.myapp.domain.Account`). Since the default name for a bean is the fully-qualified name of its type, a convenient way to declare the prototype definition is simply to omit the `id` attribute:

```
<bean class="com.xyz.myapp.domain.Account" scope="prototype">
    <property name="fundsTransferService" ref="fundsTransferService"/>
</bean>
```

If you want to explicitly specify the name of the prototype bean definition to use, you can do so directly in the annotation:

```
package com.xyz.myapp.domain;

import org.springframework.beans.factory.annotation.Configurable;

@Configurable("account")
public class Account {
    // ...
}
```

Spring will now look for a bean definition named " `account`" and use that as the definition to configure new `Account` instances.

You can also use autowiring to avoid having to specify a dedicated bean definition at all. To have Spring apply autowiring use the *`autowire`* property of the `@Configurable` annotation: specify either `@Configurable(autowire=Autowire.BY_TYPE)` or `@Configurable(autowire=Autowire.BY_NAME` for autowiring by type or by name respectively. As an alternative, as of Spring 2.5 it is preferable to specify explicit, annotation-driven dependency injection for your `@Configurable` beans by using `@Autowired` or `@Inject` at the field or method level (see Section 5.9, “Annotation-based container configuration” for further details).

Finally you can enable Spring dependency checking for the object references in the newly created and configured object by using the `dependencyCheck` attribute (for example:

`@Configurable(autowire=Autowire.BY_NAME,dependencyCheck=true)`). If this attribute is set to true, then Spring will validate after configuration that all properties (*which are not primitives or collections*) have been set.

Using the annotation on its own does nothing of course. It is the `AnnotationBeanConfigurerAspect` in `spring-aspects.jar` that acts on the presence of the annotation. In essence the aspect says "after returning from the initialization of a new object of a type annotated with `@Configurable`, configure the newly created object using Spring in accordance with the properties of the annotation". In this context, *initialization* refers to newly instantiated objects (e.g., objects instantiated with the *new* operator) as well as to `Serializable` objects that are undergoing deserialization (e.g., via readResolve()).

> **Note**
>
> One of the key phrases in the above paragraph is in essence. For most cases, the exact semantics of after returning from the initialization of a new object will be fine… in this context, after initialization means that the dependencies will be injected *after* the object has been constructed - this means that the dependencies will not be available for use in the constructor bodies of the class. If you want the dependencies to be injected *before* the constructor bodies execute, and thus be available for use in the body of the constructors, then you need to define this on the `@Configurable` declaration like so:
>
> ```
> @Configurable(preConstruction=true)
> ```
>
> You can find out more information about the language semantics of the various pointcut types in AspectJ in this appendix of the AspectJ Programming Guide.

For this to work the annotated types must be woven with the AspectJ weaver - you can either use a build-time Ant or Maven task to do this (see for example the AspectJ Development Environment Guide) or load-time weaving (see the section called “Load-time weaving with AspectJ in the Spring Framework”). The `AnnotationBeanConfigurerAspect` itself needs configuring by Spring (in order to obtain a reference to the bean factory that is to be used to configure new objects). If you are using Java based configuration simply add `@EnableSpringConfigured` to any `@Configuration` class.

```
@Configuration
@EnableSpringConfigured
public class AppConfig {

}
```

If you prefer XML based configuration, the Spring `context namespace` defines a convenient `context:spring-configured` element:

```
<context:spring-configured/>
```

Instances of `@Configurable` objects created *before* the aspect has been configured will result in a message being issued to the debug log and no configuration of the object taking place. An example might be a bean in the Spring configuration that creates domain objects when it is initialized by Spring. In this case you can use the "depends-on" bean attribute to manually specify that the bean depends on the configuration aspect.

```
<bean id="myService"
        class="com.xzy.myapp.service.MyService"
        depends-on="org.springframework.beans.factory.aspectj.AnnotationBeanConfigurerAspect">

    <!-- ... -->

</bean>
```

> **Note**
>
> Do not activate `@Configurable` processing through the bean configurer aspect unless you really mean to rely on its semantics at runtime. In particular, make sure that you do not use `@Configurable` on bean classes which are registered as regular Spring beans with the container: You would get double initialization otherwise, once through the container and once through the aspect.

Unit testing @Configurable objects

One of the goals of the `@Configurable` support is to enable independent unit testing of domain objects without the difficulties associated with hard-coded lookups. If `@Configurable` types have not been woven by AspectJ then the annotation has no affect during unit testing, and you can simply set mock or stub property references in the object under test and proceed as normal. If `@Configurable` types *have* been woven by AspectJ then you can still unit test outside of the container as normal, but you will see a warning message each time that you construct an `@Configurable` object indicating that it has not been configured by Spring.

Working with multiple application contexts

The `AnnotationBeanConfigurerAspect` used to implement the `@Configurable` support is an AspectJ singleton aspect. The scope of a singleton aspect is the same as the scope of `static` members, that is to say there is one aspect instance per classloader that defines the type. This means that if you define multiple application contexts within the same classloader hierarchy you need to consider where to define the `@EnableSpringConfigured` bean and where to place `spring-aspects.jar` on the classpath.

Consider a typical Spring web-app configuration with a shared parent application context defining common business services and everything needed to support them, and one child application context per servlet containing definitions particular to that servlet. All of these contexts will co-exist within the same classloader hierarchy, and so the `AnnotationBeanConfigurerAspect` can only hold a reference to one of them. In this case we recommend defining the `@EnableSpringConfigured` bean in the shared (parent) application context: this defines the services that you are likely to want to inject into domain objects. A consequence is that you cannot configure domain objects with references to beans defined in the child (servlet-specific) contexts using the @Configurable mechanism (probably not something you want to do anyway!).

When deploying multiple web-apps within the same container, ensure that each web-application loads the types in `spring-aspects.jar` using its own classloader (for example, by placing `spring-aspects.jar` in `'WEB-INF/lib'`). If `spring-aspects.jar` is only added to the container wide classpath (and hence loaded by the shared parent classloader), all web applications will share the same aspect instance which is probably not what you want.

Other Spring aspects for AspectJ

In addition to the `@Configurable` aspect, `spring-aspects.jar` contains an AspectJ aspect that can be used to drive Spring's transaction management for types and methods annotated with the `@Transactional` annotation. This is primarily intended for users who want to use the Spring Framework's transaction support outside of the Spring container.

The aspect that interprets `@Transactional` annotations is the `AnnotationTransactionAspect`. When using this aspect, you must annotate the *implementation* class (and/or methods within that class), *not* the interface (if any) that the class implements. AspectJ follows Java's rule that annotations on interfaces are *not inherited*.

A `@Transactional` annotation on a class specifies the default transaction semantics for the execution of any *public* operation in the class.

A `@Transactional` annotation on a method within the class overrides the default transaction semantics given by the class annotation (if present). Methods with `public`, `protected`, and default visibility may all be annotated. Annotating `protected` and default visibility methods directly is the only way to get transaction demarcation for the execution of such methods.

For AspectJ programmers that want to use the Spring configuration and transaction management support but don't want to (or cannot) use annotations, `spring-aspects.jar` also contains `abstract` aspects you can extend to provide your own pointcut definitions. See the sources for the `AbstractBeanConfigurerAspect` and `AbstractTransactionAspect` aspects for more information. As an example, the following excerpt shows how you could write an aspect to configure all instances of objects defined in the domain model using prototype bean definitions that match the fully-qualified class names:

```
public aspect DomainObjectConfiguration extends AbstractBeanConfigurerAspect {

    public DomainObjectConfiguration() {
        setBeanWiringInfoResolver(new ClassNameBeanWiringInfoResolver());
    }

    // the creation of a new bean (any object in the domain model)
    protected pointcut beanCreation(Object beanInstance) :
        initialization(new(..)) &&
        SystemArchitecture.inDomainModel() &&
        this(beanInstance);

}
```

Configuring AspectJ aspects using Spring IoC

When using AspectJ aspects with Spring applications, it is natural to both want and expect to be able to configure such aspects using Spring. The AspectJ runtime itself is responsible for aspect creation, and the means of configuring the AspectJ created aspects via Spring depends on the AspectJ instantiation model (the *`per-xxx`* clause) used by the aspect.

The majority of AspectJ aspects are *singleton* aspects. Configuration of these aspects is very easy: simply create a bean definition referencing the aspect type as normal, and include the bean attribute `'factory-method="aspectOf"'`. This ensures that Spring obtains the aspect instance by asking AspectJ for it rather than trying to create an instance itself. For example:

```
<bean id="profiler" class="com.xyz.profiler.Profiler"
        factory-method="aspectOf">

    <property name="profilingStrategy" ref="jamonProfilingStrategy"/>
</bean>
```

Non-singleton aspects are harder to configure: however it is possible to do so by creating prototype bean definitions and using the `@Configurable` support from `spring-aspects.jar` to configure the aspect instances once they have bean created by the AspectJ runtime.

If you have some @AspectJ aspects that you want to weave with AspectJ (for example, using load-time weaving for domain model types) and other @AspectJ aspects that you want to use with Spring AOP, and these aspects are all configured using Spring, then you will need to tell the Spring AOP @AspectJ autoproxying support which exact subset of the @AspectJ aspects defined in the configuration should be used for autoproxying. You can do this by using one or more `<include/>` elements inside the `<aop:aspectj-autoproxy/>` declaration. Each `<include/>` element specifies a name pattern, and only beans with names matched by at least one of the patterns will be used for Spring AOP autoproxy configuration:

```
<aop:aspectj-autoproxy>
    <aop:include name="thisBean"/>
    <aop:include name="thatBean"/>
</aop:aspectj-autoproxy>
```

> **Note**
>
> Do not be misled by the name of the `<aop:aspectj-autoproxy/>` element: using it will result in the creation of *Spring AOP proxies*. The @AspectJ style of aspect declaration is just being used here, but the AspectJ runtime is *not* involved.

Load-time weaving with AspectJ in the Spring Framework

Load-time weaving (LTW) refers to the process of weaving AspectJ aspects into an application's class files as they are being loaded into the Java virtual machine (JVM). The focus of this section is on configuring and using LTW in the specific context of the Spring Framework: this section is not an introduction to LTW though. For full details on the specifics of LTW and configuring LTW with just AspectJ (with Spring not being involved at all), see the LTW section of the AspectJ Development Environment Guide.

The value-add that the Spring Framework brings to AspectJ LTW is in enabling much finer-grained control over the weaving process. *Vanilla* AspectJ LTW is effected using a Java (5+) agent, which is switched on by specifying a VM argument when starting up a JVM. It is thus a JVM-wide setting, which may be fine in some situations, but often is a little too coarse. Spring-enabled LTW enables you to switch on LTW on a *per-ClassLoader* basis, which obviously is more fine-grained and which can make more sense in a *single-JVM-multiple-application* environment (such as is found in a typical application server environment).

Further, in certain environments, this support enables load-time weaving *without making any modifications to the application server's launch script* that will be needed to add `-javaagent:path/to/aspectjweaver.jar` or (as we describe later in this section) `-javaagent:path/to/org.springframework.instrument-{version}.jar` (previously named `spring-agent.jar`). Developers simply modify one or more files that form the application context to enable load-time weaving instead of relying on administrators who typically are in charge of the deployment configuration such as the launch script.

Now that the sales pitch is over, let us first walk through a quick example of AspectJ LTW using Spring, followed by detailed specifics about elements introduced in the following example. For a complete example, please see the Petclinic sample application.

A first example

Let us assume that you are an application developer who has been tasked with diagnosing the cause of some performance problems in a system. Rather than break out a profiling tool, what we are going to do is switch on a simple profiling aspect that will enable us to very quickly get some performance metrics, so that we can then apply a finer-grained profiling tool to that specific area immediately afterwards.

> **Note**
>
> The example presented here uses XML style configuration, it is also possible to configure and use @AspectJ with Java Configuration. Specifically the `@EnableLoadTimeWeaving` annotation can be used as an alternative to `<context:load-time-weaver/>` (see below for details).

Here is the profiling aspect. Nothing too fancy, just a quick-and-dirty time-based profiler, using the @AspectJ-style of aspect declaration.

```
package foo;

import org.aspectj.lang.ProceedingJoinPoint;
import org.aspectj.lang.annotation.Aspect;
import org.aspectj.lang.annotation.Around;
import org.aspectj.lang.annotation.Pointcut;
import org.springframework.util.StopWatch;
import org.springframework.core.annotation.Order;

@Aspect
public class ProfilingAspect {

    @Around("methodsToBeProfiled()")
    public Object profile(ProceedingJoinPoint pjp) throws Throwable {
        StopWatch sw = new StopWatch(getClass().getSimpleName());
        try {
            sw.start(pjp.getSignature().getName());
            return pjp.proceed();
        } finally {
            sw.stop();
            System.out.println(sw.prettyPrint());
        }
    }

    @Pointcut("execution(public * foo..(..))")
    public void methodsToBeProfiled(){}
}
```

We will also need to create an *META-INF/aop.xml* file, to inform the AspectJ weaver that we want to weave our `ProfilingAspect` into our classes. This file convention, namely the presence of a file (or files) on the Java classpath called *META-INF/aop.xml* is standard AspectJ.

```
<!DOCTYPE aspectj PUBLIC "-//AspectJ//DTD//EN" "http://www.eclipse.org/aspectj/dtd/aspectj.dtd">
<aspectj>

    <weaver>
        <!-- only weave classes in our application-specific packages -->
        <include within="foo.*"/>
    </weaver>

    <aspects>
        <!-- weave in just this aspect -->
        <aspect name="foo.ProfilingAspect"/>
    </aspects>

</aspectj>
```

Now to the Spring-specific portion of the configuration. We need to configure a `LoadTimeWeaver` (all explained later, just take it on trust for now). This load-time weaver is the essential component responsible for weaving the aspect configuration in one or more *`META-INF/aop.xml`* files into the classes in your application. The good thing is that it does not require a lot of configuration, as can be seen below (there are some more options that you can specify, but these are detailed later).

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <!-- a service object; we will be profiling its methods -->
    <bean id="entitlementCalculationService"
            class="foo.StubEntitlementCalculationService"/>

    <!-- this switches on the load-time weaving -->
    <context:load-time-weaver/>
</beans>
```

Now that all the required artifacts are in place - the aspect, the *`META-INF/aop.xml`* file, and the Spring configuration -, let us create a simple driver class with a `main(..)` method to demonstrate the LTW in action.

```
package foo;

import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Main {

    public static void main(String[] args) {

        ApplicationContext ctx = new ClassPathXmlApplicationContext("beans.xml", Main.class);

        EntitlementCalculationService entitlementCalculationService
            = (EntitlementCalculationService) ctx.getBean("entitlementCalculationService");

        // the profiling aspect is woven around this method execution
        entitlementCalculationService.calculateEntitlement();
    }
}
```

There is one last thing to do. The introduction to this section did say that one could switch on LTW selectively on a per- `ClassLoader` basis with Spring, and this is true. However, just for this example, we are going to use a Java agent (supplied with Spring) to switch on the LTW. This is the command line we will use to run the above `Main` class:

```
java -javaagent:C:/projects/foo/lib/global/spring-instrument.jar foo.Main
```

The *-javaagent* is a flag for specifying and enabling agents to instrument programs running on the JVM. The Spring Framework ships with such an agent, the `InstrumentationSavingAgent`, which is packaged in the `spring-instrument.jar` that was supplied as the value of the `-javaagent` argument in the above example.

The output from the execution of the `Main` program will look something like that below. (I have introduced a `Thread.sleep(..)` statement into the `calculateEntitlement()` implementation so that the profiler actually captures something other than `0` milliseconds - the `01234` milliseconds is *not* an overhead introduced by the AOP :))

```
Calculating entitlement

StopWatch 'ProfilingAspect': running time (millis) = 1234
------ ----- ----------------------------
ms     %     Task name
------ ----- ----------------------------
01234  100%  calculateEntitlement
```

Since this LTW is effected using full-blown AspectJ, we are not just limited to advising Spring beans; the following slight variation on the `Main` program will yield the same result.

```
package foo;

import org.springframework.context.support.ClassPathXmlApplicationContext;

public final class Main {

    public static void main(String[] args) {

        new ClassPathXmlApplicationContext("beans.xml", Main.class);

        EntitlementCalculationService entitlementCalculationService =
            new StubEntitlementCalculationService();

        // the profiling aspect will be woven around this method execution
        entitlementCalculationService.calculateEntitlement();
    }
}
```

Notice how in the above program we are simply bootstrapping the Spring container, and then creating a new instance of the `StubEntitlementCalculationService` totally outside the context of Spring… the profiling advice still gets woven in.

The example admittedly is simplistic… however the basics of the LTW support in Spring have all been introduced in the above example, and the rest of this section will explain the *why* behind each bit of configuration and usage in detail.

> **Note**
>
> The `ProfilingAspect` used in this example may be basic, but it is quite useful. It is a nice example of a development-time aspect that developers can use during development (of course), and then quite easily exclude from builds of the application being deployed into UAT or production.

Aspects

The aspects that you use in LTW have to be AspectJ aspects. They can be written in either the AspectJ language itself or you can write your aspects in the @AspectJ-style. It means that your aspects are

then both valid AspectJ *and* Spring AOP aspects. Furthermore, the compiled aspect classes need to be available on the classpath.

META-INF/aop.xml

The AspectJ LTW infrastructure is configured using one or more `META-INF/aop.xml` files, that are on the Java classpath (either directly, or more typically in jar files).

The structure and contents of this file is detailed in the main AspectJ reference documentation, and the interested reader is referred to that resource. (I appreciate that this section is brief, but the `aop.xml` file is 100% AspectJ - there is no Spring-specific information or semantics that apply to it, and so there is no extra value that I can contribute either as a result), so rather than rehash the quite satisfactory section that the AspectJ developers wrote, I am just directing you there.)

Required libraries (JARS)

At a minimum you will need the following libraries to use the Spring Framework's support for AspectJ LTW:

- `spring-aop.jar` (version 2.5 or later, plus all mandatory dependencies)
- `aspectjweaver.jar` (version 1.6.8 or later)

If you are using the Spring-provided agent to enable instrumentation, you will also need:

- `spring-instrument.jar`

Spring configuration

The key component in Spring's LTW support is the `LoadTimeWeaver` interface (in the `org.springframework.instrument.classloading` package), and the numerous implementations of it that ship with the Spring distribution. A `LoadTimeWeaver` is responsible for adding one or more `java.lang.instrument.ClassFileTransformers` to a `ClassLoader` at runtime, which opens the door to all manner of interesting applications, one of which happens to be the LTW of aspects.

> **Tip**
>
> If you are unfamiliar with the idea of runtime class file transformation, you are encouraged to read the javadoc API documentation for the `java.lang.instrument` package before continuing. This is not a huge chore because there is - rather annoyingly - precious little documentation there… the key interfaces and classes will at least be laid out in front of you for reference as you read through this section.

Configuring a `LoadTimeWeaver` for a particular `ApplicationContext` can be as easy as adding one line. (Please note that you almost certainly will need to be using an `ApplicationContext` as your Spring container - typically a `BeanFactory` will not be enough because the LTW support makes use of `BeanFactoryPostProcessors`.)

To enable the Spring Framework's LTW support, you need to configure a `LoadTimeWeaver`, which typically is done using the `@EnableLoadTimeWeaving` annotation.

```
@Configuration
@EnableLoadTimeWeaving
public class AppConfig {

}
```

Alternatively, if you prefer XML based configuration, use the `<context:load-time-weaver/>` element. Note that the element is defined in the *`context`* namespace.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:load-time-weaver/>

</beans>
```

The above configuration will define and register a number of LTW-specific infrastructure beans for you automatically, such as a `LoadTimeWeaver` and an `AspectJWeavingEnabler`. The default `LoadTimeWeaver` is the `DefaultContextLoadTimeWeaver` class, which attempts to decorate an automatically detected `LoadTimeWeaver`: the exact type of `LoadTimeWeaver` that will be *automatically detected* is dependent upon your runtime environment (summarized in the following table).

Table 9.1. DefaultContextLoadTimeWeaver LoadTimeWeavers

Runtime Environment	**`LoadTimeWeaver` implementation**
Running in BEA's Weblogic 10	`WebLogicLoadTimeWeaver`
Running in IBM WebSphere Application Server 7	`WebSphereLoadTimeWeaver`
Running in GlassFish	`GlassFishLoadTimeWeaver`
Running in JBoss AS	`JBossLoadTimeWeaver`
JVM started with Spring `InstrumentationSavingAgent` *(java -javaagent:path/to/spring-instrument.jar)*	`InstrumentationLoadTimeWeaver`
Fallback, expecting the underlying ClassLoader to follow common conventions (e.g. applicable to `TomcatInstrumentableClassLoader` and Resin)	`ReflectiveLoadTimeWeaver`

Note that these are just the `LoadTimeWeavers` that are autodetected when using the `DefaultContextLoadTimeWeaver`: it is of course possible to specify exactly which `LoadTimeWeaver` implementation that you wish to use.

To specify a specific `LoadTimeWeaver` with Java configuration implement the `LoadTimeWeavingConfigurer` interface and override the `getLoadTimeWeaver()` method:

```
@Configuration
@EnableLoadTimeWeaving
public class AppConfig implements LoadTimeWeavingConfigurer {

    @Override
    public LoadTimeWeaver getLoadTimeWeaver() {
        return new ReflectiveLoadTimeWeaver();
    }
}
```

If you are using XML based configuration you can specify the fully-qualified classname as the value of the *`weaver-class`* attribute on the `<context:load-time-weaver/>` element:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:load-time-weaver
            weaver-class="org.springframework.instrument.classloading.ReflectiveLoadTimeWeaver"/>

</beans>
```

The `LoadTimeWeaver` that is defined and registered by the configuration can be later retrieved from the Spring container using the well-known name *`loadTimeWeaver`*. Remember that the `LoadTimeWeaver` exists just as a mechanism for Spring's LTW infrastructure to add one or more `ClassFileTransformers`. The actual `ClassFileTransformer` that does the LTW is the `ClassPreProcessorAgentAdapter` (from the `org.aspectj.weaver.loadtime` package) class. See the class-level javadocs of the `ClassPreProcessorAgentAdapter` class for further details, because the specifics of how the weaving is actually effected is beyond the scope of this section.

There is one final attribute of the configuration left to discuss: the *`aspectjWeaving`* attribute (or *`aspectj-weaving`* if you are using XML). This is a simple attribute that controls whether LTW is enabled or not; it is as simple as that. It accepts one of three possible values, summarized below, with the default value being *`autodetect`* if the attribute is not present.

Table 9.2. AspectJ weaving attribute values

Annotation Value	XML Value	Explanation
`ENABLED`	`on`	AspectJ weaving is on, and aspects will be woven at load-time as appropriate.
`DISABLED`	`off`	LTW is off… no aspect will be woven at load-time.
`AUTODETECT`	`autodetect`	If the Spring LTW infrastructure can find at least one *`META-INF/aop.xml`* file, then AspectJ weaving is on, else it is off. This is the default value.

Environment-specific configuration

This last section contains any additional settings and configuration that you will need when using Spring's LTW support in environments such as application servers and web containers.

Tomcat

Apache Tomcat's default class loader does not support class transformation which is why Spring provides an enhanced implementation that addresses this need. Named `TomcatInstrumentableClassLoader`, the loader works on Tomcat 5.0 and above and can be registered individually for *each* web application as follows:

- Tomcat 6.0.x or higher
- Copy `org.springframework.instrument.tomcat.jar` into *$CATALINA_HOME*/lib, where *$CATALINA_HOME* represents the root of the Tomcat installation)
- Instruct Tomcat to use the custom class loader (instead of the default) by editing the web application context file:

```
<Context path="/myWebApp" docBase="/my/webApp/location">
    <Loader

  loaderClass="org.springframework.instrument.classloading.tomcat.TomcatInstrumentableClassLoader"/>
</Context>
```

Apache Tomcat (6.0+) supports several context locations:

- server configuration file - *$CATALINA_HOME/conf/server.xml*
- default context configuration - *$CATALINA_HOME/conf/context.xml* - that affects all deployed web applications
- per-web application configuration which can be deployed either on the server-side at *$CATALINA_HOME/conf/[enginename]/[hostname]/[webapp]-context.xml* or embedded inside the web-app archive at *META-INF/context.xml*

For efficiency, the embedded per-web-app configuration style is recommended because it will impact only applications that use the custom class loader and does not require any changes to the server configuration. See the Tomcat 6.0.x documentation for more details about available context locations.

Alternatively, consider the use of the Spring-provided generic VM agent, to be specified in Tomcat's launch script (see above). This will make instrumentation available to all deployed web applications, no matter what ClassLoader they happen to run on.

WebLogic, WebSphere, Resin, GlassFish, JBoss

Recent versions of WebLogic Server (version 10 and above), IBM WebSphere Application Server (version 7 and above), Resin (3.1 and above) and JBoss (6.x or above) provide a ClassLoader that is capable of local instrumentation. Spring's native LTW leverages such ClassLoaders to enable AspectJ weaving. You can enable LTW by simply activating load-time weaving as described earlier. Specifically, you do *not* need to modify the launch script to add `-javaagent:path/to/spring-instrument.jar`.

Note that GlassFish instrumentation-capable ClassLoader is available only in its EAR environment. For GlassFish web applications, follow the Tomcat setup instructions as outlined above.

Note that on JBoss 6.x, the app server scanning needs to be disabled to prevent it from loading the classes before the application actually starts. A quick workaround is to add to your artifact a file named `WEB-INF/jboss-scanning.xml` with the following content:

```
<scanning xmlns="urn:jboss:scanning:1.0"/>
```

Generic Java applications

When class instrumentation is required in environments that do not support or are not supported by the existing `LoadTimeWeaver` implementations, a JDK agent can be the only solution. For such cases, Spring provides `InstrumentationLoadTimeWeaver`, which requires a Spring-specific (but very general) VM agent, `org.springframework.instrument-{version}.jar` (previously named `spring-agent.jar`).

To use it, you must start the virtual machine with the Spring agent, by supplying the following JVM options:

```
-javaagent:/path/to/org.springframework.instrument-{version}.jar
```

Note that this requires modification of the VM launch script which may prevent you from using this in application server environments (depending on your operation policies). Additionally, the JDK agent will instrument the *entire* VM which can prove expensive.

For performance reasons, it is recommended to use this configuration only if your target environment (such as Jetty) does not have (or does not support) a dedicated LTW.

9.9 Further Resources

More information on AspectJ can be found on the AspectJ website.

The book *Eclipse AspectJ* by Adrian Colyer et. al. (Addison-Wesley, 2005) provides a comprehensive introduction and reference for the AspectJ language.

The book *AspectJ in Action* by Ramnivas Laddad (Manning, 2003) comes highly recommended; the focus of the book is on AspectJ, but a lot of general AOP themes are explored (in some depth).

10. Spring AOP APIs

10.1 Introduction

The previous chapter described the Spring's support for AOP using @AspectJ and schema-based aspect definitions. In this chapter we discuss the lower-level Spring AOP APIs and the AOP support used in Spring 1.2 applications. For new applications, we recommend the use of the Spring 2.0 and later AOP support described in the previous chapter, but when working with existing applications, or when reading books and articles, you may come across Spring 1.2 style examples. Spring 4.0 is backwards compatible with Spring 1.2 and everything described in this chapter is fully supported in Spring 4.0.

10.2 Pointcut API in Spring

Let's look at how Spring handles the crucial pointcut concept.

Concepts

Spring's pointcut model enables pointcut reuse independent of advice types. It's possible to target different advice using the same pointcut.

The `org.springframework.aop.Pointcut` interface is the central interface, used to target advices to particular classes and methods. The complete interface is shown below:

```
public interface Pointcut {

    ClassFilter getClassFilter();

    MethodMatcher getMethodMatcher();

}
```

Splitting the `Pointcut` interface into two parts allows reuse of class and method matching parts, and fine-grained composition operations (such as performing a "union" with another method matcher).

The `ClassFilter` interface is used to restrict the pointcut to a given set of target classes. If the `matches()` method always returns true, all target classes will be matched:

```
public interface ClassFilter {

    boolean matches(Class clazz);
}
```

The `MethodMatcher` interface is normally more important. The complete interface is shown below:

```
public interface MethodMatcher {

    boolean matches(Method m, Class targetClass);

    boolean isRuntime();

    boolean matches(Method m, Class targetClass, Object[] args);
}
```

The `matches(Method, Class)` method is used to test whether this pointcut will ever match a given method on a target class. This evaluation can be performed when an AOP proxy is created, to avoid the need for a test on every method invocation. If the 2-argument matches method returns true for a given method, and the `isRuntime()` method for the MethodMatcher returns true, the 3-argument matches

method will be invoked on every method invocation. This enables a pointcut to look at the arguments passed to the method invocation immediately before the target advice is to execute.

Most MethodMatchers are static, meaning that their `isRuntime()` method returns false. In this case, the 3-argument matches method will never be invoked.

> **Tip**
>
> If possible, try to make pointcuts static, allowing the AOP framework to cache the results of pointcut evaluation when an AOP proxy is created.

Operations on pointcuts

Spring supports operations on pointcuts: notably, *union* and *intersection*.

- Union means the methods that either pointcut matches.
- Intersection means the methods that both pointcuts match.
- Union is usually more useful.
- Pointcuts can be composed using the static methods in the *org.springframework.aop.support.Pointcuts* class, or using the *ComposablePointcut* class in the same package. However, using AspectJ pointcut expressions is usually a simpler approach.

AspectJ expression pointcuts

Since 2.0, the most important type of pointcut used by Spring is `org.springframework.aop.aspectj.AspectJExpressionPointcut`. This is a pointcut that uses an AspectJ supplied library to parse an AspectJ pointcut expression string.

See the previous chapter for a discussion of supported AspectJ pointcut primitives.

Convenience pointcut implementations

Spring provides several convenient pointcut implementations. Some can be used out of the box; others are intended to be subclassed in application-specific pointcuts.

Static pointcuts

Static pointcuts are based on method and target class, and cannot take into account the method's arguments. Static pointcuts are sufficient - *and best* - for most usages. It's possible for Spring to evaluate a static pointcut only once, when a method is first invoked: after that, there is no need to evaluate the pointcut again with each method invocation.

Let's consider some static pointcut implementations included with Spring.

Regular expression pointcuts

One obvious way to specify static pointcuts is regular expressions. Several AOP frameworks besides Spring make this possible. `org.springframework.aop.support.JdkRegexpMethodPointcut` is a generic regular expression pointcut, using the regular expression support in JDK 1.4+.

Using the `JdkRegexpMethodPointcut` class, you can provide a list of pattern Strings. If any of these is a match, the pointcut will evaluate to true. (So the result is effectively the union of these pointcuts.)

The usage is shown below:

```
<bean id="settersAndAbsquatulatePointcut"
        class="org.springframework.aop.support.JdkRegexpMethodPointcut">
    <property name="patterns">
        <list>
            <value>.set.</value>
            <value>.*absquatulate</value>
        </list>
    </property>
</bean>
```

Spring provides a convenience class, `RegexpMethodPointcutAdvisor`, that allows us to also reference an Advice (remember that an Advice can be an interceptor, before advice, throws advice etc.). Behind the scenes, Spring will use a `JdkRegexpMethodPointcut`. Using `RegexpMethodPointcutAdvisor` simplifies wiring, as the one bean encapsulates both pointcut and advice, as shown below:

```
<bean id="settersAndAbsquatulateAdvisor"
        class="org.springframework.aop.support.RegexpMethodPointcutAdvisor">
    <property name="advice">
        <ref bean="beanNameOfAopAllianceInterceptor"/>
    </property>
    <property name="patterns">
        <list>
            <value>.set.</value>
            <value>.*absquatulate</value>
        </list>
    </property>
</bean>
```

RegexpMethodPointcutAdvisor can be used with any Advice type.

Attribute-driven pointcuts

An important type of static pointcut is a *metadata-driven* pointcut. This uses the values of metadata attributes: typically, source-level metadata.

Dynamic pointcuts

Dynamic pointcuts are costlier to evaluate than static pointcuts. They take into account method *arguments*, as well as static information. This means that they must be evaluated with every method invocation; the result cannot be cached, as arguments will vary.

The main example is the `control flow` pointcut.

Control flow pointcuts

Spring control flow pointcuts are conceptually similar to AspectJ *cflow* pointcuts, although less powerful. (There is currently no way to specify that a pointcut executes below a join point matched by another pointcut.) A control flow pointcut matches the current call stack. For example, it might fire if the join point was invoked by a method in the `com.mycompany.web` package, or by the `SomeCaller` class. Control flow pointcuts are specified using the `org.springframework.aop.support.ControlFlowPointcut` class.

> **Note**
>
> Control flow pointcuts are significantly more expensive to evaluate at runtime than even other dynamic pointcuts. In Java 1.4, the cost is about 5 times that of other dynamic pointcuts.

Pointcut superclasses

Spring provides useful pointcut superclasses to help you to implement your own pointcuts.

Because static pointcuts are most useful, you'll probably subclass StaticMethodMatcherPointcut, as shown below. This requires implementing just one abstract method (although it's possible to override other methods to customize behavior):

```
class TestStaticPointcut extends StaticMethodMatcherPointcut {

    public boolean matches(Method m, Class targetClass) {
        // return true if custom criteria match
    }
}
```

There are also superclasses for dynamic pointcuts.

You can use custom pointcuts with any advice type in Spring 1.0 RC2 and above.

Custom pointcuts

Because pointcuts in Spring AOP are Java classes, rather than language features (as in AspectJ) it's possible to declare custom pointcuts, whether static or dynamic. Custom pointcuts in Spring can be arbitrarily complex. However, using the AspectJ pointcut expression language is recommended if possible.

> **Note**
>
> Later versions of Spring may offer support for "semantic pointcuts" as offered by JAC: for example, "all methods that change instance variables in the target object."

10.3 Advice API in Spring

Let's now look at how Spring AOP handles advice.

Advice lifecycles

Each advice is a Spring bean. An advice instance can be shared across all advised objects, or unique to each advised object. This corresponds to *per-class* or *per-instance* advice.

Per-class advice is used most often. It is appropriate for generic advice such as transaction advisors. These do not depend on the state of the proxied object or add new state; they merely act on the method and arguments.

Per-instance advice is appropriate for introductions, to support mixins. In this case, the advice adds state to the proxied object.

It's possible to use a mix of shared and per-instance advice in the same AOP proxy.

Advice types in Spring

Spring provides several advice types out of the box, and is extensible to support arbitrary advice types. Let us look at the basic concepts and standard advice types.

Interception around advice

The most fundamental advice type in Spring is *interception around advice*.

Spring is compliant with the AOP Alliance interface for around advice using method interception. MethodInterceptors implementing around advice should implement the following interface:

```
public interface MethodInterceptor extends Interceptor {

    Object invoke(MethodInvocation invocation) throws Throwable;
}
```

The `MethodInvocation` argument to the `invoke()` method exposes the method being invoked; the target join point; the AOP proxy; and the arguments to the method. The `invoke()` method should return the invocation's result: the return value of the join point.

A simple `MethodInterceptor` implementation looks as follows:

```
public class DebugInterceptor implements MethodInterceptor {

    public Object invoke(MethodInvocation invocation) throws Throwable {
        System.out.println("Before: invocation=[" + invocation + "]");
        Object rval = invocation.proceed();
        System.out.println("Invocation returned");
        return rval;
    }
}
```

Note the call to the MethodInvocation's `proceed()` method. This proceeds down the interceptor chain towards the join point. Most interceptors will invoke this method, and return its return value. However, a MethodInterceptor, like any around advice, can return a different value or throw an exception rather than invoke the proceed method. However, you don't want to do this without good reason!

> **Note**
>
> MethodInterceptors offer interoperability with other AOP Alliance-compliant AOP implementations. The other advice types discussed in the remainder of this section implement common AOP concepts, but in a Spring-specific way. While there is an advantage in using the most specific advice type, stick with MethodInterceptor around advice if you are likely to want to run the aspect in another AOP framework. Note that pointcuts are not currently interoperable between frameworks, and the AOP Alliance does not currently define pointcut interfaces.

Before advice

A simpler advice type is a *before advice*. This does not need a `MethodInvocation` object, since it will only be called before entering the method.

The main advantage of a before advice is that there is no need to invoke the `proceed()` method, and therefore no possibility of inadvertently failing to proceed down the interceptor chain.

The `MethodBeforeAdvice` interface is shown below. (Spring's API design would allow for field before advice, although the usual objects apply to field interception and it's unlikely that Spring will ever implement it).

```
public interface MethodBeforeAdvice extends BeforeAdvice {

    void before(Method m, Object[] args, Object target) throws Throwable;
}
```

Note the return type is `void`. Before advice can insert custom behavior before the join point executes, but cannot change the return value. If a before advice throws an exception, this will abort further execution

of the interceptor chain. The exception will propagate back up the interceptor chain. If it is unchecked, or on the signature of the invoked method, it will be passed directly to the client; otherwise it will be wrapped in an unchecked exception by the AOP proxy.

An example of a before advice in Spring, which counts all method invocations:

```
public class CountingBeforeAdvice implements MethodBeforeAdvice {

    private int count;

    public void before(Method m, Object[] args, Object target) throws Throwable {
        ++count;
    }

    public int getCount() {
        return count;
    }
}
```

> **Tip**
>
> Before advice can be used with any pointcut.

Throws advice

Throws advice is invoked after the return of the join point if the join point threw an exception. Spring offers typed throws advice. Note that this means that the `org.springframework.aop.ThrowsAdvice` interface does not contain any methods: It is a tag interface identifying that the given object implements one or more typed throws advice methods. These should be in the form of:

```
afterThrowing([Method, args, target], subclassOfThrowable)
```

Only the last argument is required. The method signatures may have either one or four arguments, depending on whether the advice method is interested in the method and arguments. The following classes are examples of throws advice.

The advice below is invoked if a `RemoteException` is thrown (including subclasses):

```
public class RemoteThrowsAdvice implements ThrowsAdvice {

    public void afterThrowing(RemoteException ex) throws Throwable {
        // Do something with remote exception
    }
}
```

The following advice is invoked if a `ServletException` is thrown. Unlike the above advice, it declares 4 arguments, so that it has access to the invoked method, method arguments and target object:

```
public class ServletThrowsAdviceWithArguments implements ThrowsAdvice {

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }
}
```

The final example illustrates how these two methods could be used in a single class, which handles both `RemoteException` and `ServletException`. Any number of throws advice methods can be combined in a single class.

```
public static class CombinedThrowsAdvice implements ThrowsAdvice {

    public void afterThrowing(RemoteException ex) throws Throwable {
        // Do something with remote exception
    }

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }
}
```

Note

If a throws-advice method throws an exception itself, it will override the original exception (i.e. change the exception thrown to the user). The overriding exception will typically be a RuntimeException; this is compatible with any method signature. However, if a throws-advice method throws a checked exception, it will have to match the declared exceptions of the target method and is hence to some degree coupled to specific target method signatures. *Do not throw an undeclared checked exception that is incompatible with the target method's signature!*

Tip

Throws advice can be used with any pointcut.

After Returning advice

An after returning advice in Spring must implement the *org.springframework.aop.AfterReturningAdvice* interface, shown below:

```
public interface AfterReturningAdvice extends Advice {

    void afterReturning(Object returnValue, Method m, Object[] args, Object target)
            throws Throwable;
}
```

An after returning advice has access to the return value (which it cannot modify), invoked method, methods arguments and target.

The following after returning advice counts all successful method invocations that have not thrown exceptions:

```
public class CountingAfterReturningAdvice implements AfterReturningAdvice {

    private int count;

    public void afterReturning(Object returnValue, Method m, Object[] args, Object target)
            throws Throwable {
        ++count;
    }

    public int getCount() {
        return count;
    }
}
```

This advice doesn't change the execution path. If it throws an exception, this will be thrown up the interceptor chain instead of the return value.

> **Tip**
>
> After returning advice can be used with any pointcut.

Introduction advice

Spring treats introduction advice as a special kind of interception advice.

Introduction requires an `IntroductionAdvisor`, and an `IntroductionInterceptor`, implementing the following interface:

```
public interface IntroductionInterceptor extends MethodInterceptor {

    boolean implementsInterface(Class intf);
}
```

The `invoke()` method inherited from the AOP Alliance `MethodInterceptor` interface must implement the introduction: that is, if the invoked method is on an introduced interface, the introduction interceptor is responsible for handling the method call - it cannot invoke `proceed()`.

Introduction advice cannot be used with any pointcut, as it applies only at class, rather than method, level. You can only use introduction advice with the `IntroductionAdvisor`, which has the following methods:

```
public interface IntroductionAdvisor extends Advisor, IntroductionInfo {

    ClassFilter getClassFilter();

    void validateInterfaces() throws IllegalArgumentException;
}

public interface IntroductionInfo {

    Class[] getInterfaces();
}
```

There is no `MethodMatcher`, and hence no `Pointcut`, associated with introduction advice. Only class filtering is logical.

The `getInterfaces()` method returns the interfaces introduced by this advisor.

The `validateInterfaces()` method is used internally to see whether or not the introduced interfaces can be implemented by the configured `IntroductionInterceptor`.

Let's look at a simple example from the Spring test suite. Let's suppose we want to introduce the following interface to one or more objects:

```
public interface Lockable {
    void lock();
    void unlock();
    boolean locked();
}
```

This illustrates a *mixin*. We want to be able to cast advised objects to Lockable, whatever their type, and call lock and unlock methods. If we call the lock() method, we want all setter methods to throw a `LockedException`. Thus we can add an aspect that provides the ability to make objects immutable, without them having any knowledge of it: a good example of AOP.

Firstly, we'll need an `IntroductionInterceptor` that does the heavy lifting. In this case, we extend the `org.springframework.aop.support.DelegatingIntroductionInterceptor`

convenience class. We could implement IntroductionInterceptor directly, but using `DelegatingIntroductionInterceptor` is best for most cases.

The `DelegatingIntroductionInterceptor` is designed to delegate an introduction to an actual implementation of the introduced interface(s), concealing the use of interception to do so. The delegate can be set to any object using a constructor argument; the default delegate (when the no-arg constructor is used) is this. Thus in the example below, the delegate is the `LockMixin` subclass of `DelegatingIntroductionInterceptor`. Given a delegate (by default itself), a `DelegatingIntroductionInterceptor` instance looks for all interfaces implemented by the delegate (other than IntroductionInterceptor), and will support introductions against any of them. It's possible for subclasses such as `LockMixin` to call the `suppressInterface(Class intf)` method to suppress interfaces that should not be exposed. However, no matter how many interfaces an `IntroductionInterceptor` is prepared to support, the `IntroductionAdvisor` used will control which interfaces are actually exposed. An introduced interface will conceal any implementation of the same interface by the target.

Thus `LockMixin` extends `DelegatingIntroductionInterceptor` and implements `Lockable` itself. The superclass automatically picks up that Lockable can be supported for introduction, so we don't need to specify that. We could introduce any number of interfaces in this way.

Note the use of the `locked` instance variable. This effectively adds additional state to that held in the target object.

```
public class LockMixin extends DelegatingIntroductionInterceptor implements Lockable {

    private boolean locked;

    public void lock() {
        this.locked = true;
    }

    public void unlock() {
        this.locked = false;
    }

    public boolean locked() {
        return this.locked;
    }

    public Object invoke(MethodInvocation invocation) throws Throwable {
        if (locked() && invocation.getMethod().getName().indexOf("set") == 0) {
            throw new LockedException();
        }
        return super.invoke(invocation);
    }

}
```

Often it isn't necessary to override the `invoke()` method: the `DelegatingIntroductionInterceptor` implementation - which calls the delegate method if the method is introduced, otherwise proceeds towards the join point - is usually sufficient. In the present case, we need to add a check: no setter method can be invoked if in locked mode.

The introduction advisor required is simple. All it needs to do is hold a distinct `LockMixin` instance, and specify the introduced interfaces - in this case, just `Lockable`. A more complex example might take a reference to the introduction interceptor (which would be defined as a prototype): in this case, there's no configuration relevant for a `LockMixin`, so we simply create it using `new`.

```
public class LockMixinAdvisor extends DefaultIntroductionAdvisor {

    public LockMixinAdvisor() {
        super(new LockMixin(), Lockable.class);
    }
}
```

We can apply this advisor very simply: it requires no configuration. (However, it *is* necessary: It's impossible to use an `IntroductionInterceptor` without an *IntroductionAdvisor*.) As usual with introductions, the advisor must be per-instance, as it is stateful. We need a different instance of `LockMixinAdvisor`, and hence `LockMixin`, for each advised object. The advisor comprises part of the advised object's state.

We can apply this advisor programmatically, using the `Advised.addAdvisor()` method, or (the recommended way) in XML configuration, like any other advisor. All proxy creation choices discussed below, including "auto proxy creators," correctly handle introductions and stateful mixins.

10.4 Advisor API in Spring

In Spring, an Advisor is an aspect that contains just a single advice object associated with a pointcut expression.

Apart from the special case of introductions, any advisor can be used with any advice. `org.springframework.aop.support.DefaultPointcutAdvisor` is the most commonly used advisor class. For example, it can be used with a `MethodInterceptor`, `BeforeAdvice` or `ThrowsAdvice`.

It is possible to mix advisor and advice types in Spring in the same AOP proxy. For example, you could use a interception around advice, throws advice and before advice in one proxy configuration: Spring will automatically create the necessary interceptor chain.

10.5 Using the ProxyFactoryBean to create AOP proxies

If you're using the Spring IoC container (an ApplicationContext or BeanFactory) for your business objects - and you should be! - you will want to use one of Spring's AOP FactoryBeans. (Remember that a factory bean introduces a layer of indirection, enabling it to create objects of a different type.)

> **Note**
>
> The Spring AOP support also uses factory beans under the covers.

The basic way to create an AOP proxy in Spring is to use the *org.springframework.aop.framework.ProxyFactoryBean*. This gives complete control over the pointcuts and advice that will apply, and their ordering. However, there are simpler options that are preferable if you don't need such control.

Basics

The `ProxyFactoryBean`, like other Spring `FactoryBean` implementations, introduces a level of indirection. If you define a `ProxyFactoryBean` with name `foo`, what objects referencing `foo` see is not the `ProxyFactoryBean` instance itself, but an object created by the `ProxyFactoryBean`'s implementation of the `getObject()` method. This method will create an AOP proxy wrapping a target object.

One of the most important benefits of using a `ProxyFactoryBean` or another IoC-aware class to create AOP proxies, is that it means that advices and pointcuts can also be managed by IoC. This is a powerful feature, enabling certain approaches that are hard to achieve with other AOP frameworks. For example, an advice may itself reference application objects (besides the target, which should be available in any AOP framework), benefiting from all the pluggability provided by Dependency Injection.

JavaBean properties

In common with most `FactoryBean` implementations provided with Spring, the `ProxyFactoryBean` class is itself a JavaBean. Its properties are used to:

- Specify the target you want to proxy.
- Specify whether to use CGLIB (see below and also the section called “JDK- and CGLIB-based proxies”).

Some key properties are inherited from `org.springframework.aop.framework.ProxyConfig` (the superclass for all AOP proxy factories in Spring). These key properties include:

- `proxyTargetClass`: `true` if the target class is to be proxied, rather than the target class' interfaces. If this property value is set to `true`, then CGLIB proxies will be created (but see also the section called “JDK- and CGLIB-based proxies”).
- `optimize`: controls whether or not aggressive optimizations are applied to proxies *created via CGLIB*. One should not blithely use this setting unless one fully understands how the relevant AOP proxy handles optimization. This is currently used only for CGLIB proxies; it has no effect with JDK dynamic proxies.
- `frozen`: if a proxy configuration is `frozen`, then changes to the configuration are no longer allowed. This is useful both as a slight optimization and for those cases when you don’t want callers to be able to manipulate the proxy (via the `Advised` interface) after the proxy has been created. The default value of this property is `false`, so changes such as adding additional advice are allowed.
- `exposeProxy`: determines whether or not the current proxy should be exposed in a `ThreadLocal` so that it can be accessed by the target. If a target needs to obtain the proxy and the `exposeProxy` property is set to `true`, the target can use the `AopContext.currentProxy()` method.

Other properties specific to `ProxyFactoryBean` include:

- `proxyInterfaces`: array of String interface names. If this isn’t supplied, a CGLIB proxy for the target class will be used (but see also the section called “JDK- and CGLIB-based proxies”).
- `interceptorNames`: String array of `Advisor`, interceptor or other advice names to apply. Ordering is significant, on a first come-first served basis. That is to say that the first interceptor in the list will be the first to be able to intercept the invocation.

The names are bean names in the current factory, including bean names from ancestor factories. You can’t mention bean references here since doing so would result in the `ProxyFactoryBean` ignoring the singleton setting of the advice.

You can append an interceptor name with an asterisk (`*`). This will result in the application of all advisor beans with names starting with the part before the asterisk to be applied. An example of using this feature can be found in the section called “Using *global* advisors”.

- singleton: whether or not the factory should return a single object, no matter how often the `getObject()` method is called. Several `FactoryBean` implementations offer such a method. The

default value is `true`. If you want to use stateful advice - for example, for stateful mixins - use prototype advices along with a singleton value of `false`.

JDK- and CGLIB-based proxies

This section serves as the definitive documentation on how the `ProxyFactoryBean` chooses to create one of either a JDK- and CGLIB-based proxy for a particular target object (that is to be proxied).

> **Note**
>
> The behavior of the `ProxyFactoryBean` with regard to creating JDK- or CGLIB-based proxies changed between versions 1.2.x and 2.0 of Spring. The `ProxyFactoryBean` now exhibits similar semantics with regard to auto-detecting interfaces as those of the `TransactionProxyFactoryBean` class.

If the class of a target object that is to be proxied (hereafter simply referred to as the target class) doesn't implement any interfaces, then a CGLIB-based proxy will be created. This is the easiest scenario, because JDK proxies are interface based, and no interfaces means JDK proxying isn't even possible. One simply plugs in the target bean, and specifies the list of interceptors via the `interceptorNames` property. Note that a CGLIB-based proxy will be created even if the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `false`. (Obviously this makes no sense, and is best removed from the bean definition because it is at best redundant, and at worst confusing.)

If the target class implements one (or more) interfaces, then the type of proxy that is created depends on the configuration of the `ProxyFactoryBean`.

If the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `true`, then a CGLIB-based proxy will be created. This makes sense, and is in keeping with the principle of least surprise. Even if the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, the fact that the `proxyTargetClass` property is set to `true` *will* cause CGLIB-based proxying to be in effect.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, then a JDK-based proxy will be created. The created proxy will implement all of the interfaces that were specified in the `proxyInterfaces` property; if the target class happens to implement a whole lot more interfaces than those specified in the `proxyInterfaces` property, that is all well and good but those additional interfaces will not be implemented by the returned proxy.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has *not* been set, but the target class *does implement one (or more)* interfaces, then the `ProxyFactoryBean` will auto-detect the fact that the target class does actually implement at least one interface, and a JDK-based proxy will be created. The interfaces that are actually proxied will be *all* of the interfaces that the target class implements; in effect, this is the same as simply supplying a list of each and every interface that the target class implements to the `proxyInterfaces` property. However, it is significantly less work, and less prone to typos.

Proxying interfaces

Let's look at a simple example of `ProxyFactoryBean` in action. This example involves:

- A *target bean* that will be proxied. This is the "personTarget" bean definition in the example below.
- An Advisor and an Interceptor used to provide advice.

- An AOP proxy bean definition specifying the target object (the personTarget bean) and the interfaces to proxy, along with the advices to apply.

```
<bean id="personTarget" class="com.mycompany.PersonImpl">
    <property name="name" value="Tony"/>
    <property name="age" value="51"/>
</bean>

<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty" value="Custom string property value"/>
</bean>

<bean id="debugInterceptor" class="org.springframework.aop.interceptor.DebugInterceptor">
</bean>

<bean id="person"
    class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces" value="com.mycompany.Person"/>

    <property name="target" ref="personTarget"/>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>
```

Note that the `interceptorNames` property takes a list of String: the bean names of the interceptor or advisors in the current factory. Advisors, interceptors, before, after returning and throws advice objects can be used. The ordering of advisors is significant.

> **Note**
>
> You might be wondering why the list doesn't hold bean references. The reason for this is that if the ProxyFactoryBean's singleton property is set to false, it must be able to return independent proxy instances. If any of the advisors is itself a prototype, an independent instance would need to be returned, so it's necessary to be able to obtain an instance of the prototype from the factory; holding a reference isn't sufficient.

The "person" bean definition above can be used in place of a Person implementation, as follows:

```
Person person = (Person) factory.getBean("person");
```

Other beans in the same IoC context can express a strongly typed dependency on it, as with an ordinary Java object:

```
<bean id="personUser" class="com.mycompany.PersonUser">
    <property name="person"><ref bean="person"/></property>
</bean>
```

The `PersonUser` class in this example would expose a property of type Person. As far as it's concerned, the AOP proxy can be used transparently in place of a "real" person implementation. However, its class would be a dynamic proxy class. It would be possible to cast it to the `Advised` interface (discussed below).

It's possible to conceal the distinction between target and proxy using an anonymous *inner bean*, as follows. Only the `ProxyFactoryBean` definition is different; the advice is included only for completeness:

```
<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty" value="Custom string property value"/>
</bean>

<bean id="debugInterceptor" class="org.springframework.aop.interceptor.DebugInterceptor"/>

<bean id="person" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces" value="com.mycompany.Person"/>
    <!-- Use inner bean, not local reference to target -->
    <property name="target">
        <bean class="com.mycompany.PersonImpl">
            <property name="name" value="Tony"/>
            <property name="age" value="51"/>
        </bean>
    </property>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>
```

This has the advantage that there's only one object of type `Person`: useful if we want to prevent users of the application context from obtaining a reference to the un-advised object, or need to avoid any ambiguity with Spring IoC *autowiring*. There's also arguably an advantage in that the ProxyFactoryBean definition is self-contained. However, there are times when being able to obtain the un-advised target from the factory might actually be an *advantage*: for example, in certain test scenarios.

Proxying classes

What if you need to proxy a class, rather than one or more interfaces?

Imagine that in our example above, there was no `Person` interface: we needed to advise a class called `Person` that didn't implement any business interface. In this case, you can configure Spring to use CGLIB proxying, rather than dynamic proxies. Simply set the `proxyTargetClass` property on the ProxyFactoryBean above to true. While it's best to program to interfaces, rather than classes, the ability to advise classes that don't implement interfaces can be useful when working with legacy code. (In general, Spring isn't prescriptive. While it makes it easy to apply good practices, it avoids forcing a particular approach.)

If you want to, you can force the use of CGLIB in any case, even if you do have interfaces.

CGLIB proxying works by generating a subclass of the target class at runtime. Spring configures this generated subclass to delegate method calls to the original target: the subclass is used to implement the *Decorator* pattern, weaving in the advice.

CGLIB proxying should generally be transparent to users. However, there are some issues to consider:

- `Final` methods can't be advised, as they can't be overridden.
- There is no need to add CGLIB to your classpath. As of Spring 3.2, CGLIB is repackaged and included in the spring-core JAR. In other words, CGLIB-based AOP will work "out of the box" just as do JDK dynamic proxies.

There's little performance difference between CGLIB proxying and dynamic proxies. As of Spring 1.0, dynamic proxies are slightly faster. However, this may change in the future. Performance should not be a decisive consideration in this case.

Using *global* advisors

By appending an asterisk to an interceptor name, all advisors with bean names matching the part before the asterisk, will be added to the advisor chain. This can come in handy if you need to add a standard set of *global* advisors:

```
<bean id="proxy" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="target" ref="service"/>
    <property name="interceptorNames">
        <list>
            <value>global*</value>
        </list>
    </property>
</bean>

<bean id="global_debug" class="org.springframework.aop.interceptor.DebugInterceptor"/>
<bean id="global_performance" class="org.springframework.aop.interceptor.PerformanceMonitorInterceptor"/
>
```

10.6 Concise proxy definitions

Especially when defining transactional proxies, you may end up with many similar proxy definitions. The use of parent and child bean definitions, along with inner bean definitions, can result in much cleaner and more concise proxy definitions.

First a parent, *template*, bean definition is created for the proxy:

```
<bean id="txProxyTemplate" abstract="true"
        class="org.springframework.transaction.interceptor.TransactionProxyFactoryBean">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributes">
        <props>
            <prop key="*">PROPAGATION_REQUIRED</prop>
        </props>
    </property>
</bean>
```

This will never be instantiated itself, so may actually be incomplete. Then each proxy which needs to be created is just a child bean definition, which wraps the target of the proxy as an inner bean definition, since the target will never be used on its own anyway.

```
<bean id="myService" parent="txProxyTemplate">
    <property name="target">
        <bean class="org.springframework.samples.MyServiceImpl">
        </bean>
    </property>
</bean>
```

It is of course possible to override properties from the parent template, such as in this case, the transaction propagation settings:

```
<bean id="mySpecialService" parent="txProxyTemplate">
    <property name="target">
        <bean class="org.springframework.samples.MySpecialServiceImpl">
        </bean>
    </property>
    <property name="transactionAttributes">
        <props>
            <prop key="get*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="find*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="load*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="store*">PROPAGATION_REQUIRED</prop>
        </props>
    </property>
</bean>
```

Note that in the example above, we have explicitly marked the parent bean definition as *abstract* by using the *abstract* attribute, as described previously, so that it may not actually ever be instantiated. Application contexts (but not simple bean factories) will by default pre-instantiate all singletons. It is therefore important (at least for singleton beans) that if you have a (parent) bean definition which you intend to use only as a template, and this definition specifies a class, you must make sure to set the *abstract* attribute to *true*, otherwise the application context will actually try to pre-instantiate it.

10.7 Creating AOP proxies programmatically with the ProxyFactory

It's easy to create AOP proxies programmatically using Spring. This enables you to use Spring AOP without dependency on Spring IoC.

The following listing shows creation of a proxy for a target object, with one interceptor and one advisor. The interfaces implemented by the target object will automatically be proxied:

```
ProxyFactory factory = new ProxyFactory(myBusinessInterfaceImpl);
factory.addAdvice(myMethodInterceptor);
factory.addAdvisor(myAdvisor);
MyBusinessInterface tb = (MyBusinessInterface) factory.getProxy();
```

The first step is to construct an object of type `org.springframework.aop.framework.ProxyFactory`. You can create this with a target object, as in the above example, or specify the interfaces to be proxied in an alternate constructor.

You can add advices (with interceptors as a specialized kind of advice) and/or advisors, and manipulate them for the life of the ProxyFactory. If you add an IntroductionInterceptionAroundAdvisor, you can cause the proxy to implement additional interfaces.

There are also convenience methods on ProxyFactory (inherited from `AdvisedSupport`) which allow you to add other advice types such as before and throws advice. AdvisedSupport is the superclass of both ProxyFactory and ProxyFactoryBean.

> **Tip**
>
> Integrating AOP proxy creation with the IoC framework is best practice in most applications. We recommend that you externalize configuration from Java code with AOP, as in general.

10.8 Manipulating advised objects

However you create AOP proxies, you can manipulate them using the `org.springframework.aop.framework.Advised` interface. Any AOP proxy can be cast to this interface, whichever other interfaces it implements. This interface includes the following methods:

```
Advisor[] getAdvisors();

void addAdvice(Advice advice) throws AopConfigException;

void addAdvice(int pos, Advice advice) throws AopConfigException;

void addAdvisor(Advisor advisor) throws AopConfigException;

void addAdvisor(int pos, Advisor advisor) throws AopConfigException;

int indexOf(Advisor advisor);

boolean removeAdvisor(Advisor advisor) throws AopConfigException;

void removeAdvisor(int index) throws AopConfigException;

boolean replaceAdvisor(Advisor a, Advisor b) throws AopConfigException;

boolean isFrozen();
```

The `getAdvisors()` method will return an Advisor for every advisor, interceptor or other advice type that has been added to the factory. If you added an Advisor, the returned advisor at this index will be the object that you added. If you added an interceptor or other advice type, Spring will have wrapped this in an advisor with a pointcut that always returns true. Thus if you added a `MethodInterceptor`, the advisor returned for this index will be an `DefaultPointcutAdvisor` returning your `MethodInterceptor` and a pointcut that matches all classes and methods.

The `addAdvisor()` methods can be used to add any Advisor. Usually the advisor holding pointcut and advice will be the generic `DefaultPointcutAdvisor`, which can be used with any advice or pointcut (but not for introductions).

By default, it's possible to add or remove advisors or interceptors even once a proxy has been created. The only restriction is that it's impossible to add or remove an introduction advisor, as existing proxies from the factory will not show the interface change. (You can obtain a new proxy from the factory to avoid this problem.)

A simple example of casting an AOP proxy to the `Advised` interface and examining and manipulating its advice:

```
Advised advised = (Advised) myObject;
Advisor[] advisors = advised.getAdvisors();
int oldAdvisorCount = advisors.length;
System.out.println(oldAdvisorCount + " advisors");

// Add an advice like an interceptor without a pointcut
// Will match all proxied methods
// Can use for interceptors, before, after returning or throws advice
advised.addAdvice(new DebugInterceptor());

// Add selective advice using a pointcut
advised.addAdvisor(new DefaultPointcutAdvisor(mySpecialPointcut, myAdvice));

assertEquals("Added two advisors", oldAdvisorCount + 2, advised.getAdvisors().length);
```

> **Note**
>
> It's questionable whether it's advisable (no pun intended) to modify advice on a business object in production, although there are no doubt legitimate usage cases. However, it can be very useful in development: for example, in tests. I have sometimes found it very useful to be able to add test code in the form of an interceptor or other advice, getting inside a method invocation I want to test. (For example, the advice can get inside a transaction created for that method: for example, to run SQL to check that a database was correctly updated, before marking the transaction for roll back.)

Depending on how you created the proxy, you can usually set a `frozen` flag, in which case the `Advised` `isFrozen()` method will return true, and any attempts to modify advice through addition or removal will result in an `AopConfigException`. The ability to freeze the state of an advised object is useful in some cases, for example, to prevent calling code removing a security interceptor. It may also be used in Spring 1.1 to allow aggressive optimization if runtime advice modification is known not to be required.

10.9 Using the "auto-proxy" facility

So far we've considered explicit creation of AOP proxies using a `ProxyFactoryBean` or similar factory bean.

Spring also allows us to use "auto-proxy" bean definitions, which can automatically proxy selected bean definitions. This is built on Spring "bean post processor" infrastructure, which enables modification of any bean definition as the container loads.

In this model, you set up some special bean definitions in your XML bean definition file to configure the auto proxy infrastructure. This allows you just to declare the targets eligible for auto-proxying: you don't need to use `ProxyFactoryBean`.

There are two ways to do this:

- Using an auto-proxy creator that refers to specific beans in the current context.
- A special case of auto-proxy creation that deserves to be considered separately; auto-proxy creation driven by source-level metadata attributes.

Autoproxy bean definitions

The `org.springframework.aop.framework.autoproxy` package provides the following standard auto-proxy creators.

BeanNameAutoProxyCreator

The `BeanNameAutoProxyCreator` class is a `BeanPostProcessor` that automatically creates AOP proxies for beans with names matching literal values or wildcards.

```
<bean class="org.springframework.aop.framework.autoproxy.BeanNameAutoProxyCreator">
    <property name="beanNames" value="jdk*,onlyJdk"/>
    <property name="interceptorNames">
        <list>
            <value>myInterceptor</value>
        </list>
    </property>
</bean>
```

As with `ProxyFactoryBean`, there is an `interceptorNames` property rather than a list of interceptors, to allow correct behavior for prototype advisors. Named "interceptors" can be advisors or any advice type.

As with auto proxying in general, the main point of using `BeanNameAutoProxyCreator` is to apply the same configuration consistently to multiple objects, with minimal volume of configuration. It is a popular choice for applying declarative transactions to multiple objects.

Bean definitions whose names match, such as "jdkMyBean" and "onlyJdk" in the above example, are plain old bean definitions with the target class. An AOP proxy will be created automatically by the `BeanNameAutoProxyCreator`. The same advice will be applied to all matching beans. Note that if advisors are used (rather than the interceptor in the above example), the pointcuts may apply differently to different beans.

DefaultAdvisorAutoProxyCreator

A more general and extremely powerful auto proxy creator is `DefaultAdvisorAutoProxyCreator`. This will automagically apply eligible advisors in the current context, without the need to include specific bean names in the auto-proxy advisor's bean definition. It offers the same merit of consistent configuration and avoidance of duplication as `BeanNameAutoProxyCreator`.

Using this mechanism involves:

- Specifying a `DefaultAdvisorAutoProxyCreator` bean definition.
- Specifying any number of Advisors in the same or related contexts. Note that these *must* be Advisors, not just interceptors or other advices. This is necessary because there must be a pointcut to evaluate, to check the eligibility of each advice to candidate bean definitions.

The `DefaultAdvisorAutoProxyCreator` will automatically evaluate the pointcut contained in each advisor, to see what (if any) advice it should apply to each business object (such as "businessObject1" and "businessObject2" in the example).

This means that any number of advisors can be applied automatically to each business object. If no pointcut in any of the advisors matches any method in a business object, the object will not be proxied. As bean definitions are added for new business objects, they will automatically be proxied if necessary.

Autoproxying in general has the advantage of making it impossible for callers or dependencies to obtain an un-advised object. Calling getBean("businessObject1") on this ApplicationContext will return an AOP proxy, not the target business object. (The "inner bean" idiom shown earlier also offers this benefit.)

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="customAdvisor" class="com.mycompany.MyAdvisor"/>

<bean id="businessObject1" class="com.mycompany.BusinessObject1">
    <!-- Properties omitted -->
</bean>

<bean id="businessObject2" class="com.mycompany.BusinessObject2"/>
```

The `DefaultAdvisorAutoProxyCreator` is very useful if you want to apply the same advice consistently to many business objects. Once the infrastructure definitions are in place, you can simply add new business objects without including specific proxy configuration. You can also drop in additional aspects very easily - for example, tracing or performance monitoring aspects - with minimal change to configuration.

The DefaultAdvisorAutoProxyCreator offers support for filtering (using a naming convention so that only certain advisors are evaluated, allowing use of multiple, differently configured, AdvisorAutoProxyCreators in the same factory) and ordering. Advisors can implement the `org.springframework.core.Ordered` interface to ensure correct ordering if this is an issue. The TransactionAttributeSourceAdvisor used in the above example has a configurable order value; the default setting is unordered.

AbstractAdvisorAutoProxyCreator

This is the superclass of DefaultAdvisorAutoProxyCreator. You can create your own auto-proxy creators by subclassing this class, in the unlikely event that advisor definitions offer insufficient customization to the behavior of the framework `DefaultAdvisorAutoProxyCreator`.

Using metadata-driven auto-proxying

A particularly important type of auto-proxying is driven by metadata. This produces a similar programming model to .NET `ServicedComponents`. Instead of defining metadata in XML descriptors, configuration for transaction management and other enterprise services is held in source-level attributes.

In this case, you use the `DefaultAdvisorAutoProxyCreator`, in combination with Advisors that understand metadata attributes. The metadata specifics are held in the pointcut part of the candidate advisors, rather than in the auto-proxy creation class itself.

This is really a special case of the `DefaultAdvisorAutoProxyCreator`, but deserves consideration on its own. (The metadata-aware code is in the pointcuts contained in the advisors, not the AOP framework itself.)

The `/attributes` directory of the JPetStore sample application shows the use of attribute-driven auto-proxying. In this case, there's no need to use the `TransactionProxyFactoryBean`. Simply defining transactional attributes on business objects is sufficient, because of the use of metadata-aware pointcuts. The bean definitions include the following code, in `/WEB-INF/declarativeServices.xml`. Note that this is generic, and can be used outside the JPetStore:

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="transactionInterceptor"
        class="org.springframework.transaction.interceptor.TransactionInterceptor">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributeSource">
        <bean class="org.springframework.transaction.interceptor.AttributesTransactionAttributeSource">
            <property name="attributes" ref="attributes"/>
        </bean>
    </property>
</bean>

<bean id="attributes" class="org.springframework.metadata.commons.CommonsAttributes"/>
```

The `DefaultAdvisorAutoProxyCreator` bean definition (the name is not significant, hence it can even be omitted) will pick up all eligible pointcuts in the current application context. In this case, the "transactionAdvisor" bean definition, of type `TransactionAttributeSourceAdvisor`, will apply to classes or methods carrying a transaction attribute. The TransactionAttributeSourceAdvisor depends on a TransactionInterceptor, via constructor dependency. The example resolves this via

autowiring. The `AttributesTransactionAttributeSource` depends on an implementation of the `org.springframework.metadata.Attributes` interface. In this fragment, the "attributes" bean satisfies this, using the Jakarta Commons Attributes API to obtain attribute information. (The application code must have been compiled using the Commons Attributes compilation task.)

The `/annotation` directory of the JPetStore sample application contains an analogous example for auto-proxying driven by JDK 1.5+ annotations. The following configuration enables automatic detection of Spring's `Transactional` annotation, leading to implicit proxies for beans containing that annotation:

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="transactionInterceptor"
        class="org.springframework.transaction.interceptor.TransactionInterceptor">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributeSource">
        <bean class="org.springframework.transaction.annotation.AnnotationTransactionAttributeSource"/>
    </property>
</bean>
```

The `TransactionInterceptor` defined here depends on a `PlatformTransactionManager` definition, which is not included in this generic file (although it could be) because it will be specific to the application's transaction requirements (typically JTA, as in this example, or Hibernate, JDO or JDBC):

```
<bean id="transactionManager"
        class="org.springframework.transaction.jta.JtaTransactionManager"/>
```

> **Tip**
>
> If you require only declarative transaction management, using these generic XML definitions will result in Spring automatically proxying all classes or methods with transaction attributes. You won't need to work directly with AOP, and the programming model is similar to that of .NET ServicedComponents.

This mechanism is extensible. It's possible to do auto-proxying based on custom attributes. You need to:

- Define your custom attribute.
- Specify an Advisor with the necessary advice, including a pointcut that is triggered by the presence of the custom attribute on a class or method. You may be able to use an existing advice, merely implementing a static pointcut that picks up the custom attribute.

It's possible for such advisors to be unique to each advised class (for example, mixins): they simply need to be defined as prototype, rather than singleton, bean definitions. For example, the `LockMixin` introduction interceptor from the Spring test suite, shown above, could be used in conjunction with a generic `DefaultIntroductionAdvisor`:

```
<bean id="lockMixin" class="test.mixin.LockMixin" scope="prototype"/>

<bean id="lockableAdvisor" class="org.springframework.aop.support.DefaultIntroductionAdvisor"
        scope="prototype">
    <constructor-arg ref="lockMixin"/>
</bean>
```

Note that both `lockMixin` and `lockableAdvisor` are defined as prototypes.

10.10 Using TargetSources

Spring offers the concept of a *TargetSource*, expressed in the `org.springframework.aop.TargetSource` interface. This interface is responsible for returning the "target object" implementing the join point. The `TargetSource` implementation is asked for a target instance each time the AOP proxy handles a method invocation.

Developers using Spring AOP don't normally need to work directly with TargetSources, but this provides a powerful means of supporting pooling, hot swappable and other sophisticated targets. For example, a pooling TargetSource can return a different target instance for each invocation, using a pool to manage instances.

If you do not specify a TargetSource, a default implementation is used that wraps a local object. The same target is returned for each invocation (as you would expect).

Let's look at the standard target sources provided with Spring, and how you can use them.

> **Tip**
>
> When using a custom target source, your target will usually need to be a prototype rather than a singleton bean definition. This allows Spring to create a new target instance when required.

Hot swappable target sources

The `org.springframework.aop.target.HotSwappableTargetSource` exists to allow the target of an AOP proxy to be switched while allowing callers to keep their references to it.

Changing the target source's target takes effect immediately. The `HotSwappableTargetSource` is threadsafe.

You can change the target via the `swap()` method on HotSwappableTargetSource as follows:

```
HotSwappableTargetSource swapper = (HotSwappableTargetSource) beanFactory.getBean("swapper");
Object oldTarget = swapper.swap(newTarget);
```

The XML definitions required look as follows:

```
<bean id="initialTarget" class="mycompany.OldTarget"/>

<bean id="swapper" class="org.springframework.aop.target.HotSwappableTargetSource">
    <constructor-arg ref="initialTarget"/>
</bean>

<bean id="swappable" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="swapper"/>
</bean>
```

The above `swap()` call changes the target of the swappable bean. Clients who hold a reference to that bean will be unaware of the change, but will immediately start hitting the new target.

Although this example doesn't add any advice - and it's not necessary to add advice to use a `TargetSource` - of course any `TargetSource` can be used in conjunction with arbitrary advice.

Pooling target sources

Using a pooling target source provides a similar programming model to stateless session EJBs, in which a pool of identical instances is maintained, with method invocations going to free objects in the pool.

A crucial difference between Spring pooling and SLSB pooling is that Spring pooling can be applied to any POJO. As with Spring in general, this service can be applied in a non-invasive way.

Spring provides out-of-the-box support for Jakarta Commons Pool 1.3, which provides a fairly efficient pooling implementation. You'll need the commons-pool Jar on your application's classpath to use this feature. It's also possible to subclass `org.springframework.aop.target.AbstractPoolingTargetSource` to support any other pooling API.

Sample configuration is shown below:

```
<bean id="businessObjectTarget" class="com.mycompany.MyBusinessObject"
        scope="prototype">
    ... properties omitted
</bean>

<bean id="poolTargetSource" class="org.springframework.aop.target.CommonsPoolTargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
    <property name="maxSize" value="25"/>
</bean>

<bean id="businessObject" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="poolTargetSource"/>
    <property name="interceptorNames" value="myInterceptor"/>
</bean>
```

Note that the target object - "businessObjectTarget" in the example - *must* be a prototype. This allows the `PoolingTargetSource` implementation to create new instances of the target to grow the pool as necessary. See the javadocs of `AbstractPoolingTargetSource` and the concrete subclass you wish to use for information about its properties: "maxSize" is the most basic, and always guaranteed to be present.

In this case, "myInterceptor" is the name of an interceptor that would need to be defined in the same IoC context. However, it isn't necessary to specify interceptors to use pooling. If you want only pooling, and no other advice, don't set the interceptorNames property at all.

It's possible to configure Spring so as to be able to cast any pooled object to the `org.springframework.aop.target.PoolingConfig` interface, which exposes information about the configuration and current size of the pool through an introduction. You'll need to define an advisor like this:

```
<bean id="poolConfigAdvisor" class="org.springframework.beans.factory.config.MethodInvokingFactoryBean">
    <property name="targetObject" ref="poolTargetSource"/>
    <property name="targetMethod" value="getPoolingConfigMixin"/>
</bean>
```

This advisor is obtained by calling a convenience method on the `AbstractPoolingTargetSource` class, hence the use of MethodInvokingFactoryBean. This advisor's name ("poolConfigAdvisor" here) must be in the list of interceptors names in the ProxyFactoryBean exposing the pooled object.

The cast will look as follows:

```
PoolingConfig conf = (PoolingConfig) beanFactory.getBean("businessObject");
System.out.println("Max pool size is " + conf.getMaxSize());
```

> **Note**
>
> Pooling stateless service objects is not usually necessary. We don't believe it should be the default choice, as most stateless objects are naturally thread safe, and instance pooling is problematic if resources are cached.

Simpler pooling is available using auto-proxying. It's possible to set the TargetSources used by any auto-proxy creator.

Prototype target sources

Setting up a "prototype" target source is similar to a pooling TargetSource. In this case, a new instance of the target will be created on every method invocation. Although the cost of creating a new object isn't high in a modern JVM, the cost of wiring up the new object (satisfying its IoC dependencies) may be more expensive. Thus you shouldn't use this approach without very good reason.

To do this, you could modify the `poolTargetSource` definition shown above as follows. (I've also changed the name, for clarity.)

```
<bean id="prototypeTargetSource" class="org.springframework.aop.target.PrototypeTargetSource">
    <property name="targetBeanName" ref="businessObjectTarget"/>
</bean>
```

There's only one property: the name of the target bean. Inheritance is used in the TargetSource implementations to ensure consistent naming. As with the pooling target source, the target bean must be a prototype bean definition.

ThreadLocal target sources

`ThreadLocal` target sources are useful if you need an object to be created for each incoming request (per thread that is). The concept of a `ThreadLocal` provide a JDK-wide facility to transparently store resource alongside a thread. Setting up a `ThreadLocalTargetSource` is pretty much the same as was explained for the other types of target source:

```
<bean id="threadlocalTargetSource" class="org.springframework.aop.target.ThreadLocalTargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
</bean>
```

> **Note**
>
> ThreadLocals come with serious issues (potentially resulting in memory leaks) when incorrectly using them in a multi-threaded and multi-classloader environments. One should always consider wrapping a threadlocal in some other class and never directly use the `ThreadLocal` itself (except of course in the wrapper class). Also, one should always remember to correctly set and unset (where the latter simply involved a call to `ThreadLocal.set(null)`) the resource local to the thread. Unsetting should be done in any case since not unsetting it might result in problematic behavior. Spring's ThreadLocal support does this for you and should always be considered in favor of using ThreadLocals without other proper handling code.

10.11 Defining new Advice types

Spring AOP is designed to be extensible. While the interception implementation strategy is presently used internally, it is possible to support arbitrary advice types in addition to the out-of-the-box interception around advice, before, throws advice and after returning advice.

The `org.springframework.aop.framework.adapter` package is an SPI package allowing support for new custom advice types to be added without changing the core framework. The only constraint on a custom `Advice` type is that it must implement the `org.aopalliance.aop.Advice` marker interface.

Please refer to the `org.springframework.aop.framework.adapter` javadocs for further information.

10.12 Further resources

Please refer to the Spring sample applications for further examples of Spring AOP:

- The JPetStore's default configuration illustrates the use of the `TransactionProxyFactoryBean` for declarative transaction management.
- The `/attributes` directory of the JPetStore illustrates the use of attribute-driven declarative transaction management.

11. Testing

11.1 Introduction to Spring Testing

Testing is an integral part of enterprise software development. This chapter focuses on the value-add of the IoC principle to unit testing and on the benefits of the Spring Framework's support for integration testing. *(A thorough treatment of testing in the enterprise is beyond the scope of this reference manual.)*

11.2 Unit Testing

Dependency Injection should make your code less dependent on the container than it would be with traditional Java EE development. The POJOs that make up your application should be testable in JUnit or TestNG tests, with objects simply instantiated using the `new` operator, *without Spring or any other container*. You can use mock objects (in conjunction with other valuable testing techniques) to test your code in isolation. If you follow the architecture recommendations for Spring, the resulting clean layering and componentization of your codebase will facilitate easier unit testing. For example, you can test service layer objects by stubbing or mocking DAO or Repository interfaces, without needing to access persistent data while running unit tests.

True unit tests typically run extremely quickly, as there is no runtime infrastructure to set up. Emphasizing true unit tests as part of your development methodology will boost your productivity. You may not need this section of the testing chapter to help you write effective unit tests for your IoC-based applications. For certain unit testing scenarios, however, the Spring Framework provides the following mock objects and testing support classes.

Mock Objects

Environment

The `org.springframework.mock.env` package contains mock implementations of the `Environment` and `PropertySource` abstractions (see the section called "Bean definition profiles" and the section called "PropertySource Abstraction"). `MockEnvironment` and `MockPropertySource` are useful for developing *out-of-container* tests for code that depends on environment-specific properties.

JNDI

The `org.springframework.mock.jndi` package contains an implementation of the JNDI SPI, which you can use to set up a simple JNDI environment for test suites or stand-alone applications. If, for example, JDBC `DataSources` get bound to the same JNDI names in test code as within a Java EE container, you can reuse both application code and configuration in testing scenarios without modification.

Servlet API

The `org.springframework.mock.web` package contains a comprehensive set of Servlet API mock objects, targeted at usage with Spring's Web MVC framework, which are useful for testing web contexts and controllers. These mock objects are generally more convenient to use than dynamic mock objects such as EasyMock or existing Servlet API mock objects such as MockObjects.

Portlet API

The `org.springframework.mock.web.portlet` package contains a set of Portlet API mock objects, targeted at usage with Spring's Portlet MVC framework.

Unit Testing support Classes

General utilities

The `org.springframework.test.util` package contains `ReflectionTestUtils`, which is a collection of reflection-based utility methods. Developers use these methods in unit and integration testing scenarios in which they need to set a non- `public` field or invoke a non- `public` setter method when testing application code involving, for example:

- ORM frameworks such as JPA and Hibernate that condone `private` or `protected` field access as opposed to `public` setter methods for properties in a domain entity.
- Spring's support for annotations such as `@Autowired`, `@Inject`, and `@Resource`, which provides dependency injection for `private` or `protected` fields, setter methods, and configuration methods.

Spring MVC

The `org.springframework.test.web` package contains `ModelAndViewAssert`, which you can use in combination with JUnit, TestNG, or any other testing framework for unit tests dealing with Spring MVC `ModelAndView` objects.

> **Unit testing Spring MVC Controllers**
>
> To test your Spring MVC `Controllers`, use `ModelAndViewAssert` combined with `MockHttpServletRequest`, `MockHttpSession`, and so on from the `org.springframework.mock.web` package.
>
> Note: As of Spring 4.0, the set of mocks in the `org.springframework.mock.web` package is now based on the Servlet 3.0 API.

11.3 Integration Testing

Overview

It is important to be able to perform some integration testing without requiring deployment to your application server or connecting to other enterprise infrastructure. This will enable you to test things such as:

- The correct wiring of your Spring IoC container contexts.
- Data access using JDBC or an ORM tool. This would include such things as the correctness of SQL statements, Hibernate queries, JPA entity mappings, etc.

The Spring Framework provides first-class support for integration testing in the `spring-test` module. The name of the actual JAR file might include the release version and might also be in the long `org.springframework.test` form, depending on where you get it from (see the section on Dependency Management for an explanation). This library includes the `org.springframework.test` package, which contains valuable classes for integration testing with a Spring container. This testing does not rely on an application server or other deployment environment. Such tests are slower to run than unit tests but much faster than the equivalent Selenium tests or remote tests that rely on deployment to an application server.

In Spring 2.5 and later, unit and integration testing support is provided in the form of the annotation-driven Spring TestContext Framework. The TestContext framework is agnostic of the actual testing framework in use, thus allowing instrumentation of tests in various environments including JUnit, TestNG, and so on.

Goals of Integration Testing

Spring's integration testing support has the following primary goals:

- To manage Spring IoC container caching between test execution.
- To provide Dependency Injection of test fixture instances.
- To provide transaction management appropriate to integration testing.
- To supply Spring-specific base classes that assist developers in writing integration tests.

The next few sections describe each goal and provide links to implementation and configuration details.

Context management and caching

The Spring TestContext Framework provides consistent loading of Spring `ApplicationContexts` and `WebApplicationContexts` as well as caching of those contexts. Support for the caching of loaded contexts is important, because startup time can become an issue — not because of the overhead of Spring itself, but because the objects instantiated by the Spring container take time to instantiate. For example, a project with 50 to 100 Hibernate mapping files might take 10 to 20 seconds to load the mapping files, and incurring that cost before running every test in every test fixture leads to slower overall test runs that reduce developer productivity.

Test classes typically declare either an array of *resource locations* for XML configuration metadata — often in the classpath — or an array of *annotated classes* that is used to configure the application. These locations or classes are the same as or similar to those specified in `web.xml` or other deployment configuration files.

By default, once loaded, the configured `ApplicationContext` is reused for each test. Thus the setup cost is incurred only once per test suite, and subsequent test execution is much faster. In this context, the term *test suite* means all tests run in the same JVM — for example, all tests run from an Ant, Maven, or Gradle build for a given project or module. In the unlikely case that a test corrupts the application context and requires reloading — for example, by modifying a bean definition or the state of an application object — the TestContext framework can be configured to reload the configuration and rebuild the application context before executing the next test.

See the section called "Context management" and the section called "Context caching" with the TestContext framework.

Dependency Injection of test fixtures

When the TestContext framework loads your application context, it can optionally configure instances of your test classes via Dependency Injection. This provides a convenient mechanism for setting up test fixtures using preconfigured beans from your application context. A strong benefit here is that you can reuse application contexts across various testing scenarios (e.g., for configuring Spring-managed object graphs, transactional proxies, `DataSources`, etc.), thus avoiding the need to duplicate complex test fixture setup for individual test cases.

As an example, consider the scenario where we have a class, `HibernateTitleRepository`, that implements data access logic for a `Title` domain entity. We want to write integration tests that test the following areas:

- The Spring configuration: basically, is everything related to the configuration of the `HibernateTitleRepository` bean correct and present?
- The Hibernate mapping file configuration: is everything mapped correctly, and are the correct lazy-loading settings in place?
- The logic of the `HibernateTitleRepository`: does the configured instance of this class perform as anticipated?

See dependency injection of test fixtures with the TestContext framework.

Transaction management

One common issue in tests that access a real database is their effect on the state of the persistence store. Even when you're using a development database, changes to the state may affect future tests. Also, many operations — such as inserting or modifying persistent data — cannot be performed (or verified) outside a transaction.

The TestContext framework addresses this issue. By default, the framework will create and roll back a transaction for each test. You simply write code that can assume the existence of a transaction. If you call transactionally proxied objects in your tests, they will behave correctly, according to their configured transactional semantics. In addition, if a test method deletes the contents of selected tables while running within the transaction managed for the test, the transaction will roll back by default, and the database will return to its state prior to execution of the test. Transactional support is provided to a test via a `PlatformTransactionManager` bean defined in the test's application context.

If you want a transaction to commit — unusual, but occasionally useful when you want a particular test to populate or modify the database — the TestContext framework can be instructed to cause the transaction to commit instead of roll back via the `@TransactionConfiguration` and `@Rollback` annotations.

See transaction management with the TestContext framework.

Support classes for integration testing

The Spring TestContext Framework provides several `abstract` support classes that simplify the writing of integration tests. These base test classes provide well-defined hooks into the testing framework as well as convenient instance variables and methods, which enable you to access:

- The `ApplicationContext`, for performing explicit bean lookups or testing the state of the context as a whole.
- A `JdbcTemplate`, for executing SQL statements to query the database. Such queries can be used to confirm database state both *prior to* and *after* execution of database-related application code, and Spring ensures that such queries run in the scope of the same transaction as the application code. When used in conjunction with an ORM tool, be sure to avoid false positives.

In addition, you may want to create your own custom, application-wide superclass with instance variables and methods specific to your project.

See support classes for the TestContext framework.

JDBC Testing Support

The `org.springframework.test.jdbc` package contains `JdbcTestUtils`, which is a collection of JDBC related utility functions intended to simplify standard database testing scenarios. Specifically, `JdbcTestUtils` provides the following static utility methods.

- `countRowsInTable(..)`: counts the number of rows in the given table
- `countRowsInTableWhere(..)`: counts the number of rows in the given table, using the provided `WHERE` clause
- `deleteFromTables(..)`: deletes all rows from the specified tables
- `deleteFromTableWhere(..)`: deletes rows from the given table, using the provided `WHERE` clause
- `dropTables(..)`: drops the specified tables

Note that `AbstractTransactionalJUnit4SpringContextTests` and `AbstractTransactionalTestNGSpringContextTests` provide convenience methods which delegate to the aforementioned methods in `JdbcTestUtils`.

The `spring-jdbc` module provides support for configuring and launching an embedded database which can be used in integration tests that interact with a database. For details, see Section 14.8, “Embedded database support” and the section called “Testing data access logic with an embedded database”.

Annotations

Spring Testing Annotations

The Spring Framework provides the following set of *Spring-specific* annotations that you can use in your unit and integration tests in conjunction with the TestContext framework. Refer to the corresponding javadocs for further information, including default attribute values, attribute aliases, and so on.

- `@ContextConfiguration`

  Defines class-level metadata that is used to determine how to load and configure an `ApplicationContext` for integration tests. Specifically, `@ContextConfiguration` declares the application context resource `locations` or the annotated `classes` that will be used to load the context.

  Resource locations are typically XML configuration files located in the classpath; whereas, annotated classes are typically `@Configuration` classes. However, resource locations can also refer to files in the file system, and annotated classes can be component classes, etc.

```
@ContextConfiguration("/test-config.xml")
public class XmlApplicationContextTests {
    // class body...
}
```

```
@ContextConfiguration(classes = TestConfig.class)
public class ConfigClassApplicationContextTests {
    // class body...
}
```

As an alternative or in addition to declaring resource locations or annotated classes, `@ContextConfiguration` may be used to declare `ApplicationContextInitializer` classes.

```
@ContextConfiguration(initializers = CustomContextIntializer.class)
public class ContextInitializerTests {
    // class body...
}
```

`@ContextConfiguration` may optionally be used to declare the `ContextLoader` strategy as well. Note, however, that you typically do not need to explicitly configure the loader since the default loader supports either resource `locations` or annotated `classes` as well as `initializers`.

```
@ContextConfiguration(locations = "/test-context.xml", loader = CustomContextLoader.class)
public class CustomLoaderXmlApplicationContextTests {
    // class body...
}
```

> **Note**
>
> `@ContextConfiguration` provides support for *inheriting* resource locations or configuration classes as well as context initializers declared by superclasses by default.

See the section called “Context management” and the `@ContextConfiguration` javadocs for further details.

- `@WebAppConfiguration`

  A class-level annotation that is used to declare that the `ApplicationContext` loaded for an integration test should be a `WebApplicationContext`. The mere presence of `@WebAppConfiguration` on a test class ensures that a `WebApplicationContext` will be loaded for the test, using the default value of `"file:src/main/webapp"` for the path to the root of the web application (i.e., the *resource base path*). The resource base path is used behind the scenes to create a `MockServletContext` which serves as the `ServletContext` for the test's `WebApplicationContext`.

  ```
  @ContextConfiguration
  @WebAppConfiguration
  public class WebAppTests {
      // class body...
  }
  ```

  To override the default, specify a different base resource path via the *implicit* `value` attribute. Both `classpath:` and `file:` resource prefixes are supported. If no resource prefix is supplied the path is assumed to be a file system resource.

  ```
  @ContextConfiguration
  @WebAppConfiguration("classpath:test-web-resources")
  public class WebAppTests {
      // class body...
  }
  ```

  Note that `@WebAppConfiguration` must be used in conjunction with `@ContextConfiguration`, either within a single test class or within a test class hierarchy. See the `@WebAppConfiguration` javadocs for further details.

- `@ContextHierarchy`

  A class-level annotation that is used to define a hierarchy of `ApplicationContexts` for integration tests. `@ContextHierarchy` should be declared with a list of one or more `@ContextConfiguration` instances, each of which defines a level in the context hierarchy. The following examples demonstrate the use of `@ContextHierarchy` within a single test class; however, `@ContextHierarchy` can also be used within a test class hierarchy.

```
@ContextHierarchy({
    @ContextConfiguration("/parent-config.xml"),
    @ContextConfiguration("/child-config.xml")
})
public class ContextHierarchyTests {
    // class body...
}
```

```
@WebAppConfiguration
@ContextHierarchy({
    @ContextConfiguration(classes = AppConfig.class),
    @ContextConfiguration(classes = WebConfig.class)
})
public class WebIntegrationTests {
    // class body...
}
```

  If you need to merge or override the configuration for a given level of the context hierarchy within a test class hierarchy, you must explicitly name that level by supplying the same value to the `name` attribute in `@ContextConfiguration` at each corresponding level in the class hierarchy. See the section called “Context hierarchies” and the `@ContextHierarchy` javadocs for further examples.

- `@ActiveProfiles`

  A class-level annotation that is used to declare which *bean definition profiles* should be active when loading an `ApplicationContext` for test classes.

```
@ContextConfiguration
@ActiveProfiles("dev")
public class DeveloperTests {
    // class body...
}
```

```
@ContextConfiguration
@ActiveProfiles({"dev", "integration"})
public class DeveloperIntegrationTests {
    // class body...
}
```

  > **Note**
  >
  > `@ActiveProfiles` provides support for *inheriting* active bean definition profiles declared by superclasses by default. It is also possible to resolve active bean definition profiles programmatically by implementing a custom `ActiveProfilesResolver` and registering it via the `resolver` attribute of `@ActiveProfiles`.

  See the section called “Context configuration with environment profiles” and the `@ActiveProfiles` javadocs for examples and further details.

- `@TestPropertySource`

A class-level annotation that is used to configure the locations of properties files and inlined properties to be added to the `Environment`'s set of `PropertySources` for an `ApplicationContext` loaded for an integration test.

Test property sources have higher precedence than those loaded from the operating system's environment or Java system properties as well as property sources added by the application declaratively via `@PropertySource` or programmatically. Thus, test property sources can be used to selectively override properties defined in system and application property sources. Furthermore, inlined properties have higher precedence than properties loaded from resource locations.

The following example demonstrates how to declare a properties file from the classpath.

```
@ContextConfiguration
@TestPropertySource("/test.properties")
public class MyIntegrationTests {
    // class body...
}
```

The following example demonstrates how to declare *inlined* properties.

```
@ContextConfiguration
@TestPropertySource(properties = { "timezone = GMT", "port: 4242" })
public class MyIntegrationTests {
    // class body...
}
```

- `@DirtiesContext`

Indicates that the underlying Spring `ApplicationContext` has been *dirtied* during the execution of a test (i.e., modified or corrupted in some manner — for example, by changing the state of a singleton bean) and should be closed, regardless of whether the test passed. When an application context is marked *dirty*, it is removed from the testing framework's cache and closed. As a consequence, the underlying Spring container will be rebuilt for any subsequent test that requires a context with the same configuration metadata.

`@DirtiesContext` can be used as both a class-level and method-level annotation within the same test class. In such scenarios, the `ApplicationContext` is marked as *dirty* after any such annotated method as well as after the entire class. If the `ClassMode` is set to `AFTER_EACH_TEST_METHOD`, the context is marked dirty after each test method in the class.

The following examples explain when the context would be dirtied for various configuration scenarios:

- After the current test class, when declared on a class with class mode set to `AFTER_CLASS` (i.e., the default class mode).

```
@DirtiesContext
public class ContextDirtyingTests {
    // some tests that result in the Spring container being dirtied
}
```

- After each test method in the current test class, when declared on a class with class mode set to `AFTER_EACH_TEST_METHOD`.

```
@DirtiesContext(classMode = ClassMode.AFTER_EACH_TEST_METHOD)
public class ContextDirtyingTests {
    // some tests that result in the Spring container being dirtied
}
```

- After the current test, when declared on a method.

```
@DirtiesContext
@Test
public void testProcessWhichDirtiesAppCtx() {
    // some logic that results in the Spring container being dirtied
}
```

If `@DirtiesContext` is used in a test whose context is configured as part of a context hierarchy via `@ContextHierarchy`, the `hierarchyMode` flag can be used to control how the context cache is cleared. By default an *exhaustive* algorithm will be used that clears the context cache including not only the current level but also all other context hierarchies that share an ancestor context common to the current test; all `ApplicationContexts` that reside in a sub-hierarchy of the common ancestor context will be removed from the context cache and closed. If the *exhaustive* algorithm is overkill for a particular use case, the simpler *current level* algorithm can be specified instead, as seen below.

```
@ContextHierarchy({
    @ContextConfiguration("/parent-config.xml"),
    @ContextConfiguration("/child-config.xml")
})
public class BaseTests {
    // class body...
}

public class ExtendedTests extends BaseTests {

    @Test
    @DirtiesContext(hierarchyMode = HierarchyMode.CURRENT_LEVEL)
    public void test() {
        // some logic that results in the child context being dirtied
    }
}
```

For further details regarding the `EXHAUSTIVE` and `CURRENT_LEVEL` algorithms see the `DirtiesContext.HierarchyMode` javadocs.

- `@TestExecutionListeners`

Defines class-level metadata for configuring which `TestExecutionListeners` should be registered with the `TestContextManager`. Typically, `@TestExecutionListeners` is used in conjunction with `@ContextConfiguration`.

```
@ContextConfiguration
@TestExecutionListeners({CustomTestExecutionListener.class, AnotherTestExecutionListener.class})
public class CustomTestExecutionListenerTests {
    // class body...
}
```

`@TestExecutionListeners` supports *inherited* listeners by default. See the javadocs for an example and further details.

- `@TransactionConfiguration`

Defines class-level metadata for configuring transactional tests. Specifically, the bean name of the `PlatformTransactionManager` that should be used to drive transactions can be explicitly specified if there are multiple beans of type `PlatformTransactionManager` in the test's `ApplicationContext` and if the bean name of the desired `PlatformTransactionManager` is not "transactionManager". In addition, you can change the `defaultRollback` flag to `false`. Typically, `@TransactionConfiguration` is used in conjunction with `@ContextConfiguration`.

```
@ContextConfiguration
@TransactionConfiguration(transactionManager = "txMgr", defaultRollback = false)
public class CustomConfiguredTransactionalTests {
    // class body...
}
```

> **Note**
>
> If the default conventions are sufficient for your test configuration, you can avoid using `@TransactionConfiguration` altogether. In other words, if you have only one transaction manager — or if you have multiple transaction managers but the transaction manager for tests is named "transactionManager" or specified via a `TransactionManagementConfigurer` — and if you want transactions to roll back automatically, then there is no need to annotate your test class with `@TransactionConfiguration`.

- `@Rollback`

  Indicates whether the transaction for the annotated test method should be *rolled back* after the test method has completed. If `true`, the transaction is rolled back; otherwise, the transaction is committed. Use `@Rollback` to override the default rollback flag configured at the class level.

```
@Rollback(false)
@Test
public void testProcessWithoutRollback() {
    // ...
}
```

- `@BeforeTransaction`

  Indicates that the annotated `public void` method should be executed *before* a transaction is started for test methods configured to run within a transaction via the `@Transactional` annotation.

```
@BeforeTransaction
public void beforeTransaction() {
    // logic to be executed before a transaction is started
}
```

- `@AfterTransaction`

  Indicates that the annotated `public void` method should be executed *after* a transaction has ended for test methods configured to run within a transaction via the `@Transactional` annotation.

```
@AfterTransaction
public void afterTransaction() {
    // logic to be executed after a transaction has ended
}
```

- `@Sql`

  Used to annotate a test class or test method to configure SQL scripts to be executed against a given database during integration tests.

```
@Test
@Sql({"/test-schema.sql", "/test-user-data.sql"})
public void userTest {
    // execute code that relies on the test schema and test data
}
```

See the section called “Executing SQL scripts declaratively with `@Sql`” for further details.

- `@SqlConfig`

  Defines metadata that is used to determine how to parse and execute SQL scripts configured via the `@Sql` annotation.

```
@Test
@Sql(
    scripts = "/test-user-data.sql",
    config = @SqlConfig(commentPrefix = "`", separator = "@@")
)
public void userTest {
    // execute code that relies on the test data
}
```

- `@SqlGroup`

  A container annotation that aggregates several `@Sql` annotations. Can be used natively, declaring several nested `@Sql` annotations. Can also be used in conjunction with Java 8’s support for repeatable annotations, where `@Sql` can simply be declared several times on the same class or method, implicitly generating this container annotation.

```
@Test
@SqlGroup({
    @Sql(scripts = "/test-schema.sql", config = @SqlConfig(commentPrefix = "`")),
    @Sql("/test-user-data.sql")
)}
public void userTest {
    // execute code that uses the test schema and test data
}
```

Standard Annotation Support

The following annotations are supported with standard semantics for all configurations of the Spring TestContext Framework. Note that these annotations are not specific to tests and can be used anywhere in the Spring Framework.

- `@Autowired`
- `@Qualifier`
- `@Resource` (javax.annotation) *if JSR-250 is present*
- `@Inject` (javax.inject) *if JSR-330 is present*
- `@Named` (javax.inject) *if JSR-330 is present*
- `@PersistenceContext` (javax.persistence) *if JPA is present*
- `@PersistenceUnit` (javax.persistence) *if JPA is present*
- `@Required`
- `@Transactional`

> **JSR-250 Lifecycle Annotations**
>
> In the Spring TestContext Framework `@PostConstruct` and `@PreDestroy` may be used with standard semantics on any application components configured in the `ApplicationContext`; however, these lifecycle annotations have limited usage within an actual test class.
>
> If a method within a test class is annotated with `@PostConstruct`, that method will be executed before any *before* methods of the underlying test framework (e.g., methods annotated with JUnit's `@Before`), and that will apply for every test method in the test class. On the other hand, if a method within a test class is annotated with `@PreDestroy`, that method will *never* be executed. Within a test class it is therefore recommended to use test lifecycle callbacks from the underlying test framework instead of `@PostConstruct` and `@PreDestroy`.

Spring JUnit Testing Annotations

The following annotations are *only* supported when used in conjunction with the SpringJUnit4ClassRunner or the JUnit support classes.

- `@IfProfileValue`

  Indicates that the annotated test is enabled for a specific testing environment. If the configured `ProfileValueSource` returns a matching `value` for the provided `name`, the test is enabled. This annotation can be applied to an entire class or to individual methods. Class-level usage overrides method-level usage.

  ```
  @IfProfileValue(name="java.vendor", value="Oracle Corporation")
  @Test
  public void testProcessWhichRunsOnlyOnOracleJvm() {
      // some logic that should run only on Java VMs from Oracle Corporation
  }
  ```

  Alternatively, you can configure `@IfProfileValue` with a list of `values` (with *OR* semantics) to achieve TestNG-like support for *test groups* in a JUnit environment. Consider the following example:

  ```
  @IfProfileValue(name="test-groups", values={"unit-tests", "integration-tests"})
  @Test
  public void testProcessWhichRunsForUnitOrIntegrationTestGroups() {
      // some logic that should run only for unit and integration test groups
  }
  ```

- `@ProfileValueSourceConfiguration`

  Class-level annotation that specifies what type of `ProfileValueSource` to use when retrieving *profile values* configured through the `@IfProfileValue` annotation. If `@ProfileValueSourceConfiguration` is not declared for a test, `SystemProfileValueSource` is used by default.

  ```
  @ProfileValueSourceConfiguration(CustomProfileValueSource.class)
  public class CustomProfileValueSourceTests {
      // class body...
  }
  ```

- `@Timed`

  Indicates that the annotated test method must finish execution in a specified time period (in milliseconds). If the text execution time exceeds the specified time period, the test fails.

The time period includes execution of the test method itself, any repetitions of the test (see `@Repeat`), as well as any *set up* or *tear down* of the test fixture.

```
@Timed(millis=1000)
public void testProcessWithOneSecondTimeout() {
    // some logic that should not take longer than 1 second to execute
}
```

Spring's `@Timed` annotation has different semantics than JUnit's `@Test(timeout=...)` support. Specifically, due to the manner in which JUnit handles test execution timeouts (that is, by executing the test method in a separate `Thread`), `@Test(timeout=...)` preemptively fails the test if the test takes too long. Spring's `@Timed`, on the other hand, does not preemptively fail the test but rather waits for the test to complete before failing.

- `@Repeat`

  Indicates that the annotated test method must be executed repeatedly. The number of times that the test method is to be executed is specified in the annotation.

  The scope of execution to be repeated includes execution of the test method itself as well as any *set up* or *tear down* of the test fixture.

```
@Repeat(10)
@Test
public void testProcessRepeatedly() {
    // ...
}
```

Meta-Annotation Support for Testing

As of Spring Framework 4.0, it is possible to use test-related annotations as meta-annotations in order to create custom *composed annotations* and reduce configuration duplication across a test suite.

Each of the following may be used as meta-annotations in conjunction with the TestContext framework.

- `@ContextConfiguration`
- `@ContextHierarchy`
- `@ActiveProfiles`
- `@TestPropertySource`
- `@DirtiesContext`
- `@WebAppConfiguration`
- `@TestExecutionListeners`
- `@Transactional`
- `@BeforeTransaction`
- `@AfterTransaction`
- `@TransactionConfiguration`
- `@Rollback`
- `@Sql`

- `@SqlConfig`
- `@SqlGroup`
- `@Repeat`
- `@Timed`
- `@IfProfileValue`
- `@ProfileValueSourceConfiguration`

For example, if we discover that we are repeating the following configuration across our JUnit-based test suite…

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration({"/app-config.xml", "/test-data-access-config.xml"})
@ActiveProfiles("dev")
@Transactional
public class OrderRepositoryTests { }

@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration({"/app-config.xml", "/test-data-access-config.xml"})
@ActiveProfiles("dev")
@Transactional
public class UserRepositoryTests { }
```

We can reduce the above duplication by introducing a custom *composed annotation* that centralizes the common test configuration like this:

```
@Target(ElementType.TYPE)
@Retention(RetentionPolicy.RUNTIME)
@ContextConfiguration({"/app-config.xml", "/test-data-access-config.xml"})
@ActiveProfiles("dev")
@Transactional
public @interface TransactionalDevTest { }
```

Then we can use our custom `@TransactionalDevTest` annotation to simplify the configuration of individual test classes as follows:

```
@RunWith(SpringJUnit4ClassRunner.class)
@TransactionalDevTest
public class OrderRepositoryTests { }

@RunWith(SpringJUnit4ClassRunner.class)
@TransactionalDevTest
public class UserRepositoryTests { }
```

Spring TestContext Framework

The *Spring TestContext Framework* (located in the `org.springframework.test.context` package) provides generic, annotation-driven unit and integration testing support that is agnostic of the testing framework in use. The TestContext framework also places a great deal of importance on *convention over configuration* with reasonable defaults that can be overridden through annotation-based configuration.

In addition to generic testing infrastructure, the TestContext framework provides explicit support for JUnit and TestNG in the form of `abstract` support classes. For JUnit, Spring also provides a custom JUnit `Runner` that allows one to write so-called *POJO test classes*. POJO test classes are not required to extend a particular class hierarchy.

The following section provides an overview of the internals of the TestContext framework. If you are only interested in using the framework and not necessarily interested in extending it with your own custom listeners or custom loaders, feel free to go directly to the configuration (context management, dependency injection, transaction management), support classes, and annotation support sections.

Key abstractions

The core of the framework consists of the `TestContext` and `TestContextManager` classes and the `TestExecutionListener`, `ContextLoader`, and `SmartContextLoader` interfaces. A `TestContextManager` is created on a per-test basis (e.g., for the execution of a single test method in JUnit). The `TestContextManager` in turn manages a `TestContext` that holds the context of the current test. The `TestContextManager` also updates the state of the `TestContext` as the test progresses and delegates to `TestExecutionListeners`, which instrument the actual test execution by providing dependency injection, managing transactions, and so on. A `ContextLoader` (or `SmartContextLoader`) is responsible for loading an `ApplicationContext` for a given test class. Consult the javadocs and the Spring test suite for further information and examples of various implementations.

- `TestContext`: Encapsulates the context in which a test is executed, agnostic of the actual testing framework in use, and provides context management and caching support for the test instance for which it is responsible. The `TestContext` also delegates to a `ContextLoader` (or `SmartContextLoader`) to load an `ApplicationContext` if requested.
- `TestContextManager`: The main entry point into the *Spring TestContext Framework*, which manages a single `TestContext` and signals events to all registered `TestExecutionListeners` at well-defined test execution points:
  - prior to any *before class methods* of a particular testing framework
  - test instance preparation
  - prior to any *before methods* of a particular testing framework
  - after any *after methods* of a particular testing framework
  - after any *after class methods* of a particular testing framework
- `TestExecutionListener`: Defines a *listener* API for reacting to test execution events published by the `TestContextManager` with which the listener is registered. See the section called “TestExecutionListener configuration”.
- `ContextLoader`: Strategy interface introduced in Spring 2.5 for loading an `ApplicationContext` for an integration test managed by the Spring TestContext Framework.

  Implement `SmartContextLoader` instead of this interface in order to provide support for annotated classes, active bean definition profiles, test property sources, context hierarchies, and `WebApplicationContexts`.
- `SmartContextLoader`: Extension of the `ContextLoader` interface introduced in Spring 3.1.

  The `SmartContextLoader` SPI supersedes the `ContextLoader` SPI that was introduced in Spring 2.5. Specifically, a `SmartContextLoader` can choose to process resource `locations`, annotated `classes`, or context `initializers`. Furthermore, a `SmartContextLoader` can set active bean definition profiles and test property sources in the context that it loads.

Spring provides the following implementations:

- `DelegatingSmartContextLoader`: one of two default loaders which delegates internally to an `AnnotationConfigContextLoader`, a `GenericXmlContextLoader`, or a `GenericGroovyXmlContextLoader` depending either on the configuration declared for the test class or on the presence of default locations or default configuration classes. Groovy support is only enabled if Groovy is on the classpath.
- `WebDelegatingSmartContextLoader`: one of two default loaders which delegates internally to an `AnnotationConfigWebContextLoader`, a `GenericXmlWebContextLoader`, or a `GenericGroovyXmlWebContextLoader` depending either on the configuration declared for the test class or on the presence of default locations or default configuration classes. A web `ContextLoader` will only be used if `@WebAppConfiguration` is present on the test class. Groovy support is only enabled if Groovy is on the classpath.
- `AnnotationConfigContextLoader`: loads a standard `ApplicationContext` from *annotated classes*.
- `AnnotationConfigWebContextLoader`: loads a `WebApplicationContext` from *annotated classes*.
- `GenericGroovyXmlContextLoader`: loads a standard `ApplicationContext` from *resource locations* that are either Groovy scripts or XML configuration files.
- `GenericGroovyXmlWebContextLoader`: loads a `WebApplicationContext` from *resource locations* that are either Groovy scripts or XML configuration files.
- `GenericXmlContextLoader`: loads a standard `ApplicationContext` from XML *resource locations*.
- `GenericXmlWebContextLoader`: loads a `WebApplicationContext` from XML *resource locations*.
- `GenericPropertiesContextLoader`: loads a standard `ApplicationContext` from Java Properties files.

The following sections explain how to configure the TestContext framework through annotations and provide working examples of how to write unit and integration tests with the framework.

TestExecutionListener configuration

Spring provides the following `TestExecutionListener` implementations that are registered by default, exactly in this order.

- `ServletTestExecutionListener`: configures Servlet API mocks for a `WebApplicationContext`
- `DependencyInjectionTestExecutionListener`: provides dependency injection for the test instance
- `DirtiesContextTestExecutionListener`: handles the `@DirtiesContext` annotation
- `TransactionalTestExecutionListener`: provides transactional test execution with default rollback semantics

- `SqlScriptsTestExecutionListener`: executes SQL scripts configured via the `@Sql` annotation

Registering custom TestExecutionListeners

Custom `TestExecutionListeners` can be registered for a test class and its subclasses via the `@TestExecutionListeners` annotation. See annotation support and the javadocs for `@TestExecutionListeners` for details and examples.

Automatic discovery of default TestExecutionListeners

Registering custom `TestExecutionListeners` via `@TestExecutionListeners` is suitable for custom listeners that are used in limited testing scenarios; however, it can become cumbersome if a custom listener needs to be used across a test suite. To address this issue, Spring Framework 4.1 supports automatic discovery of *default* `TestExecutionListener` implementations via the `SpringFactoriesLoader` mechanism.

Specifically, the `spring-test` module declares all core default `TestExecutionListeners` under the `org.springframework.test.context.TestExecutionListener` key in its `META-INF/spring.factories` properties file. Third-party frameworks and developers can contribute their own `TestExecutionListeners` to the list of default listeners in the same manner via their own `META-INF/spring.factories` properties file.

Ordering TestExecutionListeners

When the TestContext framework discovers default `TestExecutionListeners` via the aforementioned `SpringFactoriesLoader` mechanism, the instantiated listeners are sorted using Spring's `AnnotationAwareOrderComparator` which honors Spring's `Ordered` interface and `@Order` annotation for ordering. `AbstractTestExecutionListener` and all default `TestExecutionListeners` provided by Spring implement `Ordered` with appropriate values. Third-party frameworks and developers should therefore make sure that their *default* `TestExecutionListeners` are registered in the proper order by implementing `Ordered` or declaring `@Order`. Consult the javadocs for the `getOrder()` methods of the core default `TestExecutionListeners` for details on what values are assigned to each core listener.

Merging TestExecutionListeners

If a custom `TestExecutionListener` is registered via `@TestExecutionListeners`, the *default* listeners will not be registered. In most common testing scenarios, this effectively forces the developer to manually declare all default listeners in addition to any custom listeners. The following listing demonstrates this style of configuration.

```
@ContextConfiguration
@TestExecutionListeners({
    MyCustomTestExecutionListener.class,
    ServletTestExecutionListener.class,
    DependencyInjectionTestExecutionListener.class,
    DirtiesContextTestExecutionListener.class,
    TransactionalTestExecutionListener.class,
    SqlScriptsTestExecutionListener.class
})
public class MyTest {
    // class body...
}
```

The challenge with this approach is that it requires that the developer know exactly which listeners are registered by default. Moreover, the set of default listeners can change from

release to release — for example, `SqlScriptsTestExecutionListener` was introduced in Spring Framework 4.1. Furthermore, third-party frameworks like Spring Security register their own default `TestExecutionListeners` via the aforementioned automatic discovery mechanism.

To avoid having to be aware of and re-declare **all** *default* listeners, the `mergeMode` attribute of `@TestExecutionListeners` can be set to `MergeMode.MERGE_WITH_DEFAULTS`. `MERGE_WITH_DEFAULTS` indicates that locally declared listeners should be merged with the default listeners. The merging algorithm ensures that duplicates are removed from the list and that the resulting set of merged listeners is sorted according to the semantics of `AnnotationAwareOrderComparator` as described in the section called “Ordering TestExecutionListeners”. If a listener implements `Ordered` or is annotated with `@Order` it can influence the position in which it is merged with the defaults; otherwise, locally declared listeners will simply be appended to the list of default listeners when merged.

For example, if the `MyCustomTestExecutionListener` class in the previous example configures its `order` value (for example, `500`) to be less than the order of the `ServletTestExecutionListener` (which happens to be `1000`), the `MyCustomTestExecutionListener` can then be automatically merged with the list of defaults *in front of* the `ServletTestExecutionListener`, and the previous example could be replaced with the following.

```
@ContextConfiguration
@TestExecutionListeners(
    listeners = MyCustomTestExecutionListener.class,
    mergeMode = MERGE_WITH_DEFAULTS,
)
public class MyTest {
    // class body...
}
```

Context management

Each `TestContext` provides context management and caching support for the test instance it is responsible for. Test instances do not automatically receive access to the configured `ApplicationContext`. However, if a test class implements the `ApplicationContextAware` interface, a reference to the `ApplicationContext` is supplied to the test instance. Note that `AbstractJUnit4SpringContextTests` and `AbstractTestNGSpringContextTests` implement `ApplicationContextAware` and therefore provide access to the `ApplicationContext` automatically.

@Autowired ApplicationContext

As an alternative to implementing the `ApplicationContextAware` interface, you can inject the application context for your test class through the `@Autowired` annotation on either a field or setter method. For example:

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
public class MyTest {

    @Autowired
    private ApplicationContext applicationContext;

    // class body...
}
```

Similarly, if your test is configured to load a `WebApplicationContext`, you can inject the web application context into your test as follows:

```
@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextConfiguration
public class MyWebAppTest {
    @Autowired
    private WebApplicationContext wac;

    // class body...
}
```

Dependency injection via `@Autowired` is provided by the `DependencyInjectionTestExecutionListener` which is configured by default (see the section called “Dependency injection of test fixtures”).

Test classes that use the TestContext framework do not need to extend any particular class or implement a specific interface to configure their application context. Instead, configuration is achieved simply by declaring the `@ContextConfiguration` annotation at the class level. If your test class does not explicitly declare application context resource `locations` or annotated `classes`, the configured `ContextLoader` determines how to load a context from a default location or default configuration classes. In addition to context resource `locations` and annotated `classes`, an application context can also be configured via application context `initializers`.

The following sections explain how to configure an `ApplicationContext` via XML configuration files, annotated classes (typically `@Configuration` classes), or context initializers using Spring’s `@ContextConfiguration` annotation. Alternatively, you can implement and configure your own custom `SmartContextLoader` for advanced use cases.

Context configuration with XML resources

To load an `ApplicationContext` for your tests using XML configuration files, annotate your test class with `@ContextConfiguration` and configure the `locations` attribute with an array that contains the resource locations of XML configuration metadata. A plain or relative path — for example `"context.xml"` — will be treated as a classpath resource that is relative to the package in which the test class is defined. A path starting with a slash is treated as an absolute classpath location, for example `"/org/example/config.xml"`. A path which represents a resource URL (i.e., a path prefixed with `classpath:`, `file:`, `http:`, etc.) will be used *as is*.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from "/app-config.xml" and
// "/test-config.xml" in the root of the classpath
@ContextConfiguration(locations={"/app-config.xml", "/test-config.xml"})
public class MyTest {
    // class body...
}
```

`@ContextConfiguration` supports an alias for the `locations` attribute through the standard Java `value` attribute. Thus, if you do not need to declare additional attributes in `@ContextConfiguration`, you can omit the declaration of the `locations` attribute name and declare the resource locations by using the shorthand format demonstrated in the following example.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration({"/app-config.xml", "/test-config.xml"})
public class MyTest {
    // class body...
}
```

If you omit both the `locations` and `value` attributes from the `@ContextConfiguration` annotation, the TestContext framework will attempt to detect a default XML resource location.

Specifically, `GenericXmlContextLoader` and `GenericXmlWebContextLoader` detect a default location based on the name of the test class. If your class is named `com.example.MyTest`, `GenericXmlContextLoader` loads your application context from `"classpath:com/example/MyTest-context.xml"`.

```
package com.example;

@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from
// "classpath:com/example/MyTest-context.xml"
@ContextConfiguration
public class MyTest {
    // class body...
}
```

Context configuration with Groovy scripts

To load an `ApplicationContext` for your tests using Groovy scripts that utilize the Groovy Bean Definition DSL, annotate your test class with `@ContextConfiguration` and configure the `locations` or `value` attribute with an array that contains the resource locations of Groovy scripts. Resource lookup semantics for Groovy scripts are the same as those described for XML configuration files.

> **Enabling Groovy script support**
>
> Support for using Groovy scripts to load an `ApplicationContext` in the Spring TestContext Framework is enabled automatically if Groovy is on the classpath.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from "/AppConfig.groovy" and
// "/TestConfig.groovy" in the root of the classpath
@ContextConfiguration({"/AppConfig.groovy", "/TestConfig.Groovy"})
public class MyTest {
    // class body...
}
```

If you omit both the `locations` and `value` attributes from the `@ContextConfiguration` annotation, the TestContext framework will attempt to detect a default Groovy script. Specifically, `GenericGroovyXmlContextLoader` and `GenericGroovyXmlWebContextLoader` detect a default location based on the name of the test class. If your class is named `com.example.MyTest`, the Groovy context loader will load your application context from `"classpath:com/example/MyTestContext.groovy"`.

```
package com.example;

@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from
// "classpath:com/example/MyTestContext.groovy"
@ContextConfiguration
public class MyTest {
    // class body...
}
```

> **Declaring XML config and Groovy scripts simultaneously**
>
> Both XML configuration files and Groovy scripts can be declared simultaneously via the `locations` or `value` attribute of `@ContextConfiguration`. If the path to a configured resource location ends with `.xml` it will be loaded using an `XmlBeanDefinitionReader`; otherwise it will be loaded using a `GroovyBeanDefinitionReader`.

The following listing demonstrates how to combine both in an integration test.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from
// "/app-config.xml" and "/TestConfig.groovy"
@ContextConfiguration({ "/app-config.xml", "/TestConfig.groovy" })
public class MyTest {
    // class body...
}
```

Context configuration with annotated classes

To load an `ApplicationContext` for your tests using *annotated classes* (see Section 5.12, “Java-based container configuration”), annotate your test class with `@ContextConfiguration` and configure the `classes` attribute with an array that contains references to annotated classes.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from AppConfig and TestConfig
@ContextConfiguration(classes = {AppConfig.class, TestConfig.class})
public class MyTest {
    // class body...
}
```

> **Annotated Classes**
>
> The term *annotated class* can refer to any of the following.
>
> - A class annotated with `@Configuration`
> - A component (i.e., a class annotated with `@Component`, `@Service`, `@Repository`, etc.)
> - A JSR-330 compliant class that is annotated with `javax.inject` annotations
> - Any other class that contains `@Bean`-methods
>
> Consult the javadocs of `@Configuration` and `@Bean` for further information regarding the configuration and semantics of *annotated classes*, paying special attention to the discussion of *`@Bean` Lite Mode*.

If you omit the `classes` attribute from the `@ContextConfiguration` annotation, the TestContext framework will attempt to detect the presence of default configuration classes. Specifically, `AnnotationConfigContextLoader` and `AnnotationConfigWebContextLoader` will detect all static inner classes of the test class that meet the requirements for configuration class implementations as specified in the `@Configuration` javadocs. In the following example, the `OrderServiceTest` class declares a static inner configuration class named `Config` that will be automatically used to load the `ApplicationContext` for the test class. Note that the name of the configuration class is arbitrary. In addition, a test class can contain more than one static inner configuration class if desired.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from the
// static inner Config class
@ContextConfiguration
public class OrderServiceTest {

    @Configuration
    static class Config {

        // this bean will be injected into the OrderServiceTest class
        @Bean
        public OrderService orderService() {
            OrderService orderService = new OrderServiceImpl();
            // set properties, etc.
            return orderService;
        }
    }

    @Autowired
    private OrderService orderService;

    @Test
    public void testOrderService() {
        // test the orderService
    }

}
```

Mixing XML, Groovy scripts, and annotated classes

It may sometimes be desirable to mix XML configuration files, Groovy scripts, and annotated classes (i.e., typically `@Configuration` classes) to configure an `ApplicationContext` for your tests. For example, if you use XML configuration in production, you may decide that you want to use `@Configuration` classes to configure specific Spring-managed components for your tests, or vice versa.

Furthermore, some third-party frameworks (like Spring Boot) provide first-class support for loading an `ApplicationContext` from different types of resources simultaneously (e.g., XML configuration files, Groovy scripts, and `@Configuration` classes). The Spring Framework historically has not supported this for standard deployments. Consequently, most of the `SmartContextLoader` implementations that the Spring Framework delivers in the `spring-test` module support only one resource type per test context; however, this does not mean that you cannot use both. One exception to the general rule is that the `GenericGroovyXmlContextLoader` and `GenericGroovyXmlWebContextLoader` support both XML configuration files and Groovy scripts simultaneously. Furthermore, third-party frameworks may choose to support the declaration of both `locations` and `classes` via `@ContextConfiguration`, and with the standard testing support in the TestContext framework, you have the following options.

If you want to use resource locations (e.g., XML or Groovy) *and* `@Configuration` classes to configure your tests, you will have to pick one as the *entry point*, and that one will have to include or import the other. For example, in XML or Groovy scripts you can include `@Configuration` classes via component scanning or define them as normal Spring beans; whereas, in a `@Configuration` class you can use `@ImportResource` to import XML configuration files. Note that this behavior is semantically equivalent to how you configure your application in production: in production configuration you will define either a set of XML or Groovy resource locations or a set of `@Configuration` classes that your production `ApplicationContext` will be loaded from, but you still have the freedom to include or import the other type of configuration.

Context configuration with context initializers

To configure an `ApplicationContext` for your tests using context initializers, annotate your test class with `@ContextConfiguration` and configure the `initializers` attribute with an array that contains references to classes that implement `ApplicationContextInitializer`. The declared context initializers will then be used to initialize the `ConfigurableApplicationContext` that is loaded for your tests. Note that the concrete `ConfigurableApplicationContext` type supported by each declared initializer must be compatible with the type of `ApplicationContext` created by the `SmartContextLoader` in use (i.e., typically a `GenericApplicationContext`). Furthermore, the order in which the initializers are invoked depends on whether they implement Spring's `Ordered` interface, are annotated with Spring's `@Order` or the standard `@Priority` annotation.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from TestConfig
// and initialized by TestAppCtxInitializer
@ContextConfiguration(
    classes = TestConfig.class,
    initializers = TestAppCtxInitializer.class)
public class MyTest {
    // class body...
}
```

It is also possible to omit the declaration of XML configuration files or annotated classes in `@ContextConfiguration` entirely and instead declare only `ApplicationContextInitializer` classes which are then responsible for registering beans in the context — for example, by programmatically loading bean definitions from XML files or configuration classes.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be initialized by EntireAppInitializer
// which presumably registers beans in the context
@ContextConfiguration(initializers = EntireAppInitializer.class)
public class MyTest {
    // class body...
}
```

Context configuration inheritance

`@ContextConfiguration` supports boolean `inheritLocations` and `inheritInitializers` attributes that denote whether resource locations or annotated classes and context initializers declared by superclasses should be *inherited*. The default value for both flags is `true`. This means that a test class inherits the resource locations or annotated classes as well as the context initializers declared by any superclasses. Specifically, the resource locations or annotated classes for a test class are appended to the list of resource locations or annotated classes declared by superclasses. Similarly, the initializers for a given test class will be added to the set of initializers defined by test superclasses. Thus, subclasses have the option of *extending* the resource locations, annotated classes, or context initializers.

If `@ContextConfiguration`'s `inheritLocations` or `inheritInitializers` attribute is set to `false`, the resource locations or annotated classes and the context initializers, respectively, for the test class *shadow* and effectively replace the configuration defined by superclasses.

In the following example that uses XML resource locations, the `ApplicationContext` for `ExtendedTest` will be loaded from *"base-config.xml" and "extended-config.xml"*, in that order. Beans defined in *"extended-config.xml"* may therefore *override* (i.e., replace) those defined in *"base-config.xml"*.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from "/base-config.xml"
// in the root of the classpath
@ContextConfiguration("/base-config.xml")
public class BaseTest {
    // class body...
}

// ApplicationContext will be loaded from "/base-config.xml" and
// "/extended-config.xml" in the root of the classpath
@ContextConfiguration("/extended-config.xml")
public class ExtendedTest extends BaseTest {
    // class body...
}
```

Similarly, in the following example that uses annotated classes, the `ApplicationContext` for `ExtendedTest` will be loaded from the `BaseConfig` *and* `ExtendedConfig` classes, in that order. Beans defined in `ExtendedConfig` may therefore override (i.e., replace) those defined in `BaseConfig`.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from BaseConfig
@ContextConfiguration(classes = BaseConfig.class)
public class BaseTest {
    // class body...
}

// ApplicationContext will be loaded from BaseConfig and ExtendedConfig
@ContextConfiguration(classes = ExtendedConfig.class)
public class ExtendedTest extends BaseTest {
    // class body...
}
```

In the following example that uses context initializers, the `ApplicationContext` for `ExtendedTest` will be initialized using `BaseInitializer` *and* `ExtendedInitializer`. Note, however, that the order in which the initializers are invoked depends on whether they implement Spring's `Ordered` interface, are annotated with Spring's `@Order` or the standard `@Priority` annotation.

```
@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be initialized by BaseInitializer
@ContextConfiguration(initializers = BaseInitializer.class)
public class BaseTest {
    // class body...
}

// ApplicationContext will be initialized by BaseInitializer
// and ExtendedInitializer
@ContextConfiguration(initializers = ExtendedInitializer.class)
public class ExtendedTest extends BaseTest {
    // class body...
}
```

Context configuration with environment profiles

Spring 3.1 introduced first-class support in the framework for the notion of environments and profiles (a.k.a., *bean definition profiles*), and integration tests can be configured to activate particular bean definition profiles for various testing scenarios. This is achieved by annotating a test class with the `@ActiveProfiles` annotation and supplying a list of profiles that should be activated when loading the `ApplicationContext` for the test.

> **Note**
>
> `@ActiveProfiles` may be used with any implementation of the new `SmartContextLoader` SPI, but `@ActiveProfiles` is not supported with implementations of the older `ContextLoader` SPI.

Let's take a look at some examples with XML configuration and `@Configuration` classes.

```
<!-- app-config.xml -->
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/jdbc"
    xmlns:jee="http://www.springframework.org/schema/jee"
    xsi:schemaLocation="...">

    <bean id="transferService"
            class="com.bank.service.internal.DefaultTransferService">
        <constructor-arg ref="accountRepository"/>
        <constructor-arg ref="feePolicy"/>
    </bean>

    <bean id="accountRepository"
            class="com.bank.repository.internal.JdbcAccountRepository">
        <constructor-arg ref="dataSource"/>
    </bean>

    <bean id="feePolicy"
        class="com.bank.service.internal.ZeroFeePolicy"/>

    <beans profile="dev">
        <jdbc:embedded-database id="dataSource">
            <jdbc:script
                location="classpath:com/bank/config/sql/schema.sql"/>
            <jdbc:script
                location="classpath:com/bank/config/sql/test-data.sql"/>
        </jdbc:embedded-database>
    </beans>

    <beans profile="production">
        <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource"/>
    </beans>

    <beans profile="default">
        <jdbc:embedded-database id="dataSource">
            <jdbc:script
                location="classpath:com/bank/config/sql/schema.sql"/>
        </jdbc:embedded-database>
    </beans>

</beans>
```

```
package com.bank.service;

@RunWith(SpringJUnit4ClassRunner.class)
// ApplicationContext will be loaded from "classpath:/app-config.xml"
@ContextConfiguration("/app-config.xml")
@ActiveProfiles("dev")
public class TransferServiceTest {

    @Autowired
    private TransferService transferService;

    @Test
    public void testTransferService() {
        // test the transferService
    }
}
```

When `TransferServiceTest` is run, its `ApplicationContext` will be loaded from the `app-config.xml` configuration file in the root of the classpath. If you inspect `app-config.xml` you'll notice that the `accountRepository` bean has a dependency on a `dataSource` bean; however, `dataSource` is not defined as a top-level bean. Instead, `dataSource` is defined three times: in the *production* profile, the *dev* profile, and the *default* profile.

By annotating `TransferServiceTest` with `@ActiveProfiles("dev")` we instruct the Spring TestContext Framework to load the `ApplicationContext` with the active profiles set to `{"dev"}`. As a result, an embedded database will be created and populated with test data, and the `accountRepository` bean will be wired with a reference to the development `DataSource`. And that's likely what we want in an integration test.

It is sometimes useful to assign beans to a `default` profile. Beans within the default profile are only included when no other profile is specifically activated. This can be used to define *fallback* beans to be used in the application's default state. For example, you may explicitly provide a data source for `dev` and `production` profiles, but define an in-memory data source as a default when neither of these is active.

The following code listings demonstrate how to implement the same configuration and integration test but using `@Configuration` classes instead of XML.

```
@Configuration
@Profile("dev")
public class StandaloneDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .addScript("classpath:com/bank/config/sql/test-data.sql")
            .build();
    }
}
```

```
@Configuration
@Profile("production")
public class JndiDataConfig {

    @Bean
    public DataSource dataSource() throws Exception {
        Context ctx = new InitialContext();
        return (DataSource) ctx.lookup("java:comp/env/jdbc/datasource");
    }
}
```

```
@Configuration
@Profile("default")
public class DefaultDataConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
            .setType(EmbeddedDatabaseType.HSQL)
            .addScript("classpath:com/bank/config/sql/schema.sql")
            .build();
    }
}
```

```
@Configuration
public class TransferServiceConfig {

    @Autowired DataSource dataSource;

    @Bean
    public TransferService transferService() {
        return new DefaultTransferService(accountRepository(), feePolicy());
    }

    @Bean
    public AccountRepository accountRepository() {
        return new JdbcAccountRepository(dataSource);
    }

    @Bean
    public FeePolicy feePolicy() {
        return new ZeroFeePolicy();
    }

}
```

```
package com.bank.service;

@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes = {
        TransferServiceConfig.class,
        StandaloneDataConfig.class,
        JndiDataConfig.class,
        DefaultDataConfig.class})
@ActiveProfiles("dev")
public class TransferServiceTest {

    @Autowired
    private TransferService transferService;

    @Test
    public void testTransferService() {
        // test the transferService
    }
}
```

In this variation, we have split the XML configuration into four independent `@Configuration` classes:

- `TransferServiceConfig`: acquires a `dataSource` via dependency injection using `@Autowired`
- `StandaloneDataConfig`: defines a `dataSource` for an embedded database suitable for developer tests
- `JndiDataConfig`: defines a `dataSource` that is retrieved from JNDI in a production environment
- `DefaultDataConfig`: defines a `dataSource` for a default embedded database in case no profile is active

As with the XML-based configuration example, we still annotate `TransferServiceTest` with `@ActiveProfiles("dev")`, but this time we specify all four configuration classes via the `@ContextConfiguration` annotation. The body of the test class itself remains completely unchanged.

It is often the case that a single set of profiles is used across multiple test classes within a given project. Thus, to avoid duplicate declarations of the `@ActiveProfiles` annotation it is possible to declare `@ActiveProfiles` once on a base class, and subclasses will automatically inherit the `@ActiveProfiles` configuration from the base class. In the following example, the declaration

of `@ActiveProfiles` (as well as other annotations) has been moved to an abstract superclass, `AbstractIntegrationTest`.

```
package com.bank.service;

@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes = {
        TransferServiceConfig.class,
        StandaloneDataConfig.class,
        JndiDataConfig.class,
        DefaultDataConfig.class})
@ActiveProfiles("dev")
public abstract class AbstractIntegrationTest {
}
```

```
package com.bank.service;

// "dev" profile inherited from superclass
public class TransferServiceTest extends AbstractIntegrationTest {

    @Autowired
    private TransferService transferService;

    @Test
    public void testTransferService() {
        // test the transferService
    }
}
```

`@ActiveProfiles` also supports an `inheritProfiles` attribute that can be used to disable the inheritance of active profiles.

```
package com.bank.service;

// "dev" profile overridden with "production"
@ActiveProfiles(profiles = "production", inheritProfiles = false)
public class ProductionTransferServiceTest extends AbstractIntegrationTest {
    // test body
}
```

Furthermore, it is sometimes necessary to resolve active profiles for tests *programmatically* instead of declaratively — for example, based on:

- the current operating system
- whether tests are being executed on a continuous integration build server
- the presence of certain environment variables
- the presence of custom class-level annotations
- etc.

To resolve active bean definition profiles programmatically, simply implement a custom `ActiveProfilesResolver` and register it via the `resolver` attribute of `@ActiveProfiles`. The following example demonstrates how to implement and register a custom `OperatingSystemActiveProfilesResolver`. For further information, refer to the corresponding javadocs.

```
package com.bank.service;

// "dev" profile overridden programmatically via a custom resolver
@ActiveProfiles(
    resolver = OperatingSystemActiveProfilesResolver.class,
    inheritProfiles = false)
public class TransferServiceTest extends AbstractIntegrationTest {
    // test body
}
```

```
package com.bank.service.test;

public class OperatingSystemActiveProfilesResolver implements ActiveProfilesResolver {

    @Override
    String[] resolve(Class<?> testClass) {
        String profile = ...;
        // determine the value of profile based on the operating system
        return new String[] {profile};
    }
}
```

Context configuration with test property sources

Spring 3.1 introduced first-class support in the framework for the notion of an environment with a hierarchy of *property sources*, and since Spring 4.1 integration tests can be configured with test-specific property sources. In contrast to the `@PropertySource` annotation used on `@Configuration` classes, the `@TestPropertySource` annotation can be declared on a test class to declare resource locations for test properties files or *inlined* properties. These test property sources will be added to the `Environment`'s set of `PropertySources` for the `ApplicationContext` loaded for the annotated integration test.

> **Note**
>
> `@TestPropertySource` may be used with any implementation of the `SmartContextLoader` SPI, but `@TestPropertySource` is not supported with implementations of the older `ContextLoader` SPI.
>
> Implementations of `SmartContextLoader` gain access to merged test property source values via the `getPropertySourceLocations()` and `getPropertySourceProperties()` methods in `MergedContextConfiguration`.

Declaring test property sources

Test properties files can be configured via the `locations` or `value` attribute of `@TestPropertySource` as shown in the following example.

Both traditional and XML-based properties file formats are supported — for example, `"classpath:/com/example/test.properties"` or `"file:///path/to/file.xml"`.

Each path will be interpreted as a Spring `Resource`. A plain path — for example, `"test.properties"` — will be treated as a classpath resource that is *relative* to the package in which the test class is defined. A path starting with a slash will be treated as an *absolute* classpath resource, for example: `"/org/example/test.xml"`. A path which references a URL (e.g., a path prefixed with `classpath:`, `file:`, `http:`, etc.) will be loaded using the specified resource protocol. Resource location wildcards (e.g. `**/*.properties`) are not permitted: each location must evaluate to exactly one `.properties` or `.xml` resource.

```
@ContextConfiguration
@TestPropertySource("/test.properties")
public class MyIntegrationTests {
    // class body...
}
```

Inlined properties in the form of key-value pairs can be configured via the `properties` attribute of `@TestPropertySource` as shown in the following example. All key-value pairs will be added to the enclosing `Environment` as a single test `PropertySource` with the highest precedence.

The supported syntax for key-value pairs is the same as the syntax defined for entries in a Java properties file:

- `"key=value"`
- `"key:value"`
- `"key value"`

```
@ContextConfiguration
@TestPropertySource(properties = {"timezone = GMT", "port: 4242"})
public class MyIntegrationTests {
    // class body...
}
```

Default properties file detection

If `@TestPropertySource` is declared as an empty annotation (i.e., without explicit values for the `locations` or `properties` attributes), an attempt will be made to detect a *default* properties file relative to the class that declared the annotation. For example, if the annotated test class is `com.example.MyTest`, the corresponding default properties file is `"classpath:com/example/MyTest.properties"`. If the default cannot be detected, an `IllegalStateException` will be thrown.

Precedence

Test property sources have higher precedence than those loaded from the operating system's environment or Java system properties as well as property sources added by the application declaratively via `@PropertySource` or programmatically. Thus, test property sources can be used to selectively override properties defined in system and application property sources. Furthermore, inlined properties have higher precedence than properties loaded from resource locations.

In the following example, the `timezone` and `port` properties as well as any properties defined in `"/test.properties"` will override any properties of the same name that are defined in system and application property sources. Furthermore, if the `"/test.properties"` file defines entries for the `timezone` and `port` properties those will be overridden by the *inlined* properties declared via the `properties` attribute.

```
@ContextConfiguration
@TestPropertySource(
    locations = "/test.properties",
    properties = {"timezone = GMT", "port: 4242"}
)
public class MyIntegrationTests {
    // class body...
}
```

Inheriting and overriding test property sources

`@TestPropertySource` supports boolean `inheritLocations` and `inheritProperties` attributes that denote whether resource locations for properties files and inlined properties declared by superclasses should be *inherited*. The default value for both flags is `true`. This means that a test class inherits the locations and inlined properties declared by any superclasses. Specifically, the locations and inlined properties for a test class are appended to the locations and inlined properties declared by superclasses. Thus, subclasses have the option of *extending* the locations and inlined properties. Note that properties that appear later will *shadow* (i.e.., override) properties of the same name that appear earlier. In addition, the aforementioned precedence rules apply for inherited test property sources as well.

If `@TestPropertySource`'s `inheritLocations` or `inheritProperties` attribute is set to `false`, the locations or inlined properties, respectively, for the test class *shadow* and effectively replace the configuration defined by superclasses.

In the following example, the `ApplicationContext` for `BaseTest` will be loaded using only the `"base.properties"` file as a test property source. In contrast, the `ApplicationContext` for `ExtendedTest` will be loaded using the `"base.properties"` **and** `"extended.properties"` files as test property source locations.

```
@TestPropertySource("base.properties")
@ContextConfiguration
public class BaseTest {
    // ...
}

@TestPropertySource("extended.properties")
@ContextConfiguration
public class ExtendedTest extends BaseTest {
    // ...
}
```

In the following example, the `ApplicationContext` for `BaseTest` will be loaded using only the *inlined* `key1` property. In contrast, the `ApplicationContext` for `ExtendedTest` will be loaded using the *inlined* `key1` and `key2` properties.

```
@TestPropertySource(properties = "key1 = value1")
@ContextConfiguration
public class BaseTest {
    // ...
}

@TestPropertySource(properties = "key2 = value2")
@ContextConfiguration
public class ExtendedTest extends BaseTest {
    // ...
}
```

Loading a WebApplicationContext

Spring 3.2 introduced support for loading a `WebApplicationContext` in integration tests. To instruct the TestContext framework to load a `WebApplicationContext` instead of a standard `ApplicationContext`, simply annotate the respective test class with `@WebAppConfiguration`.

The presence of `@WebAppConfiguration` on your test class instructs the TestContext framework (TCF) that a `WebApplicationContext` (WAC) should be loaded for your integration tests. In the background the TCF makes sure that a `MockServletContext` is created and supplied to your test's WAC. By default the base resource path for your `MockServletContext` will be set to *"src/main/webapp"*. This is interpreted as a path relative to the root of your JVM (i.e., normally the path to

your project). If you're familiar with the directory structure of a web application in a Maven project, you'll know that *"src/main/webapp"* is the default location for the root of your WAR. If you need to override this default, simply provide an alternate path to the `@WebAppConfiguration` annotation (e.g., `@WebAppConfiguration("src/test/webapp")`). If you wish to reference a base resource path from the classpath instead of the file system, just use Spring's *classpath:* prefix.

Please note that Spring's testing support for `WebApplicationContexts` is on par with its support for standard `ApplicationContexts`. When testing with a `WebApplicationContext` you are free to declare either XML configuration files or `@Configuration` classes via `@ContextConfiguration`. You are of course also free to use any other test annotations such as `@TestExecutionListeners`, `@TransactionConfiguration`, `@ActiveProfiles`, etc.

The following examples demonstrate some of the various configuration options for loading a `WebApplicationContext`.

Conventions.

```
@RunWith(SpringJUnit4ClassRunner.class)

// defaults to "file:src/main/webapp"
@WebAppConfiguration

// detects "WacTests-context.xml" in same package
// or static nested @Configuration class
@ContextConfiguration

public class WacTests {
    //...
}
```

The above example demonstrates the TestContext framework's support for *convention over configuration*. If you annotate a test class with `@WebAppConfiguration` without specifying a resource base path, the resource path will effectively default to *"file:src/main/webapp"*. Similarly, if you declare `@ContextConfiguration` without specifying resource `locations`, annotated `classes`, or context `initializers`, Spring will attempt to detect the presence of your configuration using conventions (i.e., *"WacTests-context.xml"* in the same package as the `WacTests` class or static nested `@Configuration` classes).

Default resource semantics.

```
@RunWith(SpringJUnit4ClassRunner.class)

// file system resource
@WebAppConfiguration("webapp")

// classpath resource
@ContextConfiguration("/spring/test-servlet-config.xml")

public class WacTests {
    //...
}
```

This example demonstrates how to explicitly declare a resource base path with `@WebAppConfiguration` and an XML resource location with `@ContextConfiguration`. The important thing to note here is the different semantics for paths with these two annotations. By default, `@WebAppConfiguration` resource paths are file system based; whereas, `@ContextConfiguration` resource locations are classpath based.

Explicit resource semantics.

```
@RunWith(SpringJUnit4ClassRunner.class)

// classpath resource
@WebAppConfiguration("classpath:test-web-resources")

// file system resource
@ContextConfiguration("file:src/main/webapp/WEB-INF/servlet-config.xml")

public class WacTests {
    //...
}
```

In this third example, we see that we can override the default resource semantics for both annotations by specifying a Spring resource prefix. Contrast the comments in this example with the previous example.

To provide comprehensive web testing support, Spring 3.2 introduced a `ServletTestExecutionListener` that is enabled by default. When testing against a `WebApplicationContext` this TestExecutionListener sets up default thread-local state via Spring Web's `RequestContextHolder` before each test method and creates a `MockHttpServletRequest`, `MockHttpServletResponse`, and `ServletWebRequest` based on the base resource path configured via `@WebAppConfiguration`. `ServletTestExecutionListener` also ensures that the `MockHttpServletResponse` and `ServletWebRequest` can be injected into the test instance, and once the test is complete it cleans up thread-local state.

Once you have a `WebApplicationContext` loaded for your test you might find that you need to interact with the web mocks — for example, to set up your test fixture or to perform assertions after invoking your web component. The following example demonstrates which mocks can be autowired into your test instance. Note that the `WebApplicationContext` and `MockServletContext` are both cached across the test suite; whereas, the other mocks are managed per test method by the `ServletTestExecutionListener`.

Injecting mocks.

```
@WebAppConfiguration
@ContextConfiguration
public class WacTests {

    @Autowired
    WebApplicationContext wac; // cached

    @Autowired
    MockServletContext servletContext; // cached

    @Autowired
    MockHttpSession session;

    @Autowired
    MockHttpServletRequest request;

    @Autowired
    MockHttpServletResponse response;

    @Autowired
    ServletWebRequest webRequest;

    //...
}
```

Context caching

Once the TestContext framework loads an `ApplicationContext` (or `WebApplicationContext`) for a test, that context will be cached and reused for *all* subsequent tests that declare the same unique context configuration within the same test suite. To understand how caching works, it is important to understand what is meant by *unique* and *test suite*.

An `ApplicationContext` can be *uniquely* identified by the combination of configuration parameters that are used to load it. Consequently, the unique combination of configuration parameters are used to generate a *key* under which the context is cached. The TestContext framework uses the following configuration parameters to build the context cache key:

- `locations` *(from @ContextConfiguration)*
- `classes` *(from @ContextConfiguration)*
- `contextInitializerClasses` *(from @ContextConfiguration)*
- `contextLoader` *(from @ContextConfiguration)*
- `parent` *(from @ContextHierarchy)*
- `activeProfiles` *(from @ActiveProfiles)*
- `propertySourceLocations` *(from @TestPropertySource)*
- `propertySourceProperties` *(from @TestPropertySource)*
- `resourceBasePath` *(from @WebAppConfiguration)*

For example, if `TestClassA` specifies `{"app-config.xml", "test-config.xml"}` for the `locations` (or `value`) attribute of `@ContextConfiguration`, the TestContext framework will load the corresponding `ApplicationContext` and store it in a `static` context cache under a key that is based solely on those locations. So if `TestClassB` also defines `{"app-config.xml", "test-config.xml"}` for its locations (either explicitly or implicitly through inheritance) but does not define `@WebAppConfiguration`, a different `ContextLoader`, different active profiles, different context initializers, different test property sources, or a different parent context, then the same `ApplicationContext` will be shared by both test classes. This means that the setup cost for loading an application context is incurred only once (per test suite), and subsequent test execution is much faster.

> **Test suites and forked processes**
>
> The Spring TestContext framework stores application contexts in a *static* cache. This means that the context is literally stored in a `static` variable. In other words, if tests execute in separate processes the static cache will be cleared between each test execution, and this will effectively disable the caching mechanism.
>
> To benefit from the caching mechanism, all tests must run within the same process or test suite. This can be achieved by executing all tests as a group within an IDE. Similarly, when executing tests with a build framework such as Ant, Maven, or Gradle it is important to make sure that the build framework does not *fork* between tests. For example, if the forkMode for the Maven Surefire plug-in is set to `always` or `pertest`, the TestContext framework will not be able to cache

> application contexts between test classes and the build process will run significantly slower as a result.

Since having a large number of application contexts loaded within a given test suite can cause the suite to take an unnecessarily long time to execute, it is often beneficial to know exactly how many contexts have been loaded and cached. To view the statistics for the underlying context cache, simply set the log level for the `org.springframework.test.context.cache` logging category to `DEBUG`.

In the unlikely case that a test corrupts the application context and requires reloading — for example, by modifying a bean definition or the state of an application object — you can annotate your test class or test method with `@DirtiesContext` (see the discussion of `@DirtiesContext` in the section called "Spring Testing Annotations"). This instructs Spring to remove the context from the cache and rebuild the application context before executing the next test. Note that support for the `@DirtiesContext` annotation is provided by the `DirtiesContextTestExecutionListener` which is enabled by default.

Context hierarchies

When writing integration tests that rely on a loaded Spring `ApplicationContext`, it is often sufficient to test against a single context; however, there are times when it is beneficial or even necessary to test against a hierarchy of `ApplicationContexts`. For example, if you are developing a Spring MVC web application you will typically have a root `WebApplicationContext` loaded via Spring's `ContextLoaderListener` and a child `WebApplicationContext` loaded via Spring's `DispatcherServlet`. This results in a parent-child context hierarchy where shared components and infrastructure configuration are declared in the root context and consumed in the child context by web-specific components. Another use case can be found in Spring Batch applications where you often have a parent context that provides configuration for shared batch infrastructure and a child context for the configuration of a specific batch job.

As of Spring Framework 3.2.2, it is possible to write integration tests that use context hierarchies by declaring context configuration via the `@ContextHierarchy` annotation, either on an individual test class or within a test class hierarchy. If a context hierarchy is declared on multiple classes within a test class hierarchy it is also possible to merge or override the context configuration for a specific, named level in the context hierarchy. When merging configuration for a given level in the hierarchy the configuration resource type (i.e., XML configuration files or annotated classes) must be consistent; otherwise, it is perfectly acceptable to have different levels in a context hierarchy configured using different resource types.

The following JUnit-based examples demonstrate common configuration scenarios for integration tests that require the use of context hierarchies.

`ControllerIntegrationTests` represents a typical integration testing scenario for a Spring MVC web application by declaring a context hierarchy consisting of two levels, one for the *root* WebApplicationContext (loaded using the `TestAppConfig` `@Configuration` class) and one for the *dispatcher servlet* `WebApplicationContext` (loaded using the `WebConfig` `@Configuration` class). The `WebApplicationContext` that is *autowired* into the test instance is the one for the child context (i.e., the lowest context in the hierarchy).

```
@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextHierarchy({
    @ContextConfiguration(classes = TestAppConfig.class),
    @ContextConfiguration(classes = WebConfig.class)
})
public class ControllerIntegrationTests {

    @Autowired
    private WebApplicationContext wac;

    // ...
}
```

The following test classes define a context hierarchy within a test class hierarchy. `AbstractWebTests` declares the configuration for a root `WebApplicationContext` in a Spring-powered web application. Note, however, that `AbstractWebTests` does not declare `@ContextHierarchy`; consequently, subclasses of `AbstractWebTests` can optionally participate in a context hierarchy or simply follow the standard semantics for `@ContextConfiguration`. `SoapWebServiceTests` and `RestWebServiceTests` both extend `AbstractWebTests` and define a context hierarchy via `@ContextHierarchy`. The result is that three application contexts will be loaded (one for each declaration of `@ContextConfiguration`), and the application context loaded based on the configuration in `AbstractWebTests` will be set as the parent context for each of the contexts loaded for the concrete subclasses.

```
@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextConfiguration("file:src/main/webapp/WEB-INF/applicationContext.xml")
public abstract class AbstractWebTests {}

@ContextHierarchy(@ContextConfiguration("/spring/soap-ws-config.xml")
public class SoapWebServiceTests extends AbstractWebTests {}

@ContextHierarchy(@ContextConfiguration("/spring/rest-ws-config.xml")
public class RestWebServiceTests extends AbstractWebTests {}
```

The following classes demonstrate the use of *named* hierarchy levels in order to *merge* the configuration for specific levels in a context hierarchy. `BaseTests` defines two levels in the hierarchy, `parent` and `child`. `ExtendedTests` extends `BaseTests` and instructs the Spring TestContext Framework to merge the context configuration for the `child` hierarchy level, simply by ensuring that the names declared via `ContextConfiguration`'s `name` attribute are both `"child"`. The result is that three application contexts will be loaded: one for `"/app-config.xml"`, one for `"/user-config.xml"`, and one for `{"/user-config.xml", "/order-config.xml"}`. As with the previous example, the application context loaded from `"/app-config.xml"` will be set as the parent context for the contexts loaded from `"/user-config.xml"` and `{"/user-config.xml", "/order-config.xml"}`.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextHierarchy({
    @ContextConfiguration(name = "parent", locations = "/app-config.xml"),
    @ContextConfiguration(name = "child", locations = "/user-config.xml")
})
public class BaseTests {}

@ContextHierarchy(
    @ContextConfiguration(name = "child", locations = "/order-config.xml")
)
public class ExtendedTests extends BaseTests {}
```

In contrast to the previous example, this example demonstrates how to *override* the configuration for a given named level in a context hierarchy by setting `ContextConfiguration`'s `inheritLocations`

flag to `false`. Consequently, the application context for `ExtendedTests` will be loaded only from `"/test-user-config.xml"` and will have its parent set to the context loaded from `"/app-config.xml"`.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextHierarchy({
    @ContextConfiguration(name = "parent", locations = "/app-config.xml"),
    @ContextConfiguration(name = "child", locations = "/user-config.xml")
})
public class BaseTests {}

@ContextHierarchy(
    @ContextConfiguration(
        name = "child",
        locations = "/test-user-config.xml",
        inheritLocations = false
))
public class ExtendedTests extends BaseTests {}
```

> **Dirtying a context within a context hierarchy**
>
> If `@DirtiesContext` is used in a test whose context is configured as part of a context hierarchy, the `hierarchyMode` flag can be used to control how the context cache is cleared. For further details consult the discussion of `@DirtiesContext` in Spring Testing Annotations and the `@DirtiesContext` javadocs.

Dependency injection of test fixtures

When you use the `DependencyInjectionTestExecutionListener` — which is configured by default — the dependencies of your test instances are *injected* from beans in the application context that you configured with `@ContextConfiguration`. You may use setter injection, field injection, or both, depending on which annotations you choose and whether you place them on setter methods or fields. For consistency with the annotation support introduced in Spring 2.5 and 3.0, you can use Spring's `@Autowired` annotation or the `@Inject` annotation from JSR 300.

> **Tip**
>
> The TestContext framework does not instrument the manner in which a test instance is instantiated. Thus the use of `@Autowired` or `@Inject` for constructors has no effect for test classes.

Because `@Autowired` is used to perform *autowiring by type*, if you have multiple bean definitions of the same type, you cannot rely on this approach for those particular beans. In that case, you can use `@Autowired` in conjunction with `@Qualifier`. As of Spring 3.0 you may also choose to use `@Inject` in conjunction with `@Named`. Alternatively, if your test class has access to its `ApplicationContext`, you can perform an explicit lookup by using (for example) a call to `applicationContext.getBean("titleRepository")`.

If you do not want dependency injection applied to your test instances, simply do not annotate fields or setter methods with `@Autowired` or `@Inject`. Alternatively, you can disable dependency injection altogether by explicitly configuring your class with `@TestExecutionListeners` and omitting `DependencyInjectionTestExecutionListener.class` from the list of listeners.

Consider the scenario of testing a `HibernateTitleRepository` class, as outlined in the Goals section. The next two code listings demonstrate the use of `@Autowired` on fields and setter methods. The application context configuration is presented after all sample code listings.

> **Note**
>
> The dependency injection behavior in the following code listings is not specific to JUnit. The same DI techniques can be used in conjunction with any testing framework.
>
> The following examples make calls to static assertion methods such as `assertNotNull()` but without prepending the call with `Assert`. In such cases, assume that the method was properly imported through an `import static` declaration that is not shown in the example.

The first code listing shows a JUnit-based implementation of the test class that uses `@Autowired` for field injection.

```
@RunWith(SpringJUnit4ClassRunner.class)
// specifies the Spring configuration to load for this test fixture
@ContextConfiguration("repository-config.xml")
public class HibernateTitleRepositoryTests {

    // this instance will be dependency injected by type
    @Autowired
    private HibernateTitleRepository titleRepository;

    @Test
    public void findById() {
        Title title = titleRepository.findById(new Long(10));
        assertNotNull(title);
    }
}
```

Alternatively, you can configure the class to use `@Autowired` for setter injection as seen below.

```
@RunWith(SpringJUnit4ClassRunner.class)
// specifies the Spring configuration to load for this test fixture
@ContextConfiguration("repository-config.xml")
public class HibernateTitleRepositoryTests {

    // this instance will be dependency injected by type
    private HibernateTitleRepository titleRepository;

    @Autowired
    public void setTitleRepository(HibernateTitleRepository titleRepository) {
        this.titleRepository = titleRepository;
    }

    @Test
    public void findById() {
        Title title = titleRepository.findById(new Long(10));
        assertNotNull(title);
    }
}
```

The preceding code listings use the same XML context file referenced by the `@ContextConfiguration` annotation (that is, `repository-config.xml`), which looks like this:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <!-- this bean will be injected into the HibernateTitleRepositoryTests class -->
    <bean id="titleRepository" class="com.foo.repository.hibernate.HibernateTitleRepository">
        <property name="sessionFactory" ref="sessionFactory"/>
    </bean>

    <bean id="sessionFactory" class="org.springframework.orm.hibernate3.LocalSessionFactoryBean">
        <!-- configuration elided for brevity -->
    </bean>

</beans>
```

Note

If you are extending from a Spring-provided test base class that happens to use `@Autowired` on one of its setter methods, you might have multiple beans of the affected type defined in your application context: for example, multiple `DataSource` beans. In such a case, you can override the setter method and use the `@Qualifier` annotation to indicate a specific target bean as follows, but make sure to delegate to the overridden method in the superclass as well.

```
// ...

    @Autowired
    @Override
    public void setDataSource(@Qualifier("myDataSource") DataSource dataSource) {
        super.setDataSource(dataSource);
    }

// ...
```

The specified qualifier value indicates the specific `DataSource` bean to inject, narrowing the set of type matches to a specific bean. Its value is matched against `<qualifier>` declarations within the corresponding `<bean>` definitions. The bean name is used as a fallback qualifier value, so you may effectively also point to a specific bean by name there (as shown above, assuming that "myDataSource" is the bean id).

Testing request and session scoped beans

Request and session scoped beans have been supported by Spring for several years now, but it's always been a bit non-trivial to test them. As of Spring 3.2 it's a breeze to test your request-scoped and session-scoped beans by following these steps.

- Ensure that a `WebApplicationContext` is loaded for your test by annotating your test class with `@WebAppConfiguration`.
- Inject the mock request or session into your test instance and prepare your test fixture as appropriate.
- Invoke your web component that you retrieved from the configured `WebApplicationContext` (i.e., via dependency injection).
- Perform assertions against the mocks.

The following code snippet displays the XML configuration for a login use case. Note that the `userService` bean has a dependency on a request-scoped `loginAction` bean. Also, the

`LoginAction` is instantiated using SpEL expressions that retrieve the username and password from the current HTTP request. In our test, we will want to configure these request parameters via the mock managed by the TestContext framework.

Request-scoped bean configuration.

```
<beans>

    <bean id="userService"
            class="com.example.SimpleUserService"
            c:loginAction-ref="loginAction" />

    <bean id="loginAction" class="com.example.LoginAction"
            c:username="{request.getParameter('user')}"
            c:password="{request.getParameter('pswd')}"
            scope="request">
        <aop:scoped-proxy />
    </bean>

</beans>
```

In `RequestScopedBeanTests` we inject both the `UserService` (i.e., the subject under test) and the `MockHttpServletRequest` into our test instance. Within our `requestScope()` test method we set up our test fixture by setting request parameters in the provided `MockHttpServletRequest`. When the `loginUser()` method is invoked on our `userService` we are assured that the user service has access to the request-scoped `loginAction` for the current `MockHttpServletRequest` (i.e., the one we just set parameters in). We can then perform assertions against the results based on the known inputs for the username and password.

Request-scoped bean test.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
@WebAppConfiguration
public class RequestScopedBeanTests {

    @Autowired UserService userService;
    @Autowired MockHttpServletRequest request;

    @Test
    public void requestScope() {

        request.setParameter("user", "enigma");
        request.setParameter("pswd", "$pr!ng");

        LoginResults results = userService.loginUser();

        // assert results
    }
}
```

The following code snippet is similar to the one we saw above for a request-scoped bean; however, this time the `userService` bean has a dependency on a session-scoped `userPreferences` bean. Note that the `UserPreferences` bean is instantiated using a SpEL expression that retrieves the *theme* from the current HTTP session. In our test, we will need to configure a theme in the mock session managed by the TestContext framework.

Session-scoped bean configuration.

```
<beans>

    <bean id="userService"
            class="com.example.SimpleUserService"
            c:userPreferences-ref="userPreferences" />

    <bean id="userPreferences"
            class="com.example.UserPreferences"
            c:theme="#{session.getAttribute('theme')}"
            scope="session">
        <aop:scoped-proxy />
    </bean>

</beans>
```

In `SessionScopedBeanTests` we inject the `UserService` and the `MockHttpSession` into our test instance. Within our `sessionScope()` test method we set up our test fixture by setting the expected "theme" attribute in the provided `MockHttpSession`. When the `processUserPreferences()` method is invoked on our `userService` we are assured that the user service has access to the session-scoped `userPreferences` for the current `MockHttpSession`, and we can perform assertions against the results based on the configured theme.

Session-scoped bean test.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
@WebAppConfiguration
public class SessionScopedBeanTests {

    @Autowired UserService userService;
    @Autowired MockHttpSession session;

    @Test
    public void sessionScope() throws Exception {

        session.setAttribute("theme", "blue");

        Results results = userService.processUserPreferences();

        // assert results
    }
}
```

Transaction management

In the TestContext framework, transactions are managed by the `TransactionalTestExecutionListener` which is configured by default, even if you do not explicitly declare `@TestExecutionListeners` on your test class. To enable support for transactions, however, you must configure a `PlatformTransactionManager` bean in the `ApplicationContext` that is loaded via `@ContextConfiguration` semantics (further details are provided below). In addition, you must declare Spring's `@Transactional` annotation either at the class or method level for your tests.

Test-managed transactions

Test-managed transactions are transactions that are managed *declaratively* via the `TransactionalTestExecutionListener` or *programmatically* via `TestTransaction` (see below). Such transactions should not be confused with *Spring-managed transactions* (i.e., those managed directly by Spring within the `ApplicationContext` loaded for tests) or *application-managed transactions* (i.e., those managed programmatically within application code that is invoked via tests). Spring-managed and application-managed transactions will typically participate in test-managed

transactions; however, caution should be taken if Spring-managed or application-managed transactions are configured with any *propagation* type other than `REQUIRED` or `SUPPORTS` (see the discussion on transaction propagation for details).

Enabling and disabling transactions

Annotating a test method with `@Transactional` causes the test to be run within a transaction that will, by default, be automatically rolled back after completion of the test. If a test class is annotated with `@Transactional`, each test method within that class hierarchy will be run within a transaction. Test methods that are not annotated with `@Transactional` (at the class or method level) will not be run within a transaction. Furthermore, tests that are annotated with `@Transactional` but have the `propagation` type set to `NOT_SUPPORTED` will not be run within a transaction.

Note that `AbstractTransactionalJUnit4SpringContextTests` and `AbstractTransactionalTestNGSpringContextTests` are preconfigured for transactional support at the class level.

The following example demonstrates a common scenario for writing an integration test for a Hibernate-based `UserRepository`. As explained in the section called “Transaction rollback and commit behavior”, there is no need to clean up the database after the `createUser()` method is executed since any changes made to the database will be automatically rolled back by the `TransactionalTestExecutionListener`. See the section called “PetClinic Example” for an additional example.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes = TestConfig.class)
@Transactional
public class HibernateUserRepositoryTests {

    @Autowired
    HibernateUserRepository repository;

    @Autowired
    SessionFactory sessionFactory;

    JdbcTemplate jdbcTemplate;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    @Test
    public void createUser() {
        // track initial state in test database:
        final int count = countRowsInTable("user");

        User user = new User(...);
        repository.save(user);

        // Manual flush is required to avoid false positive in test
        sessionFactory.getCurrentSession().flush();
        assertNumUsers(count + 1);
    }

    protected int countRowsInTable(String tableName) {
        return JdbcTestUtils.countRowsInTable(this.jdbcTemplate, tableName);
    }

    protected void assertNumUsers(int expected) {
        assertEquals("Number of rows in the 'user' table.", expected, countRowsInTable("user"));
    }
}
```

Transaction rollback and commit behavior

By default, test transactions will be automatically rolled back after completion of the test; however, transactional commit and rollback behavior can be configured declaratively via the class-level `@TransactionConfiguration` and method-level `@Rollback` annotations. See the corresponding entries in the annotation support section for further details.

Programmatic transaction management

As of Spring Framework 4.1, it is possible to interact with test-managed transactions *programmatically* via the static methods in `TestTransaction`. For example, `TestTransaction` may be used within *test* methods, *before* methods, and *after* methods to start or end the current test-managed transaction or to configure the current test-managed transaction for rollback or commit. Support for `TestTransaction` is automatically available whenever the `TransactionalTestExecutionListener` is enabled.

The following example demonstrates some of the features of `TestTransaction`. Consult the javadocs for `TestTransaction` for further details.

```
@ContextConfiguration(classes = TestConfig.class)
public class ProgrammaticTransactionManagementTests extends
        AbstractTransactionalJUnit4SpringContextTests {

    @Test
    public void transactionalTest() {
        // assert initial state in test database:
        assertNumUsers(2);

        deleteFromTables("user");

        // changes to the database will be committed!
        TestTransaction.flagForCommit();
        TestTransaction.end();
        assertFalse(TestTransaction.isActive());
        assertNumUsers(0);

        TestTransaction.start();
        // perform other actions against the database that will
        // be automatically rolled back after the test completes...
    }

    protected void assertNumUsers(int expected) {
        assertEquals("Number of rows in the 'user' table.", expected, countRowsInTable("user"));
    }
}
```

Executing code outside of a transaction

Occasionally you need to execute certain code before or after a transactional test method but outside the transactional context — for example, to verify the initial database state prior to execution of your test or to verify expected transactional commit behavior after test execution (if the test was configured not to roll back the transaction). `TransactionalTestExecutionListener` supports the `@BeforeTransaction` and `@AfterTransaction` annotations exactly for such scenarios. Simply annotate any `public void` method in your test class with one of these annotations, and the `TransactionalTestExecutionListener` ensures that your *before transaction method* or *after transaction method* is executed at the appropriate time.

> **Tip**
>
> Any *before methods* (such as methods annotated with JUnit's `@Before`) and any *after methods* (such as methods annotated with JUnit's `@After`) are executed *within* a transaction. In addition,

> methods annotated with `@BeforeTransaction` or `@AfterTransaction` are naturally not executed for test methods that are not configured to run within a transaction.

Configuring a transaction manager

`TransactionalTestExecutionListener` expects a `PlatformTransactionManager` bean to be defined in the Spring `ApplicationContext` for the test. In case there are multiple instances of `PlatformTransactionManager` within the test's `ApplicationContext`, `@TransactionConfiguration` supports configuring the bean name of the `PlatformTransactionManager` that should be used to drive transactions. Alternatively, a *qualifier* may be declared via `@Transactional("myQualifier")`, or `TransactionManagementConfigurer` can be implemented by an `@Configuration` class. Consult the javadocs for `TestContextTransactionUtils.retrieveTransactionManager()` for details on the algorithm used to look up a transaction manager in the test's `ApplicationContext`.

Demonstration of all transaction-related annotations

The following JUnit-based example displays a fictitious integration testing scenario highlighting all transaction-related annotations. The example is **not** intended to demonstrate best practices but rather to demonstrate how these annotations can be used. Consult the annotation support section for further information and configuration examples. Transaction management for `@Sql` contains an additional example using `@Sql` for declarative SQL script execution with default transaction rollback semantics.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
@TransactionConfiguration(transactionManager="txMgr", defaultRollback=false)
@Transactional
public class FictitiousTransactionalTest {

    @BeforeTransaction
    public void verifyInitialDatabaseState() {
        // logic to verify the initial state before a transaction is started
    }

    @Before
    public void setUpTestDataWithinTransaction() {
        // set up test data within the transaction
    }

    @Test
    // overrides the class-level defaultRollback setting
    @Rollback(true)
    public void modifyDatabaseWithinTransaction() {
        // logic which uses the test data and modifies database state
    }

    @After
    public void tearDownWithinTransaction() {
        // execute "tear down" logic within the transaction
    }

    @AfterTransaction
    public void verifyFinalDatabaseState() {
        // logic to verify the final state after transaction has rolled back
    }

}
```

Avoid false positives when testing ORM code

When you test application code that manipulates the state of the Hibernate session, make sure to *flush* the underlying session within test methods that execute that code. Failing to flush the underlying session can produce *false positives*: your test may pass, but the same code throws an exception in a live, production environment. In the following Hibernate-based example test case, one method demonstrates a false positive, and the other method correctly exposes the results of flushing the session. Note that this applies to JPA and any other ORM frameworks that maintain an in-memory *unit of work*.

```
// ...

@Autowired
private SessionFactory sessionFactory;

@Test // no expected exception!
public void falsePositive() {
    updateEntityInHibernateSession();
    // False positive: an exception will be thrown once the session is
    // finally flushed (i.e., in production code)
}

@Test(expected = GenericJDBCException.class)
public void updateWithSessionFlush() {
    updateEntityInHibernateSession();
    // Manual flush is required to avoid false positive in test
    sessionFactory.getCurrentSession().flush();
}

// ...
```

Executing SQL scripts

When writing integration tests against a relational database, it is often beneficial to execute SQL scripts to modify the database schema or insert test data into tables. The `spring-jdbc` module provides support for *initializing* an embedded or existing database by executing SQL scripts when the Spring `ApplicationContext` is loaded. See Section 14.8, “Embedded database support” and the section called “Testing data access logic with an embedded database” for details.

Although it is very useful to initialize a database for testing *once* when the `ApplicationContext` is loaded, sometimes it is essential to be able to modify the database *during* integration tests. The following sections explain how to execute SQL scripts programmatically and declaratively during integration tests.

Executing SQL scripts programmatically

Spring provides the following options for executing SQL scripts programmatically within integration test methods.

- `org.springframework.jdbc.datasource.init.ScriptUtils`
- `org.springframework.jdbc.datasource.init.ResourceDatabasePopulator`
- `org.springframework.test.context.junit4.AbstractTransactionalJUnit4SpringContextTests`
- `org.springframework.test.context.testng.AbstractTransactionalTestNGSpringContextTests`

`ScriptUtils` provides a collection of static utility methods for working with SQL scripts and is mainly intended for internal use within the framework. However, if you require full control over how SQL scripts

are parsed and executed, `ScriptUtils` may suit your needs better than some of the other alternatives described below. Consult the javadocs for individual methods in `ScriptUtils` for further details.

`ResourceDatabasePopulator` provides a simple object-based API for programmatically populating, initializing, or cleaning up a database using SQL scripts defined in external resources. `ResourceDatabasePopulator` provides options for configuring the character encoding, statement separator, comment delimiters, and error handling flags used when parsing and executing the scripts, and each of the configuration options has a reasonable default value. Consult the javadocs for details on default values. To execute the scripts configured in a `ResourceDatabasePopulator`, you can invoke either the `populate(Connection)` method to execute the populator against a `java.sql.Connection` or the `execute(DataSource)` method to execute the populator against a `javax.sql.DataSource`. The following example specifies SQL scripts for a test schema and test data, sets the statement separator to `"@@"`, and then executes the scripts against a `DataSource`.

```
@Test
public void databaseTest {
    ResourceDatabasePopulator populator = new ResourceDatabasePopulator();
    populator.addScripts(
        new ClassPathResource("test-schema.sql"),
        new ClassPathResource("test-data.sql"));
    populator.setSeparator("@@");
    populator.execute(this.dataSource);
    // execute code that uses the test schema and data
}
```

Note that `ResourceDatabasePopulator` internally delegates to `ScriptUtils` for parsing and executing SQL scripts. Similarly, the `executeSqlScript(..)` methods in `AbstractTransactionalJUnit4SpringContextTests` and `AbstractTransactionalTestNGSpringContextTests` internally use a `ResourceDatabasePopulator` for executing SQL scripts. Consult the javadocs for the various `executeSqlScript(..)` methods for further details.

Executing SQL scripts declaratively with `@Sql`

In addition to the aforementioned mechanisms for executing SQL scripts *programmatically*, SQL scripts can also be configured *declaratively* in the Spring TestContext Framework. Specifically, the `@Sql` annotation can be declared on a test class or test method to configure the resource paths to SQL scripts that should be executed against a given database either before or after an integration test method. Note that method-level declarations override class-level declarations and that support for `@Sql` is provided by the `SqlScriptsTestExecutionListener` which is enabled by default.

Path resource semantics

Each path will be interpreted as a Spring `Resource`. A plain path — for example, `"schema.sql"` — will be treated as a classpath resource that is *relative* to the package in which the test class is defined. A path starting with a slash will be treated as an *absolute* classpath resource, for example: `"/org/example/schema.sql"`. A path which references a URL (e.g., a path prefixed with `classpath:`, `file:`, `http:`, etc.) will be loaded using the specified resource protocol.

The following example demonstrates how to use `@Sql` at the class level and at the method level within a JUnit-based integration test class.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
@Sql("/test-schema.sql")
public class DatabaseTests {

    @Test
    public void emptySchemaTest {
        // execute code that uses the test schema without any test data
    }

    @Test
    @Sql({"/test-schema.sql", "/test-user-data.sql"})
    public void userTest {
        // execute code that uses the test schema and test data
    }
}
```

Default script detection

If no SQL scripts are specified, an attempt will be made to detect a `default` script depending on where `@Sql` is declared. If a default cannot be detected, an `IllegalStateException` will be thrown.

- *class-level declaration*: if the annotated test class is `com.example.MyTest`, the corresponding default script is `"classpath:com/example/MyTest.sql"`.
- *method-level declaration*: if the annotated test method is named `testMethod()` and is defined in the class `com.example.MyTest`, the corresponding default script is `"classpath:com/example/MyTest.testMethod.sql"`.

Declaring multiple `@Sql` sets

If multiple sets of SQL scripts need to be configured for a given test class or test method but with different syntax configuration, different error handling rules, or different execution phases per set, it is possible to declare multiple instances of `@Sql`. With Java 8, `@Sql` can be used as a *repeatable* annotation. Otherwise, the `@SqlGroup` annotation can be used as an explicit container for declaring multiple instances of `@Sql`.

The following example demonstrates the use of `@Sql` as a repeatable annotation using Java 8. In this scenario the `test-schema.sql` script uses a different syntax for single-line comments.

```
@Test
@Sql(scripts = "/test-schema.sql", config = @SqlConfig(commentPrefix = "`"))
@Sql("/test-user-data.sql")
public void userTest {
    // execute code that uses the test schema and test data
}
```

The following example is identical to the above except that the `@Sql` declarations are grouped together within `@SqlGroup` for compatibility with Java 6 and Java 7.

```
@Test
@SqlGroup({
    @Sql(scripts = "/test-schema.sql", config = @SqlConfig(commentPrefix = "`")),
    @Sql("/test-user-data.sql")
)}
public void userTest {
    // execute code that uses the test schema and test data
}
```

Script execution phases

By default, SQL scripts will be executed *before* the corresponding test method. However, if a particular set of scripts needs to be executed *after* the test method — for example, to clean up database state — the `executionPhase` attribute in `@Sql` can be used as seen in the following example. Note that `ISOLATED` and `AFTER_TEST_METHOD` are statically imported from `Sql.TransactionMode` and `Sql.ExecutionPhase` respectively.

```
@Test
@Sql(
    scripts = "create-test-data.sql",
    config = @SqlConfig(transactionMode = ISOLATED)
)
@Sql(
    scripts = "delete-test-data.sql",
    config = @SqlConfig(transactionMode = ISOLATED),
    executionPhase = AFTER_TEST_METHOD
)
public void userTest {
    // execute code that needs the test data to be committed
    // to the database outside of the test's transaction
}
```

Script configuration with `@SqlConfig`

Configuration for script parsing and error handling can be configured via the `@SqlConfig` annotation. When declared as a class-level annotation on an integration test class, `@SqlConfig` serves as *global* configuration for all SQL scripts within the test class hierarchy. When declared directly via the `config` attribute of the `@Sql` annotation, `@SqlConfig` serves as *local* configuration for the SQL scripts declared within the enclosing `@Sql` annotation. Every attribute in `@SqlConfig` has an implicit default value which is documented in the javadocs of the corresponding attribute. Due to the rules defined for annotation attributes in the Java Language Specification, it is unfortunately not possible to assign a value of `null` to an annotation attribute. Thus, in order to support overrides of inherited global configuration, `@SqlConfig` attributes have an explicit default value of either `""` for Strings or `DEFAULT` for Enums. This approach allows local declarations of `@SqlConfig` to selectively override individual attributes from global declarations of `@SqlConfig` by providing a value other than `""` or `DEFAULT`. Global `@SqlConfig` attributes are inherited whenever local `@SqlConfig` attributes do not supply an explicit value other than `""` or `DEFAULT`. Explicit *local* configuration therefore overrides *global* configuration.

The configuration options provided by `@Sql` and `@SqlConfig` are equivalent to those supported by `ScriptUtils` and `ResourceDatabasePopulator` but are a superset of those provided by the `<jdbc:initialize-database/>` XML namespace element. Consult the javadocs of individual attributes in `@Sql` and `@SqlConfig` for details.

Transaction management for `@Sql`

By default, the `SqlScriptsTestExecutionListener` will infer the desired transaction semantics for scripts configured via `@Sql`. Specifically, SQL scripts will be executed without a transaction, within an existing Spring-managed transaction — for example, a transaction managed by the `TransactionalTestExecutionListener` for a test annotated with `@Transactional` — or within an isolated transaction, depending on the configured value of the `transactionMode` attribute in `@SqlConfig` and the presence of a `PlatformTransactionManager` in the test's `ApplicationContext`. As a bare minimum however, a `javax.sql.DataSource` must be present in the test's `ApplicationContext`.

If the algorithms used by `SqlScriptsTestExecutionListener` to detect a `DataSource` and `PlatformTransactionManager` and infer the transaction semantics do not suit your needs, you may specify explicit names via the `dataSource` and `transactionManager` attributes

of `@SqlConfig`. Furthermore, the transaction propagation behavior can be controlled via the `transactionMode` attribute of `@SqlConfig` — for example, if scripts should be executed in an isolated transaction. Although a thorough discussion of all supported options for transaction management with `@Sql` is beyond the scope of this reference manual, the javadocs for `@SqlConfig` and `SqlScriptsTestExecutionListener` provide detailed information, and the following example demonstrates a typical testing scenario using JUnit and transactional tests with `@Sql`. Note that there is no need to clean up the database after the `usersTest()` method is executed since any changes made to the database (either within the the test method or within the `/test-data.sql` script) will be automatically rolled back by the `TransactionalTestExecutionListener` (see transaction management for details).

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes = TestDatabaseConfig.class)
@Transactional
public class TransactionalSqlScriptsTests {

    protected JdbcTemplate jdbcTemplate;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    @Test
    @Sql("/test-data.sql")
    public void usersTest() {
        // verify state in test database:
        assertNumUsers(2);
        // execute code that uses the test data...
    }

    protected int countRowsInTable(String tableName) {
        return JdbcTestUtils.countRowsInTable(this.jdbcTemplate, tableName);
    }

    protected void assertNumUsers(int expected) {
        assertEquals("Number of rows in the 'user' table.", expected, countRowsInTable("user"));
    }
}
```

TestContext Framework support classes

JUnit support classes

The `org.springframework.test.context.junit4` package provides the following support classes for JUnit-based test cases.

- `AbstractJUnit4SpringContextTests`
- `AbstractTransactionalJUnit4SpringContextTests`

`AbstractJUnit4SpringContextTests` is an abstract base test class that integrates the *Spring TestContext Framework* with explicit `ApplicationContext` testing support in a JUnit 4.9+ environment. When you extend `AbstractJUnit4SpringContextTests`, you can access a `protected applicationContext` instance variable that can be used to perform explicit bean lookups or to test the state of the context as a whole.

`AbstractTransactionalJUnit4SpringContextTests` is an abstract *transactional* extension of `AbstractJUnit4SpringContextTests` that adds some convenience functionality for JDBC access. This class expects a `javax.sql.DataSource` bean and a

`PlatformTransactionManager` bean to be defined in the `ApplicationContext`. When you extend `AbstractTransactionalJUnit4SpringContextTests` you can access a `protected` `jdbcTemplate` instance variable that can be used to execute SQL statements to query the database. Such queries can be used to confirm database state both *prior to* and *after* execution of database-related application code, and Spring ensures that such queries run in the scope of the same transaction as the application code. When used in conjunction with an ORM tool, be sure to avoid false positives. As mentioned in the section called "JDBC Testing Support", `AbstractTransactionalJUnit4SpringContextTests` also provides convenience methods which delegate to methods in `JdbcTestUtils` using the aforementioned `jdbcTemplate`. Furthermore, `AbstractTransactionalJUnit4SpringContextTests` provides an `executeSqlScript(..)` method for executing SQL scripts against the configured `DataSource`.

> **Tip**
>
> These classes are a convenience for extension. If you do not want your test classes to be tied to a Spring-specific class hierarchy, you can configure your own custom test classes by using `@RunWith(SpringJUnit4ClassRunner.class)`, `@ContextConfiguration`, `@TestExecutionListeners`, and so on.

Spring JUnit Runner

The *Spring TestContext Framework* offers full integration with JUnit 4.9+ through a custom runner (tested on JUnit 4.9 — 4.11). By annotating test classes with `@RunWith(SpringJUnit4ClassRunner.class)`, developers can implement standard JUnit-based unit and integration tests and simultaneously reap the benefits of the TestContext framework such as support for loading application contexts, dependency injection of test instances, transactional test method execution, and so on. The following code listing displays the minimal requirements for configuring a test class to run with the custom Spring Runner. `@TestExecutionListeners` is configured with an empty list in order to disable the default listeners, which otherwise would require an ApplicationContext to be configured through `@ContextConfiguration`.

```
@RunWith(SpringJUnit4ClassRunner.class)
@TestExecutionListeners({})
public class SimpleTest {

    @Test
    public void testMethod() {
        // execute test logic...
    }
}
```

TestNG support classes

The `org.springframework.test.context.testng` package provides the following support classes for TestNG based test cases.

- `AbstractTestNGSpringContextTests`
- `AbstractTransactionalTestNGSpringContextTests`

`AbstractTestNGSpringContextTests` is an abstract base test class that integrates the *Spring TestContext Framework* with explicit `ApplicationContext` testing support in a TestNG environment. When you extend `AbstractTestNGSpringContextTests`, you can access a `protected` `applicationContext` instance variable that can be used to perform explicit bean lookups or to test the state of the context as a whole.

`AbstractTransactionalTestNGSpringContextTests` is an abstract *transactional* extension of `AbstractTestNGSpringContextTests` that adds some convenience functionality for JDBC access. This class expects a `javax.sql.DataSource` bean and a `PlatformTransactionManager` bean to be defined in the `ApplicationContext`. When you extend `AbstractTransactionalTestNGSpringContextTests` you can access a `protected` `jdbcTemplate` instance variable that can be used to execute SQL statements to query the database. Such queries can be used to confirm database state both *prior to* and *after* execution of database-related application code, and Spring ensures that such queries run in the scope of the same transaction as the application code. When used in conjunction with an ORM tool, be sure to avoid false positives. As mentioned in the section called "JDBC Testing Support", `AbstractTransactionalTestNGSpringContextTests` also provides convenience methods which delegate to methods in `JdbcTestUtils` using the aforementioned `jdbcTemplate`. Furthermore, `AbstractTransactionalTestNGSpringContextTests` provides an `executeSqlScript(..)` method for executing SQL scripts against the configured `DataSource`.

> **Tip**
>
> These classes are a convenience for extension. If you do not want your test classes to be tied to a Spring-specific class hierarchy, you can configure your own custom test classes by using `@ContextConfiguration`, `@TestExecutionListeners`, and so on, and by manually instrumenting your test class with a `TestContextManager`. See the source code of `AbstractTestNGSpringContextTests` for an example of how to instrument your test class.

Spring MVC Test Framework

> **Standalone project**
>
> Before inclusion in Spring Framework 3.2, the Spring MVC Test framework had already existed as a separate project on GitHub where it grew and evolved through actual use, feedback, and the contribution of many.
>
> The standalone spring-test-mvc project is still available on GitHub and can be used in conjunction with Spring Framework 3.1.x. Applications upgrading to 3.2 or later should replace the `spring-test-mvc` dependency with a dependency on `spring-test`.
>
> The `spring-test` module uses a different package `org.springframework.test.web` but otherwise is nearly identical with two exceptions. One is support for features new in 3.2 (e.g. asynchronous web requests). The other relates to the options for creating a `MockMvc` instance. In Spring Framework 3.2 and later, this can only be done through the TestContext framework, which provides caching benefits for the loaded configuration.

The *Spring MVC Test framework* provides first class JUnit support for testing client and server-side Spring MVC code through a fluent API. Typically it loads the actual Spring configuration through the *TestContext framework* and always uses the `DispatcherServlet` to process requests thus approximating full integration tests without requiring a running Servlet container.

Client-side tests are `RestTemplate`-based and allow tests for code that relies on the `RestTemplate` without requiring a running server to respond to the requests.

Server-Side Tests

Before Spring Framework 3.2, the most likely way to test a Spring MVC controller was to write a unit test that instantiates the controller, injects it with mock or stub dependencies, and then calls its methods directly, using a `MockHttpServletRequest` and `MockHttpServletResponse` where necessary.

Although this is pretty easy to do, controllers have many annotations, and much remains untested. Request mappings, data binding, type conversion, and validation are just a few examples of what isn't tested. Furthermore, there are other types of annotated methods such as `@InitBinder`, `@ModelAttribute`, and `@ExceptionHandler` that get invoked as part of request processing.

The idea behind Spring MVC Test is to be able to re-write those controller tests by performing actual requests and generating responses, as they would be at runtime, along the way invoking controllers through the Spring MVC `DispatcherServlet`. Controllers can still be injected with mock dependencies, so tests can remain focused on the web layer.

Spring MVC Test builds on the familiar "mock" implementations of the Servlet API available in the `spring-test` module. This allows performing requests and generating responses without the need for running in a Servlet container. For the most part everything should work as it does at runtime with the exception of JSP rendering, which is not available outside a Servlet container. Furthermore, if you are familiar with how the `MockHttpServletResponse` works, you'll know that forwards and redirects are not actually executed. Instead "forwarded" and "redirected" URLs are saved and can be asserted in tests. This means if you are using JSPs, you can verify the JSP page to which the request was forwarded.

All other means of rendering including `@ResponseBody` methods and `View` types (besides JSPs) such as Freemarker, Velocity, Thymeleaf, and others for rendering HTML, JSON, XML, and so on should work as expected, and the response will contain the generated content.

Below is an example of a test requesting account information in JSON format:

```
import static org.springframework.test.web.servlet.request.MockMvcRequestBuilders.*;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.*;

@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextConfiguration("test-servlet-context.xml")
public class ExampleTests {

    @Autowired
    private WebApplicationContext wac;

    private MockMvc mockMvc;

    @Before
    public void setup() {
        this.mockMvc = MockMvcBuilders.webAppContextSetup(this.wac).build();
    }

    @Test
    public void getAccount() throws Exception {
        this.mockMvc.perform(get("/accounts/1").accept(MediaType.parseMediaType("application/
json;charset=UTF-8")))
            .andExpect(status().isOk())
            .andExpect(content().contentType("application/json"))
            .andExpect(jsonPath("$.name").value("Lee"));
    }

}
```

The test relies on the `WebApplicationContext` support of the *TestContext framework*. It loads Spring configuration from an XML configuration file located in the same package as the test class (also supports

JavaConfig) and injects the created `WebApplicationContext` into the test so a `MockMvc` instance can be created with it.

The `MockMvc` is then used to perform a request to `"/accounts/1"` and verify the resulting response status is 200, the response content type is `"application/json"`, and response content has a JSON property called "name" with the value "Lee". JSON content is inspected with the help of Jayway's JsonPath project. There are lots of other options for verifying the result of the performed request and those will be discussed later.

Static Imports

The fluent API in the example above requires a few static imports such as `MockMvcRequestBuilders.*`, `MockMvcResultMatchers.*`, and `MockMvcBuilders.*`. An easy way to find these classes is to search for types matching *"MockMvc*"*. If using Eclipse, be sure to add them as "favorite static members" in the Eclipse preferences under*Java # Editor # Content Assist # Favorites*. That will allow use of content assist after typing the first character of the static method name. Other IDEs (e.g. IntelliJ) may not require any additional configuration. Just check the support for code completion on static members.

Setup Options

The goal of server-side test setup is to create an instance of `MockMvc` that can be used to perform requests. There are two main options.

The first option is to point to Spring MVC configuration through the *TestContext framework*, which loads the Spring configuration and injects a `WebApplicationContext` into the test to use to create a `MockMvc`:

```
@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextConfiguration("my-servlet-context.xml")
public class MyWebTests {

    @Autowired
    private WebApplicationContext wac;

    private MockMvc mockMvc;

    @Before
    public void setup() {
        this.mockMvc = MockMvcBuilders.webAppContextSetup(this.wac).build();
    }

    // ...

}
```

The second option is to simply register a controller instance without loading any Spring configuration. Instead basic Spring MVC configuration suitable for testing annotated controllers is automatically created. The created configuration is comparable to that of the MVC JavaConfig (and the MVC namespace) and can be customized to a degree through builder-style methods:

```
public class MyWebTests {

    private MockMvc mockMvc;

    @Before
    public void setup() {
        this.mockMvc = MockMvcBuilders.standaloneSetup(new AccountController()).build();
    }

    // ...

}
```

Which option should you use?

The *"webAppContextSetup"* loads the actual Spring MVC configuration resulting in a more complete integration test. Since the *TestContext framework* caches the loaded Spring configuration, it helps to keep tests running fast even as more tests get added. Furthermore, you can inject mock services into controllers through Spring configuration, in order to remain focused on testing the web layer. Here is an example of declaring a mock service with Mockito:

```
<bean id="accountService" class="org.mockito.Mockito" factory-method="mock">
    <constructor-arg value="org.example.AccountService"/>
</bean>
```

Then you can inject the mock service into the test in order set up and verify expectations:

```
@RunWith(SpringJUnit4ClassRunner.class)
@WebAppConfiguration
@ContextConfiguration("test-servlet-context.xml")
public class AccountTests {

    @Autowired
    private WebApplicationContext wac;

    private MockMvc mockMvc;

    @Autowired
    private AccountService accountService;

    // ...

}
```

The *"standaloneSetup"* on the other hand is a little closer to a unit test. It tests one controller at a time, the controller can be injected with mock dependencies manually, and it doesn't involve loading Spring configuration. Such tests are more focused in style and make it easier to see which controller is being tested, whether any specific Spring MVC configuration is required to work, and so on. The "standaloneSetup" is also a very convenient way to write ad-hoc tests to verify some behavior or to debug an issue.

Just like with integration vs unit testing, there is no right or wrong answer. Using the "standaloneSetup" does imply the need for some additional "webAppContextSetup" tests to verify the Spring MVC configuration. Alternatively, you can decide write all tests with "webAppContextSetup" and always test against actual Spring MVC configuration.

Performing Requests

To perform requests, use the appropriate HTTP method and additional builder-style methods corresponding to properties of `MockHttpServletRequest`. For example:

```
mockMvc.perform(post("/hotels/{id}", 42).accept(MediaType.APPLICATION_JSON));
```

In addition to all the HTTP methods, you can also perform file upload requests, which internally creates an instance of `MockMultipartHttpServletRequest`:

```
mockMvc.perform(fileUpload("/doc").file("a1", "ABC".getBytes("UTF-8")));
```

Query string parameters can be specified in the URI template:

```
mockMvc.perform(get("/hotels?foo={foo}", "bar"));
```

Or by adding Servlet request parameters:

```
mockMvc.perform(get("/hotels").param("foo", "bar"));
```

If application code relies on Servlet request parameters, and doesn't check the query string, as is most often the case, then it doesn't matter how parameters are added. Keep in mind though that parameters provided in the URI template will be decoded while parameters provided through the `param(...)` method are expected to be decoded.

In most cases it's preferable to leave out the context path and the Servlet path from the request URI. If you must test with the full request URI, be sure to set the `contextPath` and `servletPath` accordingly so that request mappings will work:

```
mockMvc.perform(get("/app/main/hotels/{id}").contextPath("/app").servletPath("/main"))
```

Looking at the above example, it would be cumbersome to set the contextPath and servletPath with every performed request. That's why you can define default request properties when building the `MockMvc`:

```
public class MyWebTests {

    private MockMvc mockMvc;

    @Before
    public void setup() {
        mockMvc = standaloneSetup(new AccountController())
            .defaultRequest(get("/")
            .contextPath("/app").servletPath("/main")
            .accept(MediaType.APPLICATION_JSON).build();
    }
```

The above properties will apply to every request performed through the `MockMvc`. If the same property is also specified on a given request, it will override the default value. That is why, the HTTP method and URI don't matter, when setting default request properties, since they must be specified on every request.

Defining Expectations

Expectations can be defined by appending one or more `.andExpect(..)` after call to perform the request:

```
mockMvc.perform(get("/accounts/1")).andExpect(status().isOk());
```

`MockMvcResultMatchers.*` defines a number of static members, some of which return types with additional methods, for asserting the result of the performed request. The assertions fall in two general categories.

The first category of assertions verify properties of the response, i.e the response status, headers, and content. Those are the most important things to test for.

The second category of assertions go beyond the response, and allow inspecting Spring MVC specific constructs such as which controller method processed the request, whether an exception was raised and handled, what the content of the model is, what view was selected, what flash attributes were added, and so on. It is also possible to verify Servlet specific constructs such as request and session attributes. The following test asserts that binding/validation failed:

```
mockMvc.perform(post("/persons"))
    .andExpect(status().isOk())
    .andExpect(model().attributeHasErrors("person"));
```

Many times when writing tests, it's useful to dump the result of the performed request. This can be done as follows, where `print()` is a static import from `MockMvcResultHandlers`:

```
mockMvc.perform(post("/persons"))
    .andDo(print())
    .andExpect(status().isOk())
    .andExpect(model().attributeHasErrors("person"));
```

As long as request processing causes an unhandled exception, the `print()` method will print all the available result data to `System.out`.

In some cases, you may want to get direct access to the result and verify something that cannot be verified otherwise. This can be done by appending `.andReturn()` at the end after all expectations:

```
MvcResult mvcResult = mockMvc.perform(post("/persons")).andExpect(status().isOk()).andReturn();
// ...
```

When all tests repeat the same expectations, you can define the common expectations once when building the `MockMvc`:

```
standaloneSetup(new SimpleController())
    .alwaysExpect(status().isOk())
    .alwaysExpect(content().contentType("application/json;charset=UTF-8"))
    .build()
```

Note that the expectation is *always* applied and cannot be overridden without creating a separate `MockMvc` instance.

When JSON response content contains hypermedia links created with Spring HATEOAS, the resulting links can be verified:

```
mockMvc.perform(get("/people").accept(MediaType.APPLICATION_JSON))
    .andExpect(jsonPath("$.links[?(@.rel == 'self')].href").value("http://localhost:8080/people"));
```

When XML response content contains hypermedia links created with Spring HATEOAS, the resulting links can be verified:

```
Map<String, String> ns = Collections.singletonMap("ns", "http://www.w3.org/2005/Atom");
mockMvc.perform(get("/handle").accept(MediaType.APPLICATION_XML))
    .andExpect(xpath("/person/ns:link[@rel='self']/@href", ns).string("http://localhost:8080/people"));
```

Filter Registrations

When setting up a `MockMvc`, you can register one or more `Filter` instances:

```
mockMvc = standaloneSetup(new PersonController()).addFilters(new CharacterEncodingFilter()).build();
```

Registered filters will be invoked through `MockFilterChain` from `spring-test` and the last filter will delegates to the `DispatcherServlet`.

Further Server-Side Test Examples

The framework's own tests include many sample tests intended to demonstrate how to use Spring MVC Test. Browse these examples for further ideas. Also the spring-mvc-showcase has full test coverage based on Spring MVC Test.

Client-Side REST Tests

Client-side tests are for code using the `RestTemplate`. The goal is to define expected requests and provide "stub" responses:

```
RestTemplate restTemplate = new RestTemplate();

MockRestServiceServer mockServer = MockRestServiceServer.createServer(restTemplate);
mockServer.expect(requestTo("/greeting")).andRespond(withSuccess("Hello world", MediaType.TEXT_PLAIN));

// use RestTemplate ...

mockServer.verify();
```

In the above example, `MockRestServiceServer` — the central class for client-side REST tests — configures the `RestTemplate` with a custom `ClientHttpRequestFactory` that asserts actual requests against expectations and returns "stub" responses. In this case we expect a single request to "/greeting" and want to return a 200 response with "text/plain" content. We could define as many additional requests and stub responses as necessary.

Once expected requests and stub responses have been defined, the `RestTemplate` can be used in client-side code as usual. At the end of the tests `mockServer.verify()` can be used to verify that all expected requests were performed.

Static Imports

Just like with server-side tests, the fluent API for client-side tests requires a few static imports. Those are easy to find by searching *"MockRest*"*. Eclipse users should add "`MockRestRequestMatchers.*`" and "`MockRestResponseCreators.*`" as "favorite static members" in the Eclipse preferences under *Java # Editor # Content Assist # Favorites*. That allows using content assist after typing the first character of the static method name. Other IDEs (e.g. IntelliJ) may not require any additional configuration. Just check the support for code completion on static members.

Further Examples of Client-side REST Tests

Spring MVC Test's own tests include example tests of client-side REST tests.

PetClinic Example

The PetClinic application, available on GitHub, illustrates several features of the *Spring TestContext Framework* in a JUnit environment. Most test functionality is included in the `AbstractClinicTests`, for which a partial listing is shown below:

```
import static org.junit.Assert.assertEquals;
// import ...

@ContextConfiguration
public abstract class AbstractClinicTests extends AbstractTransactionalJUnit4SpringContextTests {

    @Autowired
    protected Clinic clinic;

    @Test
    public void getVets() {
        Collection<Vet> vets = this.clinic.getVets();
        assertEquals("JDBC query must show the same number of vets",
            super.countRowsInTable("VETS"), vets.size());
        Vet v1 = EntityUtils.getById(vets, Vet.class, 2);
        assertEquals("Leary", v1.getLastName());
        assertEquals(1, v1.getNrOfSpecialties());
        assertEquals("radiology", (v1.getSpecialties().get(0)).getName());
        // ...
    }

    // ...
}
```

Notes:

- This test case extends the `AbstractTransactionalJUnit4SpringContextTests` class, from which it inherits configuration for Dependency Injection (through the `DependencyInjectionTestExecutionListener`) and transactional behavior (through the `TransactionalTestExecutionListener`).
- The `clinic` instance variable — the application object being tested — is set by Dependency Injection through `@Autowired` semantics.
- The `getVets()` method illustrates how you can use the inherited `countRowsInTable()` method to easily verify the number of rows in a given table, thus verifying correct behavior of the application code being tested. This allows for stronger tests and lessens dependency on the exact test data. For example, you can add additional rows in the database without breaking tests.
- Like many integration tests that use a database, most of the tests in `AbstractClinicTests` depend on a minimum amount of data already in the database before the test cases run. Alternatively, you might choose to populate the database within the test fixture set up of your test cases — again, within the same transaction as the tests.

The PetClinic application supports three data access technologies: JDBC, Hibernate, and JPA. By declaring `@ContextConfiguration` without any specific resource locations, the `AbstractClinicTests` class will have its application context loaded from the default location, `AbstractClinicTests-context.xml`, which declares a common `DataSource`. Subclasses specify additional context locations that must declare a `PlatformTransactionManager` and a concrete implementation of `Clinic`.

For example, the Hibernate implementation of the PetClinic tests contains the following implementation. For this example, `HibernateClinicTests` does not contain a single line of code: we only need to declare `@ContextConfiguration`, and the tests are inherited from `AbstractClinicTests`. Because `@ContextConfiguration` is declared without any specific resource locations, the *Spring TestContext Framework* loads an application context from all the beans defined in `AbstractClinicTests-context.xml` (i.e., the inherited locations) and `HibernateClinicTests-context.xml`, with `HibernateClinicTests-context.xml` possibly overriding beans defined in `AbstractClinicTests-context.xml`.

```
@ContextConfiguration
public class HibernateClinicTests extends AbstractClinicTests { }
```

In a large-scale application, the Spring configuration is often split across multiple files. Consequently, configuration locations are typically specified in a common base class for all application-specific integration tests. Such a base class may also add useful instance variables — populated by Dependency Injection, naturally — such as a `SessionFactory` in the case of an application using Hibernate.

As far as possible, you should have exactly the same Spring configuration files in your integration tests as in the deployed environment. One likely point of difference concerns database connection pooling and transaction infrastructure. If you are deploying to a full-blown application server, you will probably use its connection pool (available through JNDI) and JTA implementation. Thus in production you will use a `JndiObjectFactoryBean` or `<jee:jndi-lookup>` for the `DataSource` and `JtaTransactionManager`. JNDI and JTA will not be available in out-of-container integration tests, so you should use a combination like the Commons DBCP `BasicDataSource` and `DataSourceTransactionManager` or `HibernateTransactionManager` for them. You can factor out this variant behavior into a single XML file, having the choice between application server and a *local* configuration separated from all other configuration, which will not vary between the test and production environments. In addition, it is advisable to use properties files for connection settings. See the PetClinic application for an example.

11.4 Further Resources

Consult the following resources for more information about testing:

- JUnit: "*A programmer-oriented testing framework for Java*". Used by the Spring Framework in its test suite.
- TestNG: A testing framework inspired by JUnit with added support for annotations, test groups, data-driven testing, distributed testing, etc.
- MockObjects.com: Web site dedicated to mock objects, a technique for improving the design of code within test-driven development.
- "Mock Objects": Article in Wikipedia.
- EasyMock: Java library " *that provides Mock Objects for interfaces (and objects through the class extension) by generating them on the fly using Java's proxy mechanism.* " Used by the Spring Framework in its test suite.
- JMock: Library that supports test-driven development of Java code with mock objects.
- Mockito: Java mock library based on the test spy pattern.
- DbUnit: JUnit extension (also usable with Ant and Maven) targeted for database-driven projects that, among other things, puts your database into a known state between test runs.
- The Grinder: Java load testing framework.

Part IV. Data Access

This part of the reference documentation is concerned with data access and the interaction between the data access layer and the business or service layer.

Spring's comprehensive transaction management support is covered in some detail, followed by thorough coverage of the various data access frameworks and technologies that the Spring Framework integrates with.

- Chapter 12, *Transaction Management*
- Chapter 13, *DAO support*
- Chapter 14, *Data access with JDBC*
- Chapter 15, *Object Relational Mapping (ORM) Data Access*
- Chapter 16, *Marshalling XML using O/X Mappers*

12. Transaction Management

12.1 Introduction to Spring Framework transaction management

Comprehensive transaction support is among the most compelling reasons to use the Spring Framework. The Spring Framework provides a consistent abstraction for transaction management that delivers the following benefits:

- Consistent programming model across different transaction APIs such as Java Transaction API (JTA), JDBC, Hibernate, Java Persistence API (JPA), and Java Data Objects (JDO).
- Support for declarative transaction management.
- Simpler API for programmatic transaction management than complex transaction APIs such as JTA.
- Excellent integration with Spring's data access abstractions.

The following sections describe the Spring Framework's transaction value-adds and technologies. (The chapter also includes discussions of best practices, application server integration, and solutions to common problems.)

- Advantages of the Spring Framework's transaction support model describes *why* you would use the Spring Framework's transaction abstraction instead of EJB Container-Managed Transactions (CMT) or choosing to drive local transactions through a proprietary API such as Hibernate.
- Understanding the Spring Framework transaction abstraction outlines the core classes and describes how to configure and obtain `DataSource` instances from a variety of sources.
- Synchronizing resources with transactionsdescribes how the application code ensures that resources are created, reused, and cleaned up properly.
- Declarative transaction management describes support for declarative transaction management.
- Programmatic transaction management covers support for programmatic (that is, explicitly coded) transaction management.

12.2 Advantages of the Spring Framework's transaction support model

Traditionally, Java EE developers have had two choices for transaction management: *global* or *local* transactions, both of which have profound limitations. Global and local transaction management is reviewed in the next two sections, followed by a discussion of how the Spring Framework's transaction management support addresses the limitations of the global and local transaction models.

Global transactions

Global transactions enable you to work with multiple transactional resources, typically relational databases and message queues. The application server manages global transactions through the JTA, which is a cumbersome API to use (partly due to its exception model). Furthermore, a JTA `UserTransaction` normally needs to be sourced from JNDI, meaning that you *also* need to use JNDI in order to use JTA. Obviously the use of global transactions would limit any potential reuse of application code, as JTA is normally only available in an application server environment.

Previously, the preferred way to use global transactions was via EJB *CMT* (*Container Managed Transaction*): CMT is a form of *declarative transaction management* (as distinguished from *programmatic transaction management*). EJB CMT removes the need for transaction-related JNDI lookups, although of course the use of EJB itself necessitates the use of JNDI. It removes most but not all of the need to write Java code to control transactions. The significant downside is that CMT is tied to JTA and an application server environment. Also, it is only available if one chooses to implement business logic in EJBs, or at least behind a transactional EJB facade. The negatives of EJB in general are so great that this is not an attractive proposition, especially in the face of compelling alternatives for declarative transaction management.

Local transactions

Local transactions are resource-specific, such as a transaction associated with a JDBC connection. Local transactions may be easier to use, but have significant disadvantages: they cannot work across multiple transactional resources. For example, code that manages transactions using a JDBC connection cannot run within a global JTA transaction. Because the application server is not involved in transaction management, it cannot help ensure correctness across multiple resources. (It is worth noting that most applications use a single transaction resource.) Another downside is that local transactions are invasive to the programming model.

Spring Framework's consistent programming model

Spring resolves the disadvantages of global and local transactions. It enables application developers to use a *consistent* programming model *in any environment*. You write your code once, and it can benefit from different transaction management strategies in different environments. The Spring Framework provides both declarative and programmatic transaction management. Most users prefer declarative transaction management, which is recommended in most cases.

With programmatic transaction management, developers work with the Spring Framework transaction abstraction, which can run over any underlying transaction infrastructure. With the preferred declarative model, developers typically write little or no code related to transaction management, and hence do not depend on the Spring Framework transaction API, or any other transaction API.

Do you need an application server for transaction management?

The Spring Framework's transaction management support changes traditional rules as to when an enterprise Java application requires an application server.

In particular, you do not need an application server simply for declarative transactions through EJBs. In fact, even if your application server has powerful JTA capabilities, you may decide that the Spring Framework's declarative transactions offer more power and a more productive programming model than EJB CMT.

Typically you need an application server's JTA capability only if your application needs to handle transactions across multiple resources, which is not a requirement for many applications. Many high-end applications use a single, highly scalable database (such as Oracle RAC) instead. Standalone transaction managers such as Atomikos Transactions and JOTM are other options. Of course, you may need other application server capabilities such as Java Message Service (JMS) and Java EE Connector Architecture (JCA).

The Spring Framework *gives you the choice of when to scale your application to a fully loaded application server*. Gone are the days when the only alternative to using EJB CMT or JTA was to write code with local transactions such as those on JDBC connections, and face a hefty

rework if you need that code to run within global, container-managed transactions. With the Spring Framework, only some of the bean definitions in your configuration file, rather than your code, need to change.

12.3 Understanding the Spring Framework transaction abstraction

The key to the Spring transaction abstraction is the notion of a *transaction strategy*. A transaction strategy is defined by the `org.springframework.transaction.PlatformTransactionManager` interface:

```
public interface PlatformTransactionManager {

    TransactionStatus getTransaction(
            TransactionDefinition definition) throws TransactionException;

    void commit(TransactionStatus status) throws TransactionException;

    void rollback(TransactionStatus status) throws TransactionException;
}
```

This is primarily a service provider interface (SPI), although it can be used programmatically from your application code. Because `PlatformTransactionManager` is an *interface*, it can be easily mocked or stubbed as necessary. It is not tied to a lookup strategy such as JNDI. `PlatformTransactionManager` implementations are defined like any other object (or bean) in the Spring Framework IoC container. This benefit alone makes Spring Framework transactions a worthwhile abstraction even when you work with JTA. Transactional code can be tested much more easily than if it used JTA directly.

Again in keeping with Spring's philosophy, the `TransactionException` that can be thrown by any of the `PlatformTransactionManager` interface's methods is *unchecked* (that is, it extends the `java.lang.RuntimeException` class). Transaction infrastructure failures are almost invariably fatal. In rare cases where application code can actually recover from a transaction failure, the application developer can still choose to catch and handle `TransactionException`. The salient point is that developers are not *forced* to do so.

The `getTransaction(..)` method returns a `TransactionStatus` object, depending on a `TransactionDefinition` parameter. The returned `TransactionStatus` might represent a new transaction, or can represent an existing transaction if a matching transaction exists in the current call stack. The implication in this latter case is that, as with Java EE transaction contexts, a `TransactionStatus` is associated with a *thread* of execution.

The `TransactionDefinition` interface specifies:

- *Isolation*: The degree to which this transaction is isolated from the work of other transactions. For example, can this transaction see uncommitted writes from other transactions?
- *Propagation*: Typically, all code executed within a transaction scope will run in that transaction. However, you have the option of specifying the behavior in the event that a transactional method is executed when a transaction context already exists. For example, code can continue running in the existing transaction (the common case); or the existing transaction can be suspended and a new transaction created. *Spring offers all of the transaction propagation options familiar from EJB CMT*. To read about the semantics of transaction propagation in Spring, see the section called "Transaction propagation".

- *Timeout*: How long this transaction runs before timing out and being rolled back automatically by the underlying transaction infrastructure.
- *Read-only status*: A read-only transaction can be used when your code reads but does not modify data. Read-only transactions can be a useful optimization in some cases, such as when you are using Hibernate.

These settings reflect standard transactional concepts. If necessary, refer to resources that discuss transaction isolation levels and other core transaction concepts. Understanding these concepts is essential to using the Spring Framework or any transaction management solution.

The `TransactionStatus` interface provides a simple way for transactional code to control transaction execution and query transaction status. The concepts should be familiar, as they are common to all transaction APIs:

```
public interface TransactionStatus extends SavepointManager {

    boolean isNewTransaction();

    boolean hasSavepoint();

    void setRollbackOnly();

    boolean isRollbackOnly();

    void flush();

    boolean isCompleted();

}
```

Regardless of whether you opt for declarative or programmatic transaction management in Spring, defining the correct `PlatformTransactionManager` implementation is absolutely essential. You typically define this implementation through dependency injection.

`PlatformTransactionManager` implementations normally require knowledge of the environment in which they work: JDBC, JTA, Hibernate, and so on. The following examples show how you can define a local `PlatformTransactionManager` implementation. (This example works with plain JDBC.)

You define a JDBC `DataSource`

```
<bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
    <property name="driverClassName" value="${jdbc.driverClassName}" />
    <property name="url" value="${jdbc.url}" />
    <property name="username" value="${jdbc.username}" />
    <property name="password" value="${jdbc.password}" />
</bean>
```

The related `PlatformTransactionManager` bean definition will then have a reference to the `DataSource` definition. It will look like this:

```
<bean id="txManager" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
    <property name="dataSource" ref="dataSource"/>
</bean>
```

If you use JTA in a Java EE container then you use a container `DataSource`, obtained through JNDI, in conjunction with Spring's `JtaTransactionManager`. This is what the JTA and JNDI lookup version would look like:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jee="http://www.springframework.org/schema/jee"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/jee
        http://www.springframework.org/schema/jee/spring-jee.xsd">

    <jee:jndi-lookup id="dataSource" jndi-name="jdbc/jpetstore"/>

    <bean id="txManager" class="org.springframework.transaction.jta.JtaTransactionManager" />

    <!-- other <bean/> definitions here -->

</beans>
```

The `JtaTransactionManager` does not need to know about the `DataSource`, or any other specific resources, because it uses the container's global transaction management infrastructure.

> **Note**
>
> The above definition of the `dataSource` bean uses the `<jndi-lookup/>` tag from the `jee` namespace. For more information on schema-based configuration, see Chapter 34, *XML Schema-based configuration*, and for more information on the `<jee/>` tags see the section entitled the section called "the jee schema".

You can also use Hibernate local transactions easily, as shown in the following examples. In this case, you need to define a Hibernate `LocalSessionFactoryBean`, which your application code will use to obtain Hibernate `Session` instances.

The `DataSource` bean definition will be similar to the local JDBC example shown previously and thus is not shown in the following example.

> **Note**
>
> If the `DataSource`, used by any non-JTA transaction manager, is looked up via JNDI and managed by a Java EE container, then it should be non-transactional because the Spring Framework, rather than the Java EE container, will manage the transactions.

The `txManager` bean in this case is of the `HibernateTransactionManager` type. In the same way as the `DataSourceTransactionManager` needs a reference to the `DataSource`, the `HibernateTransactionManager` needs a reference to the `SessionFactory`.

```
<bean id="sessionFactory" class="org.springframework.orm.hibernate3.LocalSessionFactoryBean">
    <property name="dataSource" ref="dataSource" />
    <property name="mappingResources">
        <list>
            <value>org/springframework/samples/petclinic/hibernate/petclinic.hbm.xml</value>
        </list>
    </property>
    <property name="hibernateProperties">
        <value>
            hibernate.dialect=${hibernate.dialect}
        </value>
    </property>
</bean>

<bean id="txManager" class="org.springframework.orm.hibernate3.HibernateTransactionManager">
    <property name="sessionFactory" ref="sessionFactory" />
</bean>
```

If you are using Hibernate and Java EE container-managed JTA transactions, then you should simply use the same `JtaTransactionManager` as in the previous JTA example for JDBC.

```
<bean id="txManager" class="org.springframework.transaction.jta.JtaTransactionManager"/>
```

> **Note**
>
> If you use JTA , then your transaction manager definition will look the same regardless of what data access technology you use, be it JDBC, Hibernate JPA or any other supported technology. This is due to the fact that JTA transactions are global transactions, which can enlist any transactional resource.

In all these cases, application code does not need to change. You can change how transactions are managed merely by changing configuration, even if that change means moving from local to global transactions or vice versa.

12.4 Synchronizing resources with transactions

It should now be clear how you create different transaction managers, and how they are linked to related resources that need to be synchronized to transactions (for example `DataSourceTransactionManager` to a JDBC `DataSource`, `HibernateTransactionManager` to a Hibernate `SessionFactory`, and so forth). This section describes how the application code, directly or indirectly using a persistence API such as JDBC, Hibernate, or JDO, ensures that these resources are created, reused, and cleaned up properly. The section also discusses how transaction synchronization is triggered (optionally) through the relevant `PlatformTransactionManager`.

High-level synchronization approach

The preferred approach is to use Spring's highest level template based persistence integration APIs or to use native ORM APIs with transaction- aware factory beans or proxies for managing the native resource factories. These transaction-aware solutions internally handle resource creation and reuse, cleanup, optional transaction synchronization of the resources, and exception mapping. Thus user data access code does not have to address these tasks, but can be focused purely on non-boilerplate persistence logic. Generally, you use the native ORM API or take a *template* approach for JDBC access by using the `JdbcTemplate`. These solutions are detailed in subsequent chapters of this reference documentation.

Low-level synchronization approach

Classes such as `DataSourceUtils` (for JDBC), `EntityManagerFactoryUtils` (for JPA), `SessionFactoryUtils` (for Hibernate), `PersistenceManagerFactoryUtils` (for JDO), and so on exist at a lower level. When you want the application code to deal directly with the resource types of the native persistence APIs, you use these classes to ensure that proper Spring Framework-managed instances are obtained, transactions are (optionally) synchronized, and exceptions that occur in the process are properly mapped to a consistent API.

For example, in the case of JDBC, instead of the traditional JDBC approach of calling the `getConnection()` method on the `DataSource`, you instead use Spring's `org.springframework.jdbc.datasource.DataSourceUtils` class as follows:

```
Connection conn = DataSourceUtils.getConnection(dataSource);
```

If an existing transaction already has a connection synchronized (linked) to it, that instance is returned. Otherwise, the method call triggers the creation of a new connection, which is (optionally) synchronized to any existing transaction, and made available for subsequent reuse in that same transaction. As mentioned, any `SQLException` is wrapped in a Spring Framework `CannotGetJdbcConnectionException`, one of the Spring Framework's hierarchy of unchecked DataAccessExceptions. This approach gives you more information than can be obtained easily from the `SQLException`, and ensures portability across databases, even across different persistence technologies.

This approach also works without Spring transaction management (transaction synchronization is optional), so you can use it whether or not you are using Spring for transaction management.

Of course, once you have used Spring's JDBC support, JPA support or Hibernate support, you will generally prefer not to use `DataSourceUtils` or the other helper classes, because you will be much happier working through the Spring abstraction than directly with the relevant APIs. For example, if you use the Spring `JdbcTemplate` or `jdbc.object` package to simplify your use of JDBC, correct connection retrieval occurs behind the scenes and you won't need to write any special code.

TransactionAwareDataSourceProxy

At the very lowest level exists the `TransactionAwareDataSourceProxy` class. This is a proxy for a target `DataSource`, which wraps the target `DataSource` to add awareness of Spring-managed transactions. In this respect, it is similar to a transactional JNDI `DataSource` as provided by a Java EE server.

It should almost never be necessary or desirable to use this class, except when existing code must be called and passed a standard JDBC `DataSource` interface implementation. In that case, it is possible that this code is usable, but participating in Spring managed transactions. It is preferable to write your new code by using the higher level abstractions mentioned above.

12.5 Declarative transaction management

> **Note**
>
> Most Spring Framework users choose declarative transaction management. This option has the least impact on application code, and hence is most consistent with the ideals of a *non-invasive* lightweight container.

The Spring Framework's declarative transaction management is made possible with Spring aspect-oriented programming (AOP), although, as the transactional aspects code comes with the Spring Framework distribution and may be used in a boilerplate fashion, AOP concepts do not generally have to be understood to make effective use of this code.

The Spring Framework's declarative transaction management is similar to EJB CMT in that you can specify transaction behavior (or lack of it) down to individual method level. It is possible to make a `setRollbackOnly()` call within a transaction context if necessary. The differences between the two types of transaction management are:

- Unlike EJB CMT, which is tied to JTA, the Spring Framework's declarative transaction management works in any environment. It can work with JTA transactions or local transactions using JDBC, JPA, Hibernate or JDO by simply adjusting the configuration files.
- You can apply the Spring Framework declarative transaction management to any class, not merely special classes such as EJBs.
- The Spring Framework offers declarative *rollback rules*,a feature with no EJB equivalent. Both programmatic and declarative support for rollback rules is provided.
- The Spring Framework enables you to customize transactional behavior, by using AOP. For example, you can insert custom behavior in the case of transaction rollback. You can also add arbitrary advice, along with the transactional advice. With EJB CMT, you cannot influence the container's transaction management except with `setRollbackOnly()`.
- The Spring Framework does not support propagation of transaction contexts across remote calls, as do high-end application servers. If you need this feature, we recommend that you use EJB. However, consider carefully before using such a feature, because normally, one does not want transactions to span remote calls.

Where is TransactionProxyFactoryBean?

Declarative transaction configuration in versions of Spring 2.0 and above differs considerably from previous versions of Spring. The main difference is that there is no longer any need to configure `TransactionProxyFactoryBean` beans.

The pre-Spring 2.0 configuration style is still 100% valid configuration; think of the new `<tx:tags/>` as simply defining `TransactionProxyFactoryBean` beans on your behalf.

The concept of rollback rules is important: they enable you to specify which exceptions (and throwables) should cause automatic rollback. You specify this declaratively, in configuration, not in Java code. So, although you can still call `setRollbackOnly()` on the `TransactionStatus` object to roll back the current transaction back, most often you can specify a rule that `MyApplicationException` must always result in rollback. The significant advantage to this option is that business objects do not depend on the transaction infrastructure. For example, they typically do not need to import Spring transaction APIs or other Spring APIs.

Although EJB container default behavior automatically rolls back the transaction on a *system exception* (usually a runtime exception), EJB CMT does not roll back the transaction automatically on an*application exception* (that is, a checked exception other than `java.rmi.RemoteException`). While the Spring default behavior for declarative transaction management follows EJB convention (roll back is automatic only on unchecked exceptions), it is often useful to customize this behavior.

Understanding the Spring Framework's declarative transaction implementation

It is not sufficient to tell you simply to annotate your classes with the `@Transactional` annotation, add `@EnableTransactionManagement` to your configuration, and then expect you to understand how it all works. This section explains the inner workings of the Spring Framework's declarative transaction infrastructure in the event of transaction-related issues.

The most important concepts to grasp with regard to the Spring Framework's declarative transaction support are that this support is enabled *via AOP proxies*, and that the transactional advice is driven by *metadata* (currently XML- or annotation-based). The combination of AOP with transactional metadata yields an AOP proxy that uses a `TransactionInterceptor` in conjunction with an appropriate `PlatformTransactionManager` implementation to drive transactions *around method invocations*.

> **Note**
>
> Spring AOP is covered in Chapter 9, *Aspect Oriented Programming with Spring*.

Conceptually, calling a method on a transactional proxy looks like this…

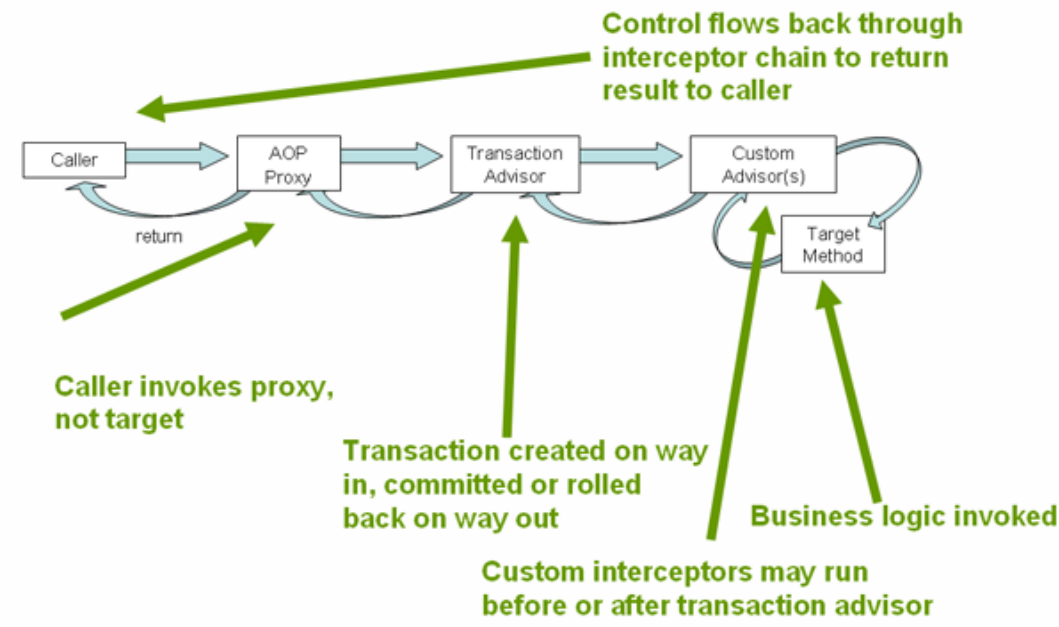


Figure 12.1.

Example of declarative transaction implementation

Consider the following interface, and its attendant implementation. This example uses `Foo` and `Bar` classes as placeholders so that you can concentrate on the transaction usage without focusing on a particular domain model. For the purposes of this example, the fact that the `DefaultFooService` class throws `UnsupportedOperationException` instances in the body of each implemented method is good; it allows you to see transactions created and then rolled back in response to the `UnsupportedOperationException` instance.

```
// the service interface that we want to make transactional

package x.y.service;

public interface FooService {

    Foo getFoo(String fooName);

    Foo getFoo(String fooName, String barName);

    void insertFoo(Foo foo);

    void updateFoo(Foo foo);

}
```

```
// an implementation of the above interface

package x.y.service;

public class DefaultFooService implements FooService {

    public Foo getFoo(String fooName) {
        throw new UnsupportedOperationException();
    }

    public Foo getFoo(String fooName, String barName) {
        throw new UnsupportedOperationException();
    }

    public void insertFoo(Foo foo) {
        throw new UnsupportedOperationException();
    }

    public void updateFoo(Foo foo) {
        throw new UnsupportedOperationException();
    }

}
```

Assume that the first two methods of the `FooService` interface, `getFoo(String)` and `getFoo(String, String)`, must execute in the context of a transaction with read-only semantics, and that the other methods, `insertFoo(Foo)` and `updateFoo(Foo)`, must execute in the context of a transaction with read-write semantics. The following configuration is explained in detail in the next few paragraphs.

```
<!-- from the file context.xml -->
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- this is the service object that we want to make transactional -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- the transactional advice (what happens; see the <aop:advisor/> bean below) -->
    <tx:advice id="txAdvice" transaction-manager="txManager">
        <!-- the transactional semantics... -->
        <tx:attributes>
            <!-- all methods starting with get are read-only -->
            <tx:method name="get*" read-only="true"/>
            <!-- other methods use the default transaction settings (see below) -->
            <tx:method name=""/>
        </tx:attributes>
    </tx:advice>

    <!-- ensure that the above transactional advice runs for any execution
        of an operation defined by the FooService interface -->
    <aop:config>
        <aop:pointcut id="fooServiceOperation" expression="execution( x.y.service.FooService.*(..))"/>
        <aop:advisor advice-ref="txAdvice" pointcut-ref="fooServiceOperation"/>
    </aop:config>

    <!-- don't forget the DataSource -->
    <bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
        <property name="driverClassName" value="oracle.jdbc.driver.OracleDriver"/>
        <property name="url" value="jdbc:oracle:thin:@rj-t42:1521:elvis"/>
        <property name="username" value="scott"/>
        <property name="password" value="tiger"/>
    </bean>

    <!-- similarly, don't forget the PlatformTransactionManager -->
    <bean id="txManager" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        <property name="dataSource" ref="dataSource"/>
    </bean>

    <!-- other <bean/> definitions here -->

</beans>
```

Examine the preceding configuration. You want to make a service object, the `fooService` bean, transactional. The transaction semantics to apply are encapsulated in the `<tx:advice/>` definition. The `<tx:advice/>` definition reads as "*... all methods on starting with `'get'` are to execute in the context of a read-only transaction, and all other methods are to execute with the default transaction semantics*". The `transaction-manager` attribute of the `<tx:advice/>` tag is set to the name of the `PlatformTransactionManager` bean that is going to *drive* the transactions, in this case, the `txManager` bean.

> **Tip**
>
> You can omit the `transaction-manager` attribute in the transactional advice (`<tx:advice/>`) if the bean name of the `PlatformTransactionManager` that you want to wire in has the name `transactionManager`. If the `PlatformTransactionManager` bean that you want to

> wire in has any other name, then you must use the `transaction-manager` attribute explicitly, as in the preceding example.

The `<aop:config/>` definition ensures that the transactional advice defined by the `txAdvice` bean executes at the appropriate points in the program. First you define a pointcut that matches the execution of any operation defined in the `FooService` interface (`fooServiceOperation`). Then you associate the pointcut with the `txAdvice` using an advisor. The result indicates that at the execution of a `fooServiceOperation`, the advice defined by `txAdvice` will be run.

The expression defined within the `<aop:pointcut/>` element is an AspectJ pointcut expression; see Chapter 9, *Aspect Oriented Programming with Spring* for more details on pointcut expressions in Spring.

A common requirement is to make an entire service layer transactional. The best way to do this is simply to change the pointcut expression to match any operation in your service layer. For example:

```
<aop:config>
    <aop:pointcut id="fooServiceMethods" expression="execution(* x.y.service..(..))"/>
    <aop:advisor advice-ref="txAdvice" pointcut-ref="fooServiceMethods"/>
</aop:config>
```

> **Note**
>
> *In this example it is assumed that all your service interfaces are defined in the `x.y.service` package; see Chapter 9, Aspect Oriented Programming with Spring for more details.*

Now that we've analyzed the configuration, you may be asking yourself, "*Okay… but what does all this configuration actually do?*".

The above configuration will be used to create a transactional proxy around the object that is created from the `fooService` bean definition. The proxy will be configured with the transactional advice, so that when an appropriate method is invoked *on the proxy*, a transaction is started, suspended, marked as read-only, and so on, depending on the transaction configuration associated with that method. Consider the following program that test drives the above configuration:

```
public final class Boot {

    public static void main(final String[] args) throws Exception {
        ApplicationContext ctx = new ClassPathXmlApplicationContext("context.xml", Boot.class);
        FooService fooService = (FooService) ctx.getBean("fooService");
        fooService.insertFoo (new Foo());
    }
}
```

The output from running the preceding program will resemble the following. (The Log4J output and the stack trace from the UnsupportedOperationException thrown by the insertFoo(..) method of the DefaultFooService class have been truncated for clarity.)

```
<!-- the Spring container is starting up... -->
[AspectJInvocationContextExposingAdvisorAutoProxyCreator] - Creating implicit proxy for bean fooService
 with 0 common interceptors and 1 specific interceptors

<!-- the DefaultFooService is actually proxied -->
[JdkDynamicAopProxy] - Creating JDK dynamic proxy for [x.y.service.DefaultFooService]

<!-- ... the insertFoo(..) method is now being invoked on the proxy -->
[TransactionInterceptor] - Getting transaction for x.y.service.FooService.insertFoo

<!-- the transactional advice kicks in here... -->
[DataSourceTransactionManager] - Creating new transaction with name [x.y.service.FooService.insertFoo]
[DataSourceTransactionManager] - Acquired Connection [org.apache.commons.dbcp.PoolableConnection@a53de4]
 for JDBC transaction

<!-- the insertFoo(..) method from DefaultFooService throws an exception... -->
[RuleBasedTransactionAttribute] - Applying rules to determine whether transaction should rollback on
 java.lang.UnsupportedOperationException
[TransactionInterceptor] - Invoking rollback for transaction on x.y.service.FooService.insertFoo due to
 throwable [java.lang.UnsupportedOperationException]

<!-- and the transaction is rolled back (by default, RuntimeException instances cause rollback) -->
[DataSourceTransactionManager] - Rolling back JDBC transaction on Connection
 [org.apache.commons.dbcp.PoolableConnection@a53de4]
[DataSourceTransactionManager] - Releasing JDBC Connection after transaction
[DataSourceUtils] - Returning JDBC Connection to DataSource

Exception in thread "main" java.lang.UnsupportedOperationException at
 x.y.service.DefaultFooService.insertFoo(DefaultFooService.java:14)
<!-- AOP infrastructure stack trace elements removed for clarity -->
at $Proxy0.insertFoo(Unknown Source)
at Boot.main(Boot.java:11)
```

Rolling back a declarative transaction

The previous section outlined the basics of how to specify transactional settings for classes, typically service layer classes, declaratively in your application. This section describes how you can control the rollback of transactions in a simple declarative fashion.

The recommended way to indicate to the Spring Framework's transaction infrastructure that a transaction's work is to be rolled back is to throw an `Exception` from code that is currently executing in the context of a transaction. The Spring Framework's transaction infrastructure code will catch any unhandled `Exception` as it bubbles up the call stack, and make a determination whether to mark the transaction for rollback.

In its default configuration, the Spring Framework's transaction infrastructure code *only* marks a transaction for rollback in the case of runtime, unchecked exceptions; that is, when the thrown exception is an instance or subclass of `RuntimeException`. (`Errors` will also - by default - result in a rollback). Checked exceptions that are thrown from a transactional method do *not* result in rollback in the default configuration.

You can configure exactly which `Exception` types mark a transaction for rollback, including checked exceptions. The following XML snippet demonstrates how you configure rollback for a checked, application-specific `Exception` type.

```
<tx:advice id="txAdvice" transaction-manager="txManager">
    <tx:attributes>
    <tx:method name="get*" read-only="true" rollback-for="NoProductInStockException"/>
    <tx:method name="*"/>
    </tx:attributes>
</tx:advice>
```

You can also specify *no rollback rules*, if you do *not* want a transaction rolled back when an exception is thrown. The following example tells the Spring Framework's transaction infrastructure to commit the attendant transaction even in the face of an unhandled `InstrumentNotFoundException`.

```
<tx:advice id="txAdvice">
    <tx:attributes>
    <tx:method name="updateStock" no-rollback-for="InstrumentNotFoundException"/>
    <tx:method name="*"/>
    </tx:attributes>
</tx:advice>
```

When the Spring Framework's transaction infrastructure catches an exception and is consults configured rollback rules to determine whether to mark the transaction for rollback, the *strongest* matching rule wins. So in the case of the following configuration, any exception other than an `InstrumentNotFoundException` results in a rollback of the attendant transaction.

```
<tx:advice id="txAdvice">
    <tx:attributes>
    <tx:method name="*" rollback-for="Throwable" no-rollback-for="InstrumentNotFoundException"/>
    </tx:attributes>
</tx:advice>
```

You can also indicate a required rollback *programmatically*. Although very simple, this process is quite invasive, and tightly couples your code to the Spring Framework's transaction infrastructure:

```
public void resolvePosition() {
    try {
        // some business logic...
    } catch (NoProductInStockException ex) {
        // trigger rollback programmatically
        TransactionAspectSupport.currentTransactionStatus().setRollbackOnly();
    }
}
```

You are strongly encouraged to use the declarative approach to rollback if at all possible. Programmatic rollback is available should you absolutely need it, but its usage flies in the face of achieving a clean POJO-based architecture.

Configuring different transactional semantics for different beans

Consider the scenario where you have a number of service layer objects, and you want to apply a *totally different* transactional configuration to each of them. You do this by defining distinct `<aop:advisor/>` elements with differing `pointcut` and `advice-ref` attribute values.

As a point of comparison, first assume that all of your service layer classes are defined in a root `x.y.service` package. To make all beans that are instances of classes defined in that package (or in subpackages) and that have names ending in `Service` have the default transactional configuration, you would write the following:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <aop:config>

        <aop:pointcut id="serviceOperation"
                expression="execution(* x.y.service..Service.(..))"/>

        <aop:advisor pointcut-ref="serviceOperation" advice-ref="txAdvice"/>

    </aop:config>

    <!-- these two beans will be transactional... -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>
    <bean id="barService" class="x.y.service.extras.SimpleBarService"/>

    <!-- ... and these two beans won't -->
    <bean id="anotherService" class="org.xyz.SomeService"/> <!-- (not in the right package) -->
    <bean id="barManager" class="x.y.service.SimpleBarManager"/> <!-- (doesn't end in Service) -->

    <tx:advice id="txAdvice">
        <tx:attributes>
            <tx:method name="get*" read-only="true"/>
            <tx:method name="*"/>
        </tx:attributes>
    </tx:advice>

    <!-- other transaction infrastructure beans such as a PlatformTransactionManager omitted... -->

</beans>
```

The following example shows how to configure two distinct beans with totally different transactional settings.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <aop:config>

        <aop:pointcut id="defaultServiceOperation"
                expression="execution(* x.y.service.Service.(..))"/>

        <aop:pointcut id="noTxServiceOperation"
                expression="execution(* x.y.service.ddl.DefaultDdlManager.(..))"/>

        <aop:advisor pointcut-ref="defaultServiceOperation" advice-ref="defaultTxAdvice"/>

        <aop:advisor pointcut-ref="noTxServiceOperation" advice-ref="noTxAdvice"/>

    </aop:config>

    <!-- this bean will be transactional (see the defaultServiceOperation pointcut) -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- this bean will also be transactional, but with totally different transactional settings -->
    <bean id="anotherFooService" class="x.y.service.ddl.DefaultDdlManager"/>

    <tx:advice id="defaultTxAdvice">
        <tx:attributes>
            <tx:method name="get" read-only="true"/>
            <tx:method name=""/>
        </tx:attributes>
    </tx:advice>

    <tx:advice id="noTxAdvice">
        <tx:attributes>
            <tx:method name="" propagation="NEVER"/>
        </tx:attributes>
    </tx:advice>

    <!-- other transaction infrastructure beans such as a PlatformTransactionManager omitted... -->

</beans>
```

<tx:advice/> settings

This section summarizes the various transactional settings that can be specified using the `<tx:advice/>` tag. The default `<tx:advice/>` settings are:

- Propagation setting is `REQUIRED`.
- Isolation level is `DEFAULT`.
- Transaction is read/write.
- Transaction timeout defaults to the default timeout of the underlying transaction system, or none if timeouts are not supported.
- Any `RuntimeException` triggers rollback, and any checked `Exception` does not.

You can change these default settings; the various attributes of the `<tx:method/>` tags that are nested within `<tx:advice/>` and `<tx:attributes/>` tags are summarized below:

Table 12.1. <tx:method/> settings

Attribute	Required?	Default	Description
`name`	Yes		Method name(s) with which the transaction attributes are to be associated. The wildcard (*) character can be used to associate the same transaction attribute settings with a number of methods; for example, `get*`, `handle*`, `on*Event`, and so forth.
`propagation`	No	REQUIRED	Transaction propagation behavior.
`isolation`	No	DEFAULT	Transaction isolation level.
`timeout`	No	-1	Transaction timeout value (in seconds).
`read-only`	No	false	Is this transaction read-only?
`rollback-for`	No		`Exception(s)` that trigger rollback; comma-delimited. For example, `com.foo.MyBusinessException,Se`
`no-rollback-for`	No		`Exception(s)` that do *not* trigger rollback; comma-delimited. For example, `com.foo.MyBusinessException,Se`

Using @Transactional

In addition to the XML-based declarative approach to transaction configuration, you can use an annotation-based approach. Declaring transaction semantics directly in the Java source code puts the declarations much closer to the affected code. There is not much danger of undue coupling, because code that is meant to be used transactionally is almost always deployed that way anyway.

The ease-of-use afforded by the use of the `@Transactional` annotation is best illustrated with an example, which is explained in the text that follows. Consider the following class definition:

```
// the service class that we want to make transactional
@Transactional
public class DefaultFooService implements FooService {

    Foo getFoo(String fooName);

    Foo getFoo(String fooName, String barName);

    void insertFoo(Foo foo);

    void updateFoo(Foo foo);
}
```

When the above POJO is defined as a bean in a Spring IoC container, the bean instance can be made transactional by adding merely *one* line of XML configuration:

```
<!-- from the file context.xml -->
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- this is the service object that we want to make transactional -->
    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- enable the configuration of transactional behavior based on annotations -->
    <tx:annotation-driven transaction-manager="txManager"/><!-- a PlatformTransactionManager is still
 required -->
    <bean id="txManager" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        <!-- (this dependency is defined somewhere else) -->
        <property name="dataSource" ref="dataSource"/>
    </bean>

    <!-- other <bean/> definitions here -->

</beans>
```

Tip

You can omit the `transaction-manager` attribute in the `<tx:annotation-driven/>` tag if the bean name of the `PlatformTransactionManager` that you want to wire in has the name `transactionManager`. If the `PlatformTransactionManager` bean that you want to dependency-inject has any other name, then you have to use the `transaction-manager` attribute explicitly, as in the preceding example.

Note

The `@EnableTransactionManagement` annotation provides equivalent support if you are using Java based configuration. Simply add the annotation to a `@Configuration` class. See the javadocs for full details.

Method visibility and @Transactional

When using proxies, you should apply the `@Transactional` annotation only to methods with *public* visibility. If you do annotate protected, private or package-visible methods with the `@Transactional` annotation, no error is raised, but the annotated method does not exhibit the configured transactional settings. Consider the use of AspectJ (see below) if you need to annotate non-public methods.

You can place the `@Transactional` annotation before an interface definition, a method on an interface, a class definition, or a *public* method on a class. However, the mere presence of the `@Transactional` annotation is not enough to activate the transactional behavior. The `@Transactional` annotation is simply metadata that can be consumed by some runtime infrastructure that is `@Transactional`-aware and that can use the metadata to configure the appropriate beans with transactional behavior. In the preceding example, the `<tx:annotation-driven/>` element *switches on* the transactional behavior.

Tip

Spring recommends that you only annotate concrete classes (and methods of concrete classes) with the `@Transactional` annotation, as opposed to annotating interfaces. You certainly can place the `@Transactional` annotation on an interface (or an interface method), but this works only as you would expect it to if you are using interface-based proxies. The fact that Java annotations are *not inherited from interfaces* means that if you are using class-based proxies (`proxy-target-class="true"`) or the weaving-based aspect (`mode="aspectj"`), then the transaction settings are not recognized by the proxying and weaving infrastructure, and the object will not be wrapped in a transactional proxy, which would be decidedly *bad*.

Note

In proxy mode (which is the default), only external method calls coming in through the proxy are intercepted. This means that self-invocation, in effect, a method within the target object calling another method of the target object, will not lead to an actual transaction at runtime even if the invoked method is marked with `@Transactional`.

Consider the use of AspectJ mode (see mode attribute in table below) if you expect self-invocations to be wrapped with transactions as well. In this case, there will not be a proxy in the first place; instead, the target class will be weaved (that is, its byte code will be modified) in order to turn `@Transactional` into runtime behavior on any kind of method.

Table 12.2. Annotation driven transaction settings

XML Attribute	Annotation Attribute	Default	Description
`transaction-manager`	N/A (See `TransactionManagementConfigurer` javadocs)	transactionManager	Name of transaction manager to use. Only required if the name of the transaction manager is not `transactionManager`, as in the example above.

XML Attribute	Annotation Attribute	Default	Description
`mode`	`mode`	proxy	The default mode "proxy" processes annotated beans to be proxied using Spring's AOP framework (following proxy semantics, as discussed above, applying to method calls coming in through the proxy only). The alternative mode "aspectj" instead weaves the affected classes with Spring's AspectJ transaction aspect, modifying the target class byte code to apply to any kind of method call. AspectJ weaving requires spring-aspects.jar in the classpath as well as load-time weaving (or compile-time weaving) enabled. (See the section called "Spring configuration" for details on how to set up load-time weaving.)
`proxy-target-class`	`proxyTargetClass`	false	Applies to proxy mode only. Controls what type of transactional proxies are created for classes annotated with the `@Transactional` annotation. If the `proxy-target-class` attribute is set to `true`, then class-based proxies are created. If `proxy-target-class` is `false` or if the attribute is omitted, then standard JDK

XML Attribute	Annotation Attribute	Default	Description
			interface-based proxies are created. (See Section 9.6, “Proxying mechanisms” for a detailed examination of the different proxy types.)
`order`	`order`	Ordered.LOWEST_PRECEDENCE	Defines the order of the transaction advice that is applied to beans annotated with `@Transactional`. (For more information about the rules related to ordering of AOP advice, see the section called “Advice ordering”.) No specified ordering means that the AOP subsystem determines the order of the advice.

Note

The `proxy-target-class` attribute controls what type of transactional proxies are created for classes annotated with the `@Transactional` annotation. If `proxy-target-class` is set to `true`, class-based proxies are created. If `proxy-target-class` is `false` or if the attribute is omitted, standard JDK interface-based proxies are created. (See Section 9.6, “Proxying mechanisms” for a discussion of the different proxy types.)

Note

`@EnableTransactionManagement` and `<tx:annotation-driven/>` only looks for `@Transactional` on beans in the same application context they are defined in. This means that, if you put annotation driven configuration in a `WebApplicationContext` for a `DispatcherServlet`, it only checks for `@Transactional` beans in your controllers, and not your services. See Section 17.2, “The DispatcherServlet” for more information.

The most derived location takes precedence when evaluating the transactional settings for a method. In the case of the following example, the `DefaultFooService` class is annotated at the class level with the settings for a read-only transaction, but the `@Transactional` annotation on the `updateFoo(Foo)` method in the same class takes precedence over the transactional settings defined at the class level.

```
@Transactional(readOnly = true)
public class DefaultFooService implements FooService {

    public Foo getFoo(String fooName) {
        // do something
    }

    // these settings have precedence for this method
    @Transactional(readOnly = false, propagation = Propagation.REQUIRES_NEW)
    public void updateFoo(Foo foo) {
        // do something
    }
}
```

@Transactional settings

The `@Transactional` annotation is metadata that specifies that an interface, class, or method must have transactional semantics; for example, "*start a brand new read-only transaction when this method is invoked, suspending any existing transaction*". The default `@Transactional` settings are as follows:

- Propagation setting is `PROPAGATION_REQUIRED.`
- Isolation level is `ISOLATION_DEFAULT.`
- Transaction is read/write.
- Transaction timeout defaults to the default timeout of the underlying transaction system, or to none if timeouts are not supported.
- Any `RuntimeException` triggers rollback, and any checked `Exception` does not.

These default settings can be changed; the various properties of the `@Transactional` annotation are summarized in the following table:

Table 12.3. @

Property	Type	Description
value	String	Optional qualifier specifying the transaction manager to be used.
propagation	enum: `Propagation`	Optional propagation setting.
`isolation`	enum: `Isolation`	Optional isolation level.
`readOnly`	boolean	Read/write vs. read-only transaction
`timeout`	int (in seconds granularity)	Transaction timeout.
`rollbackFor`	Array of `Class` objects, which must be derived from `Throwable.`	Optional array of exception classes that *must* cause rollback.
`rollbackForClassName`	Array of class names. Classes must be derived from `Throwable.`	Optional array of names of exception classes that *must* cause rollback.

Property	Type	Description
`noRollbackFor`	Array of `Class` objects, which must be derived from `Throwable`.	Optional array of exception classes that *must not* cause rollback.
`noRollbackForClassName`	Array of `String` class names, which must be derived from `Throwable`.	Optional array of names of exception classes that *must not* cause rollback.

Currently you cannot have explicit control over the name of a transaction, where *name* means the transaction name that will be shown in a transaction monitor, if applicable (for example, WebLogic's transaction monitor), and in logging output. For declarative transactions, the transaction name is always the fully-qualified class name + "." + method name of the transactionally-advised class. For example, if the `handlePayment(..)` method of the `BusinessService` class started a transaction, the name of the transaction would be: `com.foo.BusinessService.handlePayment`.

Multiple Transaction Managers with @Transactional

Most Spring applications only need a single transaction manager, but there may be situations where you want multiple independent transaction managers in a single application. The value attribute of the `@Transactional` annotation can be used to optionally specify the identity of the `PlatformTransactionManager` to be used. This can either be the bean name or the qualifier value of the transaction manager bean. For example, using the qualifier notation, the following Java code

```
public class TransactionalService {

    @Transactional("order")
    public void setSomething(String name) { ... }

    @Transactional("account")
    public void doSomething() { ... }
}
```

could be combined with the following transaction manager bean declarations in the application context.

```
<tx:annotation-driven/>


  <bean id="transactionManager1" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        ...
        <qualifier value="order"/>
    </bean>


  <bean id="transactionManager2" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        ...
        <qualifier value="account"/>
    </bean>
```

In this case, the two methods on `TransactionalService` will run under separate transaction managers, differentiated by the "order" and "account" qualifiers. The default `<tx:annotation-driven>` target bean name `transactionManager` will still be used if no specifically qualified PlatformTransactionManager bean is found.

Custom shortcut annotations

If you find you are repeatedly using the same attributes with `@Transactional` on many different methods, then Spring's meta-annotation support allows you to define custom shortcut annotations for your specific use cases. For example, defining the following annotations

```
@Target({ElementType.METHOD, ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Transactional("order")
public @interface OrderTx {
}

@Target({ElementType.METHOD, ElementType.TYPE})
@Retention(RetentionPolicy.RUNTIME)
@Transactional("account")
public @interface AccountTx {
}
```

allows us to write the example from the previous section as

```
public class TransactionalService {

    @OrderTx
    public void setSomething(String name) { ... }

    @AccountTx
    public void doSomething() { ... }
}
```

Here we have used the syntax to define the transaction manager qualifier, but could also have included propagation behavior, rollback rules, timeouts etc.

Transaction propagation

This section describes some semantics of transaction propagation in Spring. Please note that this section is not an introduction to transaction propagation proper; rather it details some of the semantics regarding transaction propagation in Spring.

In Spring-managed transactions, be aware of the difference between *physical* and *logical* transactions, and how the propagation setting applies to this difference.

Required

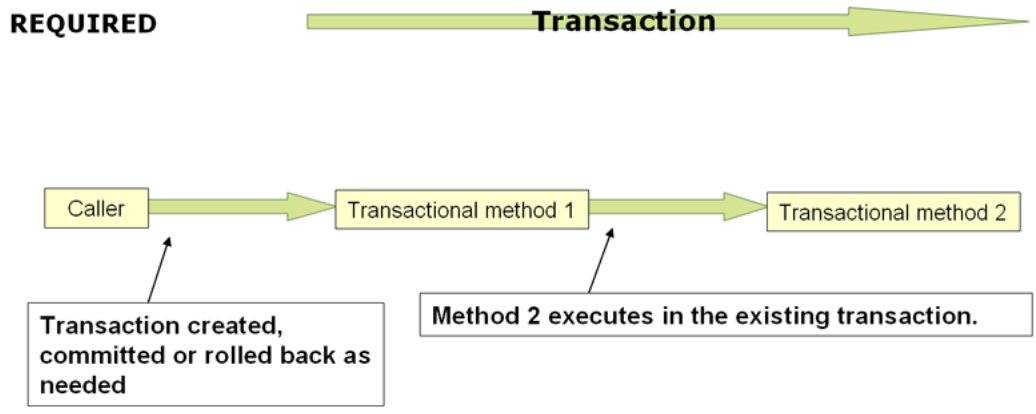


Figure 12.2.

PROPAGATION_REQUIRED

When the propagation setting is `PROPAGATION_REQUIRED`, a *logical* transaction scope is created for each method upon which the setting is applied. Each such logical transaction scope can determine rollback-only status individually, with an outer transaction scope being logically independent from the inner transaction scope. Of course, in case of standard `PROPAGATION_REQUIRED` behavior, all these scopes will be mapped to the same physical transaction. So a rollback-only marker set in the inner transaction scope does affect the outer transaction's chance to actually commit (as you would expect it to).

However, in the case where an inner transaction scope sets the rollback-only marker, the outer transaction has not decided on the rollback itself, and so the rollback (silently triggered by the inner transaction scope) is unexpected. A corresponding `UnexpectedRollbackException` is thrown at that point. This is *expected behavior* so that the caller of a transaction can never be misled to assume that a commit was performed when it really was not. So if an inner transaction (of which the outer caller is not aware) silently marks a transaction as rollback-only, the outer caller still calls commit. The outer caller needs to receive an `UnexpectedRollbackException` to indicate clearly that a rollback was performed instead.

RequiresNew

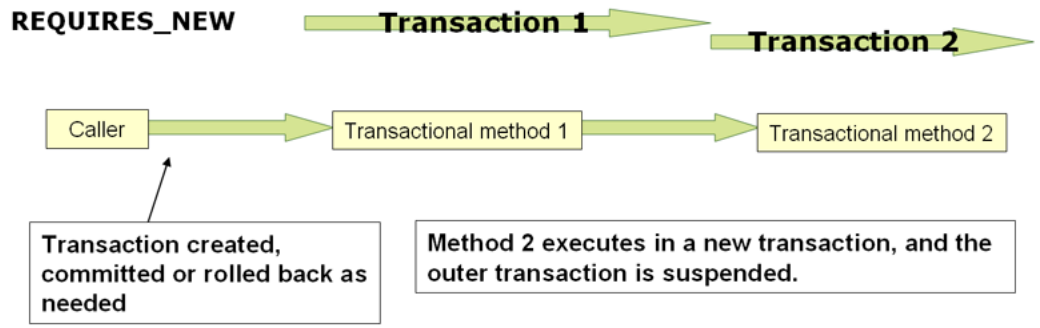


Figure 12.3.

PROPAGATION_REQUIRES_NEW

`PROPAGATION_REQUIRES_NEW`, in contrast to `PROPAGATION_REQUIRED`, uses a *completely* independent transaction for each affected transaction scope. In that case, the underlying physical transactions are different and hence can commit or roll back independently, with an outer transaction not affected by an inner transaction's rollback status.

Nested

`PROPAGATION_NESTED` uses a *single* physical transaction with multiple savepoints that it can roll back to. Such partial rollbacks allow an inner transaction scope to trigger a rollback *for its scope*, with the outer transaction being able to continue the physical transaction despite some operations having been rolled back. This setting is typically mapped onto JDBC savepoints, so will only work with JDBC resource transactions. See Spring's `DataSourceTransactionManager`.

Advising transactional operations

Suppose you want to execute *both* transactional *and* some basic profiling advice. How do you effect this in the context of `<tx:annotation-driven/>`?

When you invoke the `updateFoo(Foo)` method, you want to see the following actions:

- Configured profiling aspect starts up.
- Transactional advice executes.
- Method on the advised object executes.
- Transaction commits.
- Profiling aspect reports exact duration of the whole transactional method invocation.

> **Note**
>
> This chapter is not concerned with explaining AOP in any great detail (except as it applies to transactions). See Chapter 9, *Aspect Oriented Programming with Spring* for detailed coverage of the following AOP configuration and AOP in general.

Here is the code for a simple profiling aspect discussed above. The ordering of advice is controlled through the `Ordered` interface. For full details on advice ordering, see the section called “Advice ordering”. .

```
package x.y;

import org.aspectj.lang.ProceedingJoinPoint;
import org.springframework.util.StopWatch;
import org.springframework.core.Ordered;

public class SimpleProfiler implements Ordered {

    private int order;

    // allows us to control the ordering of advice
    public int getOrder() {
        return this.order;
    }

    public void setOrder(int order) {
        this.order = order;
    }

    // this method is the around advice
    public Object profile(ProceedingJoinPoint call) throws Throwable {
        Object returnValue;
        StopWatch clock = new StopWatch(getClass().getName());
        try {
            clock.start(call.toShortString());
            returnValue = call.proceed();
        } finally {
            clock.stop();
            System.out.println(clock.prettyPrint());
        }
        return returnValue;
    }
}
```

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- this is the aspect -->
    <bean id="profiler" class="x.y.SimpleProfiler">
        <!-- execute before the transactional advice (hence the lower order number) -->
        <property name="order" value="1"/>
    </bean>

    <tx:annotation-driven transaction-manager="txManager" order="200"/>

    <aop:config>
            <!-- this advice will execute around the transactional advice -->
            <aop:aspect id="profilingAspect" ref="profiler">
                <aop:pointcut id="serviceMethodWithReturnValue"
                        expression="execution(!void x.y..Service.(..))"/>
                <aop:around method="profile" pointcut-ref="serviceMethodWithReturnValue"/>
            </aop:aspect>
    </aop:config>

    <bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
        <property name="driverClassName" value="oracle.jdbc.driver.OracleDriver"/>
        <property name="url" value="jdbc:oracle:thin:@rj-t42:1521:elvis"/>
        <property name="username" value="scott"/>
        <property name="password" value="tiger"/>
    </bean>

    <bean id="txManager" class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        <property name="dataSource" ref="dataSource"/>
    </bean>

</beans>
```

The result of the above configuration is a `fooService` bean that has profiling and transactional aspects applied to it *in the desired order*. You configure any number of additional aspects in similar fashion.

The following example effects the same setup as above, but uses the purely XML declarative approach.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean id="fooService" class="x.y.service.DefaultFooService"/>

    <!-- the profiling advice -->
    <bean id="profiler" class="x.y.SimpleProfiler">
        <!-- execute before the transactional advice (hence the lower order number) -->
        <property name="order" value="1"/>
    </bean>

    <aop:config>
        <aop:pointcut id="entryPointMethod" expression="execution(* x.y..Service.(..))"/>
        <!-- will execute after the profiling advice (c.f. the order attribute) -->

        <aop:advisor advice-ref="txAdvice" pointcut-ref="entryPointMethod" order="2"/>
        <!-- order value is higher than the profiling aspect -->

        <aop:aspect id="profilingAspect" ref="profiler">
            <aop:pointcut id="serviceMethodWithReturnValue"
                    expression="execution(!void x.y..Service.(..))"/>
            <aop:around method="profile" pointcut-ref="serviceMethodWithReturnValue"/>
        </aop:aspect>

    </aop:config>

    <tx:advice id="txAdvice" transaction-manager="txManager">
        <tx:attributes>
            <tx:method name="get*" read-only="true"/>
            <tx:method name="*"/>
        </tx:attributes>
    </tx:advice>

    <!-- other <bean/> definitions such as a DataSource and a PlatformTransactionManager here -->

</beans>
```

The result of the above configuration will be a `fooService` bean that has profiling and transactional aspects applied to it *in that order*. If you want the profiling advice to execute *after* the transactional advice on the way in, and *before* the transactional advice on the way out, then you simply swap the value of the profiling aspect bean's `order` property so that it is higher than the transactional advice's order value.

You configure additional aspects in similar fashion.

Using @Transactional with AspectJ

It is also possible to use the Spring Framework's `@Transactional` support outside of a Spring container by means of an AspectJ aspect. To do so, you first annotate your classes (and optionally your classes' methods) with the `@Transactional` annotation, and then you link (weave) your application with the `org.springframework.transaction.aspectj.AnnotationTransactionAspect` defined in the `spring-aspects.jar` file. The aspect must also be configured with a transaction manager. You can of course use the Spring Framework's IoC container to take care of dependency-injecting the aspect. The simplest way to configure the transaction management aspect is to use the `<tx:annotation-driven/>` element and specify the `mode` attribute to `aspectj` as described in the

section called “Using @Transactional”. Because we’re focusing here on applications running outside of a Spring container, we’ll show you how to do it programmatically.

> **Note**
>
> Prior to continuing, you may want to read the section called “Using @Transactional” and Chapter 9, *Aspect Oriented Programming with Spring* respectively.

```
// construct an appropriate transaction manager
DataSourceTransactionManager txManager = new DataSourceTransactionManager(getDataSource());

// configure the AnnotationTransactionAspect to use it; this must be done before executing any
 transactional methods
AnnotationTransactionAspect.aspectOf().setTransactionManager(txManager);
```

> **Note**
>
> When using this aspect, you must annotate the *implementation* class (and/or methods within that class), *not* the interface (if any) that the class implements. AspectJ follows Java’s rule that annotations on interfaces are *not inherited*.

The `@Transactional` annotation on a class specifies the default transaction semantics for the execution of any method in the class.

The `@Transactional` annotation on a method within the class overrides the default transaction semantics given by the class annotation (if present). Any method may be annotated, regardless of visibility.

To weave your applications with the `AnnotationTransactionAspect` you must either build your application with AspectJ (see the AspectJ Development Guide) or use load-time weaving. See the section called “Load-time weaving with AspectJ in the Spring Framework” for a discussion of load-time weaving with AspectJ.

12.6 Programmatic transaction management

The Spring Framework provides two means of programmatic transaction management:

- Using the `TransactionTemplate`.
- Using a `PlatformTransactionManager` implementation directly.

The Spring team generally recommends the `TransactionTemplate` for programmatic transaction management. The second approach is similar to using the JTA `UserTransaction` API, although exception handling is less cumbersome.

Using the TransactionTemplate

The `TransactionTemplate` adopts the same approach as other Spring *templates* such as the `JdbcTemplate`. It uses a callback approach, to free application code from having to do the boilerplate acquisition and release of transactional resources, and results in code that is intention driven, in that the code that is written focuses solely on what the developer wants to do.

> **Note**
>
> As you will see in the examples that follow, using the `TransactionTemplate` absolutely couples you to Spring's transaction infrastructure and APIs. Whether or not programmatic transaction management is suitable for your development needs is a decision that you will have to make yourself.

Application code that must execute in a transactional context, and that will use the `TransactionTemplate` explicitly, looks like the following. You, as an application developer, write a `TransactionCallback` implementation (typically expressed as an anonymous inner class) that contains the code that you need to execute in the context of a transaction. You then pass an instance of your custom `TransactionCallback` to the `execute(..)` method exposed on the `TransactionTemplate`.

```
public class SimpleService implements Service {

    // single TransactionTemplate shared amongst all methods in this instance
    private final TransactionTemplate transactionTemplate;

    // use constructor-injection to supply the PlatformTransactionManager
    public SimpleService(PlatformTransactionManager transactionManager) {
        Assert.notNull(transactionManager, "The 'transactionManager' argument must not be null.");
        this.transactionTemplate = new TransactionTemplate(transactionManager);
    }

    public Object someServiceMethod() {
        return transactionTemplate.execute(new TransactionCallback() {
            // the code in this method executes in a transactional context
            public Object doInTransaction(TransactionStatus status) {
                updateOperation1();
                return resultOfUpdateOperation2();
            }
        });
    }
}
```

If there is no return value, use the convenient `TransactionCallbackWithoutResult` class with an anonymous class as follows:

```
transactionTemplate.execute(new TransactionCallbackWithoutResult() {
    protected void doInTransactionWithoutResult(TransactionStatus status) {
        updateOperation1();
        updateOperation2();
    }
});
```

Code within the callback can roll the transaction back by calling the `setRollbackOnly()` method on the supplied `TransactionStatus` object:

```
transactionTemplate.execute(new TransactionCallbackWithoutResult() {

    protected void doInTransactionWithoutResult(TransactionStatus status) {
        try {
            updateOperation1();
            updateOperation2();
        } catch (SomeBusinessExeption ex) {
            status.setRollbackOnly();
        }
    }
});
```

Specifying transaction settings

You can specify transaction settings such as the propagation mode, the isolation level, the timeout, and so forth on the `TransactionTemplate` either programmatically or in configuration. `TransactionTemplate` instances by default have the default transactional settings. The following example shows the programmatic customization of the transactional settings for a specific `TransactionTemplate`:

```
public class SimpleService implements Service {

    private final TransactionTemplate transactionTemplate;

    public SimpleService(PlatformTransactionManager transactionManager) {
        Assert.notNull(transactionManager, "The 'transactionManager' argument must not be null.");
        this.transactionTemplate = new TransactionTemplate(transactionManager);

        // the transaction settings can be set here explicitly if so desired
        this.transactionTemplate.setIsolationLevel(TransactionDefinition.ISOLATION_READ_UNCOMMITTED);
        this.transactionTemplate.setTimeout(30); // 30 seconds
        // and so forth...
    }
}
```

The following example defines a `TransactionTemplate` with some custom transactional settings, using Spring XML configuration. The `sharedTransactionTemplate` can then be injected into as many services as are required.

```
<bean id="sharedTransactionTemplate"
        class="org.springframework.transaction.support.TransactionTemplate">
    <property name="isolationLevelName" value="ISOLATION_READ_UNCOMMITTED"/>
    <property name="timeout" value="30"/>
</bean>"
```

Finally, instances of the `TransactionTemplate` class are threadsafe, in that instances do not maintain any conversational state. `TransactionTemplate` instances *do* however maintain configuration state, so while a number of classes may share a single instance of a `TransactionTemplate`, if a class needs to use a `TransactionTemplate` with different settings (for example, a different isolation level), then you need to create two distinct `TransactionTemplate` instances.

Using the PlatformTransactionManager

You can also use the `org.springframework.transaction.PlatformTransactionManager` directly to manage your transaction. Simply pass the implementation of the `PlatformTransactionManager` you are using to your bean through a bean reference. Then, using the `TransactionDefinition` and `TransactionStatus` objects you can initiate transactions, roll back, and commit.

```
DefaultTransactionDefinition def = new DefaultTransactionDefinition();
// explicitly setting the transaction name is something that can only be done programmatically
def.setName("SomeTxName");
def.setPropagationBehavior(TransactionDefinition.PROPAGATION_REQUIRED);

TransactionStatus status = txManager.getTransaction(def);
try {
    // execute your business logic here
}
catch (MyException ex) {
    txManager.rollback(status);
    throw ex;
}
txManager.commit(status);
```

12.7 Choosing between programmatic and declarative transaction management

Programmatic transaction management is usually a good idea only if you have a small number of transactional operations. For example, if you have a web application that require transactions only for certain update operations, you may not want to set up transactional proxies using Spring or any other technology. In this case, using the `TransactionTemplate` *may* be a good approach. Being able to set the transaction name explicitly is also something that can only be done using the programmatic approach to transaction management.

On the other hand, if your application has numerous transactional operations, declarative transaction management is usually worthwhile. It keeps transaction management out of business logic, and is not difficult to configure. When using the Spring Framework, rather than EJB CMT, the configuration cost of declarative transaction management is greatly reduced.

12.8 Application server-specific integration

Spring's transaction abstraction generally is application server agnostic. Additionally, Spring's `JtaTransactionManager` class, which can optionally perform a JNDI lookup for the JTA `UserTransaction` and `TransactionManager` objects, autodetects the location for the latter object, which varies by application server. Having access to the JTA `TransactionManager` allows for enhanced transaction semantics, in particular supporting transaction suspension. See the `JtaTransactionManager` javadocs for details.

Spring's `JtaTransactionManager` is the standard choice to run on Java EE application servers, and is known to work on all common servers. Advanced functionality such as transaction suspension works on many servers as well — including GlassFish, JBoss and Geronimo — without any special configuration required. However, for fully supported transaction suspension and further advanced integration, Spring ships special adapters for WebLogic Server and WebSphere. These adapters are discussed in the following sections.

For standard scenarios, including WebLogic Server and WebSphere, consider using the convenient `<tx:jta-transaction-manager/>` configuration element. When configured, this element automatically detects the underlying server and chooses the best transaction manager available for the platform. This means that you won't have to configure server-specific adapter classes (as discussed in the following sections) explicitly; rather, they are chosen automatically, with the standard `JtaTransactionManager` as default fallback.

IBM WebSphere

On WebSphere 6.1.0.9 and above, the recommended Spring JTA transaction manager to use is `WebSphereUowTransactionManager`. This special adapter leverages IBM's `UOWManager` API, which is available in WebSphere Application Server 6.0.2.19 and later and 6.1.0.9 and later. With this adapter, Spring-driven transaction suspension (suspend/resume as initiated by `PROPAGATION_REQUIRES_NEW`) is officially supported by IBM!

Oracle WebLogic Server

On WebLogic Server 9.0 or above, you typically would use the `WebLogicJtaTransactionManager` instead of the stock `JtaTransactionManager` class. This special WebLogic-specific subclass of the normal `JtaTransactionManager` supports the full power of Spring's transaction definitions in

a WebLogic-managed transaction environment, beyond standard JTA semantics: Features include transaction names, per-transaction isolation levels, and proper resuming of transactions in all cases.

12.9 Solutions to common problems

Use of the wrong transaction manager for a specific DataSource

Use the *correct* `PlatformTransactionManager` implementation based on your choice of transactional technologies and requirements. Used properly, the Spring Framework merely provides a straightforward and portable abstraction. If you are using global transactions, you *must* use the `org.springframework.transaction.jta.JtaTransactionManager` class (or an application server-specific subclass of it) for all your transactional operations. Otherwise the transaction infrastructure attempts to perform local transactions on resources such as container `DataSource` instances. Such local transactions do not make sense, and a good application server treats them as errors.

12.10 Further Resources

For more information about the Spring Framework's transaction support:

- Distributed transactions in Spring, with and without XA is a JavaWorld presentation in which Spring's David Syer guides you through seven patterns for distributed transactions in Spring applications, three of them with XA and four without.
- Java Transaction Design Strategies is a book available from InfoQ that provides a well-paced introduction to transactions in Java. It also includes side-by-side examples of how to configure and use transactions with both the Spring Framework and EJB3.

13. DAO support

13.1 Introduction

The Data Access Object (DAO) support in Spring is aimed at making it easy to work with data access technologies like JDBC, Hibernate, JPA or JDO in a consistent way. This allows one to switch between the aforementioned persistence technologies fairly easily and it also allows one to code without worrying about catching exceptions that are specific to each technology.

13.2 Consistent exception hierarchy

Spring provides a convenient translation from technology-specific exceptions like `SQLException` to its own exception class hierarchy with the `DataAccessException` as the root exception. These exceptions wrap the original exception so there is never any risk that one might lose any information as to what might have gone wrong.

In addition to JDBC exceptions, Spring can also wrap Hibernate-specific exceptions, converting them from proprietary, checked exceptions (in the case of versions of Hibernate prior to Hibernate 3.0), to a set of focused runtime exceptions (the same is true for JDO and JPA exceptions). This allows one to handle most persistence exceptions, which are non-recoverable, only in the appropriate layers, without having annoying boilerplate catch-and-throw blocks and exception declarations in one's DAOs. (One can still trap and handle exceptions anywhere one needs to though.) As mentioned above, JDBC exceptions (including database-specific dialects) are also converted to the same hierarchy, meaning that one can perform some operations with JDBC within a consistent programming model.

The above holds true for the various template classes in Springs support for various ORM frameworks. If one uses the interceptor-based classes then the application must care about handling `HibernateExceptions` and `JDOExceptions` itself, preferably via delegating to `SessionFactoryUtils`' `convertHibernateAccessException(..)` or `convertJdoAccessException()` methods respectively. These methods convert the exceptions to ones that are compatible with the exceptions in the `org.springframework.dao` exception hierarchy. As `JDOExceptions` are unchecked, they can simply get thrown too, sacrificing generic DAO abstraction in terms of exceptions though.

The exception hierarchy that Spring provides can be seen below. (Please note that the class hierarchy detailed in the image shows only a subset of the entire `DataAccessException` hierarchy.)

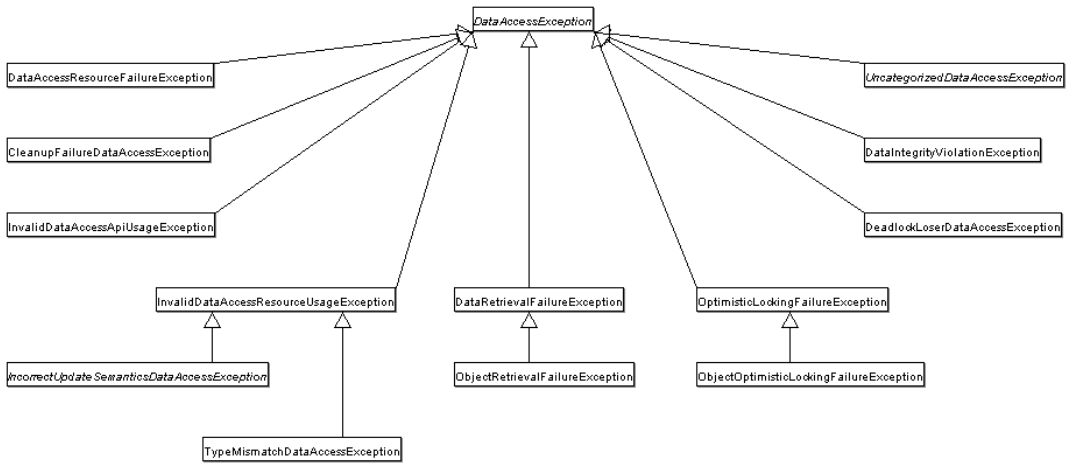


Figure 13.1.

13.3 Annotations used for configuring DAO or Repository classes

The best way to guarantee that your Data Access Objects (DAOs) or repositories provide exception translation is to use the `@Repository` annotation. This annotation also allows the component scanning support to find and configure your DAOs and repositories without having to provide XML configuration entries for them.

```
@Repository
public class SomeMovieFinder implements MovieFinder {
    // ...
}
```

Any DAO or repository implementation will need to access to a persistence resource, depending on the persistence technology used; for example, a JDBC-based repository will need access to a JDBC `DataSource`; a JPA-based repository will need access to an `EntityManager`. The easiest way to accomplish this is to have this resource dependency injected using one of the `@Autowired,`, `@Inject`, `@Resource` or `@PersistenceContext` annotations. Here is an example for a JPA repository:

```
@Repository
public class JpaMovieFinder implements MovieFinder {

    @PersistenceContext
    private EntityManager entityManager;

    // ...

}
```

If you are using the classic Hibernate APIs than you can inject the SessionFactory:

```
@Repository
public class HibernateMovieFinder implements MovieFinder {

    private SessionFactory sessionFactory;

    @Autowired
    public void setSessionFactory(SessionFactory sessionFactory) {
        this.sessionFactory = sessionFactory;
    }

    // ...

}
```

Last example we will show here is for typical JDBC support. You would have the `DataSource` injected into an initialization method where you would create a `JdbcTemplate` and other data access support classes like `SimpleJdbcCall` etc using this `DataSource`.

```
@Repository
public class JdbcMovieFinder implements MovieFinder {

    private JdbcTemplate jdbcTemplate;

    @Autowired
    public void init(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    // ...

}
```

Note

Please see the specific coverage of each persistence technology for details on how to configure the application context to take advantage of these annotations.

14. Data access with JDBC

14.1 Introduction to Spring Framework JDBC

The value-add provided by the Spring Framework JDBC abstraction is perhaps best shown by the sequence of actions outlined in the table below. The table shows what actions Spring will take care of and which actions are the responsibility of you, the application developer.

Table 14.1. Spring JDBC - who does what?

Action	Spring	You
Define connection parameters.		X
Open the connection.	X	
Specify the SQL statement.		X
Declare parameters and provide parameter values		X
Prepare and execute the statement.	X	
Set up the loop to iterate through the results (if any).	X	
Do the work for each iteration.		X
Process any exception.	X	
Handle transactions.	X	
Close the connection, statement and resultset.	X	

The Spring Framework takes care of all the low-level details that can make JDBC such a tedious API to develop with.

Choosing an approach for JDBC database access

You can choose among several approaches to form the basis for your JDBC database access. In addition to three flavors of the JdbcTemplate, a new SimpleJdbcInsert and SimplejdbcCall approach optimizes database metadata, and the RDBMS Object style takes a more object-oriented approach similar to that of JDO Query design. Once you start using one of these approaches, you can still mix and match to include a feature from a different approach. All approaches require a JDBC 2.0-compliant driver, and some advanced features require a JDBC 3.0 driver.

- *JdbcTemplate* is the classic Spring JDBC approach and the most popular. This "lowest level" approach and all others use a JdbcTemplate under the covers.
- *NamedParameterJdbcTemplate* wraps a `JdbcTemplate` to provide named parameters instead of the traditional JDBC "?" placeholders. This approach provides better documentation and ease of use when you have multiple parameters for an SQL statement.

- *SimpleJdbcInsert and SimpleJdbcCall* optimize database metadata to limit the amount of necessary configuration. This approach simplifies coding so that you only need to provide the name of the table or procedure and provide a map of parameters matching the column names. This only works if the database provides adequate metadata. If the database doesn't provide this metadata, you will have to provide explicit configuration of the parameters.

- *RDBMS Objects including MappingSqlQuery, SqlUpdate and StoredProcedure* requires you to create reusable and thread-safe objects during initialization of your data access layer. This approach is modeled after JDO Query wherein you define your query string, declare parameters, and compile the query. Once you do that, execute methods can be called multiple times with various parameter values passed in.

Package hierarchy

The Spring Framework's JDBC abstraction framework consists of four different packages, namely `core`, `datasource`, `object`, and `support`.

The `org.springframework.jdbc.core` package contains the `JdbcTemplate` class and its various callback interfaces, plus a variety of related classes. A subpackage named `org.springframework.jdbc.core.simple` contains the `SimpleJdbcInsert` and `SimpleJdbcCall` classes. Another subpackage named `org.springframework.jdbc.core.namedparam` contains the `NamedParameterJdbcTemplate` class and the related support classes. See Section 14.2, "Using the JDBC core classes to control basic JDBC processing and error handling", Section 14.4, "JDBC batch operations", and Section 14.5, "Simplifying JDBC operations with the SimpleJdbc classes"

The `org.springframework.jdbc.datasource` package contains a utility class for easy `DataSource` access, and various simple `DataSource` implementations that can be used for testing and running unmodified JDBC code outside of a Java EE container. A subpackage named `org.springfamework.jdbc.datasource.embedded` provides support for creating in-memory database instances using Java database engines such as HSQL and H2. See Section 14.3, "Controlling database connections" and Section 14.8, "Embedded database support"

The `org.springframework.jdbc.object` package contains classes that represent RDBMS queries, updates, and stored procedures as thread safe, reusable objects. See Section 14.6, "Modeling JDBC operations as Java objects".This approach is modeled by JDO, although of course objects returned by queries are "disconnected" from the database. This higher level of JDBC abstraction depends on the lower-level abstraction in the `org.springframework.jdbc.core` package.

The `org.springframework.jdbc.support` package provides `SQLException` translation functionality and some utility classes. Exceptions thrown during JDBC processing are translated to exceptions defined in the `org.springframework.dao` package. This means that code using the Spring JDBC abstraction layer does not need to implement JDBC or RDBMS-specific error handling. All translated exceptions are unchecked, which gives you the option of catching the exceptions from which you can recover while allowing other exceptions to be propagated to the caller. See the section called "SQLExceptionTranslator".

14.2 Using the JDBC core classes to control basic JDBC processing and error handling

JdbcTemplate

The `JdbcTemplate` class is the central class in the JDBC core package. It handles the creation and release of resources, which helps you avoid common errors such as forgetting to close the connection. It performs the basic tasks of the core JDBC workflow such as statement creation and execution, leaving application code to provide SQL and extract results. The `JdbcTemplate` class executes SQL queries, update statements and stored procedure calls, performs iteration over `ResultSets` and extraction of returned parameter values. It also catches JDBC exceptions and translates them to the generic, more informative, exception hierarchy defined in the `org.springframework.dao` package.

When you use the `JdbcTemplate` for your code, you only need to implement callback interfaces, giving them a clearly defined contract. The `PreparedStatementCreator` callback interface creates a prepared statement given a `Connection` provided by this class, providing SQL and any necessary parameters. The same is true for the `CallableStatementCreator` interface, which creates callable statements. The `RowCallbackHandler` interface extracts values from each row of a `ResultSet`.

The `JdbcTemplate` can be used within a DAO implementation through direct instantiation with a `DataSource` reference, or be configured in a Spring IoC container and given to DAOs as a bean reference.

> **Note**
>
> The `DataSource` should always be configured as a bean in the Spring IoC container. In the first case the bean is given to the service directly; in the second case it is given to the prepared template.

All SQL issued by this class is logged at the `DEBUG` level under the category corresponding to the fully qualified class name of the template instance (typically `JdbcTemplate`, but it may be different if you are using a custom subclass of the `JdbcTemplate` class).

Examples of JdbcTemplate class usage

This section provides some examples of `JdbcTemplate` class usage. These examples are not an exhaustive list of all of the functionality exposed by the `JdbcTemplate`; see the attendant javadocs for that.

Querying (SELECT)

Here is a simple query for getting the number of rows in a relation:

```
int rowCount = this.jdbcTemplate.queryForObject("select count(*) from t_actor", Integer.class);
```

A simple query using a bind variable:

```
int countOfActorsNamedJoe = this.jdbcTemplate.queryForObject(
        "select count(*) from t_actor where first_name = ?", Integer.class, "Joe");
```

Querying for a `String`:

```
String lastName = this.jdbcTemplate.queryForObject(
        "select last_name from t_actor where id = ?",
        new Object[]{1212L}, String.class);
```

Querying and populating a *single* domain object:

```
Actor actor = this.jdbcTemplate.queryForObject(
        "select first_name, last_name from t_actor where id = ?",
        new Object[]{1212L},
        new RowMapper<Actor>() {
            public Actor mapRow(ResultSet rs, int rowNum) throws SQLException {
                Actor actor = new Actor();
                actor.setFirstName(rs.getString("first_name"));
                actor.setLastName(rs.getString("last_name"));
                return actor;
            }
        });
```

Querying and populating a number of domain objects:

```
List<Actor> actors = this.jdbcTemplate.query(
        "select first_name, last_name from t_actor",
        new RowMapper<Actor>() {
            public Actor mapRow(ResultSet rs, int rowNum) throws SQLException {
                Actor actor = new Actor();
                actor.setFirstName(rs.getString("first_name"));
                actor.setLastName(rs.getString("last_name"));
                return actor;
            }
        });
```

If the last two snippets of code actually existed in the same application, it would make sense to remove the duplication present in the two `RowMapper` anonymous inner classes, and extract them out into a single class (typically a `static` inner class) that can then be referenced by DAO methods as needed. For example, it may be better to write the last code snippet as follows:

```
public List<Actor> findAllActors() {
    return this.jdbcTemplate.query( "select first_name, last_name from t_actor", new ActorMapper());
}

private static final class ActorMapper implements RowMapper<Actor> {

    public Actor mapRow(ResultSet rs, int rowNum) throws SQLException {
        Actor actor = new Actor();
        actor.setFirstName(rs.getString("first_name"));
        actor.setLastName(rs.getString("last_name"));
        return actor;
    }
}
```

Updating (INSERT/UPDATE/DELETE) with jdbcTemplate

You use the `update(..)` method to perform insert, update and delete operations. Parameter values are usually provided as var args or alternatively as an object array.

```
this.jdbcTemplate.update(
        "insert into t_actor (first_name, last_name) values (?, ?)",
        "Leonor", "Watling");
```

```
this.jdbcTemplate.update(
        "update t_actor set last_name = ? where id = ?",
        "Banjo", 5276L);
```

```
this.jdbcTemplate.update(
        "delete from actor where id = ?",
        Long.valueOf(actorId));
```

Other jdbcTemplate operations

You can use the `execute(..)` method to execute any arbitrary SQL, and as such the method is often used for DDL statements. It is heavily overloaded with variants taking callback interfaces, binding variable arrays, and so on.

```
this.jdbcTemplate.execute("create table mytable (id integer, name varchar(100))");
```

The following example invokes a simple stored procedure. More sophisticated stored procedure support is covered later.

```
this.jdbcTemplate.update(
        "call SUPPORT.REFRESH_ACTORS_SUMMARY(?)",
        Long.valueOf(unionId));
```

JdbcTemplate best practices

Instances of the `JdbcTemplate` class are *threadsafe once configured*. This is important because it means that you can configure a single instance of a `JdbcTemplate` and then safely inject this *shared* reference into multiple DAOs (or repositories). The `JdbcTemplate` is stateful, in that it maintains a reference to a `DataSource`, but this state is *not* conversational state.

A common practice when using the `JdbcTemplate` class (and the associated `NamedParameterJdbcTemplate` classes) is to configure a `DataSource` in your Spring configuration file, and then dependency-inject that shared `DataSource` bean into your DAO classes; the `JdbcTemplate` is created in the setter for the `DataSource`. This leads to DAOs that look in part like the following:

```
public class JdbcCorporateEventDao implements CorporateEventDao {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    // JDBC-backed implementations of the methods on the CorporateEventDao follow...
}
```

The corresponding configuration might look like this.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <bean id="corporateEventDao" class="com.example.JdbcCorporateEventDao">
        <property name="dataSource" ref="dataSource"/>
    </bean>

    <bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
        <property name="driverClassName" value="${jdbc.driverClassName}"/>
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>

    <context:property-placeholder location="jdbc.properties"/>

</beans>
```

An alternative to explicit configuration is to use component-scanning and annotation support for dependency injection. In this case you annotate the class with `@Repository` (which makes it a candidate for component-scanning) and annotate the `DataSource` setter method with `@Autowired`.

```
@Repository
public class JdbcCorporateEventDao implements CorporateEventDao {

    private JdbcTemplate jdbcTemplate;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    // JDBC-backed implementations of the methods on the CorporateEventDao follow...
}
```

The corresponding XML configuration file would look like the following:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <!-- Scans within the base package of the application for @Component classes to configure as beans
 -->
    <context:component-scan base-package="org.springframework.docs.test" />

    <bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
        <property name="driverClassName" value="${jdbc.driverClassName}"/>
        <property name="url" value="${jdbc.url}"/>
        <property name="username" value="${jdbc.username}"/>
        <property name="password" value="${jdbc.password}"/>
    </bean>

    <context:property-placeholder location="jdbc.properties"/>

</beans>
```

If you are using Spring's `JdbcDaoSupport` class, and your various JDBC-backed DAO classes extend from it, then your sub-class inherits a `setDataSource(..)` method from the `JdbcDaoSupport` class. You can choose whether to inherit from this class. The `JdbcDaoSupport` class is provided as a convenience only.

Regardless of which of the above template initialization styles you choose to use (or not), it is seldom necessary to create a new instance of a `JdbcTemplate` class each time you want to execute SQL. Once configured, a `JdbcTemplate` instance is threadsafe. You may want multiple `JdbcTemplate` instances if your application accesses multiple databases, which requires multiple `DataSources`, and subsequently multiple differently configured `JdbcTemplates`.

NamedParameterJdbcTemplate

The `NamedParameterJdbcTemplate` class adds support for programming JDBC statements using named parameters, as opposed to programming JDBC statements using only classic placeholder (`'?'`) arguments. The `NamedParameterJdbcTemplate` class wraps a `JdbcTemplate`, and delegates to the wrapped `JdbcTemplate` to do much of its work. This section describes only those areas of the `NamedParameterJdbcTemplate` class that differ from the `JdbcTemplate` itself; namely, programming JDBC statements using named parameters.

```
// some JDBC-backed DAO class...
private NamedParameterJdbcTemplate namedParameterJdbcTemplate;

public void setDataSource(DataSource dataSource) {
    this.namedParameterJdbcTemplate = new NamedParameterJdbcTemplate(dataSource);
}

public int countOfActorsByFirstName(String firstName) {

    String sql = "select count(*) from T_ACTOR where first_name = :first_name";

    SqlParameterSource namedParameters = new MapSqlParameterSource("first_name", firstName);

    return this.namedParameterJdbcTemplate.queryForObject(sql, namedParameters, Integer.class);
}
```

Notice the use of the named parameter notation in the value assigned to the `sql` variable, and the corresponding value that is plugged into the `namedParameters` variable (of type `MapSqlParameterSource`).

Alternatively, you can pass along named parameters and their corresponding values to a `NamedParameterJdbcTemplate` instance by using the `Map`-based style.The remaining methods exposed by the `NamedParameterJdbcOperations` and implemented by the `NamedParameterJdbcTemplate` class follow a similar pattern and are not covered here.

The following example shows the use of the `Map`-based style.

```
// some JDBC-backed DAO class...
private NamedParameterJdbcTemplate namedParameterJdbcTemplate;

public void setDataSource(DataSource dataSource) {
    this.namedParameterJdbcTemplate = new NamedParameterJdbcTemplate(dataSource);
}

public int countOfActorsByFirstName(String firstName) {

    String sql = "select count(*) from T_ACTOR where first_name = :first_name";

    Map<String, String> namedParameters = Collections.singletonMap("first_name", firstName);

    return this.namedParameterJdbcTemplate.queryForObject(sql, namedParameters,  Integer.class);
}
```

One nice feature related to the `NamedParameterJdbcTemplate` (and existing in the same Java package) is the `SqlParameterSource` interface. You have already seen an example of an implementation of this interface in one of the previous code snippet (the `MapSqlParameterSource` class). An `SqlParameterSource` is a source of named parameter values to a `NamedParameterJdbcTemplate`. The `MapSqlParameterSource` class is a very simple implementation that is simply an adapter around a `java.util.Map`, where the keys are the parameter names and the values are the parameter values.

Another `SqlParameterSource` implementation is the `BeanPropertySqlParameterSource` class. This class wraps an arbitrary JavaBean (that is, an instance of a class that adheres to the JavaBean conventions), and uses the properties of the wrapped JavaBean as the source of named parameter values.

```
public class Actor {

    private Long id;
    private String firstName;
    private String lastName;

    public String getFirstName() {
        return this.firstName;
    }

    public String getLastName() {
        return this.lastName;
    }

    public Long getId() {
        return this.id;
    }

    // setters omitted...

}
```

```
// some JDBC-backed DAO class...
private NamedParameterJdbcTemplate namedParameterJdbcTemplate;

public void setDataSource(DataSource dataSource) {
    this.namedParameterJdbcTemplate = new NamedParameterJdbcTemplate(dataSource);
}

public int countOfActors(Actor exampleActor) {

    // notice how the named parameters match the properties of the above Actor class
    String sql = "select count(*) from T_ACTOR where first_name = :firstName and last_name = :lastName";

    SqlParameterSource namedParameters = new BeanPropertySqlParameterSource(exampleActor);

    return this.namedParameterJdbcTemplate.queryForObject(sql, namedParameters, Integer.class);
}
```

Remember that the `NamedParameterJdbcTemplate` class *wraps* a classic `JdbcTemplate` template; if you need access to the wrapped `JdbcTemplate` instance to access functionality only present in the `JdbcTemplate` class, you can use the `getJdbcOperations()` method to access the wrapped `JdbcTemplate` through the `JdbcOperations` interface.

See also the section called “JdbcTemplate best practices” for guidelines on using the `NamedParameterJdbcTemplate` class in the context of an application.

SQLExceptionTranslator

`SQLExceptionTranslator` is an interface to be implemented by classes that can translate between `SQLExceptions` and Spring's own `org.springframework.dao.DataAccessException`, which is agnostic in regard to data access strategy. Implementations can be generic (for example, using SQLState codes for JDBC) or proprietary (for example, using Oracle error codes) for greater precision.

`SQLErrorCodeSQLExceptionTranslator` is the implementation of `SQLExceptionTranslator` that is used by default. This implementation uses specific vendor codes. It is more precise than the `SQLState` implementation. The error code translations are based on codes held in a JavaBean type class called `SQLErrorCodes`. This class is created and populated by an `SQLErrorCodesFactory` which as the name suggests is a factory for creating `SQLErrorCodes` based on the contents of a configuration file named `sql-error-codes.xml`. This file is populated with vendor codes and based on the `DatabaseProductName` taken from the `DatabaseMetaData`. The codes for the actual database you are using are used.

The `SQLErrorCodeSQLExceptionTranslator` applies matching rules in the following sequence:

> **Note**
>
> The `SQLErrorCodesFactory` is used by default to define Error codes and custom exception translations. They are looked up in a file named `sql-error-codes.xml` from the classpath and the matching `SQLErrorCodes` instance is located based on the database name from the database metadata of the database in use.

- Any custom translation implemented by a subclass. Normally the provided concrete `SQLErrorCodeSQLExceptionTranslator` is used so this rule does not apply. It only applies if you have actually provided a subclass implementation.
- Any custom implementation of the `SQLExceptionTranslator` interface that is provided as the `customSqlExceptionTranslator` property of the `SQLErrorCodes` class.

- The list of instances of the `CustomSQLErrorCodesTranslation` class, provided for the `customTranslations` property of the `SQLErrorCodes` class, are searched for a match.
- Error code matching is applied.
- Use the fallback translator. `SQLExceptionSubclassTranslator` is the default fallback translator. If this translation is not available then the next fallback translator is the `SQLStateSQLExceptionTranslator`.

You can extend `SQLErrorCodeSQLExceptionTranslator:`

```
public class CustomSQLErrorCodesTranslator extends SQLErrorCodeSQLExceptionTranslator {

    protected DataAccessException customTranslate(String task, String sql, SQLException sqlex) {
        if (sqlex.getErrorCode() == -12345) {
            return new DeadlockLoserDataAccessException(task, sqlex);
        }
        return null;
    }
}
```

In this example, the specific error code `-12345` is translated and other errors are left to be translated by the default translator implementation. To use this custom translator, it is necessary to pass it to the `JdbcTemplate` through the method `setExceptionTranslator` and to use this `JdbcTemplate` for all of the data access processing where this translator is needed. Here is an example of how this custom translator can be used:

```
private JdbcTemplate jdbcTemplate;

public void setDataSource(DataSource dataSource) {

    // create a JdbcTemplate and set data source
    this.jdbcTemplate = new JdbcTemplate();
    this.jdbcTemplate.setDataSource(dataSource);

    // create a custom translator and set the DataSource for the default translation lookup
    CustomSQLErrorCodesTranslator tr = new CustomSQLErrorCodesTranslator();
    tr.setDataSource(dataSource);
    this.jdbcTemplate.setExceptionTranslator(tr);

}

public void updateShippingCharge(long orderId, long pct) {
    // use the prepared JdbcTemplate for this update
    this.jdbcTemplate.update("update orders" +
        " set shipping_charge = shipping_charge * ? / 100" +
        " where id = ?", pct, orderId);
}
```

The custom translator is passed a data source in order to look up the error codes in `sql-error-codes.xml`.

Executing statements

Executing an SQL statement requires very little code. You need a `DataSource` and a `JdbcTemplate`, including the convenience methods that are provided with the `JdbcTemplate`. The following example shows what you need to include for a minimal but fully functional class that creates a new table:

```
import javax.sql.DataSource;
import org.springframework.jdbc.core.JdbcTemplate;

public class ExecuteAStatement {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public void doExecute() {
        this.jdbcTemplate.execute("create table mytable (id integer, name varchar(100))");
    }
}
```

Running queries

Some query methods return a single value. To retrieve a count or a specific value from one row, use `queryForObject(..)`. The latter converts the returned JDBC `Type` to the Java class that is passed in as an argument. If the type conversion is invalid, then an `InvalidDataAccessApiUsageException` is thrown. Here is an example that contains two query methods, one for an `int` and one that queries for a `String`.

```
import javax.sql.DataSource;
import org.springframework.jdbc.core.JdbcTemplate;

public class RunAQuery {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public int getCount() {
        return this.jdbcTemplate.queryForObject("select count(*) from mytable", Integer.class);
    }

    public String getName() {
        return this.jdbcTemplate.queryForObject("select name from mytable", String.class);
    }

    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
    }
}
```

In addition to the single result query methods, several methods return a list with an entry for each row that the query returned. The most generic method is `queryForList(..)` which returns a `List` where each entry is a `Map` with each entry in the map representing the column value for that row. If you add a method to the above example to retrieve a list of all the rows, it would look like this:

```
private JdbcTemplate jdbcTemplate;

public void setDataSource(DataSource dataSource) {
    this.jdbcTemplate = new JdbcTemplate(dataSource);
}

public List<Map<String, Object>> getList() {
    return this.jdbcTemplate.queryForList("select * from mytable");
}
```

The list returned would look something like this:

```
[{name=Bob, id=1}, {name=Mary, id=2}]
```

Updating the database

The following example shows a column updated for a certain primary key. In this example, an SQL statement has placeholders for row parameters. The parameter values can be passed in as varargs or alternatively as an array of objects. Thus primitives should be wrapped in the primitive wrapper classes explicitly or using auto-boxing.

```
import javax.sql.DataSource;

import org.springframework.jdbc.core.JdbcTemplate;

public class ExecuteAnUpdate {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public void setName(int id, String name) {
        this.jdbcTemplate.update("update mytable set name = ? where id = ?", name, id);
    }
}
```

Retrieving auto-generated keys

An `update()` convenience method supports the retrieval of primary keys generated by the database. This support is part of the JDBC 3.0 standard; see Chapter 13.6 of the specification for details. The method takes a `PreparedStatementCreator` as its first argument, and this is the way the required insert statement is specified. The other argument is a `KeyHolder`, which contains the generated key on successful return from the update. There is not a standard single way to create an appropriate `PreparedStatement` (which explains why the method signature is the way it is). The following example works on Oracle but may not work on other platforms:

```
final String INSERT_SQL = "insert into my_test (name) values(?)";
final String name = "Rob";

KeyHolder keyHolder = new GeneratedKeyHolder();
jdbcTemplate.update(
    new PreparedStatementCreator() {
        public PreparedStatement createPreparedStatement(Connection connection) throws SQLException {
            PreparedStatement ps = connection.prepareStatement(INSERT_SQL, new String[] {"id"});
            ps.setString(1, name);
            return ps;
        }
    },
    keyHolder);

// keyHolder.getKey() now contains the generated key
```

14.3 Controlling database connections

DataSource

Spring obtains a connection to the database through a `DataSource`. A `DataSource` is part of the JDBC specification and is a generalized connection factory. It allows a container or a framework to hide connection pooling and transaction management issues from the application code. As a developer, you

need not know details about how to connect to the database; that is the responsibility of the administrator that sets up the datasource. You most likely fill both roles as you develop and test code, but you do not necessarily have to know how the production data source is configured.

When using Spring's JDBC layer, you obtain a data source from JNDI or you configure your own with a connection pool implementation provided by a third party. Popular implementations are Apache Jakarta Commons DBCP and C3P0. Implementations in the Spring distribution are meant only for testing purposes and do not provide pooling.

This section uses Spring's `DriverManagerDataSource` implementation, and several additional implementations are covered later.

> **Note**
>
> Only use the `DriverManagerDataSource` class should only be used for testing purposes since it does not provide pooling and will perform poorly when multiple requests for a connection are made.

You obtain a connection with `DriverManagerDataSource` as you typically obtain a JDBC connection. Specify the fully qualified classname of the JDBC driver so that the `DriverManager` can load the driver class. Next, provide a URL that varies between JDBC drivers. (Consult the documentation for your driver for the correct value.) Then provide a username and a password to connect to the database. Here is an example of how to configure a `DriverManagerDataSource` in Java code:

```
DriverManagerDataSource dataSource = new DriverManagerDataSource();
dataSource.setDriverClassName("org.hsqldb.jdbcDriver");
dataSource.setUrl("jdbc:hsqldb:hsql://localhost:");
dataSource.setUsername("sa");
dataSource.setPassword("");
```

Here is the corresponding XML configuration:

```
<bean id="dataSource" class="org.springframework.jdbc.datasource.DriverManagerDataSource">
    <property name="driverClassName" value="${jdbc.driverClassName}"/>
    <property name="url" value="${jdbc.url}"/>
    <property name="username" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
</bean>

<context:property-placeholder location="jdbc.properties"/>
```

The following examples show the basic connectivity and configuration for DBCP and C3P0. To learn about more options that help control the pooling features, see the product documentation for the respective connection pooling implementations.

DBCP configuration:

```
<bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
    <property name="driverClassName" value="${jdbc.driverClassName}"/>
    <property name="url" value="${jdbc.url}"/>
    <property name="username" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
</bean>

<context:property-placeholder location="jdbc.properties"/>
```

C3P0 configuration:

```
<bean id="dataSource" class="com.mchange.v2.c3p0.ComboPooledDataSource" destroy-method="close">
    <property name="driverClass" value="${jdbc.driverClassName}"/>
    <property name="jdbcUrl" value="${jdbc.url}"/>
    <property name="user" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
</bean>

<context:property-placeholder location="jdbc.properties"/>
```

DataSourceUtils

The `DataSourceUtils` class is a convenient and powerful helper class that provides `static` methods to obtain connections from JNDI and close connections if necessary. It supports thread-bound connections with, for example, `DataSourceTransactionManager`.

SmartDataSource

The `SmartDataSource` interface should be implemented by classes that can provide a connection to a relational database. It extends the `DataSource` interface to allow classes using it to query whether the connection should be closed after a given operation. This usage is efficient when you know that you will reuse a connection.

AbstractDataSource

`AbstractDataSource` is an `abstract` base class for Spring's `DataSource` implementations that implements code that is common to all `DataSource` implementations. You extend the `AbstractDataSource` class if you are writing your own `DataSource` implementation.

SingleConnectionDataSource

The `SingleConnectionDataSource` class is an implementation of the `SmartDataSource` interface that wraps a *single* `Connection` that is *not* closed after each use. Obviously, this is not multi-threading capable.

If any client code calls `close` in the assumption of a pooled connection, as when using persistence tools, set the `suppressClose` property to `true`. This setting returns a close-suppressing proxy wrapping the physical connection. Be aware that you will not be able to cast this to a native Oracle `Connection` or the like anymore.

This is primarily a test class. For example, it enables easy testing of code outside an application server, in conjunction with a simple JNDI environment. In contrast to `DriverManagerDataSource`, it reuses the same connection all the time, avoiding excessive creation of physical connections.

DriverManagerDataSource

The `DriverManagerDataSource` class is an implementation of the standard `DataSource` interface that configures a plain JDBC driver through bean properties, and returns a new `Connection` every time.

This implementation is useful for test and stand-alone environments outside of a Java EE container, either as a `DataSource` bean in a Spring IoC container, or in conjunction with a simple JNDI environment. Pool-assuming `Connection.close()` calls will simply close the connection, so any `DataSource`-aware persistence code should work. However, using JavaBean-style connection pools such as `commons-dbcp` is so easy, even in a test environment, that it is almost always preferable to use such a connection pool over `DriverManagerDataSource`.

TransactionAwareDataSourceProxy

`TransactionAwareDataSourceProxy` is a proxy for a target `DataSource`, which wraps that target `DataSource` to add awareness of Spring-managed transactions. In this respect, it is similar to a transactional JNDI `DataSource` as provided by a Java EE server.

> **Note**
>
> It is rarely desirable to use this class, except when already existing code that must be called and passed a standard JDBC `DataSource` interface implementation. In this case, it's possible to still have this code be usable, and at the same time have this code participating in Spring managed transactions. It is generally preferable to write your own new code using the higher level abstractions for resource management, such as `JdbcTemplate` or `DataSourceUtils`.

(See the `TransactionAwareDataSourceProxy` javadocs for more details.)

DataSourceTransactionManager

The `DataSourceTransactionManager` class is a `PlatformTransactionManager` implementation for single JDBC datasources. It binds a JDBC connection from the specified data source to the currently executing thread, potentially allowing for one thread connection per data source.

Application code is required to retrieve the JDBC connection through `DataSourceUtils.getConnection(DataSource)` instead of Java EE's standard `DataSource.getConnection`. It throws unchecked `org.springframework.dao` exceptions instead of checked `SQLExceptions`. All framework classes like `JdbcTemplate` use this strategy implicitly. If not used with this transaction manager, the lookup strategy behaves exactly like the common one - it can thus be used in any case.

The `DataSourceTransactionManager` class supports custom isolation levels, and timeouts that get applied as appropriate JDBC statement query timeouts. To support the latter, application code must either use `JdbcTemplate` or call the `DataSourceUtils.applyTransactionTimeout(..)` method for each created statement.

This implementation can be used instead of `JtaTransactionManager` in the single resource case, as it does not require the container to support JTA. Switching between both is just a matter of configuration, if you stick to the required connection lookup pattern. JTA does not support custom isolation levels!

NativeJdbcExtractor

Sometimes you need to access vendor specific JDBC methods that differ from the standard JDBC API. This can be problematic if you are running in an application server or with a `DataSource` that wraps the `Connection`, `Statement` and `ResultSet` objects with its own wrapper objects. To gain access to the native objects you can configure your `JdbcTemplate` or `OracleLobHandler` with a `NativeJdbcExtractor`.

The `NativeJdbcExtractor` comes in a variety of flavors to match your execution environment:

- SimpleNativeJdbcExtractor
- C3P0NativeJdbcExtractor

- CommonsDbcpNativeJdbcExtractor
- JBossNativeJdbcExtractor
- WebLogicNativeJdbcExtractor
- WebSphereNativeJdbcExtractor
- XAPoolNativeJdbcExtractor

Usually the `SimpleNativeJdbcExtractor` is sufficient for unwrapping a `Connection` object in most environments. See the javadocs for more details.

14.4 JDBC batch operations

Most JDBC drivers provide improved performance if you batch multiple calls to the same prepared statement. By grouping updates into batches you limit the number of round trips to the database.

Basic batch operations with the JdbcTemplate

You accomplish `JdbcTemplate` batch processing by implementing two methods of a special interface, `BatchPreparedStatementSetter`, and passing that in as the second parameter in your `batchUpdate` method call. Use the `getBatchSize` method to provide the size of the current batch. Use the `setValues` method to set the values for the parameters of the prepared statement. This method will be called the number of times that you specified in the `getBatchSize` call. The following example updates the actor table based on entries in a list. The entire list is used as the batch in this example:

```
public class JdbcActorDao implements ActorDao {
    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public int[] batchUpdate(final List<Actor> actors) {
        int[] updateCounts = jdbcTemplate.batchUpdate("update t_actor set first_name = ?, " +
                "last_name = ? where id = ?",
            new BatchPreparedStatementSetter() {
                public void setValues(PreparedStatement ps, int i) throws SQLException {
                        ps.setString(1, actors.get(i).getFirstName());
                        ps.setString(2, actors.get(i).getLastName());
                        ps.setLong(3, actors.get(i).getId().longValue());
                    }

                    public int getBatchSize() {
                        return actors.size();
                    }
                });
        return updateCounts;
    }

    // ... additional methods
}
```

If you are processing a stream of updates or reading from a file, then you might have a preferred batch size, but the last batch might not have that number of entries. In this case you can use the `InterruptibleBatchPreparedStatementSetter` interface, which allows you to interrupt a batch once the input source is exhausted. The `isBatchExhausted` method allows you to signal the end of the batch.

Batch operations with a List of objects

Both the `JdbcTemplate` and the `NamedParameterJdbcTemplate` provides an alternate way of providing the batch update. Instead of implementing a special batch interface, you provide all parameter values in the call as a list. The framework loops over these values and uses an internal prepared statement setter. The API varies depending on whether you use named parameters. For the named parameters you provide an array of `SqlParameterSource`, one entry for each member of the batch. You can use the `SqlParameterSource.createBatch` method to create this array, passing in either an array of JavaBeans or an array of Maps containing the parameter values.

This example shows a batch update using named parameters:

```
public class JdbcActorDao implements ActorDao {
    private NamedParameterTemplate namedParameterJdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.namedParameterJdbcTemplate = new NamedParameterJdbcTemplate(dataSource);
    }

    public int[] batchUpdate(final List<Actor> actors) {
        SqlParameterSource[] batch = SqlParameterSourceUtils.createBatch(actors.toArray());
        int[] updateCounts = namedParameterJdbcTemplate.batchUpdate(
                "update t_actor set first_name = :firstName, last_name = :lastName where id = :id",
                batch);
        return updateCounts;
    }

    // ... additional methods
}
```

For an SQL statement using the classic "?" placeholders, you pass in a list containing an object array with the update values. This object array must have one entry for each placeholder in the SQL statement, and they must be in the same order as they are defined in the SQL statement.

The same example using classic JDBC "?" placeholders:

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public int[] batchUpdate(final List<Actor> actors) {
        List<Object[]> batch = new ArrayList<Object[]>();
        for (Actor actor : actors) {
            Object[] values = new Object[] {
                    actor.getFirstName(),
                    actor.getLastName(),
                    actor.getId()};
            batch.add(values);
        }
        int[] updateCounts = jdbcTemplate.batchUpdate(
                "update t_actor set first_name = ?, last_name = ? where id = ?",
                batch);
        return updateCounts;
    }

    // ... additional methods

}
```

All of the above batch update methods return an int array containing the number of affected rows for each batch entry. This count is reported by the JDBC driver. If the count is not available, the JDBC driver returns a -2 value.

Batch operations with multiple batches

The last example of a batch update deals with batches that are so large that you want to break them up into several smaller batches. You can of course do this with the methods mentioned above by making multiple calls to the `batchUpdate` method, but there is now a more convenient method. This method takes, in addition to the SQL statement, a Collection of objects containing the parameters, the number of updates to make for each batch and a `ParameterizedPreparedStatementSetter` to set the values for the parameters of the prepared statement. The framework loops over the provided values and breaks the update calls into batches of the size specified.

This example shows a batch update using a batch size of 100:

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
    }

    public int[][] batchUpdate(final Collection<Actor> actors) {
        int[][] updateCounts = jdbcTemplate.batchUpdate(
                "update t_actor set first_name = ?, last_name = ? where id = ?",
                actors,
                100,
                new ParameterizedPreparedStatementSetter<Actor>() {
                    public void setValues(PreparedStatement ps, Actor argument) throws SQLException {
                        ps.setString(1, argument.getFirstName());
                        ps.setString(2, argument.getLastName());
                        ps.setLong(3, argument.getId().longValue());
                    }
                });
        return updateCounts;
    }

    // ... additional methods

}
```

The batch update methods for this call returns an array of int arrays containing an array entry for each batch with an array of the number of affected rows for each update. The top level array's length indicates the number of batches executed and the second level array's length indicates the number of updates in that batch. The number of updates in each batch should be the the batch size provided for all batches except for the last one that might be less, depending on the total number of update objects provided. The update count for each update statement is the one reported by the JDBC driver. If the count is not available, the JDBC driver returns a -2 value.

14.5 Simplifying JDBC operations with the SimpleJdbc classes

The `SimpleJdbcInsert` and `SimpleJdbcCall` classes provide a simplified configuration by taking advantage of database metadata that can be retrieved through the JDBC driver. This means there is less to configure up front, although you can override or turn off the metadata processing if you prefer to provide all the details in your code.

Inserting data using SimpleJdbcInsert

Let's start by looking at the `SimpleJdbcInsert` class with the minimal amount of configuration options. You should instantiate the `SimpleJdbcInsert` in the data access layer's initialization method. For this example, the initializing method is the `setDataSource` method. You do not need to subclass the `SimpleJdbcInsert` class; simply create a new instance and set the table name using the `withTableName` method. Configuration methods for this class follow the "fluid" style that returns the instance of the `SimpleJdbcInsert`, which allows you to chain all configuration methods. This example uses only one configuration method; you will see examples of multiple ones later.

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcInsert insertActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.insertActor = new SimpleJdbcInsert(dataSource).withTableName("t_actor");
    }

    public void add(Actor actor) {
        Map<String, Object> parameters = new HashMap<String, Object>(3);
        parameters.put("id", actor.getId());
        parameters.put("first_name", actor.getFirstName());
        parameters.put("last_name", actor.getLastName());
        insertActor.execute(parameters);
    }

    // ... additional methods
}
```

The execute method used here takes a plain `java.utils.Map` as its only parameter. The important thing to note here is that the keys used for the Map must match the column names of the table as defined in the database. This is because we read the metadata in order to construct the actual insert statement.

Retrieving auto-generated keys using SimpleJdbcInsert

This example uses the same insert as the preceding, but instead of passing in the id it retrieves the auto-generated key and sets it on the new Actor object. When you create the `SimpleJdbcInsert`, in addition to specifying the table name, you specify the name of the generated key column with the `usingGeneratedKeyColumns` method.

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcInsert insertActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.insertActor = new SimpleJdbcInsert(dataSource)
                .withTableName("t_actor")
                .usingGeneratedKeyColumns("id");
    }

    public void add(Actor actor) {
        Map<String, Object> parameters = new HashMap<String, Object>(2);
        parameters.put("first_name", actor.getFirstName());
        parameters.put("last_name", actor.getLastName());
        Number newId = insertActor.executeAndReturnKey(parameters);
        actor.setId(newId.longValue());
    }

    // ... additional methods
}
```

The main difference when executing the insert by this second approach is that you do not add the id to the Map and you call the `executeReturningKey` method. This returns a `java.lang.Number` object with which you can create an instance of the numerical type that is used in our domain class. You cannot rely on all databases to return a specific Java class here; `java.lang.Number` is the base class that you can rely on. If you have multiple auto-generated columns, or the generated values are non-numeric, then you can use a `KeyHolder` that is returned from the `executeReturningKeyHolder` method.

Specifying columns for a SimpleJdbcInsert

You can limit the columns for an insert by specifying a list of column names with the `usingColumns` method:

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcInsert insertActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.insertActor = new SimpleJdbcInsert(dataSource)
                .withTableName("t_actor")
                .usingColumns("first_name", "last_name")
                .usingGeneratedKeyColumns("id");
    }

    public void add(Actor actor) {
        Map<String, Object> parameters = new HashMap<String, Object>(2);
        parameters.put("first_name", actor.getFirstName());
        parameters.put("last_name", actor.getLastName());
        Number newId = insertActor.executeAndReturnKey(parameters);
        actor.setId(newId.longValue());
    }

    // ... additional methods

}
```

The execution of the insert is the same as if you had relied on the metadata to determine which columns to use.

Using SqlParameterSource to provide parameter values

Using a `Map` to provide parameter values works fine, but it's not the most convenient class to use. Spring provides a couple of implementations of the `SqlParameterSource` interface that can be used instead.The first one is `BeanPropertySqlParameterSource`, which is a very convenient class if you have a JavaBean-compliant class that contains your values. It will use the corresponding getter method to extract the parameter values. Here is an example:

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcInsert insertActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.insertActor = new SimpleJdbcInsert(dataSource)
                .withTableName("t_actor")
                .usingGeneratedKeyColumns("id");
    }

    public void add(Actor actor) {
        SqlParameterSource parameters = new BeanPropertySqlParameterSource(actor);
        Number newId = insertActor.executeAndReturnKey(parameters);
        actor.setId(newId.longValue());
    }

    // ... additional methods

}
```

Another option is the `MapSqlParameterSource` that resembles a Map but provides a more convenient `addValue` method that can be chained.

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcInsert insertActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.insertActor = new SimpleJdbcInsert(dataSource)
                .withTableName("t_actor")
                .usingGeneratedKeyColumns("id");
    }

    public void add(Actor actor) {
        SqlParameterSource parameters = new MapSqlParameterSource()
                .addValue("first_name", actor.getFirstName())
                .addValue("last_name", actor.getLastName());
        Number newId = insertActor.executeAndReturnKey(parameters);
        actor.setId(newId.longValue());
    }

    // ... additional methods

}
```

As you can see, the configuration is the same; only the executing code has to change to use these alternative input classes.

Calling a stored procedure with SimpleJdbcCall

The `SimpleJdbcCall` class leverages metadata in the database to look up names of `in` and `out` parameters, so that you do not have to declare them explicitly. You can declare parameters if you prefer

to do that, or if you have parameters such as ARRAY or STRUCT that do not have an automatic mapping to a Java class. The first example shows a simple procedure that returns only scalar values in VARCHAR and DATE format from a MySQL database. The example procedure reads a specified actor entry and returns `first_name`, `last_name`, and `birth_date` columns in the form of `out` parameters.

```
CREATE PROCEDURE read_actor (
    IN in_id INTEGER,
    OUT out_first_name VARCHAR(100),
    OUT out_last_name VARCHAR(100),
    OUT out_birth_date DATE)
BEGIN
    SELECT first_name, last_name, birth_date
    INTO out_first_name, out_last_name, out_birth_date
    FROM t_actor where id = in_id;
END;
```

The `in_id` parameter contains the `id` of the actor you are looking up. The `out` parameters return the data read from the table.

The `SimpleJdbcCall` is declared in a similar manner to the `SimpleJdbcInsert`. You should instantiate and configure the class in the initialization method of your data access layer. Compared to the StoredProcedure class, you don't have to create a subclass and you don't have to declare parameters that can be looked up in the database metadata. Following is an example of a SimpleJdbcCall configuration using the above stored procedure. The only configuration option, in addition to the `DataSource`, is the name of the stored procedure.

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcCall procReadActor;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        this.procReadActor = new SimpleJdbcCall(dataSource)
                .withProcedureName("read_actor");
    }

    public Actor readActor(Long id) {
        SqlParameterSource in = new MapSqlParameterSource()
                .addValue("in_id", id);
        Map out = procReadActor.execute(in);
        Actor actor = new Actor();
        actor.setId(id);
        actor.setFirstName((String) out.get("out_first_name"));
        actor.setLastName((String) out.get("out_last_name"));
        actor.setBirthDate((Date) out.get("out_birth_date"));
        return actor;
    }

    // ... additional methods

}
```

The code you write for the execution of the call involves creating an `SqlParameterSource` containing the IN parameter. It's important to match the name provided for the input value with that of the parameter name declared in the stored procedure. The case does not have to match because you use metadata to determine how database objects should be referred to in a stored procedure. What is specified in the source for the stored procedure is not necessarily the way it is stored in the database. Some databases transform names to all upper case while others use lower case or use the case as specified.

The `execute` method takes the IN parameters and returns a Map containing any `out` parameters keyed by the name as specified in the stored procedure. In this case they are `out_first_name`, `out_last_name` and `out_birth_date`.

The last part of the `execute` method creates an Actor instance to use to return the data retrieved. Again, it is important to use the names of the `out` parameters as they are declared in the stored procedure. Also, the case in the names of the `out` parameters stored in the results map matches that of the `out` parameter names in the database, which could vary between databases. To make your code more portable you should do a case-insensitive lookup or instruct Spring to use a `CaseInsensitiveMap` from the Jakarta Commons project. To do the latter, you create your own `JdbcTemplate` and set the `setResultsMapCaseInsensitive` property to `true`. Then you pass this customized `JdbcTemplate` instance into the constructor of your `SimpleJdbcCall`. You must include the `commons-collections.jar` in your classpath for this to work. Here is an example of this configuration:

```
public class JdbcActorDao implements ActorDao {

    private SimpleJdbcCall procReadActor;

    public void setDataSource(DataSource dataSource) {
        JdbcTemplate jdbcTemplate = new JdbcTemplate(dataSource);
        jdbcTemplate.setResultsMapCaseInsensitive(true);
        this.procReadActor = new SimpleJdbcCall(jdbcTemplate)
                .withProcedureName("read_actor");
    }

    // ... additional methods

}
```

By taking this action, you avoid conflicts in the case used for the names of your returned `out` parameters.

Explicitly declaring parameters to use for a SimpleJdbcCall

You have seen how the parameters are deduced based on metadata, but you can declare then explicitly if you wish. You do this by creating and configuring `SimpleJdbcCall` with the `declareParameters` method, which takes a variable number of `SqlParameter` objects as input. See the next section for details on how to define an `SqlParameter`.

> **Note**
>
> Explicit declarations are necessary if the database you use is not a Spring-supported database. Currently Spring supports metadata lookup of stored procedure calls for the following databases: Apache Derby, DB2, MySQL, Microsoft SQL Server, Oracle, and Sybase. We also support metadata lookup of stored functions for: MySQL, Microsoft SQL Server, and Oracle.

You can opt to declare one, some, or all the parameters explicitly. The parameter metadata is still used where you do not declare parameters explicitly. To bypass all processing of metadata lookups for potential parameters and only use the declared parameters, you call the method `withoutProcedureColumnMetaDataAccess` as part of the declaration. Suppose that you have two or more different call signatures declared for a database function. In this case you call the `useInParameterNames` to specify the list of IN parameter names to include for a given signature.

The following example shows a fully declared procedure call, using the information from the preceding example.

```
public class JdbcActorDao implements ActorDao {

    private SimpleJdbcCall procReadActor;

    public void setDataSource(DataSource dataSource) {
        JdbcTemplate jdbcTemplate = new JdbcTemplate(dataSource);
        jdbcTemplate.setResultsMapCaseInsensitive(true);
        this.procReadActor = new SimpleJdbcCall(jdbcTemplate)
                .withProcedureName("read_actor")
                .withoutProcedureColumnMetaDataAccess()
                .useInParameterNames("in_id")
                .declareParameters(
                        new SqlParameter("in_id", Types.NUMERIC),
                        new SqlOutParameter("out_first_name", Types.VARCHAR),
                        new SqlOutParameter("out_last_name", Types.VARCHAR),
                        new SqlOutParameter("out_birth_date", Types.DATE)
                );
    }

    // ... additional methods
}
```

The execution and end results of the two examples are the same; this one specifies all details explicitly rather than relying on metadata.

How to define SqlParameters

To define a parameter for the SimpleJdbc classes and also for the RDBMS operations classes, covered in Section 14.6, “Modeling JDBC operations as Java objects”, you use an `SqlParameter` or one of its subclasses. You typically specify the parameter name and SQL type in the constructor. The SQL type is specified using the `java.sql.Types` constants. We have already seen declarations like:

```
new SqlParameter("in_id", Types.NUMERIC),
    new SqlOutParameter("out_first_name", Types.VARCHAR),
```

The first line with the `SqlParameter` declares an IN parameter. IN parameters can be used for both stored procedure calls and for queries using the `SqlQuery` and its subclasses covered in the following section.

The second line with the `SqlOutParameter` declares an `out` parameter to be used in a stored procedure call. There is also an `SqlInOutParameter` for `InOut` parameters, parameters that provide an `IN` value to the procedure and that also return a value.

> **Note**
>
> Only parameters declared as `SqlParameter` and `SqlInOutParameter` will be used to provide input values. This is different from the `StoredProcedure` class, which for backwards compatibility reasons allows input values to be provided for parameters declared as `SqlOutParameter`.

For IN parameters, in addition to the name and the SQL type, you can specify a scale for numeric data or a type name for custom database types. For `out` parameters, you can provide a `RowMapper` to handle mapping of rows returned from a `REF` cursor. Another option is to specify an `SqlReturnType` that provides an opportunity to define customized handling of the return values.

Calling a stored function using SimpleJdbcCall

You call a stored function in almost the same way as you call a stored procedure, except that you provide a function name rather than a procedure name. You use the `withFunctionName` method as

part of the configuration to indicate that we want to make a call to a function, and the corresponding string for a function call is generated. A specialized execute call, `executeFunction`, is used to execute the function and it returns the function return value as an object of a specified type, which means you do not have to retrieve the return value from the results map. A similar convenience method named `executeObject` is also available for stored procedures that only have one `out` parameter. The following example is based on a stored function named `get_actor_name` that returns an actor's full name. Here is the MySQL source for this function:

```
CREATE FUNCTION get_actor_name (in_id INTEGER)
RETURNS VARCHAR(200) READS SQL DATA
BEGIN
    DECLARE out_name VARCHAR(200);
    SELECT concat(first_name, ' ', last_name)
        INTO out_name
        FROM t_actor where id = in_id;
    RETURN out_name;
END;
```

To call this function we again create a `SimpleJdbcCall` in the initialization method.

```
public class JdbcActorDao implements ActorDao {

    private JdbcTemplate jdbcTemplate;
    private SimpleJdbcCall funcGetActorName;

    public void setDataSource(DataSource dataSource) {
        this.jdbcTemplate = new JdbcTemplate(dataSource);
        JdbcTemplate jdbcTemplate = new JdbcTemplate(dataSource);
        jdbcTemplate.setResultsMapCaseInsensitive(true);
        this.funcGetActorName = new SimpleJdbcCall(jdbcTemplate)
                .withFunctionName("get_actor_name");
    }

    public String getActorName(Long id) {
        SqlParameterSource in = new MapSqlParameterSource()
                .addValue("in_id", id);
        String name = funcGetActorName.executeFunction(String.class, in);
        return name;
    }

    // ... additional methods

}
```

The execute method used returns a `String` containing the return value from the function call.

Returning ResultSet/REF Cursor from a SimpleJdbcCall

Calling a stored procedure or function that returns a result set is a bit tricky. Some databases return result sets during the JDBC results processing while others require an explicitly registered `out` parameter of a specific type. Both approaches need additional processing to loop over the result set and process the returned rows. With the `SimpleJdbcCall` you use the `returningResultSet` method and declare a `RowMapper` implementation to be used for a specific parameter. In the case where the result set is returned during the results processing, there are no names defined, so the returned results will have to match the order in which you declare the `RowMapper` implementations. The name specified is still used to store the processed list of results in the results map that is returned from the execute statement.

The next example uses a stored procedure that takes no IN parameters and returns all rows from the t_actor table. Here is the MySQL source for this procedure:

```
CREATE PROCEDURE read_all_actors()
BEGIN
 SELECT a.id, a.first_name, a.last_name, a.birth_date FROM t_actor a;
END;
```

To call this procedure you declare the `RowMapper`. Because the class you want to map to follows the JavaBean rules, you can use a `ParameterizedBeanPropertyRowMapper` that is created by passing in the required class to map to in the `newInstance` method.

```
public class JdbcActorDao implements ActorDao {

    private SimpleJdbcCall procReadAllActors;

    public void setDataSource(DataSource dataSource) {
        JdbcTemplate jdbcTemplate = new JdbcTemplate(dataSource);
        jdbcTemplate.setResultsMapCaseInsensitive(true);
        this.procReadAllActors = new SimpleJdbcCall(jdbcTemplate)
                .withProcedureName("read_all_actors")
                .returningResultSet("actors",
                ParameterizedBeanPropertyRowMapper.newInstance(Actor.class));
    }

    public List getActorsList() {
        Map m = procReadAllActors.execute(new HashMap<String, Object>(0));
        return (List) m.get("actors");
    }

    // ... additional methods

}
```

The execute call passes in an empty Map because this call does not take any parameters. The list of Actors is then retrieved from the results map and returned to the caller.

14.6 Modeling JDBC operations as Java objects

The `org.springframework.jdbc.object` package contains classes that allow you to access the database in a more object-oriented manner. As an example, you can execute queries and get the results back as a list containing business objects with the relational column data mapped to the properties of the business object. You can also execute stored procedures and run update, delete, and insert statements.

> **Note**
>
> Many Spring developers believe that the various RDBMS operation classes described below (with the exception of the `StoredProcedure` class) can often be replaced with straight `JdbcTemplate` calls. Often it is simpler to write a DAO method that simply calls a method on a `JdbcTemplate` directly (as opposed to encapsulating a query as a full-blown class).
>
> However, if you are getting measurable value from using the RDBMS operation classes, continue using these classes.

SqlQuery

`SqlQuery` is a reusable, threadsafe class that encapsulates an SQL query. Subclasses must implement the `newRowMapper(..)` method to provide a `RowMapper` instance that can create one object per row obtained from iterating over the `ResultSet` that is created during the execution of the query. The `SqlQuery` class is rarely used directly because the `MappingSqlQuery` subclass provides a much more convenient implementation for mapping rows to Java classes. Other implementations that extend `SqlQuery` are `MappingSqlQueryWithParameters` and `UpdatableSqlQuery`.

MappingSqlQuery

`MappingSqlQuery` is a reusable query in which concrete subclasses must implement the abstract `mapRow(..)` method to convert each row of the supplied `ResultSet` into an object of the type specified. The following example shows a custom query that maps the data from the `t_actor` relation to an instance of the `Actor` class.

```
public class ActorMappingQuery extends MappingSqlQuery<Actor> {

    public ActorMappingQuery(DataSource ds) {
        super(ds, "select id, first_name, last_name from t_actor where id = ?");
        super.declareParameter(new SqlParameter("id", Types.INTEGER));
        compile();
    }

    @Override
    protected Actor mapRow(ResultSet rs, int rowNumber) throws SQLException {
        Actor actor = new Actor();
        actor.setId(rs.getLong("id"));
        actor.setFirstName(rs.getString("first_name"));
        actor.setLastName(rs.getString("last_name"));
        return actor;
    }

}
```

The class extends `MappingSqlQuery` parameterized with the `Actor` type. The constructor for this customer query takes the `DataSource` as the only parameter. In this constructor you call the constructor on the superclass with the `DataSource` and the SQL that should be executed to retrieve the rows for this query. This SQL will be used to create a `PreparedStatement` so it may contain place holders for any parameters to be passed in during execution.You must declare each parameter using the `declareParameter` method passing in an `SqlParameter`. The `SqlParameter` takes a name and the JDBC type as defined in `java.sql.Types`. After you define all parameters, you call the `compile()` method so the statement can be prepared and later executed. This class is thread-safe after it is compiled, so as long as these instances are created when the DAO is initialized they can be kept as instance variables and be reused.

```
private ActorMappingQuery actorMappingQuery;

@Autowired
public void setDataSource(DataSource dataSource) {
    this.actorMappingQuery = new ActorMappingQuery(dataSource);
}

public Customer getCustomer(Long id) {
    return actorMappingQuery.findObject(id);
}
```

The method in this example retrieves the customer with the id that is passed in as the only parameter. Since we only want one object returned we simply call the convenience method `findObject` with the id as parameter. If we had instead a query that returned a list of objects and took additional parameters then we would use one of the execute methods that takes an array of parameter values passed in as varargs.

```
public List<Actor> searchForActors(int age, String namePattern) {
    List<Actor> actors = actorSearchMappingQuery.execute(age, namePattern);
    return actors;
}
```

SqlUpdate

The `SqlUpdate` class encapsulates an SQL update. Like a query, an update object is reusable, and like all `RdbmsOperation` classes, an update can have parameters and is defined in SQL. This class provides a number of `update(..)` methods analogous to the `execute(..)` methods of query objects. The `SQLUpdate` class is concrete. It can be subclassed, for example, to add a custom update method, as in the following snippet where it's simply called `execute`. However, you don't have to subclass the `SqlUpdate` class since it can easily be parameterized by setting SQL and declaring parameters.

```
import java.sql.Types;

import javax.sql.DataSource;

import org.springframework.jdbc.core.SqlParameter;
import org.springframework.jdbc.object.SqlUpdate;

public class UpdateCreditRating extends SqlUpdate {

    public UpdateCreditRating(DataSource ds) {
        setDataSource(ds);
        setSql("update customer set credit_rating = ? where id = ?");
        declareParameter(new SqlParameter("creditRating", Types.NUMERIC));
        declareParameter(new SqlParameter("id", Types.NUMERIC));
        compile();
    }

    /**
     * @param id for the Customer to be updated
     * @param rating the new value for credit rating
     * @return number of rows updated
     */
    public int execute(int id, int rating) {
        return update(rating, id);
    }
}
```

StoredProcedure

The `StoredProcedure` class is a superclass for object abstractions of RDBMS stored procedures. This class is `abstract`, and its various `execute(..)` methods have `protected` access, preventing use other than through a subclass that offers tighter typing.

The inherited `sql` property will be the name of the stored procedure in the RDBMS.

To define a parameter for the `StoredProcedure` class, you use an `SqlParameter` or one of its subclasses. You must specify the parameter name and SQL type in the constructor like in the following code snippet. The SQL type is specified using the `java.sql.Types` constants.

```
new SqlParameter("in_id", Types.NUMERIC),
    new SqlOutParameter("out_first_name", Types.VARCHAR),
```

The first line with the `SqlParameter` declares an IN parameter. IN parameters can be used for both stored procedure calls and for queries using the `SqlQuery` and its subclasses covered in the following section.

The second line with the `SqlOutParameter` declares an `out` parameter to be used in the stored procedure call. There is also an `SqlInOutParameter` for `I nOut` parameters, parameters that provide an `in` value to the procedure and that also return a value.

For `i n` parameters, in addition to the name and the SQL type, you can specify a scale for numeric data or a type name for custom database types. For `out` parameters you can provide a `RowMapper` to

handle mapping of rows returned from a REF cursor. Another option is to specify an `SqlReturnType` that enables you to define customized handling of the return values.

Here is an example of a simple DAO that uses a `StoredProcedure` to call a function, `sysdate()`,which comes with any Oracle database. To use the stored procedure functionality you have to create a class that extends `StoredProcedure`. In this example, the `StoredProcedure` class is an inner class, but if you need to reuse the `StoredProcedure` you declare it as a top-level class. This example has no input parameters, but an output parameter is declared as a date type using the class `SqlOutParameter`. The `execute()` method executes the procedure and extracts the returned date from the results `Map`. The results `Map` has an entry for each declared output parameter, in this case only one, using the parameter name as the key.

```
import java.sql.Types;
import java.util.Date;
import java.util.HashMap;
import java.util.Map;

import javax.sql.DataSource;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.jdbc.core.SqlOutParameter;
import org.springframework.jdbc.object.StoredProcedure;

public class StoredProcedureDao {

    private GetSysdateProcedure getSysdate;

    @Autowired
    public void init(DataSource dataSource) {
        this.getSysdate = new GetSysdateProcedure(dataSource);
    }

    public Date getSysdate() {
        return getSysdate.execute();
    }

    private class GetSysdateProcedure extends StoredProcedure {

        private static final String SQL = "sysdate";

        public GetSysdateProcedure(DataSource dataSource) {
            setDataSource(dataSource);
            setFunction(true);
            setSql(SQL);
            declareParameter(new SqlOutParameter("date", Types.DATE));
            compile();
        }

        public Date execute() {
            // the sysdate sproc has no input parameters, so an empty Map is supplied...
            Map<String, Object> results = execute(new HashMap<String, Object>());
            Date sysdate = (Date) results.get("date");
            return sysdate;
        }
    }

}
```

The following example of a `StoredProcedure` has two output parameters (in this case, Oracle REF cursors).

```
import oracle.jdbc.OracleTypes;
import org.springframework.jdbc.core.SqlOutParameter;
import org.springframework.jdbc.object.StoredProcedure;

import javax.sql.DataSource;
import java.util.HashMap;
import java.util.Map;

public class TitlesAndGenresStoredProcedure extends StoredProcedure {

    private static final String SPROC_NAME = "AllTitlesAndGenres";

    public TitlesAndGenresStoredProcedure(DataSource dataSource) {
        super(dataSource, SPROC_NAME);
        declareParameter(new SqlOutParameter("titles", OracleTypes.CURSOR, new TitleMapper()));
        declareParameter(new SqlOutParameter("genres", OracleTypes.CURSOR, new GenreMapper()));
        compile();
    }

    public Map<String, Object> execute() {
        // again, this sproc has no input parameters, so an empty Map is supplied
        return super.execute(new HashMap<String, Object>());
    }
}
```

Notice how the overloaded variants of the `declareParameter(..)` method that have been used in the `TitlesAndGenresStoredProcedure` constructor are passed `RowMapper` implementation instances; this is a very convenient and powerful way to reuse existing functionality. The code for the two `RowMapper` implementations is provided below.

The `TitleMapper` class maps a `ResultSet` to a `Title` domain object for each row in the supplied `ResultSet`:

```
import org.springframework.jdbc.core.RowMapper;

import java.sql.ResultSet;
import java.sql.SQLException;

import com.foo.domain.Title;

public final class TitleMapper implements RowMapper<Title> {

    public Title mapRow(ResultSet rs, int rowNum) throws SQLException {
        Title title = new Title();
        title.setId(rs.getLong("id"));
        title.setName(rs.getString("name"));
        return title;
    }
}
```

The `GenreMapper` class maps a `ResultSet` to a `Genre` domain object for each row in the supplied `ResultSet`.

```
import org.springframework.jdbc.core.RowMapper;

import java.sql.ResultSet;
import java.sql.SQLException;

import com.foo.domain.Genre;

public final class GenreMapper implements RowMapper<Genre> {

    public Genre mapRow(ResultSet rs, int rowNum) throws SQLException {
        return new Genre(rs.getString("name"));
    }
}
```

To pass parameters to a stored procedure that has one or more input parameters in its definition in the RDBMS, you can code a strongly typed `execute(..)` method that would delegate to the superclass' untyped `execute(Map parameters)` method (which has `protected` access); for example:

```
import oracle.jdbc.OracleTypes;
import org.springframework.jdbc.core.SqlOutParameter;
import org.springframework.jdbc.core.SqlParameter;
import org.springframework.jdbc.object.StoredProcedure;

import javax.sql.DataSource;

import java.sql.Types;
import java.util.Date;
import java.util.HashMap;
import java.util.Map;

public class TitlesAfterDateStoredProcedure extends StoredProcedure {

    private static final String SPROC_NAME = "TitlesAfterDate";
    private static final String CUTOFF_DATE_PARAM = "cutoffDate";

    public TitlesAfterDateStoredProcedure(DataSource dataSource) {
        super(dataSource, SPROC_NAME);
        declareParameter(new SqlParameter(CUTOFF_DATE_PARAM, Types.DATE);
        declareParameter(new SqlOutParameter("titles", OracleTypes.CURSOR, new TitleMapper()));
        compile();
    }

    public Map<String, Object> execute(Date cutoffDate) {
        Map<String, Object> inputs = new HashMap<String, Object>();
        inputs.put(CUTOFF_DATE_PARAM, cutoffDate);
        return super.execute(inputs);
    }
}
```

14.7 Common problems with parameter and data value handling

Common problems with parameters and data values exist in the different approaches provided by the Spring Framework JDBC.

Providing SQL type information for parameters

Usually Spring determines the SQL type of the parameters based on the type of parameter passed in. It is possible to explicitly provide the SQL type to be used when setting parameter values. This is sometimes necessary to correctly set NULL values.

You can provide SQL type information in several ways:

- Many update and query methods of the `JdbcTemplate` take an additional parameter in the form of an `int` array. This array is used to indicate the SQL type of the corresponding parameter using constant values from the `java.sql.Types` class. Provide one entry for each parameter.
- You can use the `SqlParameterValue` class to wrap the parameter value that needs this additional information.Create a new instance for each value and pass in the SQL type and parameter value in the constructor. You can also provide an optional scale parameter for numeric values.
- For methods working with named parameters, use the `SqlParameterSource` classes `BeanPropertySqlParameterSource` or `MapSqlParameterSource`. They both have methods for registering the SQL type for any of the named parameter values.

Handling BLOB and CLOB objects

You can store images, other binary objects, and large chunks of text. These large object are called BLOB for binary data and CLOB for character data. In Spring you can handle these large objects by using the JdbcTemplate directly and also when using the higher abstractions provided by RDBMS Objects and the `SimpleJdbc` classes. All of these approaches use an implementation of the `LobHandler` interface for the actual management of the LOB data. The `LobHandler` provides access to a `LobCreator` class, through the `getLobCreator` method, used for creating new LOB objects to be inserted.

The `LobCreator/LobHandler` provides the following support for LOB input and output:

- BLOB
- byte[] — getBlobAsBytes and setBlobAsBytes
- InputStream — getBlobAsBinaryStream and setBlobAsBinaryStream
- CLOB
- String — getClobAsString and setClobAsString
- InputStream — getClobAsAsciiStream and setClobAsAsciiStream
- Reader — getClobAsCharacterStream and setClobAsCharacterStream

The next example shows how to create and insert a BLOB. Later you will see how to read it back from the database.

This example uses a `JdbcTemplate` and an implementation of the `AbstractLobCreatingPreparedStatementCallbac k`. It implements one method, `setValues`. This method provides a `LobCreator` that you use to set the values for the LOB columns in your SQL insert statement.

For this example we assume that there is a variable, `lobHandle r`, that already is set to an instance of a `DefaultLobHandler`. You typically set this value through dependency injection.

```
final File blobIn = new File("spring2004.jpg");
final InputStream blobIs = new FileInputStream(blobIn);
final File clobIn = new File("large.txt");
final InputStream clobIs = new FileInputStream(clobIn);
final InputStreamReader clobReader = new InputStreamReader(clobIs);
jdbcTemplate.execute(
    "INSERT INTO lob_table (id, a_clob, a_blob) VALUES (?, ?, ?)",
    new AbstractLobCreatingPreparedStatementCallback(lobHandler) { ❶
        protected void setValues(PreparedStatement ps, LobCreator lobCreator) throws SQLException {
            ps.setLong(1, 1L);
            lobCreator.setClobAsCharacterStream(ps, 2, clobReader, (int)clobIn.length()); ❷
            lobCreator.setBlobAsBinaryStream(ps, 3, blobIs, (int)blobIn.length()); ❸
        }
    }
);
blobIs.close();
clobReader.close();
```

❶ Pass in the lobHandler that in this example is a plain `DefaultLobHandler`

❷ Using the method `setClobAsCharacterStream`, pass in the contents of the CLOB.

❸ Using the method `setBlobAsBinaryStream`, pass in the contents of the BLOB.

Now it's time to read the LOB data from the database. Again, you use a `JdbcTemplate` with the same instance variable `lobHandler` and a reference to a `DefaultLobHandler`.

```
List<Map<String, Object>> l = jdbcTemplate.query("select id, a_clob, a_blob from lob_table",
    new RowMapper<Map<String, Object>>() {
        public Map<String, Object> mapRow(ResultSet rs, int i) throws SQLException {
            Map<String, Object> results = new HashMap<String, Object>();
            String clobText = lobHandler.getClobAsString(rs, "a_clob"); ❶
results.put("CLOB", clobText); byte[] blobBytes = lobHandler.getBlobAsBytes(rs, "a_blob"); ❷
results.put("BLOB", blobBytes); return results; } });
```

❶ Using the method `getClobAsString`, retrieve the contents of the CLOB.

❷ Using the method `getBlobAsBytes`, retrieve the contents of the BLOB.

Passing in lists of values for IN clause

The SQL standard allows for selecting rows based on an expression that includes a variable list of values. A typical example would be `select * from T_ACTOR where id in (1, 2, 3)`. This variable list is not directly supported for prepared statements by the JDBC standard; you cannot declare a variable number of placeholders. You need a number of variations with the desired number of placeholders prepared, or you need to generate the SQL string dynamically once you know how many placeholders are required. The named parameter support provided in the `NamedParameterJdbcTemplate` and `JdbcTemplate` takes the latter approach. Pass in the values as a `java.util.List` of primitive objects. This list will be used to insert the required placeholders and pass in the values during the statement execution.

> **Note**
>
> Be careful when passing in many values. The JDBC standard does not guarantee that you can use more than 100 values for an `in` expression list. Various databases exceed this number, but they usually have a hard limit for how many values are allowed. Oracle's limit is 1000.

In addition to the primitive values in the value list, you can create a `java.util.List` of object arrays. This list would support multiple expressions defined for the `in` clause such as `select * from T_ACTOR where (id, last_name) in ((1, 'Johnson'), (2, 'Harrop'))`. This of course requires that your database supports this syntax.

Handling complex types for stored procedure calls

When you call stored procedures you can sometimes use complex types specific to the database. To accommodate these types, Spring provides a `SqlReturnType` for handling them when they are returned from the stored procedure call and `SqlTypeValue` when they are passed in as a parameter to the stored procedure.

Here is an example of returning the value of an Oracle `STRUCT` object of the user declared type `ITEM_TYPE`. The `SqlReturnType` interface has a single method named `getTypeValue` that must be implemented. This interface is used as part of the declaration of an `SqlOutParameter`.

```
final TestItem = new TestItem(123L, "A test item",
        new SimpleDateFormat("yyyy-M-d").parse("2010-12-31"));

declareParameter(new SqlOutParameter("item", OracleTypes.STRUCT, "ITEM_TYPE",
    new SqlReturnType() {
        public Object getTypeValue(CallableStatement cs, int colIndx, int sqlType, String
 typeName) throws SQLException {
            STRUCT struct = (STRUCT) cs.getObject(colIndx);
            Object[] attr = struct.getAttributes();
            TestItem item = new TestItem();
            item.setId(((Number) attr[0]).longValue());
            item.setDescription((String) attr[1]);
            item.setExpirationDate((java.util.Date) attr[2]);
            return item;
        }
    }));
```

You use the `SqlTypeValue` to pass in the value of a Java object like `TestItem` into a stored procedure. The `SqlTypeValue` interface has a single method named `createTypeValue` that you must implement. The active connection is passed in, and you can use it to create database-specific objects such as `StructDescriptors`, as shown in the following example, or `ArrayDescriptors`.

```
final TestItem = new TestItem(123L, "A test item",
        new SimpleDateFormat("yyyy-M-d").parse("2010-12-31"));

SqlTypeValue value = new AbstractSqlTypeValue() {
    protected Object createTypeValue(Connection conn, int sqlType, String typeName) throws SQLException
 {
        StructDescriptor itemDescriptor = new StructDescriptor(typeName, conn);
        Struct item = new STRUCT(itemDescriptor, conn,
        new Object[] {
            testItem.getId(),
            testItem.getDescription(),
            new java.sql.Date(testItem.getExpirationDate().getTime())
        });
        return item;
    }
};
```

This `SqlTypeValue` can now be added to the Map containing the input parameters for the execute call of the stored procedure.

Another use for the `SqlTypeValue` is passing in an array of values to an Oracle stored procedure. Oracle has its own internal ARRAY class that must be used in this case, and you can use the `SqlTypeValue` to create an instance of the Oracle ARRAY and populate it with values from the Java ARRAY.

```
final Long[] ids = new Long[] {1L, 2L};

SqlTypeValue value = new AbstractSqlTypeValue() {
    protected Object createTypeValue(Connection conn, int sqlType, String typeName) throws SQLException
 {
        ArrayDescriptor arrayDescriptor = new ArrayDescriptor(typeName, conn);
        ARRAY idArray = new ARRAY(arrayDescriptor, conn, ids);
        return idArray;
    }
};
```

14.8 Embedded database support

The `org.springframework.jdbc.datasource.embedded` package provides support for embedded Java database engines. Support for HSQL, H2, and Derby is provided natively. You can also use an extensible API to plug in new embedded database types and `DataSource` implementations.

Why use an embedded database?

An embedded database is useful during the development phase of a project because of its lightweight nature. Benefits include ease of configuration, quick startup time, testability, and the ability to rapidly evolve SQL during development.

Creating an embedded database instance using Spring XML

If you want to expose an embedded database instance as a bean in a Spring ApplicationContext, use the embedded-database tag in the spring-jdbc namespace:

```
<jdbc:embedded-database id="dataSource">
    <jdbc:script location="classpath:schema.sql"/>
    <jdbc:script location="classpath:test-data.sql"/>
</jdbc:embedded-database>
```

The preceding configuration creates an embedded HSQL database populated with SQL from schema.sql and testdata.sql resources in the classpath. The database instance is made available to the Spring container as a bean of type `javax.sql.DataSource`. This bean can then be injected into data access objects as needed.

Creating an embedded database instance programmatically

The `EmbeddedDatabaseBuilder` class provides a fluent API for constructing an embedded database programmatically. Use this when you need to create an embedded database instance in a standalone environment, such as a data access object unit test:

```
EmbeddedDatabaseBuilder builder = new EmbeddedDatabaseBuilder();
EmbeddedDatabase db = builder.setType(H2).addScript("my-schema.sql").addScript("my-test-
data.sql").build();
// do stuff against the db (EmbeddedDatabase extends javax.sql.DataSource)
db.shutdown()
```

Extending the embedded database support

Spring JDBC embedded database support can be extended in two ways:

- Implement `EmbeddedDatabaseConfigurer` to support a new embedded database type, such as Apache Derby.
- Implement `DataSourceFactory` to support a new DataSource implementation, such as a connection pool, to manage embedded database connections.

You are encouraged to contribute back extensions to the Spring community at jira.spring.io.

Using HSQL

Spring supports HSQL 1.8.0 and above. HSQL is the default embedded database if no type is specified explicitly. To specify HSQL explicitly, set the `type` attribute of the `embedded-database` tag to `HSQL`. If you are using the builder API, call the `setType(EmbeddedDatabaseType)` method with `EmbeddedDatabaseType.HSQL`.

Using H2

Spring supports the H2 database as well. To enable H2, set the `type` attribute of the `embedded-database` tag to `H2`. If you are using the builder API, call the `setType(EmbeddedDatabaseType)` method with `EmbeddedDatabaseType.H2`.

Using Derby

Spring also supports Apache Derby 10.5 and above. To enable Derby, set the `type` attribute of the `embedded-database` tag to `Derby`. If using the builder API, call the `setType(EmbeddedDatabaseType)` method with `EmbeddedDatabaseType.Derby`.

Testing data access logic with an embedded database

Embedded databases provide a lightweight way to test data access code. The following is a data access unit test template that uses an embedded database:

```
public class DataAccessUnitTestTemplate {

    private EmbeddedDatabase db;

    @Before
    public void setUp() {
        // creates an HSQL in-memory database populated from default scripts
        // classpath:schema.sql and classpath:data.sql
        db = new EmbeddedDatabaseBuilder().addDefaultScripts().build();
    }

    @Test
    public void testDataAccess() {
        JdbcTemplate template = new JdbcTemplate(db);
        template.query(...);
    }

    @After
    public void tearDown() {
        db.shutdown();
    }

}
```

14.9 Initializing a DataSource

The `org.springframework.jdbc.datasource.init` package provides support for initializing an existing `DataSource`. The embedded database support provides one option for creating and initializing a `DataSource` for an application, but sometimes you need to initialize an instance running on a server somewhere.

Initializing a database instance using Spring XML

If you want to initialize a database and you can provide a reference to a DataSource bean, use the `initialize-database` tag in the `spring-jdbc` namespace:

```
<jdbc:initialize-database data-source="dataSource">
    <jdbc:script location="classpath:com/foo/sql/db-schema.sql"/>
    <jdbc:script location="classpath:com/foo/sql/db-test-data.sql"/>
</jdbc:initialize-database>
```

The example above runs the two scripts specified against the database: the first script is a schema creation, and the second is a test data set insert. The script locations can also be patterns with wildcards in the usual ant style used for resources in Spring (e.g. `classpath*:/com/foo/**/sql/*-data.sql`). If a pattern is used the scripts are executed in lexical order of their URL or filename.

The default behavior of the database initializer is to unconditionally execute the scripts provided. This will not always be what you want, for instance if running against an existing database that already has test data in it. The likelihood of accidentally deleting data is reduced by the commonest pattern (as

shown above) that creates the tables first and then inserts the data - the first step will fail if the tables already exist.

However, to get more control over the creation and deletion of existing data, the XML namespace provides a couple more options. The first is flag to switch the initialization on and off. This can be set according to the environment (e.g. to pull a boolean value from system properties or an environment bean), e.g.

```
<jdbc:initialize-database data-source="dataSource"
    enabled="#{systemProperties.INITIALIZE_DATABASE}">
    <jdbc:script location="..."/>
</jdbc:initialize-database>
```

The second option to control what happens with existing data is to be more tolerant of failures. To this end you can control the ability of the initializer to ignore certain errors in the SQL it executes from the scripts, e.g.

```
<jdbc:initialize-database data-source="dataSource" ignore-failures="DROPS">
    <jdbc:script location="..."/>
</jdbc:initialize-database>
```

In this example we are saying we expect that sometimes the scripts will be run against an empty database and there are some DROP statements in the scripts which would therefore fail. So failed SQL `DROP` statements will be ignored, but other failures will cause an exception. This is useful if your SQL dialect doesn't support `DROP ... IF EXISTS` (or similar) but you want to unconditionally remove all test data before re-creating it. In that case the first script is usually a set of drops, followed by a set of `CREATE` statements.

The `ignore-failures` option can be set to `NONE` (the default), `DROPS` (ignore failed drops) or `ALL` (ignore all failures).

If you need more control than you get from the XML namespace, you can simply use the `DataSourceInitializer` directly, and define it as a component in your application.

Initialization of Other Components that Depend on the Database

A large class of applications can just use the database initializer with no further complications: those that do not use the database until after the Spring context has started. If your application is *not* one of those then you might need to read the rest of this section.

The database initializer depends on a data source instance and runs the scripts provided in its initialization callback (c.f. `init-method` in an XML bean definition or `InitializingBean`). If other beans depend on the same data source and also use the data source in an initialization callback then there might be a problem because the data has not yet been initialized. A common example of this is a cache that initializes eagerly and loads up data from the database on application startup.

To get round this issue you two options: change your cache initialization strategy to a later phase, or ensure that the database initializer is initialized first.

The first option might be easy if the application is in your control, and not otherwise. Some suggestions for how to implement this are

- Make the cache initialize lazily on first usage, which improves application startup time
- Have your cache or a separate component that initializes the cache implement `Lifecycle` or `SmartLifecycle`. When the application context starts up a `SmartLifecycle` can be automatically

started if its `autoStartup` flag is set, and a `Lifecycle` can be started manually by calling `ConfigurableApplicationContext.start()` on the enclosing context.

- Use a Spring `ApplicationEvent` or similar custom observer mechanism to trigger the cache initialization. `ContextRefreshedEvent` is always published by the context when it is ready for use (after all beans have been initialized), so that is often a useful hook (this is how the `SmartLifecycle` works by default).

The second option can also be easy. Some suggestions on how to implement this are

- Rely on Spring BeanFactory default behavior, which is that beans are initialized in registration order. You can easily arrange that by adopting the common practice of a set of <import/> elements that order your application modules, and ensure that the database and database initialization are listed first
- Separate the datasource and the business components that use it and control their startup order by putting them in separate ApplicationContext instances (e.g. parent has the datasource and child has the business components). This structure is common in Spring web applications, but can be more generally applied.

15. Object Relational Mapping (ORM) Data Access

15.1 Introduction to ORM with Spring

The Spring Framework supports integration with Hibernate, Java Persistence API (JPA) and Java Data Objects (JDO) for resource management, data access object (DAO) implementations, and transaction strategies. For example, for Hibernate there is first-class support with several convenient IoC features that address many typical Hibernate integration issues. You can configure all of the supported features for O/R (object relational) mapping tools through Dependency Injection. They can participate in Spring's resource and transaction management, and they comply with Spring's generic transaction and DAO exception hierarchies. The recommended integration style is to code DAOs against plain Hibernate, JPA, and JDO APIs. The older style of using Spring's DAO templates is no longer recommended; however, coverage of this style can be found in the Section 32.1, "Classic ORM usage" in the appendices.

Spring adds significant enhancements to the ORM layer of your choice when you create data access applications. You can leverage as much of the integration support as you wish, and you should compare this integration effort with the cost and risk of building a similar infrastructure in-house. You can use much of the ORM support as you would a library, regardless of technology, because everything is designed as a set of reusable JavaBeans. ORM in a Spring IoC container facilitates configuration and deployment. Thus most examples in this section show configuration inside a Spring container.

Benefits of using the Spring Framework to create your ORM DAOs include:

- *Easier testing.* Spring's IoC approach makes it easy to swap the implementations and configuration locations of Hibernate `SessionFactory` instances, JDBC `DataSource` instances, transaction managers, and mapped object implementations (if needed). This in turn makes it much easier to test each piece of persistence-related code in isolation.

- *Common data access exceptions.* Spring can wrap exceptions from your ORM tool, converting them from proprietary (potentially checked) exceptions to a common runtime DataAccessException hierarchy. This feature allows you to handle most persistence exceptions, which are non-recoverable, only in the appropriate layers, without annoying boilerplate catches, throws, and exception declarations. You can still trap and handle exceptions as necessary. Remember that JDBC exceptions (including DB-specific dialects) are also converted to the same hierarchy, meaning that you can perform some operations with JDBC within a consistent programming model.

- *General resource management.* Spring application contexts can handle the location and configuration of Hibernate `SessionFactory` instances, JPA `EntityManagerFactory` instances, JDBC `DataSource` instances, and other related resources. This makes these values easy to manage and change. Spring offers efficient, easy, and safe handling of persistence resources. For example, related code that uses Hibernate generally needs to use the same Hibernate `Session` to ensure efficiency and proper transaction handling. Spring makes it easy to create and bind a `Session` to the current thread transparently, by exposing a current `Session` through the Hibernate `SessionFactory`. Thus Spring solves many chronic problems of typical Hibernate usage, for any local or JTA transaction environment.

- *Integrated transaction management.* You can wrap your ORM code with a declarative, aspect-oriented programming (AOP) style method interceptor either through the `@Transactional` annotation or by explicitly configuring the transaction AOP advice in an XML configuration file. In both cases, transaction semantics and exception handling (rollback, and so on) are handled for you. As discussed

below, in Resource and transaction management, you can also swap various transaction managers, without affecting your ORM-related code. For example, you can swap between local transactions and JTA, with the same full services (such as declarative transactions) available in both scenarios. Additionally, JDBC-related code can fully integrate transactionally with the code you use to do ORM. This is useful for data access that is not suitable for ORM, such as batch processing and BLOB streaming, which still need to share common transactions with ORM operations.

> **Tip**
>
> For more comprehensive ORM support, including support for alternative database technologies such as MongoDB, you might want to check out the Spring Data suite of projects. If you are a JPA user, the Getting Started Accessing Data with JPA guide from https://spring.io provides a great introduction.

15.2 General ORM integration considerations

This section highlights considerations that apply to all ORM technologies. The Section 15.3, “Hibernate” section provides more details and also show these features and configurations in a concrete context.

The major goal of Spring’s ORM integration is clear application layering, with any data access and transaction technology, and for loose coupling of application objects. No more business service dependencies on the data access or transaction strategy, no more hard-coded resource lookups, no more hard-to-replace singletons, no more custom service registries. One simple and consistent approach to wiring up application objects, keeping them as reusable and free from container dependencies as possible. All the individual data access features are usable on their own but integrate nicely with Spring’s application context concept, providing XML-based configuration and cross-referencing of plain JavaBean instances that need not be Spring-aware. In a typical Spring application, many important objects are JavaBeans: data access templates, data access objects, transaction managers, business services that use the data access objects and transaction managers, web view resolvers, web controllers that use the business services,and so on.

Resource and transaction management

Typical business applications are cluttered with repetitive resource management code. Many projects try to invent their own solutions, sometimes sacrificing proper handling of failures for programming convenience. Spring advocates simple solutions for proper resource handling, namely IoC through templating in the case of JDBC and applying AOP interceptors for the ORM technologies.

The infrastructure provides proper resource handling and appropriate conversion of specific API exceptions to an unchecked infrastructure exception hierarchy. Spring introduces a DAO exception hierarchy, applicable to any data access strategy. For direct JDBC, the `JdbcTemplate` class mentioned in a previous section provides connection handling and proper conversion of `SQLException` to the `DataAccessException` hierarchy, including translation of database-specific SQL error codes to meaningful exception classes. For ORM technologies, see the next section for how to get the same exception translation benefits.

When it comes to transaction management, the `JdbcTemplate` class hooks in to the Spring transaction support and supports both JTA and JDBC transactions, through respective Spring transaction managers. For the supported ORM technologies Spring offers Hibernate, JPA and JDO support through the Hibernate, JPA, and JDO transaction managers as well as JTA support. For details on transaction support, see the Chapter 12, *Transaction Management* chapter.

Exception translation

When you use Hibernate, JPA, or JDO in a DAO, you must decide how to handle the persistence technology's native exception classes. The DAO throws a subclass of a `HibernateException`, `PersistenceException` or `JDOException` depending on the technology. These exceptions are all run-time exceptions and do not have to be declared or caught. You may also have to deal with `IllegalArgumentException` and `IllegalStateException`. This means that callers can only treat exceptions as generally fatal, unless they want to depend on the persistence technology's own exception structure. Catching specific causes such as an optimistic locking failure is not possible without tying the caller to the implementation strategy. This trade off might be acceptable to applications that are strongly ORM-based and/or do not need any special exception treatment. However, Spring enables exception translation to be applied transparently through the `@Repository` annotation:

```
@Repository
public class ProductDaoImpl implements ProductDao {

    // class body here...

}
```

```
<beans>

    <!-- Exception translation bean post processor -->
    <bean class="org.springframework.dao.annotation.PersistenceExceptionTranslationPostProcessor"/>

    <bean id="myProductDao" class="product.ProductDaoImpl"/>

</beans>
```

The postprocessor automatically looks for all exception translators (implementations of the `PersistenceExceptionTranslator` interface) and advises all beans marked with the `@Repository` annotation so that the discovered translators can intercept and apply the appropriate translation on the thrown exceptions.

In summary: you can implement DAOs based on the plain persistence technology's API and annotations, while still benefiting from Spring-managed transactions, dependency injection, and transparent exception conversion (if desired) to Spring's custom exception hierarchies.

15.3 Hibernate

We will start with a coverage of Hibernate 3 in a Spring environment, using it to demonstrate the approach that Spring takes towards integrating O/R mappers. This section will cover many issues in detail and show different variations of DAO implementations and transaction demarcation. Most of these patterns can be directly translated to all other supported ORM tools. The following sections in this chapter will then cover the other ORM technologies, showing briefer examples there.

> **Note**
>
> As of Spring 4.0, Spring requires Hibernate 3.6 or later.

SessionFactory setup in a Spring container

To avoid tying application objects to hard-coded resource lookups, you can define resources such as a JDBC `DataSource` or a Hibernate `SessionFactory` as beans in the Spring container. Application objects that need to access resources receive references to such predefined instances through bean references, as illustrated in the DAO definition in the next section.

The following excerpt from an XML application context definition shows how to set up a JDBC `DataSource` and a Hibernate `SessionFactory` on top of it:

```
<beans>

    <bean id="myDataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
        <property name="driverClassName" value="org.hsqldb.jdbcDriver"/>
        <property name="url" value="jdbc:hsqldb:hsql://localhost:9001"/>
        <property name="username" value="sa"/>
        <property name="password" value=""/>
    </bean>

    <bean id="mySessionFactory" class="org.springframework.orm.hibernate3.LocalSessionFactoryBean">
        <property name="dataSource" ref="myDataSource"/>
        <property name="mappingResources">
            <list>
                <value>product.hbm.xml</value>
            </list>
        </property>
        <property name="hibernateProperties">
            <value>
                hibernate.dialect=org.hibernate.dialect.HSQLDialect
            </value>
        </property>
    </bean>

</beans>
```

Switching from a local Jakarta Commons DBCP `BasicDataSource` to a JNDI-located `DataSource` (usually managed by an application server) is just a matter of configuration:

```
<beans>
    <jee:jndi-lookup id="myDataSource" jndi-name="java:comp/env/jdbc/myds"/>
</beans>
```

You can also access a JNDI-located `SessionFactory`, using Spring's `JndiObjectFactoryBean` / `<jee:jndi-lookup>` to retrieve and expose it. However, that is typically not common outside of an EJB context.

Implementing DAOs based on plain Hibernate 3 API

Hibernate 3 has a feature called contextual sessions, wherein Hibernate itself manages one current `Session` per transaction. This is roughly equivalent to Spring's synchronization of one Hibernate `Session` per transaction. A corresponding DAO implementation resembles the following example, based on the plain Hibernate API:

```
public class ProductDaoImpl implements ProductDao {

    private SessionFactory sessionFactory;

    public void setSessionFactory(SessionFactory sessionFactory) {
        this.sessionFactory = sessionFactory;
    }

    public Collection loadProductsByCategory(String category) {
        return this.sessionFactory.getCurrentSession()
                .createQuery("from test.Product product where product.category=?")
                .setParameter(0, category)
                .list();
    }
}
```

This style is similar to that of the Hibernate reference documentation and examples, except for holding the `SessionFactory` in an instance variable. We strongly recommend such an instance-based

setup over the old-school `static HibernateUtil` class from Hibernate's CaveatEmptor sample application. (In general, do not keep any resources in `static` variables unless *absolutely* necessary.)

The above DAO follows the dependency injection pattern: it fits nicely into a Spring IoC container, just as it would if coded against Spring's `HibernateTemplate`. Of course, such a DAO can also be set up in plain Java (for example, in unit tests). Simply instantiate it and call `setSessionFactory(..)` with the desired factory reference. As a Spring bean definition, the DAO would resemble the following:

```
<beans>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="sessionFactory" ref="mySessionFactory"/>
    </bean>

</beans>
```

The main advantage of this DAO style is that it depends on Hibernate API only; no import of any Spring class is required. This is of course appealing from a non-invasiveness perspective, and will no doubt feel more natural to Hibernate developers.

However, the DAO throws plain `HibernateException` (which is unchecked, so does not have to be declared or caught), which means that callers can only treat exceptions as generally fatal - unless they want to depend on Hibernate's own exception hierarchy. Catching specific causes such as an optimistic locking failure is not possible without tying the caller to the implementation strategy. This trade off might be acceptable to applications that are strongly Hibernate-based and/or do not need any special exception treatment.

Fortunately, Spring's `LocalSessionFactoryBean` supports Hibernate's `SessionFactory.getCurrentSession()` method for any Spring transaction strategy, returning the current Spring-managed transactional `Session` even with `HibernateTransactionManager`. Of course, the standard behavior of that method remains the return of the current `Session` associated with the ongoing JTA transaction, if any. This behavior applies regardless of whether you are using Spring's `JtaTransactionManager`, EJB container managed transactions (CMTs), or JTA.

In summary: you can implement DAOs based on the plain Hibernate 3 API, while still being able to participate in Spring-managed transactions.

Declarative transaction demarcation

We recommend that you use Spring's declarative transaction support, which enables you to replace explicit transaction demarcation API calls in your Java code with an AOP transaction interceptor. This transaction interceptor can be configured in a Spring container using either Java annotations or XML.This declarative transaction capability allows you to keep business services free of repetitive transaction demarcation code and to focus on adding business logic, which is the real value of your application.

> **Note**
>
> Prior to continuing, you are *strongly* encouraged to read Section 12.5, "Declarative transaction management" if you have not done so.

Furthermore, transaction semantics like propagation behavior and isolation level can be changed in a configuration file and do not affect the business service implementations.

The following example shows how you can configure an AOP transaction interceptor, using XML, for a simple service class:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- SessionFactory, DataSource, etc. omitted -->

    <bean id="transactionManager"
            class="org.springframework.orm.hibernate3.HibernateTransactionManager">
        <property name="sessionFactory" ref="sessionFactory"/>
    </bean>

    <aop:config>
        <aop:pointcut id="productServiceMethods"
                expression="execution(* product.ProductService.(..))"/>
        <aop:advisor advice-ref="txAdvice" pointcut-ref="productServiceMethods"/>
    </aop:config>

    <tx:advice id="txAdvice" transaction-manager="myTxManager">
        <tx:attributes>
            <tx:method name="increasePrice" propagation="REQUIRED"/>
            <tx:method name="someOtherBusinessMethod" propagation="REQUIRES_NEW"/>
            <tx:method name="*" propagation="SUPPORTS" read-only="true"/>
        </tx:attributes>
    </tx:advice>

    <bean id="myProductService" class="product.SimpleProductService">
        <property name="productDao" ref="myProductDao"/>
    </bean>

</beans>
```

This is the service class that is advised:

```
public class ProductServiceImpl implements ProductService {

    private ProductDao productDao;

    public void setProductDao(ProductDao productDao) {
        this.productDao = productDao;
    }

    // notice the absence of transaction demarcation code in this method
    // Spring's declarative transaction infrastructure will be demarcating
    // transactions on your behalf
    public void increasePriceOfAllProductsInCategory(final String category) {
        List productsToChange = this.productDao.loadProductsByCategory(category);
        // ...
    }
}
```

We also show an attribute-support based configuration, in the following example. You annotate the service layer with @Transactional annotations and instruct the Spring container to find these annotations and provide transactional semantics for these annotated methods.

```
public class ProductServiceImpl implements ProductService {

    private ProductDao productDao;

    public void setProductDao(ProductDao productDao) {
        this.productDao = productDao;
    }

    @Transactional
    public void increasePriceOfAllProductsInCategory(final String category) {
        List productsToChange = this.productDao.loadProductsByCategory(category);
        // ...
    }

    @Transactional(readOnly = true)
    public List<Product> findAllProducts() {
        return this.productDao.findAllProducts();
    }

}
```

As you can see from the following configuration example, the configuration is much simplified, compared to the XML example above, while still providing the same functionality driven by the annotations in the service layer code. All you need to provide is the TransactionManager implementation and a "<tx:annotation-driven/>" entry.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <!-- SessionFactory, DataSource, etc. omitted -->

    <bean id="transactionManager"
            class="org.springframework.orm.hibernate3.HibernateTransactionManager">
        <property name="sessionFactory" ref="sessionFactory"/>
    </bean>

    <tx:annotation-driven/>

    <bean id="myProductService" class="product.SimpleProductService">
        <property name="productDao" ref="myProductDao"/>
    </bean>

</beans>
```

Programmatic transaction demarcation

You can demarcate transactions in a higher level of the application, on top of such lower-level data access services spanning any number of operations. Nor do restrictions exist on the implementation of the surrounding business service; it just needs a Spring `PlatformTransactionManager`. Again, the latter can come from anywhere, but preferably as a bean reference through a `setTransactionManager(..)` method, just as the `productDAO` should be set by a `setProductDao(..)` method. The following snippets show a transaction manager and a business service definition in a Spring application context, and an example for a business method implementation:

```
<beans>

    <bean id="myTxManager" class="org.springframework.orm.hibernate3.HibernateTransactionManager">
        <property name="sessionFactory" ref="mySessionFactory"/>
    </bean>

    <bean id="myProductService" class="product.ProductServiceImpl">
        <property name="transactionManager" ref="myTxManager"/>
        <property name="productDao" ref="myProductDao"/>
    </bean>

</beans>
```

```
public class ProductServiceImpl implements ProductService {

    private TransactionTemplate transactionTemplate;
    private ProductDao productDao;

    public void setTransactionManager(PlatformTransactionManager transactionManager) {
        this.transactionTemplate = new TransactionTemplate(transactionManager);
    }

    public void setProductDao(ProductDao productDao) {
        this.productDao = productDao;
    }

    public void increasePriceOfAllProductsInCategory(final String category) {
        this.transactionTemplate.execute(new TransactionCallbackWithoutResult() {
            public void doInTransactionWithoutResult(TransactionStatus status) {
                List productsToChange = this.productDao.loadProductsByCategory(category);
                // do the price increase...
            }
        });
    }
}
```

Spring's `TransactionInterceptor` allows any checked application exception to be thrown with the callback code, while `TransactionTemplate` is restricted to unchecked exceptions within the callback. `TransactionTemplate` triggers a rollback in case of an unchecked application exception, or if the transaction is marked rollback-only by the application (via `TransactionStatus`). `TransactionInterceptor` behaves the same way by default but allows configurable rollback policies per method.

Transaction management strategies

Both `TransactionTemplate` and `TransactionInterceptor` delegate the actual transaction handling to a `PlatformTransactionManager` instance, which can be a `HibernateTransactionManager` (for a single Hibernate `SessionFactory`, using a `ThreadLocal Session` under the hood) or a `JtaTransactionManager` (delegating to the JTA subsystem of the container) for Hibernate applications. You can even use a custom `PlatformTransactionManager` implementation. Switching from native Hibernate transaction management to JTA, such as when facing distributed transaction requirements for certain deployments of your application, is just a matter of configuration. Simply replace the Hibernate transaction manager with Spring's JTA transaction implementation. Both transaction demarcation and data access code will work without changes, because they just use the generic transaction management APIs.

For distributed transactions across multiple Hibernate session factories, simply combine `JtaTransactionManager` as a transaction strategy with multiple `LocalSessionFactoryBean` definitions. Each DAO then gets one specific `SessionFactory` reference passed into its corresponding bean property. If all underlying JDBC data sources are transactional container ones, a business service

can demarcate transactions across any number of DAOs and any number of session factories without special regard, as long as it is using `JtaTransactionManager` as the strategy.

```
<beans>

    <jee:jndi-lookup id="dataSource1" jndi-name="java:comp/env/jdbc/myds1"/>

    <jee:jndi-lookup id="dataSource2" jndi-name="java:comp/env/jdbc/myds2"/>

    <bean id="mySessionFactory1"
            class="org.springframework.orm.hibernate3.LocalSessionFactoryBean">
        <property name="dataSource" ref="myDataSource1"/>
        <property name="mappingResources">
            <list>
                <value>product.hbm.xml</value>
            </list>
        </property>
        <property name="hibernateProperties">
            <value>
                hibernate.dialect=org.hibernate.dialect.MySQLDialect
                hibernate.show_sql=true
            </value>
        </property>
    </bean>

    <bean id="mySessionFactory2"
            class="org.springframework.orm.hibernate3.LocalSessionFactoryBean">
        <property name="dataSource" ref="myDataSource2"/>
        <property name="mappingResources">
            <list>
                <value>inventory.hbm.xml</value>
            </list>
        </property>
        <property name="hibernateProperties">
            <value>
                hibernate.dialect=org.hibernate.dialect.OracleDialect
            </value>
        </property>
    </bean>

    <bean id="myTxManager" class="org.springframework.transaction.jta.JtaTransactionManager"/>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="sessionFactory" ref="mySessionFactory1"/>
    </bean>

    <bean id="myInventoryDao" class="product.InventoryDaoImpl">
        <property name="sessionFactory" ref="mySessionFactory2"/>
    </bean>

    <bean id="myProductService" class="product.ProductServiceImpl">
        <property name="productDao" ref="myProductDao"/>
        <property name="inventoryDao" ref="myInventoryDao"/>
    </bean>

    <aop:config>
        <aop:pointcut id="productServiceMethods"
                expression="execution(* product.ProductService.(..))"/>
        <aop:advisor advice-ref="txAdvice" pointcut-ref="productServiceMethods"/>
    </aop:config>

    <tx:advice id="txAdvice" transaction-manager="myTxManager">
        <tx:attributes>
            <tx:method name="increasePrice" propagation="REQUIRED"/>
            <tx:method name="someOtherBusinessMethod" propagation="REQUIRES_NEW"/>
            <tx:method name="*" propagation="SUPPORTS" read-only="true"/>
        </tx:attributes>
    </tx:advice>

</beans>
```

Both `HibernateTransactionManager` and `JtaTransactionManager` allow for proper JVM-level cache handling with Hibernate, without container-specific transaction manager lookup or a JCA connector (if you are not using EJB to initiate transactions).

`HibernateTransactionManager` can export the Hibernate JDBC `Connection` to plain JDBC access code, for a specific `DataSource`. This capability allows for high-level transaction demarcation with mixed Hibernate and JDBC data access completely without JTA, if you are accessing only one database. `HibernateTransactionManager` automatically exposes the Hibernate transaction as a JDBC transaction if you have set up the passed-in `SessionFactory` with a `DataSource` through the `dataSource` property of the `LocalSessionFactoryBean` class. Alternatively, you can specify explicitly the `DataSource` for which the transactions are supposed to be exposed through the `dataSource` property of the `HibernateTransactionManager` class.

Comparing container-managed and locally defined resources

You can switch between a container-managed JNDI `SessionFactory` and a locally defined one, without having to change a single line of application code. Whether to keep resource definitions in the container or locally within the application is mainly a matter of the transaction strategy that you use. Compared to a Spring-defined local `SessionFactory`, a manually registered JNDI `SessionFactory` does not provide any benefits. Deploying a `SessionFactory` through Hibernate's JCA connector provides the added value of participating in the Java EE server's management infrastructure, but does not add actual value beyond that.

Spring's transaction support is not bound to a container. Configured with any strategy other than JTA, transaction support also works in a stand-alone or test environment. Especially in the typical case of single-database transactions, Spring's single-resource local transaction support is a lightweight and powerful alternative to JTA. When you use local EJB stateless session beans to drive transactions, you depend both on an EJB container and JTA, even if you access only a single database, and only use stateless session beans to provide declarative transactions through container-managed transactions. Also, direct use of JTA programmatically requires a Java EE environment as well. JTA does not involve only container dependencies in terms of JTA itself and of JNDI `DataSource` instances. For non-Spring, JTA-driven Hibernate transactions, you have to use the Hibernate JCA connector, or extra Hibernate transaction code with the `TransactionManagerLookup` configured for proper JVM-level caching.

Spring-driven transactions can work as well with a locally defined Hibernate `SessionFactory` as they do with a local JDBC `DataSource` if they are accessing a single database. Thus you only have to use Spring's JTA transaction strategy when you have distributed transaction requirements. A JCA connector requires container-specific deployment steps, and obviously JCA support in the first place. This configuration requires more work than deploying a simple web application with local resource definitions and Spring-driven transactions. Also, you often need the Enterprise Edition of your container if you are using, for example, WebLogic Express, which does not provide JCA. A Spring application with local resources and transactions spanning one single database works in any Java EE web container (without JTA, JCA, or EJB) such as Tomcat, Resin, or even plain Jetty. Additionally, you can easily reuse such a middle tier in desktop applications or test suites.

All things considered, if you do not use EJBs, stick with local `SessionFactory` setup and Spring's `HibernateTransactionManager` or `JtaTransactionManager`. You get all of the benefits, including proper transactional JVM-level caching and distributed transactions, without the inconvenience of container deployment. JNDI registration of a Hibernate `SessionFactory` through the JCA connector only adds value when used in conjunction with EJBs.

Spurious application server warnings with Hibernate

In some JTA environments with very strict `XADataSource` implementations — currently only some WebLogic Server and WebSphere versions — when Hibernate is configured without regard to the JTA `PlatformTransactionManager` object for that environment, it is possible for spurious warning or exceptions to show up in the application server log. These warnings or exceptions indicate that the connection being accessed is no longer valid, or JDBC access is no longer valid, possibly because the transaction is no longer active. As an example, here is an actual exception from WebLogic:

```
java.sql.SQLException: The transaction is no longer active - status: Committed. No
further JDBC access is allowed within this transaction.
```

You resolve this warning by simply making Hibernate aware of the JTA `PlatformTransactionManager` instance, to which it will synchronize (along with Spring). You have two options for doing this:

- If in your application context you are already directly obtaining the JTA `PlatformTransactionManager` object (presumably from JNDI through `JndiObjectFactoryBean` or `<jee:jndi-lookup>`) and feeding it, for example, to Spring's `JtaTransactionManager`, then the easiest way is to specify a reference to the bean defining this JTA `PlatformTransactionManager` instance as the value of the `jtaTransactionManager` property for `LocalSessionFactoryBean`. Spring then makes the object available to Hibernate.
- More likely you do not already have the JTA `PlatformTransactionManager` instance, because Spring's `JtaTransactionManager` can find it itself. Thus you need to configure Hibernate to look up JTA `PlatformTransactionManager` directly. You do this by configuring an application server-specific `TransactionManagerLookup` class in the Hibernate configuration, as described in the Hibernate manual.

The remainder of this section describes the sequence of events that occur with and without Hibernate's awareness of the JTA `PlatformTransactionManager`.

When Hibernate is not configured with any awareness of the JTA `PlatformTransactionManager`, the following events occur when a JTA transaction commits:

- The JTA transaction commits.
- Spring's `JtaTransactionManager` is synchronized to the JTA transaction, so it is called back through an *afterCompletion* callback by the JTA transaction manager.
- Among other activities, this synchronization can trigger a callback by Spring to Hibernate, through Hibernate's `afterTransactionCompletion` callback (used to clear the Hibernate cache), followed by an explicit `close()` call on the Hibernate Session, which causes Hibernate to attempt to `close()` the JDBC Connection.
- In some environments, this `Connection.close()` call then triggers the warning or error, as the application server no longer considers the `Connection` usable at all, because the transaction has already been committed.

When Hibernate is configured with awareness of the JTA `PlatformTransactionManager`, the following events occur when a JTA transaction commits:

- the JTA transaction is ready to commit.

- Spring's `JtaTransactionManager` is synchronized to the JTA transaction, so the transaction is called back through a *beforeCompletion* callback by the JTA transaction manager.
- Spring is aware that Hibernate itself is synchronized to the JTA transaction, and behaves differently than in the previous scenario. Assuming the Hibernate `Session` needs to be closed at all, Spring will close it now.
- The JTA transaction commits.
- Hibernate is synchronized to the JTA transaction, so the transaction is called back through an *afterCompletion* callback by the JTA transaction manager, and can properly clear its cache.

15.4 JDO

Spring supports the standard JDO 2.0 and 2.1 APIs as data access strategy, following the same style as the Hibernate support. The corresponding integration classes reside in the `org.springframework.orm.jdo` package.

PersistenceManagerFactory setup

Spring provides a `LocalPersistenceManagerFactoryBean` class that allows you to define a local JDO `PersistenceManagerFactory` within a Spring application context:

```
<beans>

    <bean id="myPmf" class="org.springframework.orm.jdo.LocalPersistenceManagerFactoryBean">
        <property name="configLocation" value="classpath:kodo.properties"/>
    </bean>

</beans>
```

Alternatively, you can set up a `PersistenceManagerFactory` through direct instantiation of a `PersistenceManagerFactory` implementation class. A JDO `PersistenceManagerFactory` implementation class follows the JavaBeans pattern, just like a JDBC `DataSource` implementation class, which is a natural fit for a configuration that uses Spring. This setup style usually supports a Spring-defined JDBC `DataSource`, passed into the `connectionFactory` property. For example, for the open source JDO implementation DataNucleus (formerly JPOX) (http://www.datanucleus.org/), this is the XML configuration of the `PersistenceManagerFactory` implementation:

```
<beans>

 <bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource" destroy-method="close">
    <property name="driverClassName" value="${jdbc.driverClassName}"/>
    <property name="url" value="${jdbc.url}"/>
    <property name="username" value="${jdbc.username}"/>
    <property name="password" value="${jdbc.password}"/>
 </bean>

 <bean id="myPmf" class="org.datanucleus.jdo.JDOPersistenceManagerFactory" destroy-method="close">
    <property name="connectionFactory" ref="dataSource"/>
    <property name="nontransactionalRead" value="true"/>
 </bean>

</beans>
```

You can also set up JDO `PersistenceManagerFactory` in the JNDI environment of a Java EE application server, usually through the JCA connector provided by the particular JDO implementation. Spring's standard `JndiObjectFactoryBean` or `<jee:jndi-lookup>` can be used to retrieve and expose such a `PersistenceManagerFactory`. However, outside an EJB context, no real benefit

exists in holding the `PersistenceManagerFactory` in JNDI: only choose such a setup for a good reason. See the section called “Comparing container-managed and locally defined resources” for a discussion; the arguments there apply to JDO as well.

Implementing DAOs based on the plain JDO API

DAOs can also be written directly against plain JDO API, without any Spring dependencies, by using an injected `PersistenceManagerFactory`. The following is an example of a corresponding DAO implementation:

```
public class ProductDaoImpl implements ProductDao {

    private PersistenceManagerFactory persistenceManagerFactory;

    public void setPersistenceManagerFactory(PersistenceManagerFactory pmf) {
        this.persistenceManagerFactory = pmf;
    }

    public Collection loadProductsByCategory(String category) {
        PersistenceManager pm = this.persistenceManagerFactory.getPersistenceManager();
        try {
            Query query = pm.newQuery(Product.class, "category = pCategory");
            query.declareParameters("String pCategory");
            return query.execute(category);
        }
        finally {
            pm.close();
        }
    }
}
```

Because the above DAO follows the dependency injection pattern, it fits nicely into a Spring container, just as it would if coded against Spring’s `JdoTemplate`:

```
<beans>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="persistenceManagerFactory" ref="myPmf"/>
    </bean>

</beans>
```

The main problem with such DAOs is that they always get a new `PersistenceManager` from the factory. To access a Spring-managed transactional `PersistenceManager`, define a `TransactionAwarePersistenceManagerFactoryProxy` (as included in Spring) in front of your target `PersistenceManagerFactory`, then passing a reference to that proxy into your DAOs as in the following example:

```
<beans>

    <bean id="myPmfProxy"
            class="org.springframework.orm.jdo.TransactionAwarePersistenceManagerFactoryProxy">
        <property name="targetPersistenceManagerFactory" ref="myPmf"/>
    </bean>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="persistenceManagerFactory" ref="myPmfProxy"/>
    </bean>

</beans>
```

Your data access code will receive a transactional `PersistenceManager` (if any) from the `PersistenceManagerFactory.getPersistenceManager()` method that it calls. The

latter method call goes through the proxy, which first checks for a current transactional `PersistenceManager` before getting a new one from the factory. Any `close()` calls on the `PersistenceManager` are ignored in case of a transactional `PersistenceManager`.

If your data access code always runs within an active transaction (or at least within active transaction synchronization), it is safe to omit the `PersistenceManager.close()` call and thus the entire `finally` block, which you might do to keep your DAO implementations concise:

```
public class ProductDaoImpl implements ProductDao {

    private PersistenceManagerFactory persistenceManagerFactory;

    public void setPersistenceManagerFactory(PersistenceManagerFactory pmf) {
        this.persistenceManagerFactory = pmf;
    }

    public Collection loadProductsByCategory(String category) {
        PersistenceManager pm = this.persistenceManagerFactory.getPersistenceManager();
        Query query = pm.newQuery(Product.class, "category = pCategory");
        query.declareParameters("String pCategory");
        return query.execute(category);
    }
}
```

With such DAOs that rely on active transactions, it is recommended that you enforce active transactions through turning off `TransactionAwarePersistenceManagerFactoryProxy`'s `allowCreate` flag:

```
<beans>

    <bean id="myPmfProxy"
            class="org.springframework.orm.jdo.TransactionAwarePersistenceManagerFactoryProxy">
        <property name="targetPersistenceManagerFactory" ref="myPmf"/>
        <property name="allowCreate" value="false"/>
    </bean>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="persistenceManagerFactory" ref="myPmfProxy"/>
    </bean>

</beans>
```

The main advantage of this DAO style is that it depends on JDO API only; no import of any Spring class is required. This is of course appealing from a non-invasiveness perspective, and might feel more natural to JDO developers.

However, the DAO throws plain `JDOException` (which is unchecked, so does not have to be declared or caught), which means that callers can only treat exceptions as fatal, unless you want to depend on JDO's own exception structure. Catching specific causes such as an optimistic locking failure is not possible without tying the caller to the implementation strategy. This trade off might be acceptable to applications that are strongly JDO-based and/or do not need any special exception treatment.

In summary, you can DAOs based on the plain JDO API, and they can still participate in Spring-managed transactions. This strategy might appeal to you if you are already familiar with JDO. However, such DAOs throw plain `JDOException`, and you would have to convert explicitly to Spring's `DataAccessException` (if desired).

Transaction management

> **Note**
>
> You are *strongly* encouraged to read Section 12.5, “Declarative transaction management” if you have not done so, to get a more detailed coverage of Spring’s declarative transaction support.

To execute service operations within transactions, you can use Spring’s common declarative transaction facilities. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean id="myTxManager" class="org.springframework.orm.jdo.JdoTransactionManager">
        <property name="persistenceManagerFactory" ref="myPmf"/>
    </bean>

    <bean id="myProductService" class="product.ProductServiceImpl">
        <property name="productDao" ref="myProductDao"/>
    </bean>

    <tx:advice id="txAdvice" transaction-manager="txManager">
        <tx:attributes>
            <tx:method name="increasePrice*" propagation="REQUIRED"/>
            <tx:method name="someOtherBusinessMethod" propagation="REQUIRES_NEW"/>
            <tx:method name="" propagation="SUPPORTS" read-only="true"/>
        </tx:attributes>
    </tx:advice>

    <aop:config>
        <aop:pointcut id="productServiceMethods"
                expression="execution( product.ProductService.*(..))"/>
        <aop:advisor advice-ref="txAdvice" pointcut-ref="productServiceMethods"/>
    </aop:config>

</beans>
```

JDO requires an active transaction to modify a persistent object. The non-transactional flush concept does not exist in JDO, in contrast to Hibernate. For this reason, you need to set up the chosen JDO implementation for a specific environment. Specifically, you need to set it up explicitly for JTA synchronization, to detect an active JTA transaction itself. This is not necessary for local transactions as performed by Spring’s `JdoTransactionManager`, but it is necessary to participate in JTA transactions, whether driven by Spring’s `JtaTransactionManager` or by EJB CMT and plain JTA.

`JdoTransactionManager` is capable of exposing a JDO transaction to JDBC access code that accesses the same JDBC `DataSource`, provided that the registered `JdoDialect` supports retrieval of the underlying JDBC `Connection`. This is the case for JDBC-based JDO 2.0 implementations by default.

JdoDialect

As an advanced feature, both `JdoTemplate` and `JdoTransactionManager` support a custom `JdoDialect` that can be passed into the `jdoDialect` bean property. In this scenario, the DAOs will not receive a `PersistenceManagerFactory` reference but rather a full `JdoTemplate` instance (for example, passed into the `jdoTemplate` property of `JdoDaoSupport`). Using a `JdoDialect` implementation, you can enable advanced features supported by Spring, usually in a vendor-specific manner:

- Applying specific transaction semantics such as custom isolation level or transaction timeout
- Retrieving the transactional JDBC `Connection` for exposure to JDBC-based DAOs
- Applying query timeouts, which are automatically calculated from Spring-managed transaction timeouts
- Eagerly flushing a `PersistenceManager,` to make transactional changes visible to JDBC-based data access code
- Advanced translation of `JDOExceptions` to Spring `DataAccessExceptions`

See the `JdoDialect` javadocs for more details on its operations and how to use them within Spring's JDO support.

15.5 JPA

The Spring JPA, available under the `org.springframework.orm.jpa` package, offers comprehensive support for the Java Persistence API in a similar manner to the integration with Hibernate or JDO, while being aware of the underlying implementation in order to provide additional features.

Three options for JPA setup in a Spring environment

The Spring JPA support offers three ways of setting up the JPA `EntityManagerFactory` that will be used by the application to obtain an entity manager.

LocalEntityManagerFactoryBean

> **Note**
>
> Only use this option in simple deployment environments such as stand-alone applications and integration tests.

The `LocalEntityManagerFactoryBean` creates an `EntityManagerFactory` suitable for simple deployment environments where the application uses only JPA for data access. The factory bean uses the JPA `PersistenceProvider` autodetection mechanism (according to JPA's Java SE bootstrapping) and, in most cases, requires you to specify only the persistence unit name:

```
<beans>
    <bean id="myEmf" class="org.springframework.orm.jpa.LocalEntityManagerFactoryBean">
        <property name="persistenceUnitName" value="myPersistenceUnit"/>
    </bean>
</beans>
```

This form of JPA deployment is the simplest and the most limited. You cannot refer to an existing JDBC `DataSource` bean definition and no support for global transactions exists. Furthermore, weaving (byte-

code transformation) of persistent classes is provider-specific, often requiring a specific JVM agent to specified on startup. This option is sufficient only for stand-alone applications and test environments, for which the JPA specification is designed.

Obtaining an EntityManagerFactory from JNDI

> **Note**
>
> Use this option when deploying to a Java EE 5 server. Check your server's documentation on how to deploy a custom JPA provider into your server, allowing for a different provider than the server's default.

Obtaining an `EntityManagerFactory` from JNDI (for example in a Java EE 5 environment), is simply a matter of changing the XML configuration:

```
<beans>
    <jee:jndi-lookup id="myEmf" jndi-name="persistence/myPersistenceUnit"/>
</beans>
```

This action assumes standard Java EE 5 bootstrapping: the Java EE server autodetects persistence units (in effect, `META-INF/persistence.xml` files in application jars) and `persistence-unit-ref` entries in the Java EE deployment descriptor (for example, `web.xml`) and defines environment naming context locations for those persistence units.

In such a scenario, the entire persistence unit deployment, including the weaving (byte-code transformation) of persistent classes, is up to the Java EE server. The JDBC `DataSource` is defined through a JNDI location in the `META-INF/persistence.xml` file; EntityManager transactions are integrated with the server's JTA subsystem. Spring merely uses the obtained `EntityManagerFactory`, passing it on to application objects through dependency injection, and managing transactions for the persistence unit, typically through `JtaTransactionManager`.

If multiple persistence units are used in the same application, the bean names of such JNDI-retrieved persistence units should match the persistence unit names that the application uses to refer to them, for example, in `@PersistenceUnit` and `@PersistenceContext` annotations.

LocalContainerEntityManagerFactoryBean

> **Note**
>
> Use this option for full JPA capabilities in a Spring-based application environment. This includes web containers such as Tomcat as well as stand-alone applications and integration tests with sophisticated persistence requirements.

The `LocalContainerEntityManagerFactoryBean` gives full control over `EntityManagerFactory` configuration and is appropriate for environments where fine-grained customization is required. The `LocalContainerEntityManagerFactoryBean` creates a `PersistenceUnitInfo` instance based on the `persistence.xml` file, the supplied `dataSourceLookup` strategy, and the specified `loadTimeWeaver`. It is thus possible to work with custom data sources outside of JNDI and to control the weaving process. The following example shows a typical bean definition for a `LocalContainerEntityManagerFactoryBean`:

```
<beans>
    <bean id="myEmf" class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean">
        <property name="dataSource" ref="someDataSource"/>
        <property name="loadTimeWeaver">
            <bean class="org.springframework.instrument.classloading.InstrumentationLoadTimeWeaver"/>
        </property>
    </bean>
</beans>
```

The following example shows a typical `persistence.xml` file:

```
<persistence xmlns="http://java.sun.com/xml/ns/persistence" version="1.0">
    <persistence-unit name="myUnit" transaction-type="RESOURCE_LOCAL">
        <mapping-file>META-INF/orm.xml</mapping-file>
        <exclude-unlisted-classes/>
    </persistence-unit>
</persistence>
```

> **Note**
>
> The `<exclude-unlisted-classes/>` shortcut indicates that *no* scanning for annotated entity classes is supposed to occur. An explicit *true* value specified - `<exclude-unlisted-classes>true</exclude-unlisted-classes/>` - also means no scan. `<exclude-unlisted-classes>false</exclude-unlisted-classes/>` does trigger a scan; however, it is recommended to simply omit the `exclude-unlisted-classes` element if you want entity class scanning to occur.

Using the `LocalContainerEntityManagerFactoryBean` is the most powerful JPA setup option, allowing for flexible local configuration within the application. It supports links to an existing JDBC `DataSource`, supports both local and global transactions, and so on. However, it also imposes requirements on the runtime environment, such as the availability of a weaving-capable class loader if the persistence provider demands byte-code transformation.

This option may conflict with the built-in JPA capabilities of a Java EE 5 server. In a full Java EE 5 environment, consider obtaining your `EntityManagerFactory` from JNDI. Alternatively, specify a custom `persistenceXmlLocation` on your `LocalContainerEntityManagerFactoryBean` definition, for example, META-INF/my-persistence.xml, and only include a descriptor with that name in your application jar files. Because the Java EE 5 server only looks for default `META-INF/persistence.xml` files, it ignores such custom persistence units and hence avoid conflicts with a Spring-driven JPA setup upfront. (This applies to Resin 3.1, for example.)

> **When is load-time weaving required?**
>
> Not all JPA providers require a JVM agent ; Hibernate is an example of one that does not. If your provider does not require an agent or you have other alternatives, such as applying enhancements at build time through a custom compiler or an ant task, the load-time weaver *should not* be used.

The `LoadTimeWeaver` interface is a Spring-provided class that allows JPA `ClassTransformer` instances to be plugged in a specific manner, depending whether the environment is a web container or application server. Hooking `ClassTransformers` through an agent typically is not efficient. The agents work against the *entire virtual machine* and inspect *every* class that is loaded, which is usually undesirable in a production server environment.

Spring provides a number of `LoadTimeWeaver` implementations for various environments, allowing `ClassTransformer` instances to be applied only *per class loader* and not per VM.

Refer to the section called “Spring configuration” in the AOP chapter for more insight regarding the `LoadTimeWeaver` implementations and their setup, either generic or customized to various platforms (such as Tomcat, WebLogic, GlassFish, Resin and JBoss).

As described in the aforementioned section, you can configure a context-wide `LoadTimeWeaver` using the `@EnableLoadTimeWeaving` annotation of `context:load-time-weaver` XML element. Such a global weaver is picked up by all JPA `LocalContainerEntityManagerFactoryBeans` automatically. This is the preferred way of setting up a load-time weaver, delivering autodetection of the platform (WebLogic, GlassFish, Tomcat, Resin, JBoss or VM agent) and automatic propagation of the weaver to all weaver-aware beans:

```
<context:load-time-weaver/>
<bean id="emf" class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean">
    ...
</bean>
```

However, if needed, one can manually specify a dedicated weaver through the `loadTimeWeaver` property:

```
<bean id="emf" class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean">
    <property name="loadTimeWeaver">
        <bean class="org.springframework.instrument.classloading.ReflectiveLoadTimeWeaver"/>
    </property>
</bean>
```

No matter how the LTW is configured, using this technique, JPA applications relying on instrumentation can run in the target platform (ex: Tomcat) without needing an agent. This is important especially when the hosting applications rely on different JPA implementations because the JPA transformers are applied only at class loader level and thus are isolated from each other.

Dealing with multiple persistence units

For applications that rely on multiple persistence units locations, stored in various JARS in the classpath, for example, Spring offers the `PersistenceUnitManager` to act as a central repository and to avoid the persistence units discovery process, which can be expensive. The default implementation allows multiple locations to be specified that are parsed and later retrieved through the persistence unit name. (By default, the classpath is searched for `META-INF/persistence.xml` files.)

```
<bean id="pum" class="org.springframework.orm.jpa.persistenceunit.DefaultPersistenceUnitManager">
    <property name="persistenceXmlLocations">
        <list>
            <value>org/springframework/orm/jpa/domain/persistence-multi.xml</value>
            <value>classpath:/my/package/*/custom-persistence.xml</value>
            <value>classpath:META-INF/persistence.xml</value>
        </list>
    </property>
    <property name="dataSources">
        <map>
            <entry key="localDataSource" value-ref="local-db"/>
            <entry key="remoteDataSource" value-ref="remote-db"/>
        </map>
    </property>
    <!-- if no datasource is specified, use this one -->
    <property name="defaultDataSource" ref="remoteDataSource"/>
</bean>

<bean id="emf" class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean">
    <property name="persistenceUnitManager" ref="pum"/>
    <property name="persistenceUnitName" value="myCustomUnit"/>
</bean>
```

The default implementation allows customization of the `PersistenceUnitInfo` instances, before they are fed to the JPA provider, declaratively through its properties, which affect *all* hosted units, or programmatically, through the `PersistenceUnitPostProcessor`, which allows persistence unit selection. If no `PersistenceUnitManager` is specified, one is created and used internally by `LocalContainerEntityManagerFactoryBean`.

Implementing DAOs based on plain JPA

> **Note**
>
> Although `EntityManagerFactory` instances are thread-safe, `EntityManager` instances are not. The injected JPA `EntityManager` behaves like an `EntityManager` fetched from an application server's JNDI environment, as defined by the JPA specification. It delegates all calls to the current transactional `EntityManager`, if any; otherwise, it falls back to a newly created `EntityManager` per operation, in effect making its usage thread-safe.

It is possible to write code against the plain JPA without any Spring dependencies, by using an injected `EntityManagerFactory` or `EntityManager`. Spring can understand `@PersistenceUnit` and `@PersistenceContext` annotations both at field and method level if a `PersistenceAnnotationBeanPostProcessor` is enabled. A plain JPA DAO implementation using the `@PersistenceUnit` annotation might look like this:

```
public class ProductDaoImpl implements ProductDao {

    private EntityManagerFactory emf;

    @PersistenceUnit
    public void setEntityManagerFactory(EntityManagerFactory emf) {
        this.emf = emf;
    }

    public Collection loadProductsByCategory(String category) {
        EntityManager em = this.emf.createEntityManager();
        try {
            Query query = em.createQuery("from Product as p where p.category = ?1");
            query.setParameter(1, category);
            return query.getResultList();
        }
        finally {
            if (em != null) {
                em.close();
            }
        }
    }
}
```

The DAO above has no dependency on Spring and still fits nicely into a Spring application context. Moreover, the DAO takes advantage of annotations to require the injection of the default `EntityManagerFactory`:

```
<beans>

    <!-- bean post-processor for JPA annotations -->
    <bean class="org.springframework.orm.jpa.support.PersistenceAnnotationBeanPostProcessor"/>

    <bean id="myProductDao" class="product.ProductDaoImpl"/>

</beans>
```

As an alternative to defining a `PersistenceAnnotationBeanPostProcessor` explicitly, consider using the Spring `context:annotation-config` XML element in your application context configuration. Doing so automatically registers all Spring standard post-processors for annotation-based configuration, including `CommonAnnotationBeanPostProcessor` and so on.

```
<beans>

    <!-- post-processors for all standard config annotations -->
    <context:annotation-config/>

    <bean id="myProductDao" class="product.ProductDaoImpl"/>

</beans>
```

The main problem with such a DAO is that it always creates a new `EntityManager` through the factory. You can avoid this by requesting a transactional `EntityManager` (also called "shared EntityManager" because it is a shared, thread-safe proxy for the actual transactional EntityManager) to be injected instead of the factory:

```
public class ProductDaoImpl implements ProductDao {

    @PersistenceContext
    private EntityManager em;

    public Collection loadProductsByCategory(String category) {
        Query query = em.createQuery("from Product as p where p.category = :category");
        query.setParameter("category", category);
        return query.getResultList();
    }
}
```

The `@PersistenceContext` annotation has an optional attribute `type`, which defaults to `PersistenceContextType.TRANSACTION`. This default is what you need to receive a shared EntityManager proxy. The alternative, `PersistenceContextType.EXTENDED`, is a completely different affair: This results in a so-called extended EntityManager, which is *not thread-safe* and hence must not be used in a concurrently accessed component such as a Spring-managed singleton bean. Extended EntityManagers are only supposed to be used in stateful components that, for example, reside in a session, with the lifecycle of the EntityManager not tied to a current transaction but rather being completely up to the application.

Method- and field-level Injection

Annotations that indicate dependency injections (such as `@PersistenceUnit` and `@PersistenceContext`) can be applied on field or methods inside a class, hence the expressions *method-level injection* and *field-level injection*. Field-level annotations are concise and easier to use while method-level allows for further processing of the injected dependency. In both cases the member visibility (public, protected, private) does not matter.

What about class-level annotations?

On the Java EE 5 platform, they are used for dependency declaration and not for resource injection.

The injected `EntityManager` is Spring-managed (aware of the ongoing transaction). It is important to note that even though the new DAO implementation uses method level injection of an `EntityManager` instead of an `EntityManagerFactory`, no change is required in the application context XML due to annotation usage.

The main advantage of this DAO style is that it only depends on Java Persistence API; no import of any Spring class is required. Moreover, as the JPA annotations are understood, the injections are applied automatically by the Spring container. This is appealing from a non-invasiveness perspective, and might feel more natural to JPA developers.

Transaction Management

> **Note**
>
> You are *strongly* encouraged to read Section 12.5, “Declarative transaction management” if you have not done so, to get a more detailed coverage of Spring’s declarative transaction support.

To execute service operations within transactions, you can use Spring’s common declarative transaction facilities. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:tx="http://www.springframework.org/schema/tx"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/tx
        http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop
        http://www.springframework.org/schema/aop/spring-aop.xsd">

    <bean id="myTxManager" class="org.springframework.orm.jpa.JpaTransactionManager">
        <property name="entityManagerFactory" ref="myEmf"/>
    </bean>

    <bean id="myProductService" class="product.ProductServiceImpl">
        <property name="productDao" ref="myProductDao"/>
    </bean>

    <aop:config>
        <aop:pointcut id="productServiceMethods" expression="execution(* product.ProductService.(..))"/>
        <aop:advisor advice-ref="txAdvice" pointcut-ref="productServiceMethods"/>
    </aop:config>

    <tx:advice id="txAdvice" transaction-manager="myTxManager">
        <tx:attributes>
            <tx:method name="increasePrice" propagation="REQUIRED"/>
            <tx:method name="someOtherBusinessMethod" propagation="REQUIRES_NEW"/>
            <tx:method name="*" propagation="SUPPORTS" read-only="true"/>
        </tx:attributes>
    </tx:advice>

</beans>
```

Spring JPA allows a configured `JpaTransactionManager` to expose a JPA transaction to JDBC access code that accesses the same JDBC `DataSource`, provided that the registered `JpaDialect` supports retrieval of the underlying JDBC `Connection`. Out of the box, Spring provides dialects for the Toplink, Hibernate and OpenJPA JPA implementations. See the next section for details on the `JpaDialect` mechanism.

JpaDialect

As an advanced feature `JpaTemplate`, `JpaTransactionManager` and subclasses of `AbstractEntityManagerFactoryBean` support a custom `JpaDialect`, to be passed into the

`jpaDialect` bean property. In such a scenario, the DAOs do not receive an `EntityManagerFactory` reference but rather a full `JpaTemplate` instance (for example, passed into the `jpaTemplate` property of `JpaDaoSupport`). A `JpaDialect` implementation can enable some advanced features supported by Spring, usually in a vendor-specific manner:

- Applying specific transaction semantics such as custom isolation level or transaction timeout)
- Retrieving the transactional JDBC `Connection` for exposure to JDBC-based DAOs)
- Advanced translation of `PersistenceExceptions` to Spring `DataAccessExceptions`

This is particularly valuable for special transaction semantics and for advanced translation of exception. The default implementation used (`DefaultJpaDialect`) does not provide any special capabilities and if the above features are required, you have to specify the appropriate dialect.

See the `JpaDialect` javadocs for more details of its operations and how they are used within Spring's JPA support.

16. Marshalling XML using O/X Mappers

16.1 Introduction

In this chapter, we will describe Spring's Object/XML Mapping support. Object/XML Mapping, or O/X mapping for short, is the act of converting an XML document to and from an object. This conversion process is also known as XML Marshalling, or XML Serialization. This chapter uses these terms interchangeably.

Within the field of O/X mapping, a *marshaller* is responsible for serializing an object (graph) to XML. In similar fashion, an *unmarshaller* deserializes the XML to an object graph. This XML can take the form of a DOM document, an input or output stream, or a SAX handler.

Some of the benefits of using Spring for your O/X mapping needs are:

Ease of configuration

Spring's bean factory makes it easy to configure marshallers, without needing to construct JAXB context, JiBX binding factories, etc. The marshallers can be configured as any other bean in your application context. Additionally, XML Schema-based configuration is available for a number of marshallers, making the configuration even simpler.

Consistent Interfaces

Spring's O/X mapping operates through two global interfaces: the `Marshaller` and `Unmarshaller` interface. These abstractions allow you to switch O/X mapping frameworks with relative ease, with little or no changes required on the classes that do the marshalling. This approach has the additional benefit of making it possible to do XML marshalling with a mix-and-match approach (e.g. some marshalling performed using JAXB, other using XMLBeans) in a non-intrusive fashion, leveraging the strength of each technology.

Consistent Exception Hierarchy

Spring provides a conversion from exceptions from the underlying O/X mapping tool to its own exception hierarchy with the `XmlMappingException` as the root exception. As can be expected, these runtime exceptions wrap the original exception so no information is lost.

16.2 Marshaller and Unmarshaller

As stated in the introduction, a *marshaller* serializes an object to XML, and an *unmarshaller* deserializes XML stream to an object. In this section, we will describe the two Spring interfaces used for this purpose.

Marshaller

Spring abstracts all marshalling operations behind the `org.springframework.oxm.Marshaller` interface, the main methods of which is listed below.

```
public interface Marshaller {

    /**
     * Marshals the object graph with the given root into the provided Result.
     */
    void marshal(Object graph, Result result) throws XmlMappingException, IOException;

}
```

The `Marshaller` interface has one main method, which marshals the given object to a given `javax.xml.transform.Result`. Result is a tagging interface that basically represents an XML output abstraction: concrete implementations wrap various XML representations, as indicated in the table below.

Result implementation	Wraps XML representation
`DOMResult`	`org.w3c.dom.Node`
`SAXResult`	`org.xml.sax.ContentHandler`
`StreamResult`	`java.io.File`, `java.io.OutputStream`, or `java.io.Writer`

> **Note**
>
> Although the `marshal()` method accepts a plain object as its first parameter, most `Marshaller` implementations cannot handle arbitrary objects. Instead, an object class must be mapped in a mapping file, marked with an annotation, registered with the marshaller, or have a common base class. Refer to the further sections in this chapter to determine how your O/X technology of choice manages this.

Unmarshaller

Similar to the `Marshaller`, there is the `org.springframework.oxm.Unmarshaller` interface.

```
public interface Unmarshaller {

    /**
     * Unmarshals the given provided Source into an object graph.
     */
    Object unmarshal(Source source) throws XmlMappingException, IOException;
}
```

This interface also has one method, which reads from the given `javax.xml.transform.Source` (an XML input abstraction), and returns the object read. As with Result, Source is a tagging interface that has three concrete implementations. Each wraps a different XML representation, as indicated in the table below.

Source implementation	Wraps XML representation
`DOMSource`	`org.w3c.dom.Node`
`SAXSource`	`org.xml.sax.InputSource`, and `org.xml.sax.XMLReader`
`StreamSource`	`java.io.File`, `java.io.InputStream`, or `java.io.Reader`

Even though there are two separate marshalling interfaces (`Marshaller` and `Unmarshaller`), all implementations found in Spring-WS implement both in one class. This means that you can wire up one marshaller class and refer to it both as a marshaller and an unmarshaller in your `applicationContext.xml`.

XmlMappingException

Spring converts exceptions from the underlying O/X mapping tool to its own exception hierarchy with the `XmlMappingException` as the root exception. As can be expected, these runtime exceptions wrap the original exception so no information will be lost.

Additionally, the `MarshallingFailureException` and `UnmarshallingFailureException` provide a distinction between marshalling and unmarshalling operations, even though the underlying O/X mapping tool does not do so.

The O/X Mapping exception hierarchy is shown in the following figure: image::images/oxm-exceptions.png[width=400]

O/X Mapping exception hierarchy

16.3 Using Marshaller and Unmarshaller

Spring's OXM can be used for a wide variety of situations. In the following example, we will use it to marshal the settings of a Spring-managed application as an XML file. We will use a simple JavaBean to represent the settings:

```
public class Settings {

    private boolean fooEnabled;

    public boolean isFooEnabled() {
        return fooEnabled;
    }

    public void setFooEnabled(boolean fooEnabled) {
        this.fooEnabled = fooEnabled;
    }
}
```

The application class uses this bean to store its settings. Besides a main method, the class has two methods: `saveSettings()` saves the settings bean to a file named `settings.xml`, and `loadSettings()` loads these settings again. A `main()` method constructs a Spring application context, and calls these two methods.

```
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;
import javax.xml.transform.stream.StreamResult;
import javax.xml.transform.stream.StreamSource;

import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import org.springframework.oxm.Marshaller;
import org.springframework.oxm.Unmarshaller;

public class Application {

    private static final String FILE_NAME = "settings.xml";
    private Settings settings = new Settings();
    private Marshaller marshaller;
    private Unmarshaller unmarshaller;

    public void setMarshaller(Marshaller marshaller) {
        this.marshaller = marshaller;
    }

    public void setUnmarshaller(Unmarshaller unmarshaller) {
        this.unmarshaller = unmarshaller;
    }

    public void saveSettings() throws IOException {
        FileOutputStream os = null;
        try {
            os = new FileOutputStream(FILE_NAME);
            this.marshaller.marshal(settings, new StreamResult(os));
        } finally {
            if (os != null) {
                os.close();
            }
        }
    }

    public void loadSettings() throws IOException {
        FileInputStream is = null;
        try {
            is = new FileInputStream(FILE_NAME);
            this.settings = (Settings) this.unmarshaller.unmarshal(new StreamSource(is));
        } finally {
            if (is != null) {
                is.close();
            }
        }
    }

    public static void main(String[] args) throws IOException {
        ApplicationContext appContext =
                new ClassPathXmlApplicationContext("applicationContext.xml");
        Application application = (Application) appContext.getBean("application");
        application.saveSettings();
        application.loadSettings();
    }
}
```

The `Application` requires both a `marshaller` and `unmarshaller` property to be set. We can do so using the following `applicationContext.xml`:

```
<beans>
    <bean id="application" class="Application">
        <property name="marshaller" ref="castorMarshaller" />
        <property name="unmarshaller" ref="castorMarshaller" />
    </bean>
    <bean id="castorMarshaller" class="org.springframework.oxm.castor.CastorMarshaller"/>
</beans>
```

This application context uses Castor, but we could have used any of the other marshaller instances described later in this chapter. Note that Castor does not require any further configuration by default, so the bean definition is rather simple. Also note that the `CastorMarshaller` implements both `Marshaller` and `Unmarshaller`, so we can refer to the `castorMarshaller` bean in both the `marshaller` and `unmarshaller` property of the application.

This sample application produces the following `settings.xml` file:

```
<?xml version="1.0" encoding="UTF-8"?>
<settings foo-enabled="false"/>
```

16.4 XML Schema-based Configuration

Marshallers could be configured more concisely using tags from the OXM namespace. To make these tags available, the appropriate schema has to be referenced first in the preamble of the XML configuration file. Note the *oxm* related text below:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:oxm="http://www.springframework.org/schema/oxm" xsi:schemaLocation="http://
www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd http://www.springframework.org/schema/oxm http://www.springframework.org/schema/oxm/spring-
oxm.xsd">
```

Currently, the following tags are available:

- `jaxb2-marshaller`
- `xmlbeans-marshaller`
- `castor-marshaller`
- `jibx-marshaller`

Each tag will be explained in its respective marshaller's section. As an example though, here is how the configuration of a JAXB2 marshaller might look like:

```
<oxm:jaxb2-marshaller id="marshaller" contextPath="org.springframework.ws.samples.airline.schema"/>
```

16.5 JAXB

The JAXB binding compiler translates a W3C XML Schema into one or more Java classes, a `jaxb.properties` file, and possibly some resource files. JAXB also offers a way to generate a schema from annotated Java classes.

Spring supports the JAXB 2.0 API as XML marshalling strategies, following the `Marshaller` and `Unmarshaller` interfaces described in Section 16.2, "Marshaller and Unmarshaller". The corresponding integration classes reside in the `org.springframework.oxm.jaxb` package.

Jaxb2Marshaller

The `Jaxb2Marshaller` class implements both the Spring `Marshaller` and `Unmarshaller` interface. It requires a context path to operate, which you can set using the `contextPath` property. The

context path is a list of colon (:) separated Java package names that contain schema derived classes. It also offers a `classesToBeBound` property, which allows you to set an array of classes to be supported by the marshaller. Schema validation is performed by specifying one or more schema resource to the bean, like so:

```
<beans>
    <bean id="jaxb2Marshaller" class="org.springframework.oxm.jaxb.Jaxb2Marshaller">
        <property name="classesToBeBound">
            <list>
                <value>org.springframework.oxm.jaxb.Flight</value>
                <value>org.springframework.oxm.jaxb.Flights</value>
            </list>
        </property>
        <property name="schema" value="classpath:org/springframework/oxm/schema.xsd"/>
    </bean>

    ...

</beans>
```

XML Schema-based Configuration

The `jaxb2-marshaller` tag configures a `org.springframework.oxm.jaxb.Jaxb2Marshaller`. Here is an example:

```
<oxm:jaxb2-marshaller id="marshaller" contextPath="org.springframework.ws.samples.airline.schema"/>
```

Alternatively, the list of classes to bind can be provided to the marshaller via the `class-to-be-bound` child tag:

```
<oxm:jaxb2-marshaller id="marshaller">
    <oxm:class-to-be-bound name="org.springframework.ws.samples.airline.schema.Airport"/>
    <oxm:class-to-be-bound name="org.springframework.ws.samples.airline.schema.Flight"/>
    ...
</oxm:jaxb2-marshaller>
```

Available attributes are:

Attribute	Description	Required
`id`	the id of the marshaller	no
`contextPath`	the JAXB Context path	no

16.6 Castor

Castor XML mapping is an open source XML binding framework. It allows you to transform the data contained in a java object model into/from an XML document. By default, it does not require any further configuration, though a mapping file can be used to have more control over the behavior of Castor.

For more information on Castor, refer to the *Castor web site*. The Spring integration classes reside in the `org.springframework.oxm.castor` package.

CastorMarshaller

As with JAXB, the `CastorMarshaller` implements both the `Marshaller` and `Unmarshaller` interface. It can be wired up as follows:

```
<beans>
    <bean id="castorMarshaller" class="org.springframework.oxm.castor.CastorMarshaller" />
    ...
</beans>
```

Mapping

Although it is possible to rely on Castor's default marshalling behavior, it might be necessary to have more control over it. This can be accomplished using a Castor mapping file. For more information, refer to Castor XML Mapping.

The mapping can be set using the `mappingLocation` resource property, indicated below with a classpath resource.

```
<beans>
    <bean id="castorMarshaller" class="org.springframework.oxm.castor.CastorMarshaller" >
        <property name="mappingLocation" value="classpath:mapping.xml" />
    </bean>
</beans>
```

XML Schema-based Configuration

The `castor-marshaller` tag configures a `org.springframework.oxm.castor.CastorMarshaller`. Here is an example:

```
<oxm:castor-marshaller id="marshaller" mapping-location="classpath:org/springframework/oxm/castor/
mapping.xml"/>
```

The marshaller instance can be configured in two ways, by specifying either the location of a mapping file (through the `mapping-location` property), or by identifying Java POJOs (through the `target-class` or `target-package` properties) for which there exist corresponding XML descriptor classes. The latter way is usually used in conjunction with XML code generation from XML schemas.

Available attributes are:

Attribute	Description	Required
`id`	the id of the marshaller	no
`encoding`	the encoding to use for unmarshalling from XML	no
`target-class`	a Java class name for a POJO for which an XML class descriptor is available (as generated through code generation)	no
`target-package`	a Java package name that identifies a package that contains POJOs and their corresponding Castor XML descriptor classes (as generated through code generation from XML schemas)	no

Attribute	Description	Required
`mapping-location`	location of a Castor XML mapping file	no

16.7 XMLBeans

XMLBeans is an XML binding tool that has full XML Schema support, and offers full XML Infoset fidelity. It takes a different approach to that of most other O/X mapping frameworks, in that all classes that are generated from an XML Schema are all derived from `XmlObject`, and contain XML binding information in them.

For more information on XMLBeans, refer to the *XMLBeans web site* . The Spring-WS integration classes reside in the `org.springframework.oxm.xmlbeans` package.

XmlBeansMarshaller

The `XmlBeansMarshaller` implements both the `Marshaller` and `Unmarshaller` interfaces. It can be configured as follows:

```
<beans>

    <bean id="xmlBeansMarshaller" class="org.springframework.oxm.xmlbeans.XmlBeansMarshaller" />
    ...

</beans>
```

> **Note**
>
> Note that the `XmlBeansMarshaller` can only marshal objects of type `XmlObject`, and not every `java.lang.Object`.

XML Schema-based Configuration

The `xmlbeans-marshaller` tag configures a `org.springframework.oxm.xmlbeans.XmlBeansMarshaller`. Here is an example:

```
<oxm:xmlbeans-marshaller id="marshaller"/>
```

Available attributes are:

Attribute	Description	Required
`id`	the id of the marshaller	no
`options`	the bean name of the XmlOptions that is to be used for this marshaller. Typically a `XmlOptionsFactoryBean` definition	no

16.8 JiBX

The JiBX framework offers a solution similar to that which JDO provides for ORM: a binding definition defines the rules for how your Java objects are converted to or from XML. After preparing the binding

and compiling the classes, a JiBX binding compiler enhances the class files, and adds code to handle converting instances of the classes from or to XML.

For more information on JiBX, refer to the *JiBX web site*. The Spring integration classes reside in the `org.springframework.oxm.jibx` package.

JibxMarshaller

The `JibxMarshaller` class implements both the `Marshaller` and `Unmarshaller` interface. To operate, it requires the name of the class to marshal in, which you can set using the `targetClass` property. Optionally, you can set the binding name using the `bindingName` property. In the next sample, we bind the `Flights` class:

```
<beans>
    <bean id="jibxFlightsMarshaller" class="org.springframework.oxm.jibx.JibxMarshaller">
        <property name="targetClass">org.springframework.oxm.jibx.Flights</property>
    </bean>
    ...
</beans>
```

A `JibxMarshaller` is configured for a single class. If you want to marshal multiple classes, you have to configure multiple `JibxMarshallers` with different `targetClass` property values.

XML Schema-based Configuration

The `jibx-marshaller` tag configures a `org.springframework.oxm.jibx.JibxMarshaller`. Here is an example:

```
<oxm:jibx-marshaller id="marshaller" target-
class="org.springframework.ws.samples.airline.schema.Flight"/>
```

Available attributes are:

Attribute	Description	Required
`id`	the id of the marshaller	no
`target-class`	the target class for this marshaller	yes
`bindingName`	the binding name used by this marshaller	no

16.9 XStream

XStream is a simple library to serialize objects to XML and back again. It does not require any mapping, and generates clean XML.

For more information on XStream, refer to the *XStream web site*. The Spring integration classes reside in the `org.springframework.oxm.xstream` package.

XStreamMarshaller

The `XStreamMarshaller` does not require any configuration, and can be configured in an application context directly. To further customize the XML, you can set an*alias map*, which consists of string aliases mapped to classes:

```
<beans>
    <bean id="xstreamMarshaller" class="org.springframework.oxm.xstream.XStreamMarshaller">
        <property name="aliases">
            <props>
                <prop key="Flight">org.springframework.oxm.xstream.Flight</prop>
            </props>
        </property>
    </bean>
    ...
</beans>
```

Warning

By default, XStream allows for arbitrary classes to be unmarshalled, which can result in security vulnerabilities. As such, it is *not recommended to use the `XStreamMarshaller` to unmarshal XML from external sources* (i.e. the Web), as this can result in *security vulnerabilities*. If you do use the `XStreamMarshaller` to unmarshal XML from an external source, set the `supportedClasses` property on the `XStreamMarshaller`, like so:

```
<bean id="xstreamMarshaller" class="org.springframework.oxm.xstream.XStreamMarshaller">
    <property name="supportedClasses" value="org.springframework.oxm.xstream.Flight"/>
    ...
</bean>
```

This will make sure that only the registered classes are eligible for unmarshalling.

Additionally, you can register custom converters to make sure that only your supported classes can be unmarshalled. You might want to add a `CatchAllConverter` as the last converter in the list, in addition to converters that explicitly support the domain classes that should be supported. As a result, default XStream converters with lower priorities and possible security vulnerabilities do not get invoked.

Note

Note that XStream is an XML serialization library, not a data binding library. Therefore, it has limited namespace support. As such, it is rather unsuitable for usage within Web services.

Part V. The Web

This part of the reference documentation covers Spring Framework's support for the presentation tier (and specifically web-based presentation tiers) including support for WebSocket-style messaging in web applications.

Spring Framework's own web framework, Spring Web MVC, is covered in the first couple of chapters. Subsequent chapters are concerned with Spring Framework's integration with other web technologies, such as JSF and.

Following that is coverage of Spring Framework's MVC portlet framework.

The section then concludes with comprehensive coverage of the Spring Framework Chapter 21, *WebSocket Support* (including Section 21.4, "STOMP Over WebSocket Messaging Architecture").

- Chapter 17, *Web MVC framework*
- Chapter 18, *View technologies*
- Chapter 19, *Integrating with other web frameworks*
- Chapter 20, *Portlet MVC Framework*
- Chapter 21, *WebSocket Support*

17. Web MVC framework

17.1 Introduction to Spring Web MVC framework

The Spring Web model-view-controller (MVC) framework is designed around a `DispatcherServlet` that dispatches requests to handlers, with configurable handler mappings, view resolution, locale, time zone and theme resolution as well as support for uploading files. The default handler is based on the `@Controller` and `@RequestMapping` annotations, offering a wide range of flexible handling methods. With the introduction of Spring 3.0, the `@Controller` mechanism also allows you to create RESTful Web sites and applications, through the `@PathVariable` annotation and other features.

"Open for extension…" A key design principle in Spring Web MVC and in Spring in general is the "*Open for extension, closed for modification*" principle.

Some methods in the core classes of Spring Web MVC are marked `final`. As a developer you cannot override these methods to supply your own behavior. This has not been done arbitrarily, but specifically with this principle in mind.

For an explanation of this principle, refer to *Expert Spring Web MVC and Web Flow* by Seth Ladd and others; specifically see the section "A Look At Design," on page 117 of the first edition. Alternatively, see

- Bob Martin, The Open-Closed Principle (PDF)

You cannot add advice to final methods when you use Spring MVC. For example, you cannot add advice to the `AbstractController.setSynchronizeOnSession()` method. Refer to the section called “Understanding AOP proxies” for more information on AOP proxies and why you cannot add advice to final methods.

In Spring Web MVC you can use any object as a command or form-backing object; you do not need to implement a framework-specific interface or base class. Spring’s data binding is highly flexible: for example, it treats type mismatches as validation errors that can be evaluated by the application, not as system errors. Thus you need not duplicate your business objects' properties as simple, untyped strings in your form objects simply to handle invalid submissions, or to convert the Strings properly. Instead, it is often preferable to bind directly to your business objects.

Spring’s view resolution is extremely flexible. A `Controller` is typically responsible for preparing a model `Map` with data and selecting a view name but it can also write directly to the response stream and complete the request. View name resolution is highly configurable through file extension or Accept header content type negotiation, through bean names, a properties file, or even a custom `ViewResolver` implementation. The model (the M in MVC) is a `Map` interface, which allows for the complete abstraction of the view technology. You can integrate directly with template based rendering technologies such as JSP, Velocity and Freemarker, or directly generate XML, JSON, Atom, and many other types of content. The model `Map` is simply transformed into an appropriate format, such as JSP request attributes, a Velocity template model.

Features of Spring Web MVC

Spring Web Flow

Spring Web Flow (SWF) aims to be the best solution for the management of web application page flow.

SWF integrates with existing frameworks like Spring MVC and JSF, in both Servlet and Portlet environments. If you have a business process (or processes) that would benefit from a conversational model as opposed to a purely request model, then SWF may be the solution.

SWF allows you to capture logical page flows as self-contained modules that are reusable in different situations, and as such is ideal for building web application modules that guide the user through controlled navigations that drive business processes.

For more information about SWF, consult the Spring Web Flow website.

Spring's web module includes many unique web support features:

- *Clear separation of roles*. Each role — controller, validator, command object, form object, model object, `DispatcherServlet`, handler mapping, view resolver, and so on — can be fulfilled by a specialized object.
- *Powerful and straightforward configuration of both framework and application classes as JavaBeans*. This configuration capability includes easy referencing across contexts, such as from web controllers to business objects and validators.
- *Adaptability, non-intrusiveness, and flexibility.* Define any controller method signature you need, possibly using one of the parameter annotations (such as @RequestParam, @RequestHeader, @PathVariable, and more) for a given scenario.
- *Reusable business code, no need for duplication*. Use existing business objects as command or form objects instead of mirroring them to extend a particular framework base class.
- *Customizable binding and validation*. Type mismatches as application-level validation errors that keep the offending value, localized date and number binding, and so on instead of String-only form objects with manual parsing and conversion to business objects.
- *Customizable handler mapping and view resolution*. Handler mapping and view resolution strategies range from simple URL-based configuration, to sophisticated, purpose-built resolution strategies. Spring is more flexible than web MVC frameworks that mandate a particular technique.
- *Flexible model transfer*. Model transfer with a name/value `Map` supports easy integration with any view technology.
- *Customizable locale, time zone and theme resolution, support for JSPs with or without Spring tag library, support for JSTL, support for Velocity without the need for extra bridges, and so on.*
- *A simple yet powerful JSP tag library known as the Spring tag library that provides support for features such as data binding and themes*. The custom tags allow for maximum flexibility in terms of markup code. For information on the tag library descriptor, see the appendix entitled Chapter 36, *spring.tld*
- *A JSP form tag library, introduced in Spring 2.0, that makes writing forms in JSP pages much easier.* For information on the tag library descriptor, see the appendix entitled Chapter 37, *spring-form.tld*
- *Beans whose lifecycle is scoped to the current HTTP request or HTTP `Session`.* This is not a specific feature of Spring MVC itself, but rather of the `WebApplicationContext` container(s) that Spring MVC uses. These bean scopes are described in the section called "Request, session, and global session scopes"

Pluggability of other MVC implementations

Non-Spring MVC implementations are preferable for some projects. Many teams expect to leverage their existing investment in skills and tools, for example with JSF.

If you do not want to use Spring's Web MVC, but intend to leverage other solutions that Spring offers, you can integrate the web MVC framework of your choice with Spring easily. Simply start up a Spring root application context through its `ContextLoaderListener`, and access it through its `ServletContext` attribute (or Spring's respective helper method) from within any action object. No "plug-ins" are involved, so no dedicated integration is necessary. From the web layer's point of view, you simply use Spring as a library, with the root application context instance as the entry point.

Your registered beans and Spring's services can be at your fingertips even without Spring's Web MVC. Spring does not compete with other web frameworks in this scenario. It simply addresses the many areas that the pure web MVC frameworks do not, from bean configuration to data access and transaction handling. So you can enrich your application with a Spring middle tier and/or data access tier, even if you just want to use, for example, the transaction abstraction with JDBC or Hibernate.

17.2 The DispatcherServlet

Spring's web MVC framework is, like many other web MVC frameworks, request-driven, designed around a central Servlet that dispatches requests to controllers and offers other functionality that facilitates the development of web applications. Spring's `DispatcherServlet` however, does more than just that. It is completely integrated with the Spring IoC container and as such allows you to use every other feature that Spring has.

The request processing workflow of the Spring Web MVC `DispatcherServlet` is illustrated in the following diagram. The pattern-savvy reader will recognize that the `DispatcherServlet` is an expression of the "Front Controller" design pattern (this is a pattern that Spring Web MVC shares with many other leading web frameworks).

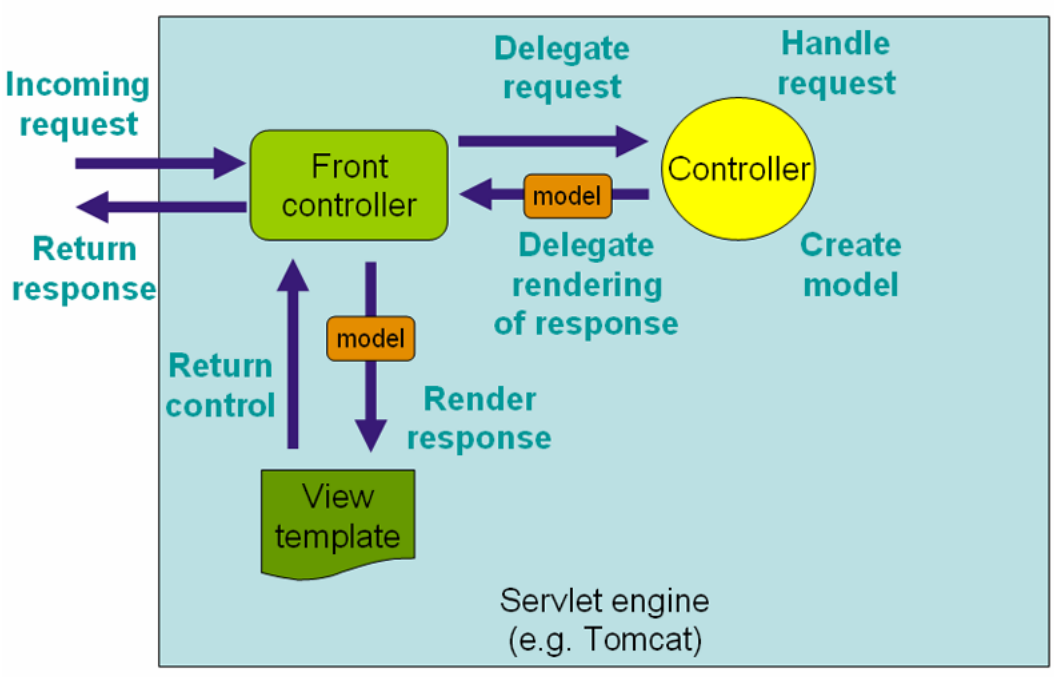


Figure 17.1.

The request processing workflow in Spring Web MVC (high level)

The `DispatcherServlet` is an actual `Servlet` (it inherits from the `HttpServlet` base class), and as such is declared in the `web.xml` of your web application. You need to map requests that you want the `DispatcherServlet` to handle, by using a URL mapping in the same `web.xml` file. This is standard Java EE Servlet configuration; the following example shows such a `DispatcherServlet` declaration and mapping:

```
<web-app>
    <servlet>
        <servlet-name>example</servlet-name>
        <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
        <load-on-startup>1</load-on-startup>
    </servlet>

    <servlet-mapping>
        <servlet-name>example</servlet-name>
        <url-pattern>/example/*</url-pattern>
    </servlet-mapping>

</web-app>
```

In the preceding example, all requests starting with `/example` will be handled by the `DispatcherServlet` instance named `example`. In a Servlet 3.0+ environment, you also have the option of configuring the Servlet container programmatically. Below is the code based equivalent of the above `web.xml` example:

```
public class MyWebApplicationInitializer implements WebApplicationInitializer {

    @Override
    public void onStartup(ServletContext container) {
        ServletRegistration.Dynamic registration = container.addServlet("dispatcher", new
 DispatcherServlet());
        registration.setLoadOnStartup(1);
        registration.addMapping("/example/*");
    }

}
```

`WebApplicationInitializer` is an interface provided by Spring MVC that ensures your code-based configuration is detected and automatically used to initialize any Servlet 3 container. An abstract base class implementation of this interace named `AbstractDispatcherServletInitializer` makes it even easier to register the `DispatcherServlet` by simply specifying its servlet mapping. See Code-based Servlet container initialization for more details.

The above is only the first step in setting up Spring Web MVC. You now need to configure the various beans used by the Spring Web MVC framework (over and above the `DispatcherServlet` itself).

As detailed in Section 5.15, “Additional Capabilities of the ApplicationContext”, `ApplicationContext` instances in Spring can be scoped. In the Web MVC framework, each `DispatcherServlet` has its own `WebApplicationContext`, which inherits all the beans already defined in the root `WebApplicationContext`. These inherited beans can be overridden in the servlet-specific scope, and you can define new scope-specific beans local to a given Servlet instance.

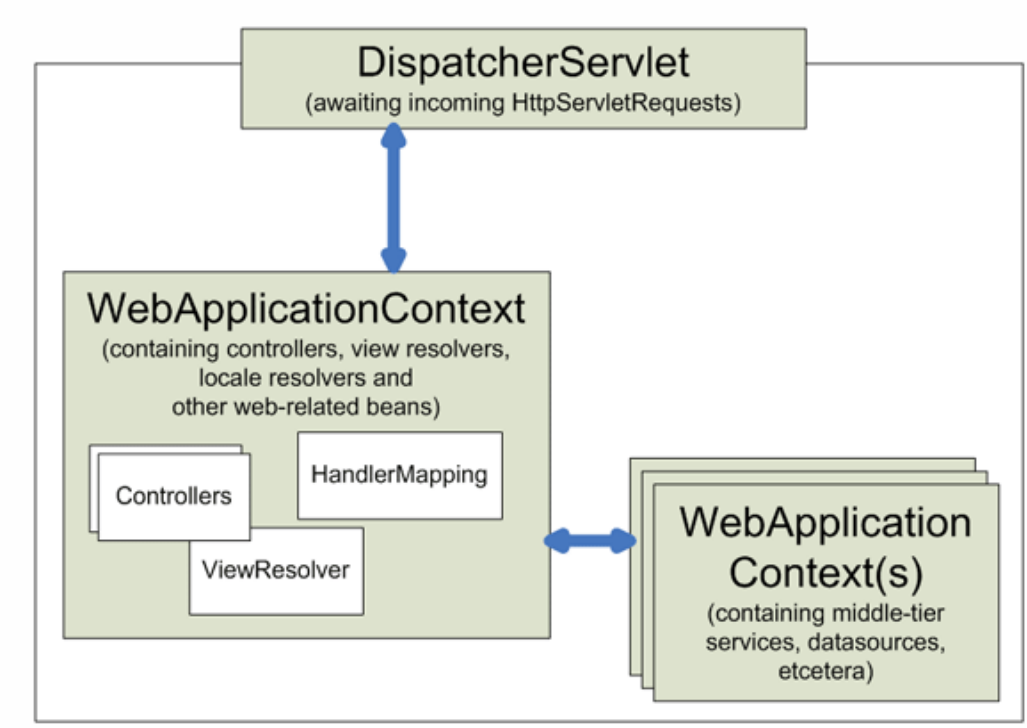


Figure 17.2. Context hierarchy in Spring Web MVC

Upon initialization of a `DispatcherServlet`, Spring MVC looks for a file named *[servlet-name]-servlet.xml* in the `WEB-INF` directory of your web application and creates the beans defined there, overriding the definitions of any beans defined with the same name in the global scope.

Consider the following `DispatcherServlet` Servlet configuration (in the `web.xml` file):

```
<web-app>
    <servlet>
        <servlet-name>golfing</servlet-name>
        <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
        <load-on-startup>1</load-on-startup>
    </servlet>
    <servlet-mapping>
        <servlet-name>golfing</servlet-name>
        <url-pattern>/golfing/*</url-pattern>
    </servlet-mapping>
</web-app>
```

With the above Servlet configuration in place, you will need to have a file called `/WEB-INF/golfing-servlet.xml` in your application; this file will contain all of your Spring Web MVC-specific components (beans). You can change the exact location of this configuration file through a Servlet initialization parameter (see below for details).

It is also possible to have just one root context for single DispatcherServlet scenarios by setting an empty contextConfigLocation servlet init parameter, as shown below:

```
<web-app>
    <context-param>
        <param-name>contextConfigLocation</param-name>
        <param-value>/WEB-INF/root-context.xml</param-value>
    </context-param>
    <servlet>
        <servlet-name>dispatcher</servlet-name>
        <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
        <init-param>
            <param-name>contextConfigLocation</param-name>
            <param-value></param-value>
        </init-param>
        <load-on-startup>1</load-on-startup>
    </servlet>
    <servlet-mapping>
        <servlet-name>dispatcher</servlet-name>
        <url-pattern>/*</url-pattern>
    </servlet-mapping>
    <listener>
        <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
    </listener>
</web-app>
```

The `WebApplicationContext` is an extension of the plain `ApplicationContext` that has some extra features necessary for web applications. It differs from a normal `ApplicationContext` in that it is capable of resolving themes (see Section 17.9, “Using themes”), and that it knows which Servlet it is associated with (by having a link to the `ServletContext`). The `WebApplicationContext` is bound in the `ServletContext`, and by using static methods on the `RequestContextUtils` class you can always look up the `WebApplicationContext` if you need access to it.

Special Bean Types In the WebApplicationContext

The Spring `DispatcherServlet` uses special beans to process requests and render the appropriate views. These beans are part of Spring MVC. You can choose which special beans to use by simply configuring one or more of them in the `WebApplicationContext`. However, you don’t need to do that initially since Spring MVC maintains a list of default beans to use if you don’t configure any. More on that in the next section. First see the table below listing the special bean types the `DispatcherServlet` relies on.

Table 17.1. Special bean types in the WebApplicationContext

Bean type	Explanation
HandlerMapping	Maps incoming requests to handlers and a list of pre- and post-processors (handler interceptors) based on some criteria the details of which vary by `HandlerMapping` implementation. The most popular implementation supports annotated controllers but other implementations exists as well.
HandlerAdapter	Helps the `DispatcherServlet` to invoke a handler mapped to a request regardless of the handler is actually invoked. For example, invoking an annotated controller requires resolving various annotations. Thus the main purpose of a `HandlerAdapter` is to shield the `DispatcherServlet` from such details.

Bean type	Explanation
HandlerExceptionResolver	Maps exceptions to views also allowing for more complex exception handling code.
ViewResolver	Resolves logical String-based view names to actual `View` types.
LocaleResolver & LocaleContextResolver	Resolves the locale a client is using and possibly their time zone, in order to be able to offer internationalized views
ThemeResolver	Resolves themes your web application can use, for example, to offer personalized layouts
MultipartResolver	Parses multi-part requests for example to support processing file uploads from HTML forms.
FlashMapManager	Stores and retrieves the "input" and the "output" `FlashMap` that can be used to pass attributes from one request to another, usually across a redirect.

Default DispatcherServlet Configuration

As mentioned in the previous section for each special bean the `DispatcherServlet` maintains a list of implementations to use by default. This information is kept in the file `DispatcherServlet.properties` in the package `org.springframework.web.servlet`.

All special beans have some reasonable defaults of their own. Sooner or later though you'll need to customize one or more of the properties these beans provide. For example it's quite common to configure an `InternalResourceViewResolver` settings its `prefix` property to the parent location of view files.

Regardless of the details, the important concept to understand here is that once you configure a special bean such as an `InternalResourceViewResolver` in your `WebApplicationContext`, you effectively override the list of default implementations that would have been used otherwise for that special bean type. For example if you configure an `InternalResourceViewResolver`, the default list of `ViewResolver` implementations is ignored.

In Section 17.16, "Configuring Spring MVC" you'll learn about other options for configuring Spring MVC including MVC Java config and the MVC XML namespace both of which provide a simple starting point and assume little knowledge of how Spring MVC works. Regardless of how you choose to configure your application, the concepts explained in this section are fundamental should be of help to you.

DispatcherServlet Processing Sequence

After you set up a `DispatcherServlet`, and a request comes in for that specific `DispatcherServlet`, the `DispatcherServlet` starts processing the request as follows:

- The `WebApplicationContext` is searched for and bound in the request as an attribute that the controller and other elements in the process can use. It is bound by default under the key `DispatcherServlet.WEB_APPLICATION_CONTEXT_ATTRIBUTE`.

- The locale resolver is bound to the request to enable elements in the process to resolve the locale to use when processing the request (rendering the view, preparing data, and so on). If you do not need locale resolving, you do not need it.
- The theme resolver is bound to the request to let elements such as views determine which theme to use. If you do not use themes, you can ignore it.
- If you specify a multipart file resolver, the request is inspected for multiparts; if multiparts are found, the request is wrapped in a `MultipartHttpServletRequest` for further processing by other elements in the process. See Section 17.10, “Spring’s multipart (file upload) support” for further information about multipart handling.
- An appropriate handler is searched for. If a handler is found, the execution chain associated with the handler (preprocessors, postprocessors, and controllers) is executed in order to prepare a model or rendering.
- If a model is returned, the view is rendered. If no model is returned, (may be due to a preprocessor or postprocessor intercepting the request, perhaps for security reasons), no view is rendered, because the request could already have been fulfilled.

Handler exception resolvers that are declared in the `WebApplicationContext` pick up exceptions that are thrown during processing of the request. Using these exception resolvers allows you to define custom behaviors to address exceptions.

The Spring `DispatcherServlet` also supports the return of the *last-modification-date*, as specified by the Servlet API. The process of determining the last modification date for a specific request is straightforward: the `DispatcherServlet` looks up an appropriate handler mapping and tests whether the handler that is found implements the *LastModified* interface. If so, the value of the `long getLastModified(request)` method of the `LastModified` interface is returned to the client.

You can customize individual `DispatcherServlet` instances by adding Servlet initialization parameters (`init-param` elements) to the Servlet declaration in the `web.xml` file. See the following table for the list of supported parameters.

Table 17.2. DispatcherServlet initialization parameters

Parameter	Explanation
`contextClass`	Class that implements `WebApplicationContext`, which instantiates the context used by this Servlet. By default, the `XmlWebApplicationContext` is used.
`contextConfigLocation`	String that is passed to the context instance (specified by `contextClass`) to indicate where context(s) can be found. The string consists potentially of multiple strings (using a comma as a delimiter) to support multiple contexts. In case of multiple context locations with beans that are defined twice, the latest location takes precedence.
`namespace`	Namespace of the `WebApplicationContext`. Defaults to `[servlet-name]-servlet`.

17.3 Implementing Controllers

Controllers provide access to the application behavior that you typically define through a service interface. Controllers interpret user input and transform it into a model that is represented to the user by the view. Spring implements a controller in a very abstract way, which enables you to create a wide variety of controllers.

Spring 2.5 introduced an annotation-based programming model for MVC controllers that uses annotations such as `@RequestMapping`, `@RequestParam`, `@ModelAttribute`, and so on. This annotation support is available for both Servlet MVC and Portlet MVC. Controllers implemented in this style do not have to extend specific base classes or implement specific interfaces. Furthermore, they do not usually have direct dependencies on Servlet or Portlet APIs, although you can easily configure access to Servlet or Portlet facilities.

> **Tip**
>
> Available in the spring-projects Org on Github, a number of web applications leverage the annotation support described in this section including *MvcShowcase*, *MvcAjax*, *MvcBasic*, *PetClinic*, *PetCare*, and others.

```
@Controller
public class HelloWorldController {

    @RequestMapping("/helloWorld")
    public String helloWorld(Model model) {
        model.addAttribute("message", "Hello World!");
        return "helloWorld";
    }
}
```

As you can see, the `@Controller` and `@RequestMapping` annotations allow flexible method names and signatures. In this particular example the method accepts a `Model` and returns a view name as a `String`, but various other method parameters and return values can be used as explained later in this section. `@Controller` and `@RequestMapping` and a number of other annotations form the basis for the Spring MVC implementation. This section documents these annotations and how they are most commonly used in a Servlet environment.

Defining a controller with @Controller

The `@Controller` annotation indicates that a particular class serves the role of a *controller*. Spring does not require you to extend any controller base class or reference the Servlet API. However, you can still reference Servlet-specific features if you need to.

The `@Controller` annotation acts as a stereotype for the annotated class, indicating its role. The dispatcher scans such annotated classes for mapped methods and detects `@RequestMapping` annotations (see the next section).

You can define annotated controller beans explicitly, using a standard Spring bean definition in the dispatcher's context. However, the `@Controller` stereotype also allows for autodetection, aligned with Spring general support for detecting component classes in the classpath and auto-registering bean definitions for them.

To enable autodetection of such annotated controllers, you add component scanning to your configuration. Use the *spring-context* schema as shown in the following XML snippet:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:p="http://www.springframework.org/schema/p"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:component-scan base-package="org.springframework.samples.petclinic.web"/>

    <!-- ... -->

</beans>
```

Mapping Requests With @RequestMapping

You use the `@RequestMapping` annotation to map URLs such as `/appointments` onto an entire class or a particular handler method. Typically the class-level annotation maps a specific request path (or path pattern) onto a form controller, with additional method-level annotations narrowing the primary mapping for a specific HTTP method request method ("GET", "POST", etc.) or an HTTP request parameter condition.

The following example from the *Petcare* sample shows a controller in a Spring MVC application that uses this annotation:

```
@Controller
@RequestMapping("/appointments")
public class AppointmentsController {

    private final AppointmentBook appointmentBook;

    @Autowired
    public AppointmentsController(AppointmentBook appointmentBook) {
        this.appointmentBook = appointmentBook;
    }

    @RequestMapping(method = RequestMethod.GET)
    public Map<String, Appointment> get() {
        return appointmentBook.getAppointmentsForToday();
    }

    @RequestMapping(value="/{day}", method = RequestMethod.GET)
    public Map<String, Appointment> getForDay(@PathVariable @DateTimeFormat(iso=ISO.DATE) Date day,
 Model model) {
        return appointmentBook.getAppointmentsForDay(day);
    }

    @RequestMapping(value="/new", method = RequestMethod.GET)
    public AppointmentForm getNewForm() {
        return new AppointmentForm();
    }

    @RequestMapping(method = RequestMethod.POST)
    public String add(@Valid AppointmentForm appointment, BindingResult result) {
        if (result.hasErrors()) {
            return "appointments/new";
        }
        appointmentBook.addAppointment(appointment);
        return "redirect:/appointments";
    }
}
```

In the example, the `@RequestMapping` is used in a number of places. The first usage is on the type (class) level, which indicates that all handling methods on this controller are relative to the `/appointments` path. The `get()` method has a further `@RequestMapping` refinement: it only accepts GET requests, meaning that an HTTP GET for `/appointments` invokes this method. The `add()` has a similar refinement, and the `getNewForm()` combines the definition of HTTP method and path into one, so that GET requests for `appointments/new` are handled by that method.

The `getForDay()` method shows another usage of `@RequestMapping`: URI templates. (See the next section).

A `@RequestMapping` on the class level is not required. Without it, all paths are simply absolute, and not relative. The following example from the *PetClinic* sample application shows a multi-action controller using `@RequestMapping`:

```
@Controller
public class ClinicController {

    private final Clinic clinic;

    @Autowired
    public ClinicController(Clinic clinic) {
        this.clinic = clinic;
    }

    @RequestMapping("/")
    public void welcomeHandler() {
    }

    @RequestMapping("/vets")
    public ModelMap vetsHandler() {
        return new ModelMap(this.clinic.getVets());
    }

}
```

The above example does not specify GET vs. PUT, POST, and so forth, because `@RequestMapping` maps all HTTP methods by default. Use `@RequestMapping(method=GET)` to narrow the mapping.

`@Controller`'s and AOP Proxying

In some cases a controller may need to be decorated with an AOP proxy at runtime. One example is if you choose to have `@Transactional` annotations directly on the controller. When this is the case, for controllers specifically, we recommend using class-based proxying. This is typically the default choice with controllers. However if a controller must implement an interface that is not a Spring Context callback (e.g. `InitializingBean`, `*Aware`, etc), you may need to explicitly configure class-based proxying. For example with `<tx:annotation-driven />`, change to `<tx:annotation-driven proxy-target-class="true" />`.

New Support Classes for @RequestMapping methods in Spring MVC 3.1

Spring 3.1 introduced a new set of support classes for `@RequestMapping` methods called `RequestMappingHandlerMapping` and `RequestMappingHandlerAdapter` respectively. They are recommended for use and even required to take advantage of new features in Spring MVC 3.1 and going forward. The new support classes are enabled by default by the MVC namespace and the MVC Java config but must be configured explicitly if using neither. This section describes a few important differences between the old and the new support classes.

Prior to Spring 3.1, type and method-level request mappings were examined in two separate stages — a controller was selected first by the `DefaultAnnotationHandlerMapping` and the actual method to invoke was narrowed down second by the `AnnotationMethodHandlerAdapter`.

With the new support classes in Spring 3.1, the `RequestMappingHandlerMapping` is the only place where a decision is made about which method should process the request. Think of controller methods as a collection of unique endpoints with mappings for each method derived from type and method-level `@RequestMapping` information.

This enables some new possibilities. For once a `HandlerInterceptor` or a `HandlerExceptionResolver` can now expect the Object-based handler to be a `HandlerMethod`, which allows them to examine the exact method, its parameters and associated annotations. The processing for a URL no longer needs to be split across different controllers.

There are also several things no longer possible:

- Select a controller first with a `SimpleUrlHandlerMapping` or `BeanNameUrlHandlerMapping` and then narrow the method based on `@RequestMapping` annotations.
- Rely on method names as a fall-back mechanism to disambiguate between two `@RequestMapping` methods that don't have an explicit path mapping URL path but otherwise match equally, e.g. by HTTP method. In the new support classes `@RequestMapping` methods have to be mapped uniquely.
- Have a single default method (without an explicit path mapping) with which requests are processed if no other controller method matches more concretely. In the new support classes if a matching method is not found a 404 error is raised.

The above features are still supported with the existing support classes. However to take advantage of new Spring MVC 3.1 features you'll need to use the new support classes.

URI Template Patterns

URI templates can be used for convenient access to selected parts of a URL in a `@RequestMapping` method.

A URI Template is a URI-like string, containing one or more variable names. When you substitute values for these variables, the template becomes a URI. The proposed RFC for URI Templates defines how a URI is parameterized. For example, the URI Template `http://www.example.com/users/{userId}` contains the variable *userId*. Assigning the value *fred* to the variable yields `http://www.example.com/users/fred`.

In Spring MVC you can use the `@PathVariable` annotation on a method argument to bind it to the value of a URI template variable:

```
@RequestMapping(value="/owners/{ownerId}", method=RequestMethod.GET)
public String findOwner(@PathVariable String ownerId, Model model) {
    Owner owner = ownerService.findOwner(ownerId);
    model.addAttribute("owner", owner);
    return "displayOwner";
}
```

The URI Template "`/owners/{ownerId}`" specifies the variable name `ownerId`. When the controller handles this request, the value of `ownerId` is set to the value found in the appropriate part of the URI. For example, when a request comes in for `/owners/fred`, the value of `ownerId` is `fred`.

Tip

To process the @PathVariable annotation, Spring MVC needs to find the matching URI template variable by name. You can specify it in the annotation:

```
@RequestMapping(value="/owners/{ownerId}", method=RequestMethod.GET)
public String findOwner(@PathVariable("ownerId") String theOwner, Model model) {
    // implementation omitted
}
```

Or if the URI template variable name matches the method argument name you can omit that detail. As long as your code is not compiled without debugging information, Spring MVC will match the method argument name to the URI template variable name:

```
@RequestMapping(value="/owners/{ownerId}", method=RequestMethod.GET)
public String findOwner(@PathVariable String ownerId, Model model) {
    // implementation omitted
}
```

A method can have any number of `@PathVariable` annotations:

```
@RequestMapping(value="/owners/{ownerId}/pets/{petId}", method=RequestMethod.GET)
public String findPet(@PathVariable String ownerId, @PathVariable String petId, Model model) {
    Owner owner = ownerService.findOwner(ownerId);
    Pet pet = owner.getPet(petId);
    model.addAttribute("pet", pet);
    return "displayPet";
}
```

When a `@PathVariable` annotation is used on a `Map<String, String>` argument, the map is populated with all URI template variables.

A URI template can be assembled from type and path level *@RequestMapping* annotations. As a result the `findPet()` method can be invoked with a URL such as `/owners/42/pets/21`.

```
@Controller
@RequestMapping("/owners/{ownerId}")
public class RelativePathUriTemplateController {

    @RequestMapping("/pets/{petId}")
    public void findPet(@PathVariable String ownerId, @PathVariable String petId, Model model) {
        // implementation omitted
    }

}
```

A `@PathVariable` argument can be of *any simple type* such as int, long, Date, etc. Spring automatically converts to the appropriate type or throws a `TypeMismatchException` if it fails to do so. You can also register support for parsing additional data types. See the section called “Method Parameters And Type Conversion” and the section called “Customizing WebDataBinder initialization”.

URI Template Patterns with Regular Expressions

Sometimes you need more precision in defining URI template variables. Consider the URL `"/spring-web/spring-web-3.0.5.jar"`. How do you break it down into multiple parts?

The `@RequestMapping` annotation supports the use of regular expressions in URI template variables. The syntax is `{varName:regex}` where the first part defines the variable name and the second - the regular expression.For example:

```
@RequestMapping("/spring-web/{symbolicName:[a-z-]}-{version:\\d\\.\\d\\.\\d}{extension:\\.[a-z]}")
    public void handle(@PathVariable String version, @PathVariable String extension) {
        // ...
    }
}
```

Path Patterns

In addition to URI templates, the `@RequestMapping` annotation also supports Ant-style path patterns (for example, `/myPath/*.do`). A combination of URI template variables and Ant-style globs is also supported (e.g. `/owners/*/pets/{petId}`).

Path Pattern Comparison

When a URL matches multiple patterns, a sort is used to find the most specific match.

A pattern with a lower count of URI variables and wild cards is considered more specific. For example `/hotels/{hotel}/*` has 1 URI variable and 1 wild card and is considered more specific than `/hotels/{hotel}/**` which as 1 URI variable and 2 wild cards.

If two patterns have the same count, the one that is longer is considered more specific. For example `/foo/bar*` is longer and considered more specific than `/foo/*`.

When two patterns have the same count and length, the pattern with fewer wild cards is considered more specific. For example `/hotels/{hotel}` is more specific than `/hotels/*`.

There are also some additional special rules:

- The **default mapping pattern** `/**` is less specific than any other pattern. For example `/api/{a}/{b}/{c}` is more specific.
- A **prefix pattern** such as `/public/**` is less specific than any other pattern that doesn't contain double wildcards. For example `/public/path3/{a}/{b}/{c}` is more specific.

For the full details see `AntPatternComparator` in `AntPathMatcher`. Note that the PathMatcher can be customized (see the section called "Path Matching" in the section on configuring Spring MVC).

Path Patterns with Placeholders

Patterns in `@RequestMapping` annotations support ${…} placeholders against local properties and/or system properties and environment variables. This may be useful in cases where the path a controller is mapped to may need to be customized through configuration. For more information on placeholders, see the javadocs of the `PropertyPlaceholderConfigurer` class.

Path Pattern Matching By Suffix

By default Spring MVC automatically performs `".*"` suffix pattern matching so that a controller mapped to `/person` is also implicitly mapped to `/person.*`. This allows indicating content types via file extensions, e.g. `/person.pdf`, `/person.xml`, etc. A common pitfall however is when the last path segment of the mapping is a URI variable, e.g. `/person/{id}`. While a request for `/person/1.json` would correctly result in path variable id=1 and extension ".json", when the id naturally contains a dot, e.g. `/person/joe@email.com` the result does not match expectations. Clearly here ".com" is not a file extension.

The proper way to address this is to configure Spring MVC to only do suffix pattern matching against file extensions registered for content negotiation purposes. For more on this, first see the section called

“Content Negotiation” and then the section called “Path Matching” showing how to enable suffix pattern matching along with how to use registered suffix patterns only.

Matrix Variables

The URI specification RFC 3986 defines the possibility of including name-value pairs within path segments. There is no specific term used in the spec. The general "URI path parameters" could be applied although the more unique "Matrix URIs", originating from an old post by Tim Berners-Lee, is also frequently used and fairly well known. Within Spring MVC these are referred to as matrix variables.

Matrix variables can appear in any path segment, each matrix variable separated with a ";" (semicolon). For example: `"/cars;color=red;year=2012"`. Multiple values may be either "," (comma) separated `"color=red,green,blue"` or the variable name may be repeated `"color=red;color=green;color=blue"`.

If a URL is expected to contain matrix variables, the request mapping pattern must represent them with a URI template. This ensures the request can be matched correctly regardless of whether matrix variables are present or not and in what order they are provided.

Below is an example of extracting the matrix variable "q":

```
// GET /pets/42;q=11;r=22

@RequestMapping(value = "/pets/{petId}", method = RequestMethod.GET)
public void findPet(@PathVariable String petId, @MatrixVariable int q) {

    // petId == 42
    // q == 11

}
```

Since all path segments may contain matrix variables, in some cases you need to be more specific to identify where the variable is expected to be:

```
// GET /owners/42;q=11/pets/21;q=22

@RequestMapping(value = "/owners/{ownerId}/pets/{petId}", method = RequestMethod.GET)
public void findPet(
        @MatrixVariable(value="q", pathVar="ownerId") int q1,
        @MatrixVariable(value="q", pathVar="petId") int q2) {

    // q1 == 11
    // q2 == 22

}
```

A matrix variable may be defined as optional and a default value specified:

```
// GET /pets/42

@RequestMapping(value = "/pets/{petId}", method = RequestMethod.GET)
public void findPet(@MatrixVariable(required=false, defaultValue="1") int q) {

    // q == 1

}
```

All matrix variables may be obtained in a Map:

```
// GET /owners/42;q=11;r=12/pets/21;q=22;s=23

@RequestMapping(value = "/owners/{ownerId}/pets/{petId}", method = RequestMethod.GET)
public void findPet(
        @MatrixVariable Map<String, String> matrixVars,
        @MatrixVariable(pathVar="petId"") Map<String, String> petMatrixVars) {

    // matrixVars: ["q" : [11,22], "r" : 12, "s" : 23]
    // petMatrixVars: ["q" : 11, "s" : 23]

}
```

Note that to enable the use of matrix variables, you must set the `removeSemicolonContent` property of `RequestMappingHandlerMapping` to `false`. By default it is set to `true`.

> **Tip**
>
> The MVC Java config and the MVC namespace both provide options for enabling the use of matrix variables.
>
> If you are using Java config, The Advanced Customizations with MVC Java Config section describes how the `RequestMappingHandlerMapping` can be customized.
>
> In the MVC namespace, the `<mvc:annotation-driven>` element has an `enable-matrix-variables` attribute that should be set to `true`. By default it is set to `false`.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <mvc:annotation-driven enable-matrix-variables="true"/>

</beans>
```

Consumable Media Types

You can narrow the primary mapping by specifying a list of consumable media types. The request will be matched only if the *Content-Type* request header matches the specified media type. For example:

```
@Controller
@RequestMapping(value = "/pets", method = RequestMethod.POST, consumes="application/json")
public void addPet(@RequestBody Pet pet, Model model) {
    // implementation omitted
}
```

Consumable media type expressions can also be negated as in *!text/plain* to match to all requests other than those with *Content-Type* of *text/plain*.

> **Tip**
>
> The *consumes* condition is supported on the type and on the method level. Unlike most other conditions, when used at the type level, method-level consumable types override rather than extend type-level consumable types.

Producible Media Types

You can narrow the primary mapping by specifying a list of producible media types. The request will be matched only if the *Accept* request header matches one of these values. Furthermore, use of the *produces* condition ensures the actual content type used to generate the response respects the media types specified in the *produces* condition. For example:

```
@Controller
@RequestMapping(value = "/pets/{petId}", method = RequestMethod.GET, produces="application/json")
@ResponseBody
public Pet getPet(@PathVariable String petId, Model model) {
    // implementation omitted
}
```

Just like with *consumes*, producible media type expressions can be negated as in *!text/plain* to match to all requests other than those with an *Accept* header value of *text/plain*.

> **Tip**
>
> The *produces* condition is supported on the type and on the method level. Unlike most other conditions, when used at the type level, method-level producible types override rather than extend type-level producible types.

Request Parameters and Header Values

You can narrow request matching through request parameter conditions such as `"myParam"`, `"!myParam"`, or `"myParam=myValue"`. The first two test for request parameter presence/absence and the third for a specific parameter value. Here is an example with a request parameter value condition:

```
@Controller
@RequestMapping("/owners/{ownerId}")
public class RelativePathUriTemplateController {

    @RequestMapping(value = "/pets/{petId}", method = RequestMethod.GET, params="myParam=myValue")
    public void findPet(@PathVariable String ownerId, @PathVariable String petId, Model model) {
        // implementation omitted
    }

}
```

The same can be done to test for request header presence/absence or to match based on a specific request header value:

```
@Controller
@RequestMapping("/owners/{ownerId}")
public class RelativePathUriTemplateController {

    @RequestMapping(value = "/pets", method = RequestMethod.GET, headers="myHeader=myValue")
    public void findPet(@PathVariable String ownerId, @PathVariable String petId, Model model) {
        // implementation omitted
    }

}
```

> **Tip**
>
> Although you can match to *Content-Type* and *Accept* header values using media type wild cards (for example *"content-type=text/*"* will match to *"text/plain"* and *"text/html"*), it is recommended to use the *consumes* and *produces* conditions respectively instead. They are intended specifically for that purpose.

Defining @RequestMapping handler methods

An `@RequestMapping` handler method can have a very flexible signatures. The supported method arguments and return values are described in the following section. Most arguments can be used in arbitrary order with the only exception of `BindingResult` arguments. This is described in the next section.

> **Note**
>
> Spring 3.1 introduced a new set of support classes for `@RequestMapping` methods called `RequestMappingHandlerMapping` and `RequestMappingHandlerAdapter` respectively. They are recommended for use and even required to take advantage of new features in Spring MVC 3.1 and going forward. The new support classes are enabled by default from the MVC namespace and with use of the MVC Java config but must be configured explicitly if using neither.

Supported method argument types

The following are the supported method arguments:

- Request or response objects (Servlet API). Choose any specific request or response type, for example `ServletRequest` or `HttpServletRequest`.
- Session object (Servlet API): of type `HttpSession`. An argument of this type enforces the presence of a corresponding session. As a consequence, such an argument is never `null`.

> **Note**
>
> Session access may not be thread-safe, in particular in a Servlet environment. Consider setting the `RequestMappingHandlerAdapter`'s "synchronizeOnSession" flag to "true" if multiple requests are allowed to access a session concurrently.

- `org.springframework.web.context.request.WebRequest` or `org.springframework.web.context.request.NativeWebRequest`. Allows for generic request parameter access as well as request/session attribute access, without ties to the native Servlet/Portlet API.
- `java.util.Locale` for the current request locale, determined by the most specific locale resolver available, in effect, the configured `LocaleResolver` in a Servlet environment.
- `java.io.InputStream` / `java.io.Reader` for access to the request's content. This value is the raw InputStream/Reader as exposed by the Servlet API.
- `java.io.OutputStream` / `java.io.Writer` for generating the response's content. This value is the raw OutputStream/Writer as exposed by the Servlet API.
- `org.springframework.http.HttpMethod` for the HTTP request method.
- `java.security.Principal` containing the currently authenticated user.
- `@PathVariable` annotated parameters for access to URI template variables. See the section called "URI Template Patterns".
- `@MatrixVariable` annotated parameters for access to name-value pairs located in URI path segments. See the section called "Matrix Variables".

- `@RequestParam` annotated parameters for access to specific Servlet request parameters. Parameter values are converted to the declared method argument type. See the section called “Binding request parameters to method parameters with @RequestParam”.
- `@RequestHeader` annotated parameters for access to specific Servlet request HTTP headers. Parameter values are converted to the declared method argument type. See the section called “Mapping request header attributes with the @RequestHeader annotation”.
- `@RequestBody` annotated parameters for access to the HTTP request body. Parameter values are converted to the declared method argument type using `HttpMessageConverters`. See the section called “Mapping the request body with the @RequestBody annotation”.
- `@RequestPart` annotated parameters for access to the content of a "multipart/form-data" request part. See the section called “Handling a file upload request from programmatic clients” and Section 17.10, “Spring’s multipart (file upload) support”.
- `HttpEntity<?>` parameters for access to the Servlet request HTTP headers and contents. The request stream will be converted to the entity body using `HttpMessageConverters`. See the section called “Using HttpEntity”.
- `java.util.Map` / `org.springframework.ui.Model` / `org.springframework.ui.ModelMap` for enriching the implicit model that is exposed to the web view.
- `org.springframework.web.servlet.mvc.support.RedirectAttributes` to specify the exact set of attributes to use in case of a redirect and also to add flash attributes (attributes stored temporarily on the server-side to make them available to the request after the redirect). `RedirectAttributes` is used instead of the implicit model if the method returns a "redirect:" prefixed view name or `RedirectView`.
- Command or form objects to bind request parameters to bean properties (via setters) or directly to fields, with customizable type conversion, depending on `@InitBinder` methods and/or the HandlerAdapter configuration. See the `webBindingInitializer` property on `RequestMappingHandlerAdapter`. Such command objects along with their validation results will be exposed as model attributes by default, using the command class class name - e.g. model attribute "orderAddress" for a command object of type "some.package.OrderAddress". The `ModelAttribute` annotation can be used on a method argument to customize the model attribute name used.
- `org.springframework.validation.Errors` / `org.springframework.validation.BindingResult` validation results for a preceding command or form object (the immediately preceding method argument).
- `org.springframework.web.bind.support.SessionStatus` status handle for marking form processing as complete, which triggers the cleanup of session attributes that have been indicated by the `@SessionAttributes` annotation at the handler type level.
- `org.springframework.web.util.UriComponentsBuilder` a builder for preparing a URL relative to the current request’s host, port, scheme, context path, and the literal part of the servlet mapping.

The `Errors` or `BindingResult` parameters have to follow the model object that is being bound immediately as the method signature might have more that one model object and Spring will create a separate `BindingResult` instance for each of them so the following sample won’t work:

Invalid ordering of BindingResult and @ModelAttribute.

```
@RequestMapping(method = RequestMethod.POST)
public String processSubmit(@ModelAttribute("pet") Pet pet, Model model, BindingResult result) { ... }
```

Note, that there is a `Model` parameter in between `Pet` and `BindingResult`. To get this working you have to reorder the parameters as follows:

```
@RequestMapping(method = RequestMethod.POST)
public String processSubmit(@ModelAttribute("pet") Pet pet, BindingResult result, Model model) { ... }
```

> **Note**
>
> JDK 1.8's `java.util.Optional` is supported as a method parameter type with annotations that have a `required` attribute (e.g. `@RequestParam`, `@RequestHeader`, etc. The use of `java.util.Optional` in those cases is equivalent to having `required=false`.

Supported method return types

The following are the supported return types:

- A `ModelAndView` object, with the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.
- A `Model` object, with the view name implicitly determined through a `RequestToViewNameTranslator` and the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.
- A `Map` object for exposing a model, with the view name implicitly determined through a `RequestToViewNameTranslator` and the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.
- A `View` object, with the model implicitly determined through command objects and `@ModelAttribute` annotated reference data accessor methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above).
- A `String` value that is interpreted as the logical view name, with the model implicitly determined through command objects and `@ModelAttribute` annotated reference data accessor methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above).
- `void` if the method handles the response itself (by writing the response content directly, declaring an argument of type `ServletResponse` / `HttpServletResponse` for that purpose) or if the view name is supposed to be implicitly determined through a `RequestToViewNameTranslator` (not declaring a response argument in the handler method signature).
- If the method is annotated with `@ResponseBody`, the return type is written to the response HTTP body. The return value will be converted to the declared method argument type using `HttpMessageConverters`. See the section called "Mapping the response body with the @ResponseBody annotation".
- An `HttpEntity<?>` or `ResponseEntity<?>` object to provide access to the Servlet response HTTP headers and contents. The entity body will be converted to the response stream using `HttpMessageConverters`. See the section called "Using HttpEntity".

- An `HttpHeaders` object to return a response with no body.
- A `Callable<?>` can be returned when the application wants to produce the return value asynchronously in a thread managed by Spring MVC.
- A `DeferredResult<?>` can be returned when the application wants to produce the return value from a thread of its own choosing.
- A `ListenableFuture<?>` can be returned when the application wants to produce the return value from a thread of its own choosing.
- Any other return type is considered to be a single model attribute to be exposed to the view, using the attribute name specified through `@ModelAttribute` at the method level (or the default attribute name based on the return type class name). The model is implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.

Binding request parameters to method parameters with @RequestParam

Use the `@RequestParam` annotation to bind request parameters to a method parameter in your controller.

The following code snippet shows the usage:

```
@Controller
@RequestMapping("/pets")
@SessionAttributes("pet")
public class EditPetForm {

    // ...

    @RequestMapping(method = RequestMethod.GET)
    public String setupForm(@RequestParam("petId") int petId, ModelMap model) {
        Pet pet = this.clinic.loadPet(petId);
        model.addAttribute("pet", pet);
        return "petForm";
    }

    // ...

}
```

Parameters using this annotation are required by default, but you can specify that a parameter is optional by setting `@RequestParam`'s `required` attribute to `false` (e.g., `@RequestParam(value="id", required=false)`).

Type conversion is applied automatically if the target method parameter type is not `String`. See the section called “Method Parameters And Type Conversion”.

When an `@RequestParam` annotation is used on a `Map<String, String>` or `MultiValueMap<String, String>` argument, the map is populated with all request parameters.

Mapping the request body with the @RequestBody annotation

The `@RequestBody` method parameter annotation indicates that a method parameter should be bound to the value of the HTTP request body. For example:

```
@RequestMapping(value = "/something", method = RequestMethod.PUT)
public void handle(@RequestBody String body, Writer writer) throws IOException {
    writer.write(body);
}
```

You convert the request body to the method argument by using an `HttpMessageConverter`. `HttpMessageConverter` is responsible for converting from the HTTP request message to an object and converting from an object to the HTTP response body. The `RequestMappingHandlerAdapter` supports the `@RequestBody` annotation with the following default `HttpMessageConverters`:

- `ByteArrayHttpMessageConverter` converts byte arrays.
- `StringHttpMessageConverter` converts strings.
- `FormHttpMessageConverter` converts form data to/from a MultiValueMap<String, String>.
- `SourceHttpMessageConverter` converts to/from a javax.xml.transform.Source.

For more information on these converters, see Message Converters. Also note that if using the MVC namespace or the MVC Java config, a wider range of message converters are registered by default. See the section called “Enabling the MVC Java Config or the MVC XML Namespace” for more information.

If you intend to read and write XML, you will need to configure the `MarshallingHttpMessageConverter` with a specific `Marshaller` and an `Unmarshaller` implementation from the `org.springframework.oxm` package. The example below shows how to do that directly in your configuration but if your application is configured through the MVC namespace or the MVC Java config see the section called “Enabling the MVC Java Config or the MVC XML Namespace” instead.

```
<bean class="org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerAdapter">
    <property name="messageConverters">
        <util:list id="beanList">
            <ref bean="stringHttpMessageConverter"/>
            <ref bean="marshallingHttpMessageConverter"/>
        </util:list>
    </property>
</bean>

<bean id="stringHttpMessageConverter"
        class="org.springframework.http.converter.StringHttpMessageConverter"/>

<bean id="marshallingHttpMessageConverter"
        class="org.springframework.http.converter.xml.MarshallingHttpMessageConverter">
    <property name="marshaller" ref="castorMarshaller" />
    <property name="unmarshaller" ref="castorMarshaller" />
</bean>

<bean id="castorMarshaller" class="org.springframework.oxm.castor.CastorMarshaller"/>
```

An `@RequestBody` method parameter can be annotated with `@Valid`, in which case it will be validated using the configured `Validator` instance. When using the MVC namespace or the MVC Java config, a JSR-303 validator is configured automatically assuming a JSR-303 implementation is available on the classpath.

Just like with `@ModelAttribute` parameters, an `Errors` argument can be used to examine the errors. If such an argument is not declared, a `MethodArgumentNotValidException` will be raised. The exception is handled in the `DefaultHandlerExceptionResolver`, which sends a `400` error back to the client.

> **Note**
>
> Also see the section called “Enabling the MVC Java Config or the MVC XML Namespace” for information on configuring message converters and a validator through the MVC namespace or the MVC Java config.

Mapping the response body with the @ResponseBody annotation

The `@ResponseBody` annotation is similar to `@RequestBody`. This annotation can be put on a method and indicates that the return type should be written straight to the HTTP response body (and not placed in a Model, or interpreted as a view name). For example:

```
@RequestMapping(value = "/something", method = RequestMethod.PUT)
@ResponseBody
public String helloWorld() {
    return "Hello World";
}
```

The above example will result in the text `Hello World` being written to the HTTP response stream.

As with `@RequestBody`, Spring converts the returned object to a response body by using an `HttpMessageConverter`. For more information on these converters, see the previous section and Message Converters.

Creating REST Controllers with the @RestController annotation

It's a very common use case to have Controllers implement a REST API, thus serving only JSON, XML or custom MediaType content. For convenience, instead of annotating all your `@RequestMapping` methods with `@ResponseBody`, you can annotate your Controller Class with `@RestController`.

`@RestController` is a stereotype annotation that combines `@ResponseBody` and `@Controller`. More than that, it gives more meaning to your Controller and also may carry additional semantics in future releases of the framework.

As with regular `@Controllers`, a `@RestController` may be assisted by a `@ControllerAdvice` Bean. See the the section called "Advising controllers with the `@ControllerAdvice` annotation" section for more details.

Using HttpEntity

The `HttpEntity` is similar to `@RequestBody` and `@ResponseBody`. Besides getting access to the request and response body, `HttpEntity` (and the response-specific subclass `ResponseEntity`) also allows access to the request and response headers, like so:

```
@RequestMapping("/something")
public ResponseEntity<String> handle(HttpEntity<byte[]> requestEntity) throws
 UnsupportedEncodingException {
    String requestHeader = requestEntity.getHeaders().getFirst("MyRequestHeader"));
    byte[] requestBody = requestEntity.getBody();

    // do something with request header and body

    HttpHeaders responseHeaders = new HttpHeaders();
    responseHeaders.set("MyResponseHeader", "MyValue");
    return new ResponseEntity<String>("Hello World", responseHeaders, HttpStatus.CREATED);
}
```

The above example gets the value of the `MyRequestHeader` request header, and reads the body as a byte array. It adds the `MyResponseHeader` to the response, writes `Hello World` to the response stream, and sets the response status code to 201 (Created).

As with `@RequestBody` and `@ResponseBody`, Spring uses `HttpMessageConverter` to convert from and to the request and response streams. For more information on these converters, see the previous section and Message Converters.

Using @ModelAttribute on a method

The `@ModelAttribute` annotation can be used on methods or on method arguments. This section explains its usage on methods while the next section explains its usage on method arguments.

An `@ModelAttribute` on a method indicates the purpose of that method is to add one or more model attributes. Such methods support the same argument types as `@RequestMapping` methods but cannot be mapped directly to requests. Instead `@ModelAttribute` methods in a controller are invoked before `@RequestMapping` methods, within the same controller. A couple of examples:

```
// Add one attribute
// The return value of the method is added to the model under the name "account"
// You can customize the name via @ModelAttribute("myAccount")

@ModelAttribute
public Account addAccount(@RequestParam String number) {
    return accountManager.findAccount(number);
}

// Add multiple attributes

@ModelAttribute
public void populateModel(@RequestParam String number, Model model) {
    model.addAttribute(accountManager.findAccount(number));
    // add more ...
}
```

`@ModelAttribute` methods are used to populate the model with commonly needed attributes for example to fill a drop-down with states or with pet types, or to retrieve a command object like Account in order to use it to represent the data on an HTML form. The latter case is further discussed in the next section.

Note the two styles of `@ModelAttribute` methods. In the first, the method adds an attribute implicitly by returning it. In the second, the method accepts a `Model` and adds any number of model attributes to it. You can choose between the two styles depending on your needs.

A controller can have any number of `@ModelAttribute` methods. All such methods are invoked before `@RequestMapping` methods of the same controller.

`@ModelAttribute` methods can also be defined in an `@ControllerAdvice`-annotated class and such methods apply to many controllers. See the the section called “Advising controllers with the `@ControllerAdvice` annotation” section for more details.

> **Tip**
>
> What happens when a model attribute name is not explicitly specified? In such cases a default name is assigned to the model attribute based on its type. For example if the method returns an object of type `Account`, the default name used is "account". You can change that through the value of the `@ModelAttribute` annotation. If adding attributes directly to the `Model`, use the appropriate overloaded `addAttribute(..)` method - i.e., with or without an attribute name.

The `@ModelAttribute` annotation can be used on `@RequestMapping` methods as well. In that case the return value of the `@RequestMapping` method is interpreted as a model attribute rather than as a view name. The view name is derived from view name conventions instead much like for methods returning void — see the section called “The View - RequestToViewNameTranslator”.

Using @ModelAttribute on a method argument

As explained in the previous section `@ModelAttribute` can be used on methods or on method arguments. This section explains its usage on method arguments.

An `@ModelAttribute` on a method argument indicates the argument should be retrieved from the model. If not present in the model, the argument should be instantiated first and then added to the model. Once present in the model, the argument's fields should be populated from all request parameters that have matching names. This is known as data binding in Spring MVC, a very useful mechanism that saves you from having to parse each form field individually.

```
@RequestMapping(value="/owners/{ownerId}/pets/{petId}/edit", method = RequestMethod.POST)
public String processSubmit(@ModelAttribute Pet pet) { }
```

Given the above example where can the Pet instance come from? There are several options:

- It may already be in the model due to use of `@SessionAttributes` — see the section called "Using @SessionAttributes to store model attributes in the HTTP session between requests".
- It may already be in the model due to an `@ModelAttribute` method in the same controller — as explained in the previous section.
- It may be retrieved based on a URI template variable and type converter (explained in more detail below).
- It may be instantiated using its default constructor.

An `@ModelAttribute` method is a common way to to retrieve an attribute from the database, which may optionally be stored between requests through the use of `@SessionAttributes`. In some cases it may be convenient to retrieve the attribute by using an URI template variable and a type converter. Here is an example:

```
@RequestMapping(value="/accounts/{account}", method = RequestMethod.PUT)
public String save(@ModelAttribute("account") Account account) {

}
```

In this example the name of the model attribute (i.e. "account") matches the name of a URI template variable. If you register `Converter<String, Account>` that can turn the `String` account value into an `Account` instance, then the above example will work without the need for an `@ModelAttribute` method.

The next step is data binding. The `WebDataBinder` class matches request parameter names — including query string parameters and form fields — to model attribute fields by name. Matching fields are populated after type conversion (from String to the target field type) has been applied where necessary. Data binding and validation are covered in Chapter 7, *Validation, Data Binding, and Type Conversion*. Customizing the data binding process for a controller level is covered in the section called "Customizing WebDataBinder initialization".

As a result of data binding there may be errors such as missing required fields or type conversion errors. To check for such errors add a `BindingResult` argument immediately following the `@ModelAttribute` argument:

```
@RequestMapping(value="/owners/{ownerId}/pets/{petId}/edit", method = RequestMethod.POST)
public String processSubmit(@ModelAttribute("pet") Pet pet, BindingResult result) {

    if (result.hasErrors()) {
        return "petForm";
    }

    // ...

}
```

With a `BindingResult` you can check if errors were found in which case it's common to render the same form where the errors can be shown with the help of Spring's `<errors>` form tag.

In addition to data binding you can also invoke validation using your own custom validator passing the same `BindingResult` that was used to record data binding errors. That allows for data binding and validation errors to be accumulated in one place and subsequently reported back to the user:

```
@RequestMapping(value="/owners/{ownerId}/pets/{petId}/edit", method = RequestMethod.POST)
public String processSubmit(@ModelAttribute("pet") Pet pet, BindingResult result) {

    new PetValidator().validate(pet, result);
    if (result.hasErrors()) {
        return "petForm";
    }

    // ...

}
```

Or you can have validation invoked automatically by adding the JSR-303 `@Valid` annotation:

```
@RequestMapping(value="/owners/{ownerId}/pets/{petId}/edit", method = RequestMethod.POST)
public String processSubmit(@Valid @ModelAttribute("pet") Pet pet, BindingResult result) {

    if (result.hasErrors()) {
        return "petForm";
    }

    // ...

}
```

See Section 7.8, "Spring Validation" and Chapter 7, *Validation, Data Binding, and Type Conversion* for details on how to configure and use validation.

Using @SessionAttributes to store model attributes in the HTTP session between requests

The type-level `@SessionAttributes` annotation declares session attributes used by a specific handler. This will typically list the names of model attributes or types of model attributes which should be transparently stored in the session or some conversational storage, serving as form-backing beans between subsequent requests.

The following code snippet shows the usage of this annotation, specifying the model attribute name:

```
@Controller
@RequestMapping("/editPet.do")
@SessionAttributes("pet")
public class EditPetForm {
    // ...
}
```

Specifying redirect and flash attributes

By default all model attributes are considered to be exposed as URI template variables in the redirect URL. Of the remaining attributes those that are primitive types or collections/arrays of primitive types are automatically appended as query parameters.

In annotated controllers however the model may contain additional attributes originally added for rendering purposes (e.g. drop-down field values). To gain precise control over the attributes used in a redirect scenario, an `@RequestMapping` method can declare an argument of type `RedirectAttributes` and use it to add attributes for use in `RedirectView`. If the controller method does redirect, the content of `RedirectAttributes` is used. Otherwise the content of the default `Model` is used.

The `RequestMappingHandlerAdapter` provides a flag called `"ignoreDefaultModelOnRedirect"` that can be used to indicate the content of the default `Model` should never be used if a controller method redirects. Instead the controller method should declare an attribute of type `RedirectAttributes` or if it doesn't do so no attributes should be passed on to `RedirectView`. Both the MVC namespace and the MVC Java config keep this flag set to `false` in order to maintain backwards compatibility. However, for new applications we recommend setting it to `true`

The `RedirectAttributes` interface can also be used to add flash attributes. Unlike other redirect attributes, which end up in the target redirect URL, flash attributes are saved in the HTTP session (and hence do not appear in the URL). The model of the controller serving the target redirect URL automatically receives these flash attributes after which they are removed from the session. See Section 17.6, "Using flash attributes" for an overview of the general support for flash attributes in Spring MVC.

Working with "application/x-www-form-urlencoded" data

The previous sections covered use of `@ModelAttribute` to support form submission requests from browser clients. The same annotation is recommended for use with requests from non-browser clients as well. However there is one notable difference when it comes to working with HTTP PUT requests. Browsers can submit form data via HTTP GET or HTTP POST. Non-browser clients can also submit forms via HTTP PUT. This presents a challenge because the Servlet specification requires the `ServletRequest.getParameter*()` family of methods to support form field access only for HTTP POST, not for HTTP PUT.

To support HTTP PUT and PATCH requests, the `spring-web` module provides the filter `HttpPutFormContentFilter`, which can be configured in `web.xml`:

```
<filter>
    <filter-name>httpPutFormFilter</filter-name>
    <filter-class>org.springframework.web.filter.HttpPutFormContentFilter</filter-class>
</filter>

<filter-mapping>
    <filter-name>httpPutFormFilter</filter-name>
    <servlet-name>dispatcherServlet</servlet-name>
</filter-mapping>

<servlet>
    <servlet-name>dispatcherServlet</servlet-name>
    <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
</servlet>
```

The above filter intercepts HTTP PUT and PATCH requests with content type `application/x-www-form-urlencoded`, reads the form data from the body of the request, and wraps the `ServletRequest` in order to make the form data available through the `ServletRequest.getParameter*()` family of methods.

> **Note**
>
> As `HttpPutFormContentFilter` consumes the body of the request, it should not be configured for PUT or PATCH URLs that rely on other converters for `application/x-www-form-urlencoded`. This includes `@RequestBody MultiValueMap<String, String>` and `HttpEntity<MultiValueMap<String, String>>`.

Mapping cookie values with the @CookieValue annotation

The `@CookieValue` annotation allows a method parameter to be bound to the value of an HTTP cookie.

Let us consider that the following cookie has been received with an http request:

```
JSESSIONID=415A4AC178C59DACE0B2C9CA727CDD84
```

The following code sample demonstrates how to get the value of the `JSESSIONID` cookie:

```
@RequestMapping("/displayHeaderInfo.do")
public void displayHeaderInfo(@CookieValue("JSESSIONID") String cookie) {
    //...
}
```

Type conversion is applied automatically if the target method parameter type is not `String`. See the section called “Method Parameters And Type Conversion”.

This annotation is supported for annotated handler methods in Servlet and Portlet environments.

Mapping request header attributes with the @RequestHeader annotation

The `@RequestHeader` annotation allows a method parameter to be bound to a request header.

Here is a sample request header:

```
Host                    localhost:8080
Accept                  text/html,application/xhtml+xml,application/xml;q=0.9
Accept-Language         fr,en-gb;q=0.7,en;q=0.3
Accept-Encoding         gzip,deflate
Accept-Charset          ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive              300
```

The following code sample demonstrates how to get the value of the `Accept-Encoding` and `Keep-Alive` headers:

```
@RequestMapping("/displayHeaderInfo.do")
public void displayHeaderInfo(@RequestHeader("Accept-Encoding") String encoding,
        @RequestHeader("Keep-Alive") long keepAlive) {
    //...
}
```

Type conversion is applied automatically if the method parameter is not `String`. See the section called “Method Parameters And Type Conversion”.

When an `@RequestHeader` annotation is used on a `Map<String, String>`, `MultiValueMap<String, String>`, or `HttpHeaders` argument, the map is populated with all header values.

> **Tip**
>
> Built-in support is available for converting a comma-separated string into an array/collection of strings or other types known to the type conversion system. For example a method parameter annotated with `@RequestHeader("Accept")` may be of type `String` but also `String[]` or `List<String>`.

This annotation is supported for annotated handler methods in Servlet and Portlet environments.

Method Parameters And Type Conversion

String-based values extracted from the request including request parameters, path variables, request headers, and cookie values may need to be converted to the target type of the method parameter or field (e.g., binding a request parameter to a field in an `@ModelAttribute` parameter) they're bound to. If the target type is not `String`, Spring automatically converts to the appropriate type. All simple types such as int, long, Date, etc. are supported. You can further customize the conversion process through a `WebDataBinder` (see the section called "Customizing WebDataBinder initialization") or by registering `Formatters` with the `FormattingConversionService` (see Section 7.6, "Spring Field Formatting").

Customizing WebDataBinder initialization

To customize request parameter binding with PropertyEditors through Spring's `WebDataBinder`, you can use `@InitBinder`-annotated methods within your controller, `@InitBinder` methods within an `@ControllerAdvice` class, or provide a custom `WebBindingInitializer`. See the the section called "Advising controllers with the `@ControllerAdvice` annotation" section for more details.

Customizing data binding with @InitBinder

Annotating controller methods with `@InitBinder` allows you to configure web data binding directly within your controller class. `@InitBinder` identifies methods that initialize the `WebDataBinder` that will be used to populate command and form object arguments of annotated handler methods.

Such init-binder methods support all arguments that `@RequestMapping` supports, except for command/form objects and corresponding validation result objects. Init-binder methods must not have a return value. Thus, they are usually declared as `void`. Typical arguments include `WebDataBinder` in combination with `WebRequest` or `java.util.Locale`, allowing code to register context-specific editors.

The following example demonstrates the use of `@InitBinder` to configure a `CustomDateEditor` for all `java.util.Date` form properties.

```
@Controller
public class MyFormController {

    @InitBinder
    public void initBinder(WebDataBinder binder) {
        SimpleDateFormat dateFormat = new SimpleDateFormat("yyyy-MM-dd");
        dateFormat.setLenient(false);
        binder.registerCustomEditor(Date.class, new CustomDateEditor(dateFormat, false));
    }

    // ...

}
```

Configuring a custom WebBindingInitializer

To externalize data binding initialization, you can provide a custom implementation of the `WebBindingInitializer` interface, which you then enable by supplying a custom bean configuration for an `AnnotationMethodHandlerAdapter`, thus overriding the default configuration.

The following example from the PetClinic application shows a configuration using a custom implementation of the `WebBindingInitializer` interface, `org.springframework.samples.petclinic.web.ClinicBindingInitializer`, which configures PropertyEditors required by several of the PetClinic controllers.

```
<bean class="org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerAdapter">
    <property name="cacheSeconds" value="0" />
    <property name="webBindingInitializer">
        <bean class="org.springframework.samples.petclinic.web.ClinicBindingInitializer" />
    </property>
</bean>
```

`@InitBinder` methods can also be defined in an `@ControllerAdvice`-annotated class in which case they apply to matching controllers. This provides an alternative to using a `WebBindingInitializer`. See the the section called “Advising controllers with the `@ControllerAdvice` annotation” section for more details.

Support for the Last-Modified Response Header To Facilitate Content Caching

An `@RequestMapping` method may wish to support `'Last-Modified'` HTTP requests, as defined in the contract for the Servlet API’s `getLastModified` method, to facilitate content caching. This involves calculating a lastModified `long` value for a given request, comparing it against the `'If-Modified-Since'` request header value, and potentially returning a response with status code 304 (Not Modified). An annotated controller method can achieve that as follows:

```
@RequestMapping
public String myHandleMethod(WebRequest webRequest, Model model) {

    long lastModified = // 1. application-specific calculation

    if (request.checkNotModified(lastModified)) {
        // 2. shortcut exit - no further processing necessary
        return null;
    }

    // 3. or otherwise further request processing, actually preparing content
    model.addAttribute(...);
    return "myViewName";
}
```

There are two key elements to note: calling `request.checkNotModified(lastModified)` and returning `null`. The former sets the response status to 304 before it returns `true`. The latter, in combination with the former, causes Spring MVC to do no further processing of the request.

Advising controllers with the `@ControllerAdvice` annotation

The `@ControllerAdvice` annotation is a component annotation allowing implementation classes to be auto-detected through classpath scanning. It is automatically enabled when using the MVC namespace or the MVC Java config.

Classes annotated with `@ControllerAdvice` can contain `@ExceptionHandler`, `@InitBinder`, and `@ModelAttribute` annotated methods, and these methods will apply to `@RequestMapping` methods across all controller hierarchies as opposed to the controller hierarchy within which they are declared.

The `@ControllerAdvice` annotation can also target a subset of controllers with its attributes:

```
// Target all Controllers annotated with @RestController
@ControllerAdvice(annotations = RestController.class)
public class AnnotationAdvice {}

// Target all Controllers within specific packages
@ControllerAdvice("org.example.controllers")
public class BasePackageAdvice {}

// Target all Controllers assignable to specific classes
@ControllerAdvice(assignableTypes = {ControllerInterface.class, AbstractController.class})
public class AssignableTypesAdvice {}
```

Check out the `@ControllerAdvice` documentation for more details.

Jackson Serialization View Support

It can sometimes be useful to filter contextually the object that will be serialized to the HTTP response body. In order to provide such capability, Spring MVC has built-in support for rendering with Jackson's Serialization Views.

To use it with an `@ResponseBody` controller method or controller methods that return `ResponseEntity`, simply add the `@JsonView` annotation with a class argument specifying the view class or interface to be used:

```
@RestController
public class UserController {

    @RequestMapping(value = "/user", method = RequestMethod.GET)
    @JsonView(User.WithoutPasswordView.class)
    public User getUser() {
        return new User("eric", "7!jd#h23");
    }
}

public class User {

    public interface WithoutPasswordView {};
    public interface WithPasswordView extends WithoutPasswordView {};

    private String username;
    private String password;

    public User() {
    }

    public User(String username, String password) {
        this.username = username;
        this.password = password;
    }

    @JsonView(WithoutPasswordView.class)
    public String getUsername() {
        return this.username;
    }

    @JsonView(WithPasswordView.class)
    public String getPassword() {
        return this.password;
    }
}
```

> **Note**
>
> Note that despite `@JsonView` allowing for more than one class to be specified, the use on a controller method is only supported with exactly one class argument. Consider the use of a composite interface if you need to enable multiple views.

For controllers relying on view resolution, simply add the serialization view class to the model:

```
@Controller
public class UserController extends AbstractController {

    @RequestMapping(value = "/user", method = RequestMethod.GET)
    public String getUser(Model model) {
        model.addAttribute("user", new User("eric", "7!jd#h23"));
        model.addAttribute(JsonView.class.getName(), User.WithoutPasswordView.class);
        return "userView";
    }
}
```

Jackson JSONP Support

In order to enable JSONP support for `@ResponseBody` and `ResponseEntity` methods, declare an `@ControllerAdvice` bean that extends `AbstractJsonpResponseBodyAdvice` as shown below where the constructor argument indicates the JSONP query parameter name(s):

```
@ControllerAdvice
public class JsonpAdvice extends AbstractJsonpResponseBodyAdvice {

    public JsonpAdvice() {
        super("callback");
    }
}
```

For controllers relying on view resolution, JSONP is automatically enabled when the request has a query parameter named `jsonp` or `callback`. Those names can be customized through `jsonpParameterNames` property.

Asynchronous Request Processing

Spring MVC 3.2 introduced Servlet 3 based asynchronous request processing. Instead of returning a value, as usual, a controller method can now return a `java.util.concurrent.Callable` and produce the return value from a separate thread. Meanwhile the main Servlet container thread is released and allowed to process other requests. Spring MVC invokes the `Callable` in a separate thread with the help of a `TaskExecutor` and when the `Callable` returns, the request is dispatched back to the Servlet container to resume processing with the value returned by the `Callable`. Here is an example controller method:

```
@RequestMapping(method=RequestMethod.POST)
public Callable<String> processUpload(final MultipartFile file) {

    return new Callable<String>() {
        public String call() throws Exception {
            // ...
            return "someView";
        }
    };

}
```

A second option is for the controller to return an instance of `DeferredResult`. In this case the return value will also be produced from a separate thread. However, that thread is not known to Spring MVC. For example the result may be produced in response to some external event such as a JMS message, a scheduled task, etc. Here is an example controller method:

```
@RequestMapping("/quotes")
@ResponseBody
public DeferredResult<String> quotes() {
    DeferredResult<String> deferredResult = new DeferredResult<String>();
    // Save the deferredResult in in-memory queue ...
    return deferredResult;
}

// In some other thread...
deferredResult.setResult(data);
```

This may be difficult to understand without any knowledge of the Servlet 3 async processing feature. It would certainly help to read up on it. At a very minimum consider the following basic facts:

- A `ServletRequest` can be put in asynchronous mode by calling `request.startAsync()`. The main effect of doing so is that the Servlet, as well as any Filters, can exit but the response will remain open allowing some other thread to complete processing.
- The call to `request.startAsync()` returns an `AsyncContext`, which can be used for further control over async processing. For example it provides the method `dispatch`, which can be called

from an application thread in order to "dispatch" the request back to the Servlet container. An async dispatch is similar to a forward except it is made from one (application) thread to another (Servlet container) thread whereas a forward occurs synchronously in the same (Servlet container) thread.

- `ServletRequest` provides access to the current `DispatcherType`, which can be used to distinguish if a `Servlet` or a `Filter` is processing on the initial request processing thread and when it is processing in an async dispatch.

With the above in mind, the following is the sequence of events for async request processing with a `Callable`: (1) Controller returns a `Callable`, (2) Spring MVC starts async processing and submits the `Callable` to a `TaskExecutor` for processing in a separate thread, (3) the `DispatcherServlet` and all Filter's exit the request processing thread but the response remains open, (4) the `Callable` produces a result and Spring MVC dispatches the request back to the Servlet container, (5) the `DispatcherServlet` is invoked again and processing resumes with the asynchronously produced result from the `Callable`. The exact sequencing of (2), (3), and (4) may vary depending on the speed of execution of the concurrent threads.

The sequence of events for async request processing with a `DeferredResult` is the same in principal except it's up to the application to produce the asynchronous result from some thread: (1) Controller returns a `DeferredResult` and saves it in some in-memory queue or list where it can be accessed, (2) Spring MVC starts async processing, (3) the `DispatcherServlet` and all configured Filter's exit the request processing thread but the response remains open, (4) the application sets the `DeferredResult` from some thread and Spring MVC dispatches the request back to the Servlet container, (5) the `DispatcherServlet` is invoked again and processing resumes with the asynchronously produced result.

Explaining the motivation for async request processing and when or why to use it are beyond the scope of this document. For further information you may wish to read this blog post series.

Exception Handling for Async Requests

What happens if a `Callable` returned from a controller method raises an Exception while being executed? The effect is similar to what happens when any controller method raises an exception. It is handled by a matching `@ExceptionHandler` method in the same controller or by one of the configured `HandlerExceptionResolver` instances.

> **Note**
>
> Under the covers, when a `Callable` raises an Exception, Spring MVC still dispatches to the Servlet container to resume processing. The only difference is that the result of executing the `Callable` is an `Exception` that must be processed with the configured `HandlerExceptionResolver` instances.

When using a `DeferredResult`, you have a choice of calling its `setErrorResult(Object)` method and provide an `Exception` or any other Object you'd like to use as the result. If the result is an `Exception`, it will be processed with a matching `@ExceptionHandler` method in the same controller or with any configured `HandlerExceptionResolver` instance.

Intercepting Async Requests

An existing `HandlerInterceptor` can implement `AsyncHandlerInterceptor`, which provides one additional method `afterConcurrentHandlingStarted`. It is invoked after async

processing starts and when the initial request processing thread is being exited. See the `AsyncHandlerInterceptor` javadocs for more details on that.

Further options for async request lifecycle callbacks are provided directly on `DeferredResult`, which has the methods `onTimeout(Runnable)` and `onCompletion(Runnable)`. Those are called when the async request is about to time out or has completed respectively. The timeout event can be handled by setting the `DeferredResult` to some value. The completion callback however is final and the result can no longer be set.

Similar callbacks are also available with a `Callable`. However, you will need to wrap the `Callable` in an instance of `WebAsyncTask` and then use that to register the timeout and completion callbacks. Just like with `DeferredResult`, the timeout event can be handled and a value can be returned while the completion event is final.

You can also register a `CallableProcessingInterceptor` or a `DeferredResultProcessingInterceptor` globally through the MVC Java config or the MVC namespace. Those interceptors provide a full set of callbacks and apply every time a `Callable` or a `DeferredResult` is used.

Configuration for Async Request Processing

Servlet 3 Async Config

To use Servlet 3 async request processing, you need to update `web.xml` to version 3.0:

```
<web-app xmlns="http://java.sun.com/xml/ns/javaee"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
            http://java.sun.com/xml/ns/javaee
            http://java.sun.com/xml/ns/javaee/web-app_3_0.xsd"
    version="3.0">

    ...

</web-app>
```

The `DispatcherServlet` and any `Filter` configuration need to have the `<async-supported>true</async-supported>` sub-element. Additionally, any `Filter` that also needs to get involved in async dispatches should also be configured to support the ASYNC dispatcher type. Note that it is safe to enable the ASYNC dispatcher type for all filters provided with the Spring Framework since they will not get involved in async dispatches unless needed.

> **Warning**
>
> Note that for some Filters it is absolutely critical to ensure they are mapped to be invoked during asynchronous dispatches. For example if a filter such as the `OpenEntityManagerInViewFilter` is responsible for releasing database connection resources and must be invoked at the end of an async request.
>
> Below is an example of a propertly configured filter:

```
<web-app xmlns="http://java.sun.com/xml/ns/javaee"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
            http://java.sun.com/xml/ns/javaee
            http://java.sun.com/xml/ns/javaee/web-app_3_0.xsd"
    version="3.0">

    <filter>
        <filter-name>Spring OpenEntityManagerInViewFilter</filter-name>
        <filter-class>org.springframework.~.OpenEntityManagerInViewFilter</filter-class>
        <async-supported>true</async-supported>
    </filter>

    <filter-mapping>
        <filter-name>Spring OpenEntityManagerInViewFilter</filter-name>
        <url-pattern>/*</url-pattern>
        <dispatcher>REQUEST</dispatcher>
        <dispatcher>ASYNC</dispatcher>
    </filter-mapping>

</web-app>
```

If using Servlet 3, Java based configuration, e.g. via `WebApplicationInitializer`, you'll also need to set the "asyncSupported" flag as well as the ASYNC dispatcher type just like with `web.xml`. To simplify all this configuration, consider extending `AbstractDispatcherServletInitializer` or `AbstractAnnotationConfigDispatcherServletInitializer`, which automatically set those options and make it very easy to register `Filter` instances.

Spring MVC Async Config

The MVC Java config and the MVC namespace both provide options for configuring async request processing. `WebMvcConfigurer` has the method `configureAsyncSupport` while <mvc:annotation-driven> has an <async-support> sub-element.

Those allow you to configure the default timeout value to use for async requests, which if not set depends on the underlying Servlet container (e.g. 10 seconds on Tomcat). You can also configure an `AsyncTaskExecutor` to use for executing `Callable` instances returned from controller methods. It is highly recommended to configure this property since by default Spring MVC uses `SimpleAsyncTaskExecutor`. The MVC Java config and the MVC namespace also allow you to register `CallableProcessingInterceptor` and `DeferredResultProcessingInterceptor` instances.

If you need to override the default timeout value for a specific `DeferredResult`, you can do so by using the appropriate class constructor. Similarly, for a `Callable`, you can wrap it in a `WebAsyncTask` and use the appropriate class constructor to customize the timeout value. The class constructor of `WebAsyncTask` also allows providing an `AsyncTaskExecutor`.

Testing Controllers

The `spring-test` module offers first class support for testing annotated controllers. See the section called “Spring MVC Test Framework”.

17.4 Handler mappings

In previous versions of Spring, users were required to define one or more `HandlerMapping` beans in the web application context to map incoming web requests to appropriate handlers. With the introduction of annotated controllers, you generally don't need to do that because the `RequestMappingHandlerMapping` automatically looks for `@RequestMapping` annotations on all

`@Controller` beans. However, do keep in mind that all `HandlerMapping` classes extending from `AbstractHandlerMapping` have the following properties that you can use to customize their behavior:

- `interceptors` List of interceptors to use. `HandlerInterceptors` are discussed in the section called “Intercepting requests with a HandlerInterceptor”.
- `defaultHandler` Default handler to use, when this handler mapping does not result in a matching handler.
- `order` Based on the value of the order property (see the `org.springframework.core.Ordered` interface), Spring sorts all handler mappings available in the context and applies the first matching handler.
- `alwaysUseFullPath` If `true` , Spring uses the full path within the current Servlet context to find an appropriate handler. If `false` (the default), the path within the current Servlet mapping is used. For example, if a Servlet is mapped using `/testing/*` and the `alwaysUseFullPath` property is set to true, `/testing/viewPage.html` is used, whereas if the property is set to false, `/viewPage.html` is used.
- `urlDecode` Defaults to `true`, as of Spring 2.5. If you prefer to compare encoded paths, set this flag to `false`. However, the `HttpServletRequest` always exposes the Servlet path in decoded form. Be aware that the Servlet path will not match when compared with encoded paths.

The following example shows how to configure an interceptor:

```
<beans>

  <bean id="handlerMapping" class="org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerMapping">
        <property name="interceptors">
            <bean class="example.MyInterceptor"/>
        </property>
    </bean>
<beans>
```

Intercepting requests with a HandlerInterceptor

Spring’s handler mapping mechanism includes handler interceptors, which are useful when you want to apply specific functionality to certain requests, for example, checking for a principal.

Interceptors located in the handler mapping must implement `HandlerInterceptor` from the `org.springframework.web.servlet` package. This interface defines three methods: `preHandle(..)` is called *before* the actual handler is executed; `postHandle(..)` is called *after* the handler is executed; and `afterCompletion(..)` is called *after the complete request has finished*. These three methods should provide enough flexibility to do all kinds of preprocessing and postprocessing.

The `preHandle(..)` method returns a boolean value. You can use this method to break or continue the processing of the execution chain. When this method returns `true`, the handler execution chain will continue; when it returns false, the `DispatcherServlet` assumes the interceptor itself has taken care of requests (and, for example, rendered an appropriate view) and does not continue executing the other interceptors and the actual handler in the execution chain.

Interceptors can be configured using the `interceptors` property, which is present on all `HandlerMapping` classes extending from `AbstractHandlerMapping`. This is shown in the example below:

```
<beans>
    <bean id="handlerMapping"
            class="org.springframework.web.servlet.mvc.method.annotation.RequestMappingHandlerMapping">
        <property name="interceptors">
            <list>
                <ref bean="officeHoursInterceptor"/>
            </list>
        </property>
    </bean>

    <bean id="officeHoursInterceptor"
            class="samples.TimeBasedAccessInterceptor">
        <property name="openingTime" value="9"/>
        <property name="closingTime" value="18"/>
    </bean>
<beans>
```

```
package samples;

public class TimeBasedAccessInterceptor extends HandlerInterceptorAdapter {

    private int openingTime;
    private int closingTime;

    public void setOpeningTime(int openingTime) {
        this.openingTime = openingTime;
    }

    public void setClosingTime(int closingTime) {
        this.closingTime = closingTime;
    }

    public boolean preHandle(HttpServletRequest request, HttpServletResponse response,
            Object handler) throws Exception {
        Calendar cal = Calendar.getInstance();
        int hour = cal.get(HOUR_OF_DAY);
        if (openingTime <= hour && hour < closingTime) {
            return true;
        }
        response.sendRedirect("http://host.com/outsideOfficeHours.html");
        return false;
    }
}
```

Any request handled by this mapping is intercepted by the `TimeBasedAccessInterceptor`. If the current time is outside office hours, the user is redirected to a static HTML file that says, for example, you can only access the website during office hours.

> **Note**
>
> When using the `RequestMappingHandlerMapping` the actual handler is an instance of `HandlerMethod` which identifies the specific controller method that will be invoked.

As you can see, the Spring adapter class `HandlerInterceptorAdapter` makes it easier to extend the `HandlerInterceptor` interface.

> **Tip**
>
> In the example above, the configured interceptor will apply to all requests handled with annotated controller methods. If you want to narrow down the URL paths to which an interceptor applies, you can use the MVC namespace or the MVC Java config, or declare bean instances of type `MappedInterceptor` to do that. See the section called “Enabling the MVC Java Config or the MVC XML Namespace”.

Note that the `postHandle` method of `HandlerInterceptor` is not always ideally suited for use with `@ResponseBody` and `ResponseEntity` methods. In such cases an `HttpMessageConverter` writes to and commits the response before `postHandle` is called which makes it impossible to change the response, for example to add a header. Instead an application can implement `ResponseBodyAdvice` and either declare it as an `@ControllerAdvice` bean or configure it directly on `RequestMappingHandlerAdapter`.

17.5 Resolving views

All MVC frameworks for web applications provide a way to address views. Spring provides view resolvers, which enable you to render models in a browser without tying you to a specific view technology. Out of the box, Spring enables you to use JSPs, Velocity templates and XSLT views, for example. See Chapter 18, *View technologies* for a discussion of how to integrate and use a number of disparate view technologies.

The two interfaces that are important to the way Spring handles views are `ViewResolver` and `View`. The `ViewResolver` provides a mapping between view names and actual views. The `View` interface addresses the preparation of the request and hands the request over to one of the view technologies.

Resolving views with the ViewResolver interface

As discussed in Section 17.3, “Implementing Controllers”, all handler methods in the Spring Web MVC controllers must resolve to a logical view name, either explicitly (e.g., by returning a `String`, `View`, or `ModelAndView`) or implicitly (i.e., based on conventions). Views in Spring are addressed by a logical view name and are resolved by a view resolver. Spring comes with quite a few view resolvers. This table lists most of them; a couple of examples follow.

Table 17.3. View resolvers

ViewResolver	Description
`AbstractCachingViewResolver`	Abstract view resolver that caches views. Often views need preparation before they can be used; extending this view resolver provides caching.
`XmlViewResolver`	Implementation of `ViewResolver` that accepts a configuration file written in XML with the same DTD as Spring’s XML bean factories. The default configuration file is `/WEB-INF/views.xml`.
`ResourceBundleViewResolver`	Implementation of `ViewResolver` that uses bean definitions in a `ResourceBundle`, specified by the bundle base name. Typically you define the bundle in a properties file, located in the classpath. The default file name is `views.properties`.
`UrlBasedViewResolver`	Simple implementation of the `ViewResolver` interface that effects the direct resolution of logical view names to URLs, without an explicit mapping definition. This is appropriate if your logical names match the names of your view

ViewResolver	Description
	resources in a straightforward manner, without the need for arbitrary mappings.
`InternalResourceViewResolver`	Convenient subclass of `UrlBasedViewResolver` that supports `InternalResourceView` (in effect, Servlets and JSPs) and subclasses such as `JstlView` and `TilesView`. You can specify the view class for all views generated by this resolver by using `setViewClass(..)`. See the `UrlBasedViewResolver` javadocs for details.
`VelocityViewResolver` / `FreeMarkerViewResolver`	Convenient subclass of `UrlBasedViewResolver` that supports `VelocityView` (in effect, Velocity templates) or `FreeMarkerView` ,respectively, and custom subclasses of them.
`ContentNegotiatingViewResolver`	Implementation of the `ViewResolver` interface that resolves a view based on the request file name or `Accept` header. See the section called “ContentNegotiatingViewResolver”.

As an example, with JSP as a view technology, you can use the `UrlBasedViewResolver`. This view resolver translates a view name to a URL and hands the request over to the RequestDispatcher to render the view.

```
<bean id="viewResolver"
        class="org.springframework.web.servlet.view.UrlBasedViewResolver">
    <property name="viewClass" value="org.springframework.web.servlet.view.JstlView"/>
    <property name="prefix" value="/WEB-INF/jsp/"/>
    <property name="suffix" value=".jsp"/>
</bean>
```

When returning `test` as a logical view name, this view resolver forwards the request to the `RequestDispatcher` that will send the request to `/WEB-INF/jsp/test.jsp`.

When you combine different view technologies in a web application, you can use the `ResourceBundleViewResolver`:

```
<bean id="viewResolver"
        class="org.springframework.web.servlet.view.ResourceBundleViewResolver">
    <property name="basename" value="views"/>
    <property name="defaultParentView" value="parentView"/>
</bean>
```

The `ResourceBundleViewResolver` inspects the `ResourceBundle` identified by the basename, and for each view it is supposed to resolve, it uses the value of the property `[viewname].(class)` as the view class and the value of the property `[viewname].url` as the view url. Examples can be found in the next chapter which covers view technologies. As you can see, you can identify a parent view, from which all views in the properties file "extend". This way you can specify a default view class, for example.

> **Note**
>
> Subclasses of `AbstractCachingViewResolver` cache view instances that they resolve. Caching improves performance of certain view technologies. It's possible to turn off the cache by setting the `cache` property to `false`. Furthermore, if you must refresh a certain view at runtime (for example when a Velocity template is modified), you can use the `removeFromCache(String viewName, Locale loc)` method.

Chaining ViewResolvers

Spring supports multiple view resolvers. Thus you can chain resolvers and, for example, override specific views in certain circumstances. You chain view resolvers by adding more than one resolver to your application context and, if necessary, by setting the `order` property to specify ordering. Remember, the higher the order property, the later the view resolver is positioned in the chain.

In the following example, the chain of view resolvers consists of two resolvers, an `InternalResourceViewResolver`, which is always automatically positioned as the last resolver in the chain, and an `XmlViewResolver` for specifying Excel views. Excel views are not supported by the `InternalResourceViewResolver`.

```
<bean id="jspViewResolver" class="org.springframework.web.servlet.view.InternalResourceViewResolver">
    <property name="viewClass" value="org.springframework.web.servlet.view.JstlView"/>
    <property name="prefix" value="/WEB-INF/jsp/"/>
    <property name="suffix" value=".jsp"/>
</bean>

<bean id="excelViewResolver" class="org.springframework.web.servlet.view.XmlViewResolver">
    <property name="order" value="1"/>
    <property name="location" value="/WEB-INF/views.xml"/>
</bean>

<!-- in views.xml -->

<beans>
    <bean name="report" class="org.springframework.example.ReportExcelView"/>
</beans>
```

If a specific view resolver does not result in a view, Spring examines the context for other view resolvers. If additional view resolvers exist, Spring continues to inspect them until a view is resolved. If no view resolver returns a view, Spring throws a `ServletException`.

The contract of a view resolver specifies that a view resolver *can* return null to indicate the view could not be found. Not all view resolvers do this, however, because in some cases, the resolver simply cannot detect whether or not the view exists. For example, the `InternalResourceViewResolver` uses the `RequestDispatcher` internally, and dispatching is the only way to figure out if a JSP exists, but this action can only execute once. The same holds for the `VelocityViewResolver` and some others. Check the javadocs of the specific view resolver to see whether it reports non-existing views. Thus, putting an `InternalResourceViewResolver` in the chain in a place other than the last results in the chain not being fully inspected, because the `InternalResourceViewResolver` will *always* return a view!

Redirecting to views

As mentioned previously, a controller typically returns a logical view name, which a view resolver resolves to a particular view technology. For view technologies such as JSPs that are processed through the Servlet or JSP engine, this resolution is usually handled through the combination of `InternalResourceViewResolver` and `InternalResourceView`, which issues

an internal forward or include via the Servlet API's `RequestDispatcher.forward(..)` method or `RequestDispatcher.include()` method. For other view technologies, such as Velocity, XSLT, and so on, the view itself writes the content directly to the response stream.

It is sometimes desirable to issue an HTTP redirect back to the client, before the view is rendered. This is desirable, for example, when one controller has been called with `POST` data, and the response is actually a delegation to another controller (for example on a successful form submission). In this case, a normal internal forward will mean that the other controller will also see the same `POST` data, which is potentially problematic if it can confuse it with other expected data. Another reason to perform a redirect before displaying the result is to eliminate the possibility of the user submitting the form data multiple times. In this scenario, the browser will first send an initial `POST`; it will then receive a response to redirect to a different URL; and finally the browser will perform a subsequent `GET` for the URL named in the redirect response. Thus, from the perspective of the browser, the current page does not reflect the result of a `POST` but rather of a `GET`. The end effect is that there is no way the user can accidentally re- `POST` the same data by performing a refresh. The refresh forces a `GET` of the result page, not a resend of the initial `POST` data.

RedirectView

One way to force a redirect as the result of a controller response is for the controller to create and return an instance of Spring's `RedirectView`. In this case, `DispatcherServlet` does not use the normal view resolution mechanism. Rather because it has been given the (redirect) view already, the `DispatcherServlet` simply instructs the view to do its work.

The `RedirectView` issues an `HttpServletResponse.sendRedirect()` call that returns to the client browser as an HTTP redirect. By default all model attributes are considered to be exposed as URI template variables in the redirect URL. Of the remaining attributes those that are primitive types or collections/arrays of primitive types are automatically appended as query parameters.

Appending primitive type attributes as query parameters may be the desired result if a model instance was prepared specifically for the redirect. However, in annotated controllers the model may contain additional attributes added for rendering purposes (e.g. drop-down field values). To avoid the possibility of having such attributes appear in the URL an annotated controller can declare an argument of type `RedirectAttributes` and use it to specify the exact attributes to make available to `RedirectView`. If the controller method decides to redirect, the content of `RedirectAttributes` is used. Otherwise the content of the model is used.

Note that URI template variables from the present request are automatically made available when expanding a redirect URL and do not need to be added explicitly neither through `Model` nor `RedirectAttributes`. For example:

```
@RequestMapping(value = "/files/{path}", method = RequestMethod.POST)
public String upload(...) {
    // ...
    return "redirect:files/{path}";
}
```

If you use `RedirectView` and the view is created by the controller itself, it is recommended that you configure the redirect URL to be injected into the controller so that it is not baked into the controller but configured in the context along with the view names. The next section discusses this process.

The redirect: prefix

While the use of `RedirectView` works fine, if the controller itself creates the `RedirectView`, there is no avoiding the fact that the controller is aware that a redirection is happening. This is really suboptimal

and couples things too tightly. The controller should not really care about how the response gets handled. In general it should operate only in terms of view names that have been injected into it.

The special `redirect:` prefix allows you to accomplish this. If a view name is returned that has the prefix `redirect:`, the `UrlBasedViewResolver` (and all subclasses) will recognize this as a special indication that a redirect is needed. The rest of the view name will be treated as the redirect URL.

The net effect is the same as if the controller had returned a `RedirectView`, but now the controller itself can simply operate in terms of logical view names. A logical view name such as `redirect:/myapp/some/resource` will redirect relative to the current Servlet context, while a name such as `redirect:http://myhost.com/some/arbitrary/path` will redirect to an absolute URL.

The forward: prefix

It is also possible to use a special `forward:` prefix for view names that are ultimately resolved by `UrlBasedViewResolver` and subclasses. This creates an `InternalResourceView` (which ultimately does a `RequestDispatcher.forward()`) around the rest of the view name, which is considered a URL. Therefore, this prefix is not useful with `InternalResourceViewResolver` and `InternalResourceView` (for JSPs for example). But the prefix can be helpful when you are primarily using another view technology, but still want to force a forward of a resource to be handled by the Servlet/JSP engine. (Note that you may also chain multiple view resolvers, instead.)

As with the `redirect:` prefix, if the view name with the `forward:` prefix is injected into the controller, the controller does not detect that anything special is happening in terms of handling the response.

ContentNegotiatingViewResolver

The `ContentNegotiatingViewResolver` does not resolve views itself but rather delegates to other view resolvers, selecting the view that resembles the representation requested by the client. Two strategies exist for a client to request a representation from the server:

- Use a distinct URI for each resource, typically by using a different file extension in the URI. For example, the URI `http://www.example.com/users/fred.pdf` requests a PDF representation of the user fred, and `http://www.example.com/users/fred.xml` requests an XML representation.
- Use the same URI for the client to locate the resource, but set the `Accept` HTTP request header to list the media types that it understands. For example, an HTTP request for `http://www.example.com/users/fred` with an `Accept` header set to `application/pdf` requests a PDF representation of the user fred, while `http://www.example.com/users/fred` with an `Accept` header set to `text/xml` requests an XML representation. This strategy is known as content negotiation.

> **Note**
>
> One issue with the `Accept` header is that it is impossible to set it in a web browser within HTML. For example, in Firefox, it is fixed to:
>
> ```
> Accept: text/html,application/xhtml+xml,application/xml;q=0.9,/;q=0.8
> ```
>
> For this reason it is common to see the use of a distinct URI for each representation when developing browser based web applications.

To support multiple representations of a resource, Spring provides the `ContentNegotiatingViewResolver` to resolve a view based on the file extension or `Accept` header of the HTTP request. `ContentNegotiatingViewResolver` does not perform the view resolution itself but instead delegates to a list of view resolvers that you specify through the bean property `ViewResolvers`.

The `ContentNegotiatingViewResolver` selects an appropriate `View` to handle the request by comparing the request media type(s) with the media type (also known as `Content-Type`) supported by the `View` associated with each of its `ViewResolvers`. The first `View` in the list that has a compatible `Content-Type` returns the representation to the client. If a compatible view cannot be supplied by the `ViewResolver` chain, then the list of views specified through the `DefaultViews` property will be consulted. This latter option is appropriate for singleton `Views` that can render an appropriate representation of the current resource regardless of the logical view name. The `Accept` header may include wild cards, for example `text/*`, in which case a `View` whose Content-Type was `text/xml` is a compatible match.

To support the resolution of a view based on a file extension, use the `ContentNegotiatingViewResolver` bean property `mediaTypes` to specify a mapping of file extensions to media types. For more information on the algorithm used to determine the request media type, refer to the API documentation for `ContentNegotiatingViewResolver`.

Here is an example configuration of a `ContentNegotiatingViewResolver`:

```
<bean class="org.springframework.web.servlet.view.ContentNegotiatingViewResolver">
    <property name="mediaTypes">
        <map>
            <entry key="atom" value="application/atom+xml"/>
            <entry key="html" value="text/html"/>
            <entry key="json" value="application/json"/>
        </map>
    </property>
    <property name="viewResolvers">
        <list>
            <bean class="org.springframework.web.servlet.view.BeanNameViewResolver"/>
            <bean class="org.springframework.web.servlet.view.InternalResourceViewResolver">
                <property name="prefix" value="/WEB-INF/jsp/"/>
                <property name="suffix" value=".jsp"/>
            </bean>
        </list>
    </property>
    <property name="defaultViews">
        <list>
            <bean class="org.springframework.web.servlet.view.json.MappingJackson2JsonView" />
        </list>
    </property>
</bean>

<bean id="content" class="com.foo.samples.rest.SampleContentAtomView"/>
```

The `InternalResourceViewResolver` handles the translation of view names and JSP pages, while the `BeanNameViewResolver` returns a view based on the name of a bean. (See "Resolving views with the ViewResolver interface" for more details on how Spring looks up and instantiates a view.) In this example, the `content` bean is a class that inherits from `AbstractAtomFeedView`, which returns an Atom RSS feed. For more information on creating an Atom Feed representation, see the section Atom Views.

In the above configuration, if a request is made with an `.html` extension, the view resolver looks for a view that matches the `text/html` media type. The `InternalResourceViewResolver` provides the matching view for `text/html`. If the request is made with the file extension `.atom`, the view resolver

looks for a view that matches the `application/atom+xml` media type. This view is provided by the `BeanNameViewResolver` that maps to the `SampleContentAtomView` if the view name returned is `content`. If the request is made with the file extension `.json`, the `MappingJackson2JsonView` instance from the `DefaultViews` list will be selected regardless of the view name. Alternatively, client requests can be made without a file extension but with the `Accept` header set to the preferred media-type, and the same resolution of request to views would occur.

> **Note**
>
> If `ContentNegotiatingViewResolver`'s list of ViewResolvers is not configured explicitly, it automatically uses any ViewResolvers defined in the application context.

The corresponding controller code that returns an Atom RSS feed for a URI of the form `http://localhost/content.atom` or `http://localhost/content` with an `Accept` header of application/atom+xml is shown below.

```
@Controller
public class ContentController {

    private List<SampleContent> contentList = new ArrayList<SampleContent>();

    @RequestMapping(value="/content", method=RequestMethod.GET)
    public ModelAndView getContent() {
        ModelAndView mav = new ModelAndView();
        mav.setViewName("content");
        mav.addObject("sampleContentList", contentList);
        return mav;
    }

}
```

17.6 Using flash attributes

Flash attributes provide a way for one request to store attributes intended for use in another. This is most commonly needed when redirecting — for example, the *Post/Redirect/Get* pattern. Flash attributes are saved temporarily before the redirect (typically in the session) to be made available to the request after the redirect and removed immediately.

Spring MVC has two main abstractions in support of flash attributes. `FlashMap` is used to hold flash attributes while `FlashMapManager` is used to store, retrieve, and manage `FlashMap` instances.

Flash attribute support is always "on" and does not need to enabled explicitly although if not used, it never causes HTTP session creation. On each request there is an "input" `FlashMap` with attributes passed from a previous request (if any) and an "output" `FlashMap` with attributes to save for a subsequent request. Both `FlashMap` instances are accessible from anywhere in Spring MVC through static methods in `RequestContextUtils`.

Annotated controllers typically do not need to work with `FlashMap` directly. Instead an `@RequestMapping` method can accept an argument of type `RedirectAttributes` and use it to add flash attributes for a redirect scenario. Flash attributes added via `RedirectAttributes` are automatically propagated to the "output" FlashMap. Similarly after the redirect attributes from the "input" `FlashMap` are automatically added to the `Model` of the controller serving the target URL.

Matching requests to flash attributes

The concept of flash attributes exists in many other Web frameworks and has proven to be exposed sometimes to concurrency issues. This is because by definition flash attributes are to be stored until the next request. However the very "next" request may not be the intended recipient but another asynchronous request (e.g. polling or resource requests) in which case the flash attributes are removed too early.

To reduce the possibility of such issues, `RedirectView` automatically "stamps" `FlashMap` instances with the path and query parameters of the target redirect URL. In turn the default `FlashMapManager` matches that information to incoming requests when looking up the "input" `FlashMap`.

This does not eliminate the possibility of a concurrency issue entirely but nevertheless reduces it greatly with information that is already available in the redirect URL. Therefore the use of flash attributes is recommended mainly for redirect scenarios .

17.7 Building URIs

Spring MVC provides a mechanism for building and encoding a URI using `UriComponentsBuilder` and `UriComponents`.

For example you can expand and encode a URI template string:

```
UriComponents uriComponents = UriComponentsBuilder.fromUriString(
        "http://example.com/hotels/{hotel}/bookings/{booking}").build();

URI uri = uriComponents.expand("42", "21").encode().toUri();
```

Note that `UriComponents` is immutable and the `expand()` and `encode()` operations return new instances if necessary.

You can also expand and encode using individual URI components:

```
UriComponents uriComponents = UriComponentsBuilder.newInstance()
        .scheme("http").host("example.com").path("/hotels/{hotel}/bookings/{booking}").build()
        .expand("42", "21")
        .encode();
```

In a Servlet environment the `ServletUriComponentsBuilder` sub-class provides static factory methods to copy available URL information from a Servlet requests:

```
HttpServletRequest request = ...

// Re-use host, scheme, port, path and query string
// Replace the "accountId" query param

ServletUriComponentsBuilder ucb = ServletUriComponentsBuilder.fromRequest(request)
        .replaceQueryParam("accountId", "{id}").build()
        .expand("123")
        .encode();
```

Alternatively, you may choose to copy a subset of the available information up to and including the context path:

```
// Re-use host, port and context path
// Append "/accounts" to the path

ServletUriComponentsBuilder ucb = ServletUriComponentsBuilder.fromContextPath(request)
        .path("/accounts").build()
```

Or in cases where the `DispatcherServlet` is mapped by name (e.g. `/main/*`), you can also have the literal part of the servlet mapping included:

```
// Re-use host, port, context path
// Append the literal part of the servlet mapping to the path
// Append "/accounts" to the path

ServletUriComponentsBuilder ucb = ServletUriComponentsBuilder.fromServletMapping(request)
        .path("/accounts").build()
```

Building URIs to Controllers and methods

Spring MVC provides another mechanism for building and encoding URIs that link to Controllers and methods defined within an application. `MvcUriComponentsBuilder` extends `UriComponentsBuilder` and provides such possibilities.

Given this Controller:

```
@Controller
@RequestMapping("/hotels/{hotel}")
public class BookingController {

    @RequestMapping("/bookings/{booking}")
    public String getBooking(@PathVariable Long booking) {

    // ...

}
```

and using the `MvcUriComponentsBuilder`, the previous example is now:

```
UriComponents uriComponents = MvcUriComponentsBuilder
    .fromMethodName(BookingController.class, "getBooking",21).buildAndExpand(42);

URI uri = uriComponents.encode().toUri();
```

The `MvcUriComponentsBuilder` can also create "mock Controllers", thus enabling to create URIs by coding against the actual Controller's API:

```
UriComponents uriComponents = MvcUriComponentsBuilder
    .fromMethodCall(on(BookingController.class).getBooking(21)).buildAndExpand(42);

URI uri = uriComponents.encode().toUri();
```

Building URIs to Controllers and methods from views

It is also useful to build links to annotated controllers from views (e.g. JSP). This can be done through a method on `MvcUriComponentsBuilder` which refers to mappings by name called `fromMappingName`.

As of 4.1 every `@RequestMapping` is assigned a default name based on the capital letters of the class and the full method name. For example, the method `getFoo` in class `FooController` is assigned the name "FC#getFoo". This naming strategy is

pluggable by implementing `HandlerMethodMappingNamingStrategy` and configuring it on your `RequestMappingHandlerMapping`. Furthermore the `@RequestMapping` annotation includes a name attribute that can be used to override the default strategy.

> **Note**
>
> The assigned request mapping names are logged at TRACE level on startup.

The Spring JSP tag library provides a function called `mvcUrl` that can be used to prepare links to controller methods based on this mechanism.

For example given:

```
@RequestMapping("/people/{id}/addresses")
public class MyController {

    @RequestMapping("/{country}")
    public HttpEntity getAddress(@PathVariable String country) { ... }
}
```

The following JSP code can prepare a link:

```
<%@ taglib uri="http://www.springframework.org/tags" prefix="s" %>
...
<a href="${s:mvcUrl('PC#getPerson').arg(0,'US').buildAndExpand('123')}">Get Person</a>
```

17.8 Using locales

Most parts of Spring's architecture support internationalization, just as the Spring web MVC framework does. `DispatcherServlet` enables you to automatically resolve messages using the client's locale. This is done with `LocaleResolver` objects.

When a request comes in, the `DispatcherServlet` looks for a locale resolver, and if it finds one it tries to use it to set the locale. Using the `RequestContext.getLocale()` method, you can always retrieve the locale that was resolved by the locale resolver.

In addition to automatic locale resolution, you can also attach an interceptor to the handler mapping (see the section called "Intercepting requests with a HandlerInterceptor" for more information on handler mapping interceptors) to change the locale under specific circumstances, for example, based on a parameter in the request.

Locale resolvers and interceptors are defined in the `org.springframework.web.servlet.i18n` package and are configured in your application context in the normal way. Here is a selection of the locale resolvers included in Spring.

Obtaining Time Zone Information

In addition to obtaining the client's locale, it is often useful to know their time zone. The `LocaleContextResolver` interface offers an extension to `LocaleResolver` that allows resolvers to provide a richer `LocaleContext`, which may include time zone information.

When available, the user's `TimeZone` can be obtained using the `RequestContext.getTimeZone()` method. Time zone information will automatically be used by Date/Time `Converter` and `Formatter` objects registered with Spring's `ConversionService`.

AcceptHeaderLocaleResolver

This locale resolver inspects the `accept-language` header in the request that was sent by the client (e.g., a web browser). Usually this header field contains the locale of the client's operating system. *Note that this resolver does not support time zone information.*

CookieLocaleResolver

This locale resolver inspects a `Cookie` that might exist on the client to see if a `Locale` or `TimeZone` is specified. If so, it uses the specified details. Using the properties of this locale resolver, you can specify the name of the cookie as well as the maximum age. Find below an example of defining a `CookieLocaleResolver`.

```
<bean id="localeResolver" class="org.springframework.web.servlet.i18n.CookieLocaleResolver">

    <property name="cookieName" value="clientlanguage"/>

    <!-- in seconds. If set to -1, the cookie is not persisted (deleted when browser shuts down) -->
    <property name="cookieMaxAge" value="100000">

</bean>
```

Table 17.4. CookieLocaleResolver properties

Property	Default	Description
cookieName	classname + LOCALE	The name of the cookie
cookieMaxAge	Integer.MAX_INT	The maximum time a cookie will stay persistent on the client. If -1 is specified, the cookie will not be persisted; it will only be available until the client shuts down their browser.
cookiePath	/	Limits the visibility of the cookie to a certain part of your site. When cookiePath is specified, the cookie will only be visible to that path and the paths below it.

SessionLocaleResolver

The `SessionLocaleResolver` allows you to retrieve `Locale` and `TimeZone` from the session that might be associated with the user's request.

LocaleChangeInterceptor

You can enable changing of locales by adding the `LocaleChangeInterceptor` to one of the handler mappings (see Section 17.4, "Handler mappings"). It will detect a parameter in the request and change the locale. It calls `setLocale()` on the `LocaleResolver` that also exists in the context. The following example shows that calls to all `*.view` resources containing a parameter named `siteLanguage` will now change the locale. So, for example, a request for the following URL, `http://www.sf.net/home.view?siteLanguage=nl` will change the site language to Dutch.

```
<bean id="localeChangeInterceptor"
        class="org.springframework.web.servlet.i18n.LocaleChangeInterceptor">
    <property name="paramName" value="siteLanguage"/>
</bean>

<bean id="localeResolver"
        class="org.springframework.web.servlet.i18n.CookieLocaleResolver"/>

<bean id="urlMapping"
        class="org.springframework.web.servlet.handler.SimpleUrlHandlerMapping">
    <property name="interceptors">
        <list>
            <ref bean="localeChangeInterceptor"/>
        </list>
    </property>
    <property name="mappings">
        <value>/*/.view=someController</value>
    </property>
</bean>
```

17.9 Using themes

Overview of themes

You can apply Spring Web MVC framework themes to set the overall look-and-feel of your application, thereby enhancing user experience. A theme is a collection of static resources, typically style sheets and images, that affect the visual style of the application.

Defining themes

To use themes in your web application, you must set up an implementation of the `org.springframework.ui.context.ThemeSource` interface. The `WebApplicationContext` interface extends `ThemeSource` but delegates its responsibilities to a dedicated implementation. By default the delegate will be an `org.springframework.ui.context.support.ResourceBundleThemeSource` implementation that loads properties files from the root of the classpath. To use a custom `ThemeSource` implementation or to configure the base name prefix of the `ResourceBundleThemeSource`, you can register a bean in the application context with the reserved name `themeSource`. The web application context automatically detects a bean with that name and uses it.

When using the `ResourceBundleThemeSource`, a theme is defined in a simple properties file. The properties file lists the resources that make up the theme. Here is an example:

```
styleSheet=/themes/cool/style.css
background=/themes/cool/img/coolBg.jpg
```

The keys of the properties are the names that refer to the themed elements from view code. For a JSP, you typically do this using the `spring:theme` custom tag, which is very similar to the `spring:message` tag. The following JSP fragment uses the theme defined in the previous example to customize the look and feel:

```
<%@ taglib prefix="spring" uri="http://www.springframework.org/tags"%>
<html>
    <head>
        <link rel="stylesheet" href="<spring:theme code='styleSheet'/>" type="text/css"/>
    </head>
    <body style="background=<spring:theme code='background'/>">
        ...
    </body>
</html>
```

By default, the `ResourceBundleThemeSource` uses an empty base name prefix. As a result, the properties files are loaded from the root of the classpath. Thus you would put the `cool.properties` theme definition in a directory at the root of the classpath, for example, in `/WEB-INF/classes`. The `ResourceBundleThemeSource` uses the standard Java resource bundle loading mechanism, allowing for full internationalization of themes. For example, we could have a `/WEB-INF/classes/cool_nl.properties` that references a special background image with Dutch text on it.

Theme resolvers

After you define themes, as in the preceding section, you decide which theme to use. The `DispatcherServlet` will look for a bean named `themeResolver` to find out which `ThemeResolver` implementation to use. A theme resolver works in much the same way as a `LocaleResolver`. It detects the theme to use for a particular request and can also alter the request's theme. The following theme resolvers are provided by Spring:

Table 17.5. ThemeResolver implementations

Class	Description
`FixedThemeResolver`	Selects a fixed theme, set using the `defaultThemeName` property.
`SessionThemeResolver`	The theme is maintained in the user's HTTP session. It only needs to be set once for each session, but is not persisted between sessions.
`CookieThemeResolver`	The selected theme is stored in a cookie on the client.

Spring also provides a `ThemeChangeInterceptor` that allows theme changes on every request with a simple request parameter.

17.10 Spring's multipart (file upload) support

Introduction

Spring's built-in multipart support handles file uploads in web applications. You enable this multipart support with pluggable `MultipartResolver` objects, defined in the `org.springframework.web.multipart` package. Spring provides one `MultipartResolver` implementation for use with *Commons FileUpload* and another for use with Servlet 3.0 multipart request parsing.

By default, Spring does no multipart handling, because some developers want to handle multiparts themselves. You enable Spring multipart handling by adding a multipart resolver to the web application's context. Each request is inspected to see if it contains a multipart. If no multipart is found, the request continues as expected. If a multipart is found in the request, the `MultipartResolver` that has been declared in your context is used. After that, the multipart attribute in your request is treated like any other attribute.

Using a MultipartResolver with *Commons FileUpload*

The following example shows how to use the `CommonsMultipartResolver`:

```
<bean id="multipartResolver"
        class="org.springframework.web.multipart.commons.CommonsMultipartResolver">

    <!-- one of the properties available; the maximum file size in bytes -->
    <property name="maxUploadSize" value="100000"/>

</bean>
```

Of course you also need to put the appropriate jars in your classpath for the multipart resolver to work. In the case of the `CommonsMultipartResolver`, you need to use `commons-fileupload.jar`.

When the Spring `DispatcherServlet` detects a multi-part request, it activates the resolver that has been declared in your context and hands over the request. The resolver then wraps the current `HttpServletRequest` into a `MultipartHttpServletRequest` that supports multipart file uploads. Using the `MultipartHttpServletRequest`, you can get information about the multiparts contained by this request and actually get access to the multipart files themselves in your controllers.

Using a MultipartResolver with *Servlet 3.0*

In order to use Servlet 3.0 based multipart parsing, you need to mark the `DispatcherServlet` with a `"multipart-config"` section in `web.xml`, or with a `javax.servlet.MultipartConfigElement` in programmatic Servlet registration, or in case of a custom Servlet class possibly with a `javax.servlet.annotation.MultipartConfig` annotation on your Servlet class. Configuration settings such as maximum sizes or storage locations need to be applied at that Servlet registration level as Servlet 3.0 does not allow for those settings to be done from the MultipartResolver.

Once Servlet 3.0 multipart parsing has been enabled in one of the above mentioned ways you can add the `StandardServletMultipartResolver` to your Spring configuration:

```
<bean id="multipartResolver"
        class="org.springframework.web.multipart.support.StandardServletMultipartResolver">
</bean>
```

Handling a file upload in a form

After the `MultipartResolver` completes its job, the request is processed like any other. First, create a form with a file input that will allow the user to upload a form. The encoding attribute (`enctype="multipart/form-data"`) lets the browser know how to encode the form as multipart request:

```
<html>
    <head>
        <title>Upload a file please</title>
    </head>
    <body>
        <h1>Please upload a file</h1>
        <form method="post" action="/form" enctype="multipart/form-data">
            <input type="text" name="name"/>
            <input type="file" name="file"/>
            <input type="submit"/>
        </form>
    </body>
</html>
```

The next step is to create a controller that handles the file upload. This controller is very similar to a normal annotated `@Controller`, except that we use `MultipartHttpServletRequest` or `MultipartFile` in the method parameters:

```
@Controller
public class FileUploadController {

    @RequestMapping(value = "/form", method = RequestMethod.POST)
    public String handleFormUpload(@RequestParam("name") String name,
            @RequestParam("file") MultipartFile file) {

        if (!file.isEmpty()) {
            byte[] bytes = file.getBytes();
            // store the bytes somewhere
            return "redirect:uploadSuccess";
        }

        return "redirect:uploadFailure";
    }

}
```

Note how the `@RequestParam` method parameters map to the input elements declared in the form. In this example, nothing is done with the `byte[]`, but in practice you can save it in a database, store it on the file system, and so on.

When using Servlet 3.0 multipart parsing you can also use `javax.servlet.http.Part` for the method parameter:

```
@Controller
public class FileUploadController {

    @RequestMapping(value = "/form", method = RequestMethod.POST)
    public String handleFormUpload(@RequestParam("name") String name,
            @RequestParam("file") Part file) {

        InputStream inputStream = file.getInputStream();
        // store bytes from uploaded file somewhere

        return "redirect:uploadSuccess";
    }

}
```

Handling a file upload request from programmatic clients

Multipart requests can also be submitted from non-browser clients in a RESTful service scenario. All of the above examples and configuration apply here as well. However, unlike browsers that typically submit files and simple form fields, a programmatic client can also send more complex data of a specific content type — for example a multipart request with a file and second part with JSON formatted data:

```
POST /someUrl
Content-Type: multipart/mixed

--edt7Tfrdusa7r3lNQc79vXuhIIMlatb7PQg7Vp
Content-Disposition: form-data; name="meta-data"
Content-Type: application/json; charset=UTF-8
Content-Transfer-Encoding: 8bit

{
 "name": "value"
}
--edt7Tfrdusa7r3lNQc79vXuhIIMlatb7PQg7Vp
Content-Disposition: form-data; name="file-data"; filename="file.properties"
Content-Type: text/xml
Content-Transfer-Encoding: 8bit
... File Data ...
```

You could access the part named "meta-data" with a `@RequestParam("meta-data") String metadata` controller method argument. However, you would probably prefer to accept a strongly typed object initialized from the JSON formatted data in the body of the request part, very similar to the way `@RequestBody` converts the body of a non-multipart request to a target object with the help of an `HttpMessageConverter`.

You can use the `@RequestPart` annotation instead of the `@RequestParam` annotation for this purpose. It allows you to have the content of a specific multipart passed through an `HttpMessageConverter` taking into consideration the `'Content-Type'` header of the multipart:

```
@RequestMapping(value="/someUrl", method = RequestMethod.POST)
public String onSubmit(@RequestPart("meta-data") MetaData metadata,
        @RequestPart("file-data") MultipartFile file) {

    // ...

}
```

Notice how `MultipartFile` method arguments can be accessed with `@RequestParam` or with `@RequestPart` interchangeably. However, the `@RequestPart("meta-data") MetaData` method argument in this case is read as JSON content based on its `'Content-Type'` header and converted with the help of the `MappingJackson2HttpMessageConverter`.

17.11 Handling exceptions

HandlerExceptionResolver

Spring `HandlerExceptionResolver` implementations deal with unexpected exceptions that occur during controller execution. A `HandlerExceptionResolver` somewhat resembles the exception mappings you can define in the web application descriptor `web.xml`. However, they provide a more flexible way to do so. For example they provide information about which handler was executing when the exception was thrown. Furthermore, a programmatic way of handling exceptions gives you more options for responding appropriately before the request is forwarded to another URL (the same end result as when you use the Servlet specific exception mappings).

Besides implementing the `HandlerExceptionResolver` interface, which is only a matter of implementing the `resolveException(Exception, Handler)` method and returning a `ModelAndView`, you may also use the provided `SimpleMappingExceptionResolver` or create `@ExceptionHandler` methods. The `SimpleMappingExceptionResolver` enables you to take the class name of any exception that might be thrown and map it to a view name. This is functionally equivalent to the exception mapping feature from the Servlet API, but it is also possible to implement more finely grained mappings of exceptions from different handlers. The `@ExceptionHandler` annotation on the other hand can be used on methods that should be invoked to handle an exception. Such methods may be defined locally within an `@Controller` or may apply to many `@Controller` classes when defined within an `@ControllerAdvice` class. The following sections explain this in more detail.

@ExceptionHandler

The `HandlerExceptionResolver` interface and the `SimpleMappingExceptionResolver` implementations allow you to map Exceptions to specific views declaratively along with some optional Java logic before forwarding to those views. However, in some cases, especially when relying on `@ResponseBody` methods rather than on view resolution, it may be more convenient to directly set the status of the response and optionally write error content to the body of the response.

You can do that with `@ExceptionHandler` methods. When declared within a controller such methods apply to exceptions raised by `@RequestMapping` methods of that contoroller (or any of its sub-classes). You can also declare an `@ExceptionHandler` method within an `@ControllerAdvice` class in which case it handles exceptions from `@RequestMapping` methods from many controllers. Below is an example of a controller-local `@ExceptionHandler` method:

```
@Controller
public class SimpleController {

    // @RequestMapping methods omitted ...

    @ExceptionHandler(IOException.class)
    public ResponseEntity<String> handleIOException(IOException ex) {
        // prepare responseEntity
        return responseEntity;
    }

}
```

The `@ExceptionHandler` value can be set to an array of Exception types. If an exception is thrown that matches one of the types in the list, then the method annotated with the matching `@ExceptionHandler` will be invoked. If the annotation value is not set then the exception types listed as method arguments are used.

Much like standard controller methods annotated with a `@RequestMapping` annotation, the method arguments and return values of `@ExceptionHandler` methods can be flexible. For example, the `HttpServletRequest` can be accessed in Servlet environments and the `PortletRequest` in Portlet environments. The return type can be a `String`, which is interpreted as a view name, a `ModelAndView` object, a `ResponseEntity`, or you can also add the `@ResponseBody` to have the method return value converted with message converters and written to the response stream.

Handling Standard Spring MVC Exceptions

Spring MVC may raise a number of exceptions while processing a request. The `SimpleMappingExceptionResolver` can easily map any exception to a default error view as needed. However, when working with clients that interpret responses in an automated way you will want to set specific status code on the response. Depending on the exception raised the status code may indicate a client error (4xx) or a server error (5xx).

The `DefaultHandlerExceptionResolver` translates Spring MVC exceptions to specific error status codes. It is registered by default with the MVC namespace, the MVC Java config, and also by the the `DispatcherServlet` (i.e. when not using the MVC namespace or Java config). Listed below are some of the exceptions handled by this resolver and the corresponding status codes:

Exception	HTTP Status Code
`BindException`	400 (Bad Request)
`ConversionNotSupportedException`	500 (Internal Server Error)
`HttpMediaTypeNotAcceptableException`	406 (Not Acceptable)
`HttpMediaTypeNotSupportedException`	415 (Unsupported Media Type)
`HttpMessageNotReadableException`	400 (Bad Request)
`HttpMessageNotWritableException`	500 (Internal Server Error)

Exception	HTTP Status Code
`HttpRequestMethodNotSupportedException`	405 (Method Not Allowed)
`MethodArgumentNotValidException`	400 (Bad Request)
`MissingServletRequestParameterException`	400 (Bad Request)
`MissingServletRequestPartException`	400 (Bad Request)
`NoHandlerFoundException`	404 (Not Found)
`NoSuchRequestHandlingMethodException`	404 (Not Found)
`TypeMismatchException`	400 (Bad Request)

The `DefaultHandlerExceptionResolver` works transparently by setting the status of the response. However, it stops short of writing any error content to the body of the response while your application may need to add developer-friendly content to every error response for example when providing a REST API. You can prepare a `ModelAndView` and render error content through view resolution — i.e. by configuring a `ContentNegotiatingViewResolver`, `MappingJackson2JsonView`, and so on. However, you may prefer to use `@ExceptionHandler` methods instead.

If you prefer to write error content via `@ExceptionHandler` methods you can extend `ResponseEntityExceptionHandler` instead. This is a convenient base for `@ControllerAdvice` classes providing an `@ExceptionHandler` method to handle standard Spring MVC exceptions and return `ResponseEntity`. That allows you to customize the response and write error content with message converters. See the `ResponseEntityExceptionHandler` javadocs for more details.

Annotating Business Exceptions With @ResponseStatus

A business exception can be annotated with `@ResponseStatus`. When the exception is raised, the `ResponseStatusExceptionResolver` handles it by setting the status of the response accordingly. By default the `DispatcherServlet` registers the `ResponseStatusExceptionResolver` and it is available for use.

Customizing the Default Servlet Container Error Page

When the status of the response is set to an error status code and the body of the response is empty, Servlet containers commonly render an HTML formatted error page. To customize the default error page of the container, you can declare an `<error-page>` element in `web.xml`. Up until Servlet 3, that element had to be mapped to a specific status code or exception type. Starting with Servlet 3 an error page does not need to be mapped, which effectively means the specified location customizes the default Servlet container error page.

```
<error-page>
    <location>/error</location>
</error-page>
```

Note that the actual location for the error page can be a JSP page or some other URL within the container including one handled through an `@Controller` method:

When writing error information, the status code and the error message set on the `HttpServletResponse` can be accessed through request attributes in a controller:

```
@Controller
public class ErrorController {

    @RequestMapping(value="/error", produces="application/json")
    @ResponseBody
    public Map<String, Object> handle(HttpServletRequest request) {

        Map<String, Object> map = new HashMap<String, Object>();
        map.put("status", request.getAttribute("javax.servlet.error.status_code"));
        map.put("reason", request.getAttribute("javax.servlet.error.message"));

        return map;
    }

}
```

or in a JSP:

```
<%@ page contentType="application/json" pageEncoding="UTF-8"%>
{
    status:<%=request.getAttribute("javax.servlet.error.status_code") %>,
    reason:<%=request.getAttribute("javax.servlet.error.message") %>
}
```

17.12 Web Security

The Spring Security project provides features to protect web applications from malicious exploits. Check out the reference documentation in the sections on "CSRF protection", "Security Response Headers", and also "Spring MVC Integration". Note that using Spring Security to secure the application is not necessarily required for all features. For example CSRF protection can be added simply by adding the `CsrfFilter` and `CsrfRequestDataValueProcessor` to your configuration. See the Spring MVC Showcase for an example.

Another option is to use a framework dedicated to Web Security. HDIV is one such framework and integrates with Spring MVC.

17.13 Convention over configuration support

For a lot of projects, sticking to established conventions and having reasonable defaults is just what they (the projects) need, and Spring Web MVC now has explicit support for *convention over configuration*. What this means is that if you establish a set of naming conventions and suchlike, you can *substantially* cut down on the amount of configuration that is required to set up handler mappings, view resolvers, `ModelAndView` instances, etc. This is a great boon with regards to rapid prototyping, and can also lend a degree of (always good-to-have) consistency across a codebase should you choose to move forward with it into production.

Convention-over-configuration support addresses the three core areas of MVC: models, views, and controllers.

The Controller ControllerClassNameHandlerMapping

The `ControllerClassNameHandlerMapping` class is a `HandlerMapping` implementation that uses a convention to determine the mapping between request URLs and the `Controller` instances that are to handle those requests.

Consider the following simple `Controller` implementation. Take special notice of the *name* of the class.

```
public class ViewShoppingCartController implements Controller {

    public ModelAndView handleRequest(HttpServletRequest request, HttpServletResponse response) {
        // the implementation is not hugely important for this example...
    }

}
```

Here is a snippet from the corresponding Spring Web MVC configuration file:

```
<bean class="org.springframework.web.servlet.mvc.support.ControllerClassNameHandlerMapping"/>

<bean id="viewShoppingCart" class="x.y.z.ViewShoppingCartController">
    <!-- inject dependencies as required... -->
</bean>
```

The `ControllerClassNameHandlerMapping` finds all of the various handler (or `Controller`) beans defined in its application context and strips `Controller` off the name to define its handler mappings. Thus, `ViewShoppingCartController` maps to the `/viewshoppingcart*` request URL.

Let's look at some more examples so that the central idea becomes immediately familiar. (Notice all lowercase in the URLs, in contrast to camel-cased `Controller` class names.)

- `WelcomeController` maps to the `/welcome*` request URL
- `HomeController` maps to the `/home*` request URL
- `IndexController` maps to the `/index*` request URL
- `RegisterController` maps to the `/register*` request URL

In the case of `MultiActionController` handler classes, the mappings generated are slightly more complex. The `Controller` names in the following examples are assumed to be `MultiActionController` implementations:

- `AdminController` maps to the `/admin/*` request URL
- `CatalogController` maps to the `/catalog/*` request URL

If you follow the convention of naming your `Controller` implementations as `xxxController`, the `ControllerClassNameHandlerMapping` saves you the tedium of defining and maintaining a potentially *looooong* `SimpleUrlHandlerMapping` (or suchlike).

The `ControllerClassNameHandlerMapping` class extends the `AbstractHandlerMapping` base class so you can define `HandlerInterceptor` instances and everything else just as you would with many other `HandlerMapping` implementations.

The Model ModelMap (ModelAndView)

The `ModelMap` class is essentially a glorified `Map` that can make adding objects that are to be displayed in (or on) a `View` adhere to a common naming convention. Consider the following `Controller` implementation; notice that objects are added to the `ModelAndView` without any associated name specified.

```
public class DisplayShoppingCartController implements Controller {

    public ModelAndView handleRequest(HttpServletRequest request, HttpServletResponse response) {

        List cartItems = // get a List of CartItem objects
        User user = // get the User doing the shopping

        ModelAndView mav = new ModelAndView("displayShoppingCart"); <-- the logical view name

        mav.addObject(cartItems); <-- look ma, no name, just the object
        mav.addObject(user); <-- and again ma!

        return mav;
    }
}
```

The `ModelAndView` class uses a `ModelMap` class that is a custom `Map` implementation that automatically generates a key for an object when an object is added to it. The strategy for determining the name for an added object is, in the case of a scalar object such as `User`, to use the short class name of the object's class. The following examples are names that are generated for scalar objects put into a `ModelMap` instance.

- An `x.y.User` instance added will have the name `user` generated.
- An `x.y.Registration` instance added will have the name `registration` generated.
- An `x.y.Foo` instance added will have the name `foo` generated.
- A `java.util.HashMap` instance added will have the name `hashMap` generated. You probably want to be explicit about the name in this case because `hashMap` is less than intuitive.
- Adding `null` will result in an `IllegalArgumentException` being thrown. If the object (or objects) that you are adding could be `null`, then you will also want to be explicit about the name.

What, no automatic pluralization?

Spring Web MVC's convention-over-configuration support does not support automatic pluralization. That is, you cannot add a `List` of `Person` objects to a `ModelAndView` and have the generated name be `people`.

This decision was made after some debate, with the "Principle of Least Surprise" winning out in the end.

The strategy for generating a name after adding a `Set` or a `List` is to peek into the collection, take the short class name of the first object in the collection, and use that with `List` appended to the name. The same applies to arrays although with arrays it is not necessary to peek into the array contents. A few examples will make the semantics of name generation for collections clearer:

- An `x.y.User[]` array with zero or more `x.y.User` elements added will have the name `userList` generated.
- An `x.y.Foo[]` array with zero or more `x.y.User` elements added will have the name `fooList` generated.
- A `java.util.ArrayList` with one or more `x.y.User` elements added will have the name `userList` generated.
- A `java.util.HashSet` with one or more `x.y.Foo` elements added will have the name `fooList` generated.

- An *empty* `java.util.ArrayList` will not be added at all (in effect, the `addObject(..)` call will essentially be a no-op).

The View - RequestToViewNameTranslator

The `RequestToViewNameTranslator` interface determines a logical `View` name when no such logical view name is explicitly supplied. It has just one implementation, the `DefaultRequestToViewNameTranslator` class.

The `DefaultRequestToViewNameTranslator` maps request URLs to logical view names, as with this example:

```
public class RegistrationController implements Controller {

    public ModelAndView handleRequest(HttpServletRequest request, HttpServletResponse response) {
        // process the request...
        ModelAndView mav = new ModelAndView();
        // add data as necessary to the model...
        return mav;
        // notice that no View or logical view name has been set
    }

}
```

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <!-- this bean with the well known name generates view names for us -->
    <bean id="viewNameTranslator"
            class="org.springframework.web.servlet.view.DefaultRequestToViewNameTranslator"/>

    <bean class="x.y.RegistrationController">
        <!-- inject dependencies as necessary -->
    </bean>

    <!-- maps request URLs to Controller names -->
    <bean class="org.springframework.web.servlet.mvc.support.ControllerClassNameHandlerMapping"/>

    <bean id="viewResolver" class="org.springframework.web.servlet.view.InternalResourceViewResolver">
        <property name="prefix" value="/WEB-INF/jsp/"/>
        <property name="suffix" value=".jsp"/>
    </bean>

</beans>
```

Notice how in the implementation of the `handleRequest(..)` method no `View` or logical view name is ever set on the `ModelAndView` that is returned. The `DefaultRequestToViewNameTranslator` is tasked with generating a *logical view name* from the URL of the request. In the case of the above `RegistrationController`, which is used in conjunction with the `ControllerClassNameHandlerMapping`, a request URL of `http://localhost/registration.html` results in a logical view name of `registration` being generated by the `DefaultRequestToViewNameTranslator`. This logical view name is then resolved into the `/WEB-INF/jsp/registration.jsp` view by the `InternalResourceViewResolver` bean.

> **Tip**
>
> You do not need to define a `DefaultRequestToViewNameTranslator` bean explicitly. If you like the default settings of the `DefaultRequestToViewNameTranslator`, you can rely on the

> Spring Web MVC `DispatcherServlet` to instantiate an instance of this class if one is not explicitly configured.

Of course, if you need to change the default settings, then you do need to configure your own `DefaultRequestToViewNameTranslator` bean explicitly. Consult the comprehensive `DefaultRequestToViewNameTranslator` javadocs for details on the various properties that can be configured.

17.14 ETag support

An ETag (entity tag) is an HTTP response header returned by an HTTP/1.1 compliant web server used to determine change in content at a given URL. It can be considered to be the more sophisticated successor to the `Last-Modified` header. When a server returns a representation with an ETag header, the client can use this header in subsequent GETs, in an `If-None-Match` header. If the content has not changed, the server returns `304: Not Modified`.

Support for ETags is provided by the Servlet filter `ShallowEtagHeaderFilter`. It is a plain Servlet Filter, and thus can be used in combination with any web framework. The `ShallowEtagHeaderFilter` filter creates so-called shallow ETags (as opposed to deep ETags, more about that later).The filter caches the content of the rendered JSP (or other content), generates an MD5 hash over that, and returns that as an ETag header in the response. The next time a client sends a request for the same resource, it uses that hash as the `If-None-Match` value. The filter detects this, renders the view again, and compares the two hashes. If they are equal, a `304` is returned. This filter will not save processing power, as the view is still rendered. The only thing it saves is bandwidth, as the rendered response is not sent back over the wire.

You configure the `ShallowEtagHeaderFilter` in `web.xml`:

```
<filter>
    <filter-name>etagFilter</filter-name>
    <filter-class>org.springframework.web.filter.ShallowEtagHeaderFilter</filter-class>
</filter>

<filter-mapping>
    <filter-name>etagFilter</filter-name>
    <servlet-name>petclinic</servlet-name>
</filter-mapping>
```

17.15 Code-based Servlet container initialization

In a Servlet 3.0+ environment, you have the option of configuring the Servlet container programmatically as an alternative or in combination with a `web.xml` file. Below is an example of registering a `DispatcherServlet`:

```
import org.springframework.web.WebApplicationInitializer;

public class MyWebApplicationInitializer implements WebApplicationInitializer {

    @Override
    public void onStartup(ServletContext container) {
        XmlWebApplicationContext appContext = new XmlWebApplicationContext();
        appContext.setConfigLocation("/WEB-INF/spring/dispatcher-config.xml");

        ServletRegistration.Dynamic registration = container.addServlet("dispatcher", new
 DispatcherServlet(appContext));
        registration.setLoadOnStartup(1);
        registration.addMapping("/");
    }

}
```

`WebApplicationInitializer` is an interface provided by Spring MVC that ensures your implementation is detected and automatically used to initialize any Servlet 3 container. An abstract base class implementation of `WebApplicationInitializer` named `AbstractDispatcherServletInitializer` makes it even easier to register the `DispatcherServlet` by simply overriding methods to specify the servlet mapping and the location of the `DispatcherServlet` configuration:

```
public class MyWebAppInitializer extends AbstractAnnotationConfigDispatcherServletInitializer {

    @Override
    protected Class<?>[] getRootConfigClasses() {
        return null;
    }

    @Override
    protected Class<?>[] getServletConfigClasses() {
        return new Class[] { MyWebConfig.class };
    }

    @Override
    protected String[] getServletMappings() {
        return new String[] { "/" };
    }

}
```

The above example is for an application that uses Java-based Spring configuration. If using XML-based Spring configuration, extend directly from `AbstractDispatcherServletInitializer`:

```
public class MyWebAppInitializer extends AbstractDispatcherServletInitializer {

    @Override
    protected WebApplicationContext createRootApplicationContext() {
        return null;
    }

    @Override
    protected WebApplicationContext createServletApplicationContext() {
        XmlWebApplicationContext cxt = new XmlWebApplicationContext();
        cxt.setConfigLocation("/WEB-INF/spring/dispatcher-config.xml");
        return cxt;
    }

    @Override
    protected String[] getServletMappings() {
        return new String[] { "/" };
    }

}
```

`AbstractDispatcherServletInitializer` also provides a convenient way to add `Filter` instances and have them automatically mapped to the `DispatcherServlet`:

```
public class MyWebAppInitializer extends AbstractDispatcherServletInitializer {

    // ...

    @Override
    protected Filter[] getServletFilters() {
        return new Filter[] { new HiddenHttpMethodFilter(), new CharacterEncodingFilter() };
    }

}
```

Each filter is added with a default name based on its concrete type and automatically mapped to the `DispatcherServlet`.

The `isAsyncSupported` protected method of `AbstractDispatcherServletInitializer` provides a single place to enable async support on the `DispatcherServlet` and all filters mapped to it. By default this flag is set to `true`.

17.16 Configuring Spring MVC

the section called “Special Bean Types In the WebApplicationContext” and the section called “Default DispatcherServlet Configuration” explained about Spring MVC’s special beans and the default implementations used by the `DispatcherServlet`. In this section you’ll learn about two additional ways of configuring Spring MVC. Namely the MVC Java config and the MVC XML namespace.

The MVC Java config and the MVC namespace provide similar default configuration that overrides the `DispatcherServlet` defaults. The goal is to spare most applications from having to having to create the same configuration and also to provide higher-level constructs for configuring Spring MVC that serve as a simple starting point and require little or no prior knowledge of the underlying configuration.

You can choose either the MVC Java config or the MVC namespace depending on your preference. Also as you will see further below, with the MVC Java config it is easier to see the underlying configuration as well as to make fine-grained customizations directly to the created Spring MVC beans. But let’s start from the beginning.

Enabling the MVC Java Config or the MVC XML Namespace

To enable MVC Java config add the annotation `@EnableWebMvc` to one of your `@Configuration` classes:

```
@Configuration
@EnableWebMvc
public class WebConfig {

}
```

To achieve the same in XML use the `mvc:annotation-driven` element in your DispatcherServlet context (or in your root context if you have no DispatcherServlet context defined):

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:mvc="http://www.springframework.org/schema/mvc"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/mvc
        http://www.springframework.org/schema/mvc/spring-mvc.xsd">

    <mvc:annotation-driven />

</beans>
```

The above registers a `RequestMappingHandlerMapping`, a `RequestMappingHandlerAdapter`, and an `ExceptionHandlerExceptionResolver` (among others) in support of processing requests with annotated controller methods using annotations such as `@RequestMapping`, `@ExceptionHandler`, and others.

It also enables the following:

1. Spring 3 style type conversion through a ConversionService instance in addition to the JavaBeans PropertyEditors used for Data Binding.
2. Support for formatting Number fields using the `@NumberFormat` annotation through the `ConversionService`.
3. Support for formatting Date, Calendar, Long, and Joda Time fields using the `@DateTimeFormat` annotation.
4. Support for validating `@Controller` inputs with `@Valid`, if a JSR-303 Provider is present on the classpath.
5. HttpMessageConverter support for `@RequestBody` method parameters and `@ResponseBody` method return values from `@RequestMapping` or `@ExceptionHandler` methods.

   This is the complete list of HttpMessageConverters set up by mvc:annotation-driven:

   a. `ByteArrayHttpMessageConverter` converts byte arrays.

   b. `StringHttpMessageConverter` converts strings.

   c. `ResourceHttpMessageConverter` converts to/from `org.springframework.core.io.Resource` for all media types.

   d. `SourceHttpMessageConverter` converts to/from a `javax.xml.transform.Source`.

   e. `FormHttpMessageConverter` converts form data to/from a `MultiValueMap<String, String>`.

   f. `Jaxb2RootElementHttpMessageConverter` converts Java objects to/from XML — added if JAXB2 is present and Jackson 2 XML extension is not present on the classpath.

   g. `MappingJackson2HttpMessageConverter` converts to/from JSON — added if Jackson 2 is present on the classpath.

   h. `MappingJackson2XmlHttpMessageConverter` converts to/from XML — added if Jackson 2 XML extension is present on the classpath.

i. `AtomFeedHttpMessageConverter` converts Atom feeds — added if Rome is present on the classpath.

j. `RssChannelHttpMessageConverter` converts RSS feeds — added if Rome is present on the classpath.

Customizing the Provided Configuration

To customize the default configuration in Java you simply implement the `WebMvcConfigurer` interface or more likely extend the class `WebMvcConfigurerAdapter` and override the methods you need. Below is an example of some of the available methods to override. See `WebMvcConfigurer` for a list of all methods and the javadocs for further details:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    protected void addFormatters(FormatterRegistry registry) {
        // Add formatters and/or converters
    }

    @Override
    public void configureMessageConverters(List<HttpMessageConverter<?>> converters) {
        // Configure the list of HttpMessageConverters to use
    }

}
```

To customize the default configuration of `<mvc:annotation-driven />` check what attributes and sub-elements it supports. You can view the Spring MVC XML schema or use the code completion feature of your IDE to discover what attributes and sub-elements are available. The sample below shows a subset of what is available:

```
<mvc:annotation-driven conversion-service="conversionService">
    <mvc:message-converters>
        <bean class="org.example.MyHttpMessageConverter"/>
        <bean class="org.example.MyOtherHttpMessageConverter"/>
    </mvc:message-converters>
</mvc:annotation-driven>

<bean id="conversionService" class="org.springframework.format.support.FormattingConversionServiceFactoryBean">
    <property name="formatters">
        <list>
            <bean class="org.example.MyFormatter"/>
            <bean class="org.example.MyOtherFormatter"/>
        </list>
    </property>
</bean>
```

Interceptors

You can configure `HandlerInterceptors` or `WebRequestInterceptors` to be applied to all incoming requests or restricted to specific URL path patterns.

An example of registering interceptors in Java:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addInterceptors(InterceptorRegistry registry) {
        registry.addInterceptor(new LocaleInterceptor());
        registry.addInterceptor(new ThemeInterceptor()).addPathPatterns("/").excludePathPatterns("/
admin/");
        registry.addInterceptor(new SecurityInterceptor()).addPathPatterns("/secure/*");
    }

}
```

And in XML use the `<mvc:interceptors>` element:

```
<mvc:interceptors>
    <bean class="org.springframework.web.servlet.i18n.LocaleChangeInterceptor" />
    <mvc:interceptor>
        <mvc:mapping path="/"/>
        <mvc:exclude-mapping path="/admin/"/>
        <bean class="org.springframework.web.servlet.theme.ThemeChangeInterceptor" />
    </mvc:interceptor>
    <mvc:interceptor>
        <mvc:mapping path="/secure/*"/>
        <bean class="org.example.SecurityInterceptor" />
    </mvc:interceptor>
</mvc:interceptors>
```

Content Negotiation

You can configure how Spring MVC determines the requested media types from the client for request mapping as well as for content negotiation purposes. The available options are to check the file extension in the request URI, the "Accept" header, a request parameter, as well as to fall back on a default content type. By default, file extension in the request URI is checked first and the "Accept" header is checked next.

For file extensions in the request URI, the MVC Java config and the MVC namespace, automatically register extensions such as `.json`, `.xml`, `.rss`, and `.atom` if the corresponding dependencies such as Jackson, JAXB2, or Rome are present on the classpath. Additional extensions may be not need to be registered explicitly if they can be discovered via `ServletContext.getMimeType(String)` or the *Java Activation Framework* (see `javax.activation.MimetypesFileTypeMap`). You can register more extensions with the setUseRegisteredSuffixPatternMatch method.

The introduction of `ContentNegotiationManager` also enables selective suffix pattern matching for incoming requests. For more details, see its javadocs.

Below is an example of customizing content negotiation options through the MVC Java config:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configureContentNegotiation(ContentNegotiationConfigurer configurer) {
        configurer.favorPathExtension(false).favorParameter(true);
    }
}
```

In the MVC namespace, the `<mvc:annotation-driven>` element has a `content-negotiation-manager` attribute, which expects a `ContentNegotiationManager` that in turn can be created with a `ContentNegotiationManagerFactoryBean`:

```
<mvc:annotation-driven content-negotiation-manager="contentNegotiationManager" />

<bean id="contentNegotiationManager" class="org.springframework.web.accept.ContentNegotiationManagerFactoryBean">
    <property name="favorPathExtension" value="false" />
    <property name="favorParameter" value="true" />
    <property name="mediaTypes" >
        <value>
            json=application/json
            xml=application/xml
        </value>
    </property>
</bean>
```

If not using the MVC Java config or the MVC namespace, you'll need to create an instance of `ContentNegotiationManager` and use it to configure `RequestMappingHandlerMapping` for request mapping purposes, and `RequestMappingHandlerAdapter` and `ExceptionHandlerExceptionResolver` for content negotiation purposes.

Note that `ContentNegotiatingViewResolver` now can also be configured with a `ContentNegotiatingViewResolver`, so you can use one instance throughout Spring MVC.

In more advanced cases, it may be useful to configure multiple `ContentNegotiationManager` instances that in turn may contain custom `ContentNegotiationStrategy` implementations. For example you could configure `ExceptionHandlerExceptionResolver` with a `ContentNegotiationManager` that always resolves the requested media type to `"application/json"`. Or you may want to plug a custom strategy that has some logic to select a default content type (e.g. either XML or JSON) if no content types were requested.

View Controllers

This is a shortcut for defining a `ParameterizableViewController` that immediately forwards to a view when invoked. Use it in static cases when there is no Java controller logic to execute before the view generates the response.

An example of forwarding a request for `"/"` to a view called `"home"` in Java:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addViewControllers(ViewControllerRegistry registry) {
        registry.addViewController("/").setViewName("home");
    }

}
```

And the same in XML use the `<mvc:view-controller>` element:

```
<mvc:view-controller path="/" view-name="home"/>
```

View Resolvers

The MVC config simplifies the registration of view resolvers.

The following is a Java config example that configures content negotiation view resolution using FreeMarker HTML templates and Jackson as a default `View` for JSON rendering:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.enableContentNegotiation(new MappingJackson2JsonView());
        registry.jsp();
    }

}
```

And the same in XML:

```
<mvc:view-resolvers>
    <mvc:content-negotiation>
        <mvc:default-views>
            <bean class="org.springframework.web.servlet.view.json.MappingJackson2JsonView" />
        </mvc:default-views>
    </mvc:content-negotiation>
    <mvc:jsp />
</mvc:view-resolvers>
```

Note however that FreeMarker, Velocity, Tiles, and Groovy Markup also require configuration of the underlying view technology.

The MVC namespace provides dedicated elements. For example with FreeMarker:

```
<mvc:view-resolvers>
    <mvc:content-negotiation>
        <mvc:default-views>
            <bean class="org.springframework.web.servlet.view.json.MappingJackson2JsonView" />
        </mvc:default-views>
    </mvc:content-negotiation>
    <mvc:freemarker cache="false" />
</mvc:view-resolvers>

<mvc:freemarker-configurer>
    <mvc:template-loader-path location="/freemarker" />
</mvc:freemarker-configurer>
```

In Java config simply add the respective "Configurer" bean:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configureViewResolvers(ViewResolverRegistry registry) {
        registry.enableContentNegotiation(new MappingJackson2JsonView());
        registry.freeMarker().cache(false);
    }

    @Bean
    public FreeMarkerConfigurer freeMarkerConfigurer() {
        FreeMarkerConfigurer configurer = new FreeMarkerConfigurer();
        configurer.setTemplateLoaderPath("/WEB-INF/");
        return configurer;
    }

}
```

Serving of Resources

This option allows static resource requests following a particular URL pattern to be served by a `ResourceHttpRequestHandler` from any of a list of `Resource` locations. This provides a convenient way to serve static resources from locations other than the web application root, including locations on the classpath. The `cache-period` property may be used to set far future expiration headers (1 year is the recommendation of optimization tools such as Page Speed and YSlow) so that they will be more efficiently utilized by the client. The handler also properly evaluates the `Last-Modified` header (if present) so that a `304` status code will be returned as appropriate, avoiding unnecessary overhead for resources that are already cached by the client. For example, to serve resource requests with a URL pattern of `/resources/**` from a `public-resources` directory within the web application root you would use:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/**").addResourceLocations("/public-resources/");
    }

}
```

And the same in XML:

```
<mvc:resources mapping="/resources/**" location="/public-resources/"/>
```

To serve these resources with a 1-year future expiration to ensure maximum use of the browser cache and a reduction in HTTP requests made by the browser:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/**").addResourceLocations("/public-
resources/").setCachePeriod(31556926);
    }

}
```

And in XML:

```
<mvc:resources mapping="/resources/**" location="/public-resources/" cache-period="31556926"/>
```

The `mapping` attribute must be an Ant pattern that can be used by `SimpleUrlHandlerMapping`, and the `location` attribute must specify one or more valid resource directory locations. Multiple resource locations may be specified using a comma-separated list of values. The locations specified will be checked in the specified order for the presence of the resource for any given request. For example, to enable the serving of resources from both the web application root and from a known path of `/META-INF/public-web-resources/` in any jar on the classpath use:

```
@EnableWebMvc
@Configuration
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/**")
                .addResourceLocations("/", "classpath:/META-INF/public-web-resources/");
    }

}
```

And in XML:

```
<mvc:resources mapping="/resources/**" location="/, classpath:/META-INF/public-web-resources/"/>
```

When serving resources that may change when a new version of the application is deployed it is recommended that you incorporate a version string into the mapping pattern used to request the resources so that you may force clients to request the newly deployed version of your application's resources. Support for versioned URLs is built into the framework and can be enabled by configuring a resource chain on the resource handler. The chain consists of one more `ResourceResolver` instances followed by one or more `ResourceTransformer` instances. Together they can provide arbitrary resolution and transformation of resources.

The built-in `VersionResourceResolver` can be configured with different strategies. For example a `FixedVersionStrategy` can use a property, a date, or other as the version. A `ContentVersionStrategy` uses an MD5 hash computed from the content of the resource (known as "fingerprinting" URLs).

`ContentVersionStrategy` is a good default choice to use except in cases where it cannot be used (e.g. with JavaScript module loaders). You can configure different version strategies against different patterns as shown below. Keep in mind also that computing content-based versions is expensive and therefore resource chain caching should be enabled in production.

Java config example;

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void addResourceHandlers(ResourceHandlerRegistry registry) {
        registry.addResourceHandler("/resources/")
                .addResourceLocations("/public-resources/")
                .resourceChain(true).addResolver(
                    new VersionResourceResolver().addContentVersionStrategy("/"));
    }

}
```

XML example:

```
<mvc:resources mapping="/resources/" location="/public-resources/">
 <mvc:resource-chain>
  <mvc:resource-cache />
  <mvc:resolvers>
   <mvc:version-resolver>
    <mvc:content-version-strategy patterns="/"/>
   </mvc:version-resolver>
  </mvc:resolvers>
 </mvc:resource-chain>
</mvc:resources>
```

In order for the above to work the application must also render URLs with versions. The easiest way to do that is to configure the `ResourceUrlEncodingFilter` which wraps the response and overrides its `encodeURL` method. This will work in JSPs, FreeMarker, Velocity, and any other view technology that calls the response `encodeURL` method. Alternatively, an application can also inject and use directly the `ResourceUrlProvider` bean, which is automatically declared with the MVC Java config and the MVC namespace.

Falling Back On the "Default" Servlet To Serve Resources

This allows for mapping the `DispatcherServlet` to "/" (thus overriding the mapping of the container's default Servlet), while still allowing static resource requests to be handled by the container's default Servlet. It configures a `DefaultServletHttpRequestHandler` with a URL mapping of "/**" and the lowest priority relative to other URL mappings.

This handler will forward all requests to the default Servlet. Therefore it is important that it remains last in the order of all other URL `HandlerMappings`. That will be the case if you use `<mvc:annotation-driven>` or alternatively if you are setting up your own customized `HandlerMapping` instance be sure to set its `order` property to a value lower than that of the `DefaultServletHttpRequestHandler`, which is `Integer.MAX_VALUE`.

To enable the feature using the default setup use:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configureDefaultServletHandling(DefaultServletHandlerConfigurer configurer) {
        configurer.enable();
    }

}
```

Or in XML:

```
<mvc:default-servlet-handler/>
```

The caveat to overriding the "/" Servlet mapping is that the `RequestDispatcher` for the default Servlet must be retrieved by name rather than by path. The `DefaultServletHttpRequestHandler` will attempt to auto-detect the default Servlet for the container at startup time, using a list of known names for most of the major Servlet containers (including Tomcat, Jetty, GlassFish, JBoss, Resin, WebLogic, and WebSphere). If the default Servlet has been custom configured with a different name, or if a different Servlet container is being used where the default Servlet name is unknown, then the default Servlet's name must be explicitly provided as in the following example:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configureDefaultServletHandling(DefaultServletHandlerConfigurer configurer) {
        configurer.enable("myCustomDefaultServlet");
    }

}
```

Or in XML:

```
<mvc:default-servlet-handler default-servlet-name="myCustomDefaultServlet"/>
```

Path Matching

This allows customizing various settings related to URL mapping and path matching. For details on the individual options check out the PathMatchConfigurer API.

Below is an example in Java config:

```
@Configuration
@EnableWebMvc
public class WebConfig extends WebMvcConfigurerAdapter {

    @Override
    public void configurePathMatch(PathMatchConfigurer configurer) {
        configurer
            .setUseSuffixPatternMatch(true)
            .setUseTrailingSlashMatch(false)
            .setUseRegisteredSuffixPatternMatch(true)
            .setPathMatcher(antPathMatcher())
            .setUrlPathHelper(urlPathHelper());
    }

    @Bean
    public UrlPathHelper urlPathHelper() {
        //...
    }

    @Bean
    public PathMatcher antPathMatcher() {
        //...
    }

}
```

And the same in XML, use the `<mvc:path-matching>` element:

```
<mvc:annotation-driven>
    <mvc:path-matching
        suffix-pattern="true"
        trailing-slash="false"
        registered-suffixes-only="true"
        path-helper="pathHelper"
        path-matcher="pathMatcher" />
</mvc:annotation-driven>

<bean id="pathHelper" class="org.example.app.MyPathHelper" />
<bean id="pathMatcher" class="org.example.app.MyPathMatcher" />
```

Advanced Customizations with MVC Java Config

As you can see from the above examples, MVC Java config and the MVC namespace provide higher level constructs that do not require deep knowledge of the underlying beans created for you. Instead it helps you to focus on your application needs. However, at some point you may need more fine-grained control or you may simply wish to understand the underlying configuration.

The first step towards more fine-grained control is to see the underlying beans created for you. In MVC Java config you can see the javadocs and the `@Bean` methods in `WebMvcConfigurationSupport`. The configuration in this class is automatically imported through the `@EnableWebMvc` annotation. In fact if you open `@EnableWebMvc` you can see the `@Import` statement.

The next step towards more fine-grained control is to customize a property on one of the beans created in `WebMvcConfigurationSupport` or perhaps to provide your own instance. This requires two things — remove the `@EnableWebMvc` annotation in order to prevent the import and then extend

from `DelegatingWebMvcConfiguration`, a subclass of `WebMvcConfigurationSupport`. Here is an example:

```
@Configuration
public class WebConfig extends DelegatingWebMvcConfiguration {

    @Override
    public void addInterceptors(InterceptorRegistry registry){
        // ...
    }

    @Override
    @Bean
    public RequestMappingHandlerAdapter requestMappingHandlerAdapter() {
        // Create or let "super" create the adapter
        // Then customize one of its properties
    }

}
```

Note

An application should have only one configuration extending `DelegatingWebMvcConfiguration` or a single `@EnableWebMvc` annotated class, since they both register the same underlying beans.

Modifying beans in this way does not prevent you from using any of the higher-level constructs shown earlier in this section. `WebMvcConfigurerAdapter` subclasses and `WebMvcConfigurer` implementations are still being used.

Advanced Customizations with the MVC Namespace

Fine-grained control over the configuration created for you is a bit harder with the MVC namespace.

If you do need to do that, rather than replicating the configuration it provides, consider configuring a `BeanPostProcessor` that detects the bean you want to customize by type and then modifying its properties as necessary. For example:

```
@Component
public class MyPostProcessor implements BeanPostProcessor {

    public Object postProcessBeforeInitialization(Object bean, String name) throws BeansException {
        if (bean instanceof RequestMappingHandlerAdapter) {
            // Modify properties of the adapter
        }
    }

}
```

Note that `MyPostProcessor` needs to be included in an `<component scan />` in order for it to be detected or if you prefer you can declare it explicitly with an XML bean declaration.

18. View technologies

18.1 Introduction

One of the areas in which Spring excels is in the separation of view technologies from the rest of the MVC framework. For example, deciding to use Velocity or XSLT in place of an existing JSP is primarily a matter of configuration. This chapter covers the major view technologies that work with Spring and touches briefly on how to add new ones. This chapter assumes you are already familiar with Section 17.5, “Resolving views” which covers the basics of how views in general are coupled to the MVC framework.

18.2 JSP & JSTL

Spring provides a couple of out-of-the-box solutions for JSP and JSTL views. Using JSP or JSTL is done using a normal view resolver defined in the `WebApplicationContext`. Furthermore, of course you need to write some JSPs that will actually render the view.

> **Note**
>
> Setting up your application to use JSTL is a common source of error, mainly caused by confusion over the different servlet spec., JSP and JSTL version numbers, what they mean and how to declare the taglibs correctly. The article How to Reference and Use JSTL in your Web Application provides a useful guide to the common pitfalls and how to avoid them. Note that as of Spring 3.0, the minimum supported servlet version is 2.4 (JSP 2.0 and JSTL 1.1), which reduces the scope for confusion somewhat.

View resolvers

Just as with any other view technology you’re integrating with Spring, for JSPs you’ll need a view resolver that will resolve your views. The most commonly used view resolvers when developing with JSPs are the `InternalResourceViewResolver` and the `ResourceBundleViewResolver`. Both are declared in the `WebApplicationContext`:

```
<!-- the ResourceBundleViewResolver -->
<bean id="viewResolver" class="org.springframework.web.servlet.view.ResourceBundleViewResolver">
    <property name="basename" value="views"/>
</bean>

# And a sample properties file is uses (views.properties in WEB-INF/classes):
welcome.(class)=org.springframework.web.servlet.view.JstlView
welcome.url=/WEB-INF/jsp/welcome.jsp

productList.(class)=org.springframework.web.servlet.view.JstlView
productList.url=/WEB-INF/jsp/productlist.jsp
```

As you can see, the `ResourceBundleViewResolver` needs a properties file defining the view names mapped to 1) a class and 2) a URL. With a `ResourceBundleViewResolver` you can mix different types of views using only one resolver.

```
<bean id="viewResolver" class="org.springframework.web.servlet.view.InternalResourceViewResolver">
    <property name="viewClass" value="org.springframework.web.servlet.view.JstlView"/>
    <property name="prefix" value="/WEB-INF/jsp/"/>
    <property name="suffix" value=".jsp"/>
</bean>
```

The `InternalResourceBundleViewResolver` can be configured for using JSPs as described above. As a best practice, we strongly encourage placing your JSP files in a directory under the `'WEB-INF'` directory, so there can be no direct access by clients.

Plain-old JSPs versus JSTL

When using the Java Standard Tag Library you must use a special view class, the `JstlView`, as JSTL needs some preparation before things such as the I18N features will work.

Additional tags facilitating development

Spring provides data binding of request parameters to command objects as described in earlier chapters. To facilitate the development of JSP pages in combination with those data binding features, Spring provides a few tags that make things even easier. All Spring tags have*HTML escaping* features to enable or disable escaping of characters.

The tag library descriptor (TLD) is included in the `spring-webmvc.jar`. Further information about the individual tags can be found in the appendix entitled Chapter 36, *spring.tld*.

Using Spring's form tag library

As of version 2.0, Spring provides a comprehensive set of data binding-aware tags for handling form elements when using JSP and Spring Web MVC. Each tag provides support for the set of attributes of its corresponding HTML tag counterpart, making the tags familiar and intuitive to use. The tag-generated HTML is HTML 4.01/XHTML 1.0 compliant.

Unlike other form/input tag libraries, Spring's form tag library is integrated with Spring Web MVC, giving the tags access to the command object and reference data your controller deals with. As you will see in the following examples, the form tags make JSPs easier to develop, read and maintain.

Let's go through the form tags and look at an example of how each tag is used. We have included generated HTML snippets where certain tags require further commentary.

Configuration

The form tag library comes bundled in `spring-webmvc.jar`. The library descriptor is called `spring-form.tld`.

To use the tags from this library, add the following directive to the top of your JSP page:

```
<%@ taglib prefix="form" uri="http://www.springframework.org/tags/form" %>
```

where `form` is the tag name prefix you want to use for the tags from this library.

The form tag

This tag renders an HTML *form* tag and exposes a binding path to inner tags for binding. It puts the command object in the `PageContext` so that the command object can be accessed by inner tags. *All the other tags in this library are nested tags of the `form` tag*.

Let's assume we have a domain object called `User`. It is a JavaBean with properties such as `firstName` and `lastName`. We will use it as the form backing object of our form controller which returns `form.jsp`. Below is an example of what `form.jsp` would look like:

```
<form:form>
    <table>
        <tr>
            <td>First Name:</td>
            <td><form:input path="firstName" /></td>
        </tr>
        <tr>
            <td>Last Name:</td>
            <td><form:input path="lastName" /></td>
        </tr>
        <tr>
            <td colspan="2">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form:form>
```

The `firstName` and `lastName` values are retrieved from the command object placed in the `PageContext` by the page controller. Keep reading to see more complex examples of how inner tags are used with the `form` tag.

The generated HTML looks like a standard form:

```
<form method="POST">
    <table>
        <tr>
            <td>First Name:</td>
            <td><input name="firstName" type="text" value="Harry"/></td>
        </tr>
        <tr>
            <td>Last Name:</td>
            <td><input name="lastName" type="text" value="Potter"/></td>
        </tr>
        <tr>
            <td colspan="2">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form>
```

The preceding JSP assumes that the variable name of the form backing object is `'command'`. If you have put the form backing object into the model under another name (definitely a best practice), then you can bind the form to the named variable like so:

```
<form:form commandName="user">
    <table>
        <tr>
            <td>First Name:</td>
            <td><form:input path="firstName" /></td>
        </tr>
        <tr>
            <td>Last Name:</td>
            <td><form:input path="lastName" /></td>
        </tr>
        <tr>
            <td colspan="2">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form:form>
```

The input tag

This tag renders an HTML *input* tag using the bound value and type=*text* by default. For an example of this tag, see the section called “The form tag”. Starting with Spring 3.1 you can use other types such HTML5-specific types like *email*, *tel*, *date*, and others.

The checkbox tag

This tag renders an HTML *input* tag with type *checkbox*.

Let’s assume our `User` has preferences such as newsletter subscription and a list of hobbies. Below is an example of the `Preferences` class:

```
public class Preferences {

    private boolean receiveNewsletter;
    private String[] interests;
    private String favouriteWord;

    public boolean isReceiveNewsletter() {
        return receiveNewsletter;
    }

    public void setReceiveNewsletter(boolean receiveNewsletter) {
        this.receiveNewsletter = receiveNewsletter;
    }

    public String[] getInterests() {
        return interests;
    }

    public void setInterests(String[] interests) {
        this.interests = interests;
    }

    public String getFavouriteWord() {
        return favouriteWord;
    }

    public void setFavouriteWord(String favouriteWord) {
        this.favouriteWord = favouriteWord;
    }
}
```

The `form.jsp` would look like:

```
<form:form>
    <table>
        <tr>
            <td>Subscribe to newsletter?:</td>
            <%-- Approach 1: Property is of type java.lang.Boolean --%>
            <td><form:checkbox path="preferences.receiveNewsletter"/></td>
        </tr>

        <tr>
            <td>Interests:</td>
            <%-- Approach 2: Property is of an array or of type java.util.Collection --%>
            <td>
                Quidditch: <form:checkbox path="preferences.interests" value="Quidditch"/>
                Herbology: <form:checkbox path="preferences.interests" value="Herbology"/>
                Defence Against the Dark
 Arts: <form:checkbox path="preferences.interests" value="Defence Against the Dark Arts"/>
            </td>
        </tr>

        <tr>
            <td>Favourite Word:</td>
            <%-- Approach 3: Property is of type java.lang.Object --%>
            <td>
                Magic: <form:checkbox path="preferences.favouriteWord" value="Magic"/>
            </td>
        </tr>
    </table>
</form:form>
```

There are 3 approaches to the `checkbox` tag which should meet all your checkbox needs.

- Approach One - When the bound value is of type `java.lang.Boolean`, the `input(checkbox)` is marked as *checked* if the bound value is `true`. The `value` attribute corresponds to the resolved value of the `setValue(Object)` value property.
- Approach Two - When the bound value is of type `array` or `java.util.Collection`, the `input(checkbox)` is marked as *checked* if the configured `setValue(Object)` value is present in the bound `Collection`.
- Approach Three - For any other bound value type, the `input(checkbox)` is marked as *checked* if the configured `setValue(Object)` is equal to the bound value.

Note that regardless of the approach, the same HTML structure is generated. Below is an HTML snippet of some checkboxes:

```
<tr>
    <td>Interests:</td>
    <td>
        Quidditch: <input name="preferences.interests" type="checkbox" value="Quidditch"/>
        <input type="hidden" value="1" name="_preferences.interests"/>
        Herbology: <input name="preferences.interests" type="checkbox" value="Herbology"/>
        <input type="hidden" value="1" name="_preferences.interests"/>
        Defence Against the Dark
 Arts: <input name="preferences.interests" type="checkbox" value="Defence Against the Dark Arts"/>
        <input type="hidden" value="1" name="_preferences.interests"/>
    </td>
</tr>
```

What you might not expect to see is the additional hidden field after each checkbox. When a checkbox in an HTML page is *not* checked, its value will not be sent to the server as part of the HTTP request parameters once the form is submitted, so we need a workaround for this quirk in HTML in order for Spring form data binding to work. The `checkbox` tag follows the existing Spring convention of including a hidden parameter prefixed by an underscore ("_") for each checkbox. By doing this, you are effectively

telling Spring that "*the checkbox was visible in the form and I want my object to which the form data will be bound to reflect the state of the checkbox no matter what*".

The checkboxes tag

This tag renders multiple HTML *input* tags with type *checkbox*.

Building on the example from the previous `checkbox` tag section. Sometimes you prefer not to have to list all the possible hobbies in your JSP page. You would rather provide a list at runtime of the available options and pass that in to the tag. That is the purpose of the `checkboxes` tag. You pass in an `Array`, a `List` or a `Map` containing the available options in the "items" property. Typically the bound property is a collection so it can hold multiple values selected by the user. Below is an example of the JSP using this tag:

```
<form:form>
    <table>
        <tr>
            <td>Interests:</td>
            <td>
                <%-- Property is of an array or of type java.util.Collection --%>
                <form:checkboxes path="preferences.interests" items="${interestList}"/>
            </td>
        </tr>
    </table>
</form:form>
```

This example assumes that the "interestList" is a `List` available as a model attribute containing strings of the values to be selected from. In the case where you use a Map, the map entry key will be used as the value and the map entry's value will be used as the label to be displayed. You can also use a custom object where you can provide the property names for the value using "itemValue" and the label using "itemLabel".

The radiobutton tag

This tag renders an HTML *input* tag with type *radio*.

A typical usage pattern will involve multiple tag instances bound to the same property but with different values.

```
<tr>
    <td>Sex:</td>
    <td>
        Male: <form:radiobutton path="sex" value="M"/> <br/>
        Female: <form:radiobutton path="sex" value="F"/>
    </td>
</tr>
```

The radiobuttons tag

This tag renders multiple HTML *input* tags with type *radio*.

Just like the `checkboxes` tag above, you might want to pass in the available options as a runtime variable. For this usage you would use the `radiobuttons` tag. You pass in an `Array`, a `List` or a `Map` containing the available options in the "items" property. In the case where you use a Map, the map entry key will be used as the value and the map entry's value will be used as the label to be displayed. You can also use a custom object where you can provide the property names for the value using "itemValue" and the label using "itemLabel".

```
<tr>
    <td>Sex:</td>
    <td><form:radiobuttons path="sex" items="${sexOptions}"/></td>
</tr>
```

The password tag

This tag renders an HTML *input* tag with type *password* using the bound value.

```
<tr>
    <td>Password:</td>
    <td>
        <form:password path="password" />
    </td>
</tr>
```

Please note that by default, the password value is *not* shown. If you do want the password value to be shown, then set the value of the `'showPassword'` attribute to true, like so.

```
<tr>
    <td>Password:</td>
    <td>
        <form:password path="password" value="^76525bvHGq" showPassword="true" />
    </td>
</tr>
```

The select tag

This tag renders an HTML *select* element. It supports data binding to the selected option as well as the use of nested `option` and `options` tags.

Let's assume a `User` has a list of skills.

```
<tr>
    <td>Skills:</td>
    <td><form:select path="skills" items="${skills}"/></td>
</tr>
```

If the `User's` skill were in Herbology, the HTML source of the *Skills* row would look like:

```
<tr>
    <td>Skills:</td>
    <td>
        <select name="skills" multiple="true">
            <option value="Potions">Potions</option>
            <option value="Herbology" selected="selected">Herbology</option>
            <option value="Quidditch">Quidditch</option>
        </select>
    </td>
</tr>
```

The option tag

This tag renders an HTML *option*. It sets *selected* as appropriate based on the bound value.

```
<tr>
    <td>House:</td>
    <td>
        <form:select path="house">
            <form:option value="Gryffindor"/>
            <form:option value="Hufflepuff"/>
            <form:option value="Ravenclaw"/>
            <form:option value="Slytherin"/>
        </form:select>
    </td>
</tr>
```

If the `User`'s house was in Gryffindor, the HTML source of the *House* row would look like:

```
<tr>
    <td>House:</td>
    <td>
        <select name="house">
            <option value="Gryffindor" selected="selected">Gryffindor</option>
            <option value="Hufflepuff">Hufflepuff</option>
            <option value="Ravenclaw">Ravenclaw</option>
            <option value="Slytherin">Slytherin</option>
        </select>
    </td>
</tr>
```

The options tag

This tag renders a list of HTML *option* tags. It sets the *selected* attribute as appropriate based on the bound value.

```
<tr>
    <td>Country:</td>
    <td>
        <form:select path="country">
            <form:option value="-" label="--Please Select"/>
            <form:options items="${countryList}" itemValue="code" itemLabel="name"/>
        </form:select>
    </td>
</tr>
```

If the `User` lived in the UK, the HTML source of the *Country* row would look like:

```
<tr>
    <td>Country:</td>
    <td>
        <select name="country">
            <option value="-">--Please Select</option>
            <option value="AT">Austria</option>
            <option value="UK" selected="selected">United Kingdom</option>
            <option value="US">United States</option>
        </select>
    </td>
</tr>
```

As the example shows, the combined usage of an `option` tag with the `options` tag generates the same standard HTML, but allows you to explicitly specify a value in the JSP that is for display only (where it belongs) such as the default string in the example: "-- Please Select".

The `items` attribute is typically populated with a collection or array of item objects. `itemValue` and `itemLabel` simply refer to bean properties of those item objects, if specified; otherwise, the item objects themselves will be stringified. Alternatively, you may specify a `Map` of items, in which case the map keys are interpreted as option values and the map values correspond to option labels. If `itemValue` and/or

`itemLabel` happen to be specified as well, the item value property will apply to the map key and the item label property will apply to the map value.

The textarea tag

This tag renders an HTML *textarea*.

```
<tr>
    <td>Notes:</td>
    <td><form:textarea path="notes" rows="3" cols="20" /></td>
    <td><form:errors path="notes" /></td>
</tr>
```

The hidden tag

This tag renders an HTML *input* tag with type *hidden* using the bound value. To submit an unbound hidden value, use the HTML `input` tag with type *hidden*.

```
<form:hidden path="house" />
```

If we choose to submit the *house* value as a hidden one, the HTML would look like:

```
<input name="house" type="hidden" value="Gryffindor"/>
```

The errors tag

This tag renders field errors in an HTML *span* tag. It provides access to the errors created in your controller or those that were created by any validators associated with your controller.

Let's assume we want to display all error messages for the `firstName` and `lastName` fields once we submit the form. We have a validator for instances of the `User` class called `UserValidator`.

```
public class UserValidator implements Validator {

    public boolean supports(Class candidate) {
        return User.class.isAssignableFrom(candidate);
    }

    public void validate(Object obj, Errors errors) {
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "firstName", "required", "Field is
 required.");
        ValidationUtils.rejectIfEmptyOrWhitespace(errors, "lastName", "required", "Field is required.");
    }
}
```

The `form.jsp` would look like:

```
<form:form>
    <table>
        <tr>
            <td>First Name:</td>
            <td><form:input path="firstName" /></td>
            <%-- Show errors for firstName field --%>
            <td><form:errors path="firstName" /></td>
        </tr>

        <tr>
            <td>Last Name:</td>
            <td><form:input path="lastName" /></td>
            <%-- Show errors for lastName field --%>
            <td><form:errors path="lastName" /></td>
        </tr>
        <tr>
            <td colspan="3">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form:form>
```

If we submit a form with empty values in the `firstName` and `lastName` fields, this is what the HTML would look like:

```
<form method="POST">
    <table>
        <tr>
            <td>First Name:</td>
            <td><input name="firstName" type="text" value=""/></td>
            <%-- Associated errors to firstName field displayed --%>
            <td><span name="firstName.errors">Field is required.</span></td>
        </tr>

        <tr>
            <td>Last Name:</td>
            <td><input name="lastName" type="text" value=""/></td>
            <%-- Associated errors to lastName field displayed --%>
            <td><span name="lastName.errors">Field is required.</span></td>
        </tr>
        <tr>
            <td colspan="3">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form>
```

What if we want to display the entire list of errors for a given page? The example below shows that the `errors` tag also supports some basic wildcarding functionality.

- `path="*"` - displays all errors
- `path="lastName"` - displays all errors associated with the `lastName` field
- if `path` is omitted - object errors only are displayed

The example below will display a list of errors at the top of the page, followed by field-specific errors next to the fields:

```
<form:form>
    <form:errors path="*" cssClass="errorBox" />
    <table>
        <tr>
            <td>First Name:</td>
            <td><form:input path="firstName" /></td>
            <td><form:errors path="firstName" /></td>
        </tr>
        <tr>
            <td>Last Name:</td>
            <td><form:input path="lastName" /></td>
            <td><form:errors path="lastName" /></td>
        </tr>
        <tr>
            <td colspan="3">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
    </table>
</form:form>
```

The HTML would look like:

```
<form method="POST">
    <span name="*.errors" class="errorBox">Field is required.<br/>Field is required.</span>
    <table>
        <tr>
            <td>First Name:</td>
            <td><input name="firstName" type="text" value=""/></td>
            <td><span name="firstName.errors">Field is required.</span></td>
        </tr>

        <tr>
            <td>Last Name:</td>
            <td><input name="lastName" type="text" value=""/></td>
            <td><span name="lastName.errors">Field is required.</span></td>
        </tr>
        <tr>
            <td colspan="3">
                <input type="submit" value="Save Changes" />
            </td>
        </tr>
</form>
```

HTTP Method Conversion

A key principle of REST is the use of the Uniform Interface. This means that all resources (URLs) can be manipulated using the same four HTTP methods: GET, PUT, POST, and DELETE. For each method, the HTTP specification defines the exact semantics. For instance, a GET should always be a safe operation, meaning that is has no side effects, and a PUT or DELETE should be idempotent, meaning that you can repeat these operations over and over again, but the end result should be the same. While HTTP defines these four methods, HTML only supports two: GET and POST. Fortunately, there are two possible workarounds: you can either use JavaScript to do your PUT or DELETE, or simply do a POST with the *real* method as an additional parameter (modeled as a hidden input field in an HTML form). This latter trick is what Spring's `HiddenHttpMethodFilter` does. This filter is a plain Servlet Filter and therefore it can be used in combination with any web framework (not just Spring MVC). Simply add this filter to your web.xml, and a POST with a hidden _method parameter will be converted into the corresponding HTTP method request.

To support HTTP method conversion the Spring MVC form tag was updated to support setting the HTTP method. For example, the following snippet taken from the updated Petclinic sample

```
<form:form method="delete">
    <p class="submit"><input type="submit" value="Delete Pet"/></p>
</form:form>
```

This will actually perform an HTTP POST, with the *real* DELETE method hidden behind a request parameter, to be picked up by the `HiddenHttpMethodFilter`, as defined in web.xml:

```
<filter>
    <filter-name>httpMethodFilter</filter-name>
    <filter-class>org.springframework.web.filter.HiddenHttpMethodFilter</filter-class>
</filter>

<filter-mapping>
    <filter-name>httpMethodFilter</filter-name>
    <servlet-name>petclinic</servlet-name>
</filter-mapping>
```

The corresponding `@Controller` method is shown below:

```
@RequestMapping(method = RequestMethod.DELETE)
public String deletePet(@PathVariable int ownerId, @PathVariable int petId) {
    this.clinic.deletePet(petId);
    return "redirect:/owners/" + ownerId;
}
```

HTML5 Tags

Starting with Spring 3, the Spring form tag library allows entering dynamic attributes, which means you can enter any HTML5 specific attributes.

In Spring 3.1, the form input tag supports entering a type attribute other than *text*. This is intended to allow rendering new HTML5 specific input types such as *email*, *date*, *range*, and others. Note that entering type=*text* is not required since *text* is the default type.

18.3 Tiles

It is possible to integrate Tiles - just as any other view technology - in web applications using Spring. The following describes in a broad way how to do this.

> **Note**
>
> This section focuses on Spring's support for Tiles v3 in the `org.springframework.web.servlet.view.tiles3` package.

Dependencies

To be able to use Tiles, you have to add a dependency on Tiles version 3.0.1 or higher and its transitive dependencies to your project.

How to integrate Tiles

To be able to use Tiles, you have to configure it using files containing definitions (for basic information on definitions and other Tiles concepts, please have a look at http://tiles.apache.org). In Spring this is done using the `TilesConfigurer`. Have a look at the following piece of example ApplicationContext configuration:

```
<bean id="tilesConfigurer" class="org.springframework.web.servlet.view.tiles3.TilesConfigurer">
    <property name="definitions">
        <list>
            <value>/WEB-INF/defs/general.xml</value>
            <value>/WEB-INF/defs/widgets.xml</value>
            <value>/WEB-INF/defs/administrator.xml</value>
            <value>/WEB-INF/defs/customer.xml</value>
            <value>/WEB-INF/defs/templates.xml</value>
        </list>
    </property>
</bean>
```

As you can see, there are five files containing definitions, which are all located in the `'WEB-INF/defs'` directory. At initialization of the `WebApplicationContext`, the files will be loaded and the definitions factory will be initialized. After that has been done, the Tiles includes in the definition files can be used as views within your Spring web application. To be able to use the views you have to have a `ViewResolver` just as with any other view technology used with Spring. Below you can find two possibilities, the `UrlBasedViewResolver` and the `ResourceBundleViewResolver`.

You can specify locale specific Tiles definitions by adding an underscore and then the locale. For example:

```
<bean id="tilesConfigurer" class="org.springframework.web.servlet.view.tiles3.TilesConfigurer">
    <property name="definitions">
        <list>
            <value>/WEB-INF/defs/tiles.xml</value>
            <value>/WEB-INF/defs/tiles_fr_FR.xml</value>
        </list>
    </property>
</bean>
```

With this configuration, `tiles_fr_FR.xml` will be used for requests with the `fr_FR` locale, and `tiles.xml` will be used by default.

> **Note**
>
> Since underscores are used to indicate locales, it is recommended to avoid using them otherwise in the file names for Tiles definitions.

UrlBasedViewResolver

The `UrlBasedViewResolver` instantiates the given `viewClass` for each view it has to resolve.

```
<bean id="viewResolver" class="org.springframework.web.servlet.view.UrlBasedViewResolver">
    <property name="viewClass" value="org.springframework.web.servlet.view.tiles3.TilesView"/>
</bean>
```

ResourceBundleViewResolver

The `ResourceBundleViewResolver` has to be provided with a property file containing viewnames and viewclasses the resolver can use:

```
<bean id="viewResolver" class="org.springframework.web.servlet.view.ResourceBundleViewResolver">
    <property name="basename" value="views"/>
</bean>
```

```
...
welcomeView.(class)=org.springframework.web.servlet.view.tiles3.TilesView
welcomeView.url=welcome (this is the name of a Tiles definition)

vetsView.(class)=org.springframework.web.servlet.view.tiles3.TilesView
vetsView.url=vetsView (again, this is the name of a Tiles definition)

findOwnersForm.(class)=org.springframework.web.servlet.view.JstlView
findOwnersForm.url=/WEB-INF/jsp/findOwners.jsp
...
```

As you can see, when using the `ResourceBundleViewResolver`, you can easily mix different view technologies.

Note that the `TilesView` class supports JSTL (the JSP Standard Tag Library) out of the box.

SimpleSpringPreparerFactory and SpringBeanPreparerFactory

As an advanced feature, Spring also supports two special Tiles `PreparerFactory` implementations. Check out the Tiles documentation for details on how to use `ViewPreparer` references in your Tiles definition files.

Specify `SimpleSpringPreparerFactory` to autowire ViewPreparer instances based on specified preparer classes, applying Spring's container callbacks as well as applying configured Spring BeanPostProcessors. If Spring's context-wide annotation-config has been activated, annotations in ViewPreparer classes will be automatically detected and applied. Note that this expects preparer *classes* in the Tiles definition files, just like the default `PreparerFactory` does.

Specify `SpringBeanPreparerFactory` to operate on specified preparer *names* instead of classes, obtaining the corresponding Spring bean from the DispatcherServlet's application context. The full bean creation process will be in the control of the Spring application context in this case, allowing for the use of explicit dependency injection configuration, scoped beans etc. Note that you need to define one Spring bean definition per preparer name (as used in your Tiles definitions).

```
<bean id="tilesConfigurer" class="org.springframework.web.servlet.view.tiles3.TilesConfigurer">
    <property name="definitions">
        <list>
            <value>/WEB-INF/defs/general.xml</value>
            <value>/WEB-INF/defs/widgets.xml</value>
            <value>/WEB-INF/defs/administrator.xml</value>
            <value>/WEB-INF/defs/customer.xml</value>
            <value>/WEB-INF/defs/templates.xml</value>
        </list>
    </property>

    <!-- resolving preparer names as Spring bean definition names -->
    <property name="preparerFactoryClass"
            value="org.springframework.web.servlet.view.tiles3.SpringBeanPreparerFactory"/>

</bean>
```

18.4 Velocity & FreeMarker

Velocity and FreeMarker are two templating languages that can be used as view technologies within Spring MVC applications. The languages are quite similar and serve similar needs and so are considered together in this section. For semantic and syntactic differences between the two languages, see the FreeMarker web site.

Dependencies

Your web application will need to include `velocity-1.x.x.jar` or `freemarker-2.x.jar` in order to work with Velocity or FreeMarker respectively and `commons-collections.jar` is required for Velocity. Typically they are included in the `WEB-INF/lib` folder where they are guaranteed to be found by a Java EE server and added to the classpath for your application. It is of course assumed that you already have the `spring-webmvc.jar` in your `'WEB-INF/lib'` directory too! If you make use of Spring's *dateToolAttribute* or *numberToolAttribute* in your Velocity views, you will also need to include the `velocity-tools-generic-1.x.jar`

Context configuration

A suitable configuration is initialized by adding the relevant configurer bean definition to your `'*-servlet.xml'` as shown below:

```
<!--
This bean sets up the Velocity environment for us based on a root path for templates.
Optionally, a properties file can be specified for more control over the Velocity
environment, but the defaults are pretty sane for file based template loading.
-->
<bean id="velocityConfig" class="org.springframework.web.servlet.view.velocity.VelocityConfigurer">
    <property name="resourceLoaderPath" value="/WEB-INF/velocity/"/>
</bean>

<!--
View resolvers can also be configured with ResourceBundles or XML files. If you need
different view resolving based on Locale, you have to use the resource bundle resolver.
-->
<bean id="viewResolver" class="org.springframework.web.servlet.view.velocity.VelocityViewResolver">
    <property name="cache" value="true"/>
    <property name="prefix" value=""/>
    <property name="suffix" value=".vm"/>
</bean>
```

```
<!-- freemarker config -->
<bean id="freemarkerConfig" class="org.springframework.web.servlet.view.freemarker.FreeMarkerConfigurer">
    <property name="templateLoaderPath" value="/WEB-INF/freemarker/"/>
</bean>

<!--
View resolvers can also be configured with ResourceBundles or XML files. If you need
different view resolving based on Locale, you have to use the resource bundle resolver.
-->
<bean id="viewResolver" class="org.springframework.web.servlet.view.freemarker.FreeMarkerViewResolver">
    <property name="cache" value="true"/>
    <property name="prefix" value=""/>
    <property name="suffix" value=".ftl"/>
</bean>
```

> **Note**
>
> For non web-apps add a `VelocityConfigurationFactoryBean` or a `FreeMarkerConfigurationFactoryBean` to your application context definition file.

Creating templates

Your templates need to be stored in the directory specified by the `*Configurer` bean shown above. This document does not cover details of creating templates for the two languages - please see their relevant websites for information. If you use the view resolvers highlighted, then the logical view names relate to the template file names in similar fashion to `InternalResourceViewResolver` for

JSP's. So if your controller returns a ModelAndView object containing a view name of "welcome" then the resolvers will look for the `/WEB-INF/freemarker/welcome.ftl` or `/WEB-INF/velocity/welcome.vm` template as appropriate.

Advanced configuration

The basic configurations highlighted above will be suitable for most application requirements, however additional configuration options are available for when unusual or advanced requirements dictate.

velocity.properties

This file is completely optional, but if specified, contains the values that are passed to the Velocity runtime in order to configure velocity itself. Only required for advanced configurations, if you need this file, specify its location on the `VelocityConfigurer` bean definition above.

```
<bean id="velocityConfig" class="org.springframework.web.servlet.view.velocity.VelocityConfigurer">
    <property name="configLocation" value="/WEB-INF/velocity.properties"/>
</bean>
```

Alternatively, you can specify velocity properties directly in the bean definition for the Velocity config bean by replacing the "configLocation" property with the following inline properties.

```
<bean id="velocityConfig" class="org.springframework.web.servlet.view.velocity.VelocityConfigurer">
    <property name="velocityProperties">
        <props>
            <prop key="resource.loader">file</prop>
            <prop key="file.resource.loader.class">
                org.apache.velocity.runtime.resource.loader.FileResourceLoader
            </prop>
            <prop key="file.resource.loader.path">${webapp.root}/WEB-INF/velocity</prop>
            <prop key="file.resource.loader.cache">false</prop>
        </props>
    </property>
</bean>
```

Refer to the API documentation for Spring configuration of Velocity, or the Velocity documentation for examples and definitions of the `'velocity.properties'` file itself.

FreeMarker

FreeMarker *Settings* and *SharedVariables* can be passed directly to the FreeMarker `Configuration` object managed by Spring by setting the appropriate bean properties on the `FreeMarkerConfigurer` bean. The `freemarkerSettings` property requires a `java.util.Properties` object and the `freemarkerVariables` property requires a `java.util.Map`.

```
<bean id="freemarkerConfig" class="org.springframework.web.servlet.view.freemarker.FreeMarkerConfigurer">
    <property name="templateLoaderPath" value="/WEB-INF/freemarker/"/>
    <property name="freemarkerVariables">
        <map>
            <entry key="xml_escape" value-ref="fmXmlEscape"/>
        </map>
    </property>
</bean>

<bean id="fmXmlEscape" class="freemarker.template.utility.XmlEscape"/>
```

See the FreeMarker documentation for details of settings and variables as they apply to the `Configuration` object.

Bind support and form handling

Spring provides a tag library for use in JSP's that contains (amongst other things) a `<spring:bind/>` tag. This tag primarily enables forms to display values from form backing objects and to show the results of failed validations from a `Validator` in the web or business tier. From version 1.1, Spring now has support for the same functionality in both Velocity and FreeMarker, with additional convenience macros for generating form input elements themselves.

The bind macros

A standard set of macros are maintained within the `spring-webmvc.jar` file for both languages, so they are always available to a suitably configured application.

Some of the macros defined in the Spring libraries are considered internal (private) but no such scoping exists in the macro definitions making all macros visible to calling code and user templates. The following sections concentrate only on the macros you need to be directly calling from within your templates. If you wish to view the macro code directly, the files are called spring.vm / spring.ftl and are in the packages `org.springframework.web.servlet.view.velocity` or `org.springframework.web.servlet.view.freemarker` respectively.

Simple binding

In your html forms (vm / ftl templates) that act as the *formView* for a Spring form controller, you can use code similar to the following to bind to field values and display error messages for each input field in similar fashion to the JSP equivalent. Note that the name of the command object is "command" by default, but can be overridden in your MVC configuration by setting the *commandName* bean property on your form controller. Example code is shown below for the `personFormV` and `personFormF` views configured earlier;

```
<!-- velocity macros are automatically available -->
<html>
    ...
    <form action="" method="POST">
        Name:
        #springBind( "command.name" )
        <input type="text"
            name="${status.expression}"
            value="$!status.value" /><br>
        #foreach($error in $status.errorMessages) <b>$error</b> <br> #end
        <br>
        ...
        <input type="submit" value="submit"/>
    </form>
    ...
</html>
```

```
<!-- freemarker macros have to be imported into a namespace. We strongly
recommend sticking to spring -->
<#import "/spring.ftl" as spring />
<html>
    ...
    <form action="" method="POST">
        Name:
        <@spring.bind "command.name" />
        <input type="text"
            name="${spring.status.expression}"
            value="${spring.status.value?default("")}" /><br>
        <#list spring.status.errorMessages as error> <b>${error}</b> <br> </#list>
        <br>
        ...
        <input type="submit" value="submit"/>
    </form>
    ...
</html>
```

`#springBind` / `<@spring.bind>` requires a *path* argument which consists of the name of your command object (it will be *command* unless you changed it in your FormController properties) followed by a period and the name of the field on the command object you wish to bind to. Nested fields can be used too such as "command.address.street". The `bind` macro assumes the default HTML escaping behavior specified by the ServletContext parameter `defaultHtmlEscape` in web.xml

The optional form of the macro called `#springBindEscaped` / `<@spring.bindEscaped>` takes a second argument and explicitly specifies whether HTML escaping should be used in the status error messages or values. Set to true or false as required. Additional form handling macros simplify the use of HTML escaping and these macros should be used wherever possible. They are explained in the next section.

Form input generation macros

Additional convenience macros for both languages simplify both binding and form generation (including validation error display). It is never necessary to use these macros to generate form input fields, and they can be mixed and matched with simple HTML or calls direct to the spring bind macros highlighted previously.

The following table of available macros show the VTL and FTL definitions and the parameter list that each takes.

Table 18.1. Table of macro definitions

macro	VTL definition	FTL definition
message (output a string from a resource bundle based on the code parameter)	#springMessage($code)	<@spring.message code/>
messageText (output a string from a resource bundle based on the code parameter, falling back to the value of the default parameter)	#springMessageText($code $text)	<@spring.messageText code, text/>
url (prefix a relative URL with the application's context root)	#springUrl($relativeUrl)	<@spring.url relativeUrl/>
formInput (standard input field for gathering user input)	#springFormInput($path $attributes)	<@spring.formInput path, attributes, fieldType/>

macro	VTL definition	FTL definition
formHiddenInput * (hidden input field for submitting non-user input)	#springFormHiddenInput($path $attributes)	<@spring.formHiddenInput path, attributes/>
formPasswordInput * (standard input field for gathering passwords. Note that no value will ever be populated in fields of this type)	#springFormPasswordInput($path $attributes)	<@spring.formPasswordInput path, attributes/>
formTextarea (large text field for gathering long, freeform text input)	#springFormTextarea($path $attributes)	<@spring.formTextarea path, attributes/>
formSingleSelect (drop down box of options allowing a single required value to be selected)	#springFormSingleSelect($path $options $attributes)	<@spring.formSingleSelect path, options, attributes/>
formMultiSelect (a list box of options allowing the user to select 0 or more values)	#springFormMultiSelect($path $options $attributes)	<@spring.formMultiSelect path, options, attributes/>
formRadioButtons (a set of radio buttons allowing a single selection to be made from the available choices)	#springFormRadioButtons($path $options $separator $attributes)	<@spring.formRadioButtons path, options separator, attributes/>
formCheckboxes (a set of checkboxes allowing 0 or more values to be selected)	#springFormCheckboxes($path $options $separator $attributes)	<@spring.formCheckboxes path, options, separator, attributes/>
formCheckbox (a single checkbox)	#springFormCheckbox($path $attributes)	<@spring.formCheckbox path, attributes/>
showErrors (simplify display of validation errors for the bound field)	#springShowErrors($separator $classOrStyle)	<@spring.showErrors separator, classOrStyle/>

- In FTL (FreeMarker), these two macros are not actually required as you can use the normal `formInput` macro, specifying '`hidden`' or '`password`' as the value for the `fieldType` parameter.

The parameters to any of the above macros have consistent meanings:

- path: the name of the field to bind to (ie "command.name")
- options: a Map of all the available values that can be selected from in the input field. The keys to the map represent the values that will be POSTed back from the form and bound to the command object. Map objects stored against the keys are the labels displayed on the form to the user and may be different from the corresponding values posted back by the form. Usually such a map is supplied as reference data by the controller. Any Map implementation can be used depending on required behavior. For strictly sorted maps, a `SortedMap` such as a `TreeMap` with a suitable Comparator may be used and for arbitrary Maps that should return values in insertion order, use a `LinkedHashMap` or a `LinkedMap` from commons-collections.
- separator: where multiple options are available as discreet elements (radio buttons or checkboxes), the sequence of characters used to separate each one in the list (ie "
").

- attributes: an additional string of arbitrary tags or text to be included within the HTML tag itself. This string is echoed literally by the macro. For example, in a textarea field you may supply attributes as *rows="5" cols="60"* or you could pass style information such as *style="border:1px solid silver"*.
- classOrStyle: for the showErrors macro, the name of the CSS class that the span tag wrapping each error will use. If no information is supplied (or the value is empty) then the errors will be wrapped in tags.

Examples of the macros are outlined below some in FTL and some in VTL. Where usage differences exist between the two languages, they are explained in the notes.

Input Fields

```
<!-- the Name field example from above using form macros in VTL -->
...
Name:
#springFormInput("command.name" "")<br>
#springShowErrors("<br>" "")<br>
```

The formInput macro takes the path parameter (command.name) and an additional attributes parameter which is empty in the example above. The macro, along with all other form generation macros, performs an implicit spring bind on the path parameter. The binding remains valid until a new bind occurs so the showErrors macro doesn't need to pass the path parameter again - it simply operates on whichever field a bind was last created for.

The showErrors macro takes a separator parameter (the characters that will be used to separate multiple errors on a given field) and also accepts a second parameter, this time a class name or style attribute. Note that FreeMarker is able to specify default values for the attributes parameter, unlike Velocity, and the two macro calls above could be expressed as follows in FTL:

```
<@spring.formInput "command.name"/>
<@spring.showErrors "<br>"/>
```

Output is shown below of the form fragment generating the name field, and displaying a validation error after the form was submitted with no value in the field. Validation occurs through Spring's Validation framework.

The generated HTML looks like this:

```
Name:
<input type="text" name="name" value="">
<br>
    <b>required</b>
<br>
<br>
```

The formTextarea macro works the same way as the formInput macro and accepts the same parameter list. Commonly, the second parameter (attributes) will be used to pass style information or rows and cols attributes for the textarea.

Selection Fields

Four selection field macros can be used to generate common UI value selection inputs in your HTML forms.

- formSingleSelect
- formMultiSelect

- formRadioButtons
- formCheckboxes

Each of the four macros accepts a Map of options containing the value for the form field, and the label corresponding to that value. The value and the label can be the same.

An example of radio buttons in FTL is below. The form backing object specifies a default value of *London* for this field and so no validation is necessary. When the form is rendered, the entire list of cities to choose from is supplied as reference data in the model under the name *cityMap*.

```
...
Town:
<@spring.formRadioButtons "command.address.town", cityMap, "" /><br><br>
```

This renders a line of radio buttons, one for each value in `cityMap` using the separator "". No additional attributes are supplied (the last parameter to the macro is missing). The cityMap uses the same String for each key-value pair in the map. The map's keys are what the form actually submits as POSTed request parameters, map values are the labels that the user sees. In the example above, given a list of three well known cities and a default value in the form backing object, the HTML would be

```
Town:
<input type="radio" name="address.town" value="London">London</input>
<input type="radio" name="address.town" value="Paris" checked="checked">Paris</input>
<input type="radio" name="address.town" value="New York">New York</input>
```

If your application expects to handle cities by internal codes for example, the map of codes would be created with suitable keys like the example below.

```
protected Map referenceData(HttpServletRequest request) throws Exception {
    Map cityMap = new LinkedHashMap();
    cityMap.put("LDN", "London");
    cityMap.put("PRS", "Paris");
    cityMap.put("NYC", "New York");

    Map m = new HashMap();
    m.put("cityMap", cityMap);
    return m;
}
```

The code would now produce output where the radio values are the relevant codes but the user still sees the more user friendly city names.

```
Town:
<input type="radio" name="address.town" value="LDN">London</input>
<input type="radio" name="address.town" value="PRS" checked="checked">Paris</input>
<input type="radio" name="address.town" value="NYC">New York</input>
```

HTML escaping and XHTML compliance

Default usage of the form macros above will result in HTML tags that are HTML 4.01 compliant and that use the default value for HTML escaping defined in your web.xml as used by Spring's bind support. In order to make the tags XHTML compliant or to override the default HTML escaping value, you can specify two variables in your template (or in your model where they will be visible to your templates). The advantage of specifying them in the templates is that they can be changed to different values later in the template processing to provide different behavior for different fields in your form.

To switch to XHTML compliance for your tags, specify a value of *true* for a model/context variable named xhtmlCompliant:

```
# for Velocity..
#set($springXhtmlCompliant = true)

<-- for FreeMarker -->
<#assign xhtmlCompliant = true in spring>
```

Any tags generated by the Spring macros will now be XHTML compliant after processing this directive.

In similar fashion, HTML escaping can be specified per field:

```
<#-- until this point, default HTML escaping is used -->

<#assign htmlEscape = true in spring>
<#-- next field will use HTML escaping -->
<@spring.formInput "command.name" />

<#assign htmlEscape = false in spring>
<#-- all future fields will be bound with HTML escaping off -->
```

18.5 XSLT

XSLT is a transformation language for XML and is popular as a view technology within web applications. XSLT can be a good choice as a view technology if your application naturally deals with XML, or if your model can easily be converted to XML. The following section shows how to produce an XML document as model data and have it transformed with XSLT in a Spring Web MVC application.

My First Words

This example is a trivial Spring application that creates a list of words in the `Controller` and adds them to the model map. The map is returned along with the view name of our XSLT view. See Section 17.3, “Implementing Controllers” for details of Spring Web MVC’s `Controller` interface. The XSLT view will turn the list of words into a simple XML document ready for transformation.

Bean definitions

Configuration is standard for a simple Spring application. The dispatcher servlet config file contains a reference to a `ViewResolver`, URL mappings and a single controller bean…

```
<bean id="homeController"class="xslt.HomeController"/>
```

i. that encapsulates our word generation logic.

Standard MVC controller code

The controller logic is encapsulated in a subclass of `AbstractController`, with the handler method being defined like so…

```
protected ModelAndView handleRequestInternal(HttpServletRequest request,
        HttpServletResponse response) throws Exception {

    Map map = new HashMap();
    List wordList = new ArrayList();

    wordList.add("hello");
    wordList.add("world");

    map.put("wordList", wordList);

    return new ModelAndView("home", map);
}
```

So far we've done nothing that's XSLT specific. The model data has been created in the same way as you would for any other Spring MVC application. Depending on the configuration of the application now, that list of words could be rendered by JSP/JSTL by having them added as request attributes, or they could be handled by Velocity by adding the object to the `VelocityContext`. In order to have XSLT render them, they of course have to be converted into an XML document somehow. There are software packages available that will automatically *domify* an object graph, but within Spring, you have complete flexibility to create the DOM from your model in any way you choose. This prevents the transformation of XML playing too great a part in the structure of your model data which is a danger when using tools to manage the domification process.

Convert the model data to XML

In order to create a DOM document from our list of words or any other model data, we must subclass the (provided) `org.springframework.web.servlet.view.xslt.AbstractXsltView` class. In doing so, we must also typically implement the abstract method `createXsltSource(..)` method. The first parameter passed to this method is our model map. Here's the complete listing of the `HomePage` class in our trivial word application:

```
package xslt;

// imports omitted for brevity

public class HomePage extends AbstractXsltView {

    protected Source createXsltSource(Map model, String rootName,
            HttpServletRequest request, HttpServletResponse response) throws Exception {

        Document document = DocumentBuilderFactory.newInstance().newDocumentBuilder().newDocument();
        Element root = document.createElement(rootName);

        List words = (List) model.get("wordList");
        for (Iterator it = words.iterator(); it.hasNext();) {
            String nextWord = (String) it.next();
            Element wordNode = document.createElement("word");
            Text textNode = document.createTextNode(nextWord);
            wordNode.appendChild(textNode);
            root.appendChild(wordNode);
        }
        return new DOMSource(root);
    }

}
```

A series of parameter name/value pairs can optionally be defined by your subclass which will be added to the transformation object. The parameter names must match those defined in your XSLT template declared with `<xsl:param name="myParam">defaultValue</xsl:param>`. To specify the parameters, override the `getParameters()` method of the `AbstractXsltView` class and return a `Map` of the name/value pairs. If your parameters need to derive information from the current request, you can override the `getParameters(HttpServletRequest request)` method instead.

Defining the view properties

The views.properties file (or equivalent xml definition if you're using an XML based view resolver as we did in the Velocity examples above) looks like this for the one-view application that is *My First Words*:

```
home.(class)=xslt.HomePage
home.stylesheetLocation=/WEB-INF/xsl/home.xslt
home.root=words
```

Here, you can see how the view is tied in with the `HomePage` class just written which handles the model domification in the first property `'.(class)'`. The `'stylesheetLocation'` property points to the XSLT file which will handle the XML transformation into HTML for us and the final property `'.root'` is the name that will be used as the root of the XML document. This gets passed to the `HomePage` class above in the second parameter to the `createXsltSource(..)` method(s).

Document transformation

Finally, we have the XSLT code used for transforming the above document. As shown in the above `'views.properties'` file, the stylesheet is called `'home.xslt'` and it lives in the war file in the `'WEB-INF/xsl'` directory.

```
<?xml version="1.0" encoding="utf-8"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">

    <xsl:output method="html" omit-xml-declaration="yes"/>

    <xsl:template match="/">
        <html>
            <head><title>Hello!</title></head>
            <body>
                <h1>My First Words</h1>
                <xsl:apply-templates/>
            </body>
        </html>
    </xsl:template>

    <xsl:template match="word">
        <xsl:value-of select="."/><br/>
    </xsl:template>

</xsl:stylesheet>
```

Summary

A summary of the files discussed and their location in the WAR file is shown in the simplified WAR structure below.

```
ProjectRoot
  |
  +- WebContent
      |
      +- WEB-INF
          |
          +- classes
          |    |
          |    +- xslt
          |    |   |
          |    |   +- HomePageController.class
          |    |   +- HomePage.class
          |    |
          |    +- views.properties
          |
          +- lib
          |   |
          |   +- spring-*.jar
          |
          +- xsl
          |   |
          |   +- home.xslt
          |
          +- frontcontroller-servlet.xml
```

You will also need to ensure that an XML parser and an XSLT engine are available on the classpath. JDK 1.4 provides them by default, and most Java EE containers will also make them available by default, but it's a possible source of errors to be aware of.

18.6 Document views (PDF/Excel)

Introduction

Returning an HTML page isn't always the best way for the user to view the model output, and Spring makes it simple to generate a PDF document or an Excel spreadsheet dynamically from the model data. The document is the view and will be streamed from the server with the correct content type to (hopefully) enable the client PC to run their spreadsheet or PDF viewer application in response.

In order to use Excel views, you need to add the *poi* library to your classpath, and for PDF generation, the iText library.

Configuration and setup

Document based views are handled in an almost identical fashion to XSLT views, and the following sections build upon the previous one by demonstrating how the same controller used in the XSLT example is invoked to render the same model as both a PDF document and an Excel spreadsheet (which can also be viewed or manipulated in Open Office).

Document view definitions

First, let's amend the views.properties file (or xml equivalent) and add a simple view definition for both document types. The entire file now looks like this with the XSLT view shown from earlier:

```
home.(class)=xslt.HomePage
home.stylesheetLocation=/WEB-INF/xsl/home.xslt
home.root=words

xl.(class)=excel.HomePage

pdf.(class)=pdf.HomePage
```

If you want to start with a template spreadsheet or a fillable PDF form to add your model data to, specify the location as the url *property in the view definition*

Controller code

The controller code we'll use remains exactly the same from the XSLT example earlier other than to change the name of the view to use. Of course, you could be clever and have this selected based on a URL parameter or some other logic - proof that Spring really is very good at decoupling the views from the controllers!

Subclassing for Excel views

Exactly as we did for the XSLT example, we'll subclass suitable abstract classes in order to implement custom behavior in generating our output documents. For Excel, this involves writing a subclass of `org.springframework.web.servlet.view.document.AbstractExcelView` (for Excel files generated by POI) or `org.springframework.web.servlet.view.document.AbstractJExcelView` (for JExcelApi-generated Excel files) and implementing the `buildExcelDocument()` method.

Here's the complete listing for our POI Excel view which displays the word list from the model map in consecutive rows of the first column of a new spreadsheet:

```
package excel;

// imports omitted for brevity

public class HomePage extends AbstractExcelView {

    protected void buildExcelDocument(Map model, HSSFWorkbook wb, HttpServletRequest req,
            HttpServletResponse resp) throws Exception {

        HSSFSheet sheet;
        HSSFRow sheetRow;
        HSSFCell cell;

        // Go to the first sheet
        // getSheetAt: only if wb is created from an existing document
        // sheet = wb.getSheetAt(0);
        sheet = wb.createSheet("Spring");
        sheet.setDefaultColumnWidth((short) 12);

        // write a text at A1
        cell = getCell(sheet, 0, 0);
        setText(cell, "Spring-Excel test");

        List words = (List) model.get("wordList");
        for (int i=0; i < words.size(); i++) {
            cell = getCell(sheet, 2+i, 0);
            setText(cell, (String) words.get(i));
        }
    }

}
```

And the following is a view generating the same Excel file, now using JExcelApi:

```
package excel;

// imports omitted for brevity

public class HomePage extends AbstractJExcelView {

    protected void buildExcelDocument(Map model, WritableWorkbook wb,
            HttpServletRequest request, HttpServletResponse response) throws Exception {

        WritableSheet sheet = wb.createSheet("Spring", 0);

        sheet.addCell(new Label(0, 0, "Spring-Excel test"));

        List words = (List) model.get("wordList");
        for (int i = 0; i < words.size(); i++) {
            sheet.addCell(new Label(2+i, 0, (String) words.get(i)));
        }
    }
}
```

Note the differences between the APIs. We've found that the JExcelApi is somewhat more intuitive, and furthermore, JExcelApi has slightly better image-handling capabilities. There have been memory problems with large Excel files when using JExcelApi however.

If you now amend the controller such that it returns `xl` as the name of the view (`return new ModelAndView("xl", map);`) and run your application again, you should find that the Excel spreadsheet is created and downloaded automatically when you request the same page as before.

Subclassing for PDF views

The PDF version of the word list is even simpler. This time, the class extends `org.springframework.web.servlet.view.document.AbstractPdfView` and implements the `buildPdfDocument()` method as follows:

```
package pdf;

// imports omitted for brevity

public class PDFPage extends AbstractPdfView {

    protected void buildPdfDocument(Map model, Document doc, PdfWriter writer,
        HttpServletRequest req, HttpServletResponse resp) throws Exception {
        List words = (List) model.get("wordList");
        for (int i=0; i<words.size(); i++) {
            doc.add( new Paragraph((String) words.get(i)));
        }
    }

}
```

Once again, amend the controller to return the `pdf` view with `return new ModelAndView("pdf", map);`, and reload the URL in your application. This time a PDF document should appear listing each of the words in the model map.

18.7 JasperReports

JasperReports (http://jasperreports.sourceforge.net) is a powerful open-source reporting engine that supports the creation of report designs using an easily understood XML file format. JasperReports is capable of rendering reports in four different formats: CSV, Excel, HTML and PDF.

Dependencies

Your application will need to include the latest release of JasperReports, which at the time of writing was 0.6.1. JasperReports itself depends on the following projects:

- BeanShell
- Commons BeanUtils
- Commons Collections
- Commons Digester
- Commons Logging
- iText
- POI

JasperReports also requires a JAXP compliant XML parser.

Configuration

To configure JasperReports views in your Spring container configuration you need to define a `ViewResolver` to map view names to the appropriate view class depending on which format you want your report rendered in.

Configuring the ViewResolver

Typically, you will use the `ResourceBundleViewResolver` to map view names to view classes and files in a properties file.

```
<bean id="viewResolver" class="org.springframework.web.servlet.view.ResourceBundleViewResolver">
    <property name="basename" value="views"/>
</bean>
```

Here we've configured an instance of the `ResourceBundleViewResolver` class that will look for view mappings in the resource bundle with base name `views`. (The content of this file is described in the next section.)

Configuring the Views

The Spring Framework contains five different `View` implementations for JasperReports, four of which correspond to one of the four output formats supported by JasperReports, and one that allows for the format to be determined at runtime:

Table 18.2. JasperReports View classes

Class Name	Render Format
`JasperReportsCsvView`	CSV
`JasperReportsHtmlView`	HTML
`JasperReportsPdfView`	PDF
`JasperReportsXlsView`	Microsoft Excel
`JasperReportsMultiFormatView`	The view is decided upon at runtime

Mapping one of these classes to a view name and a report file is a matter of adding the appropriate entries in the resource bundle configured in the previous section as shown here:

```
simpleReport.(class)=org.springframework.web.servlet.view.jasperreports.JasperReportsPdfView
simpleReport.url=/WEB-INF/reports/DataSourceReport.jasper
```

Here you can see that the view with name `simpleReport` is mapped to the `JasperReportsPdfView` class, causing the output of this report to be rendered in PDF format. The `url` property of the view is set to the location of the underlying report file.

About Report Files

JasperReports has two distinct types of report file: the design file, which has a `.jrxml` extension, and the compiled report file, which has a `.jasper` extension. Typically, you use the JasperReports Ant task to compile your `.jrxml` design file into a `.jasper` file before deploying it into your application. With the Spring Framework you can map either of these files to your report file and the framework will take care of compiling the `.jrxml` file on the fly for you. You should note that after a `.jrxml` file is compiled by the Spring Framework, the compiled report is cached for the lifetime of the application. Thus, to make changes to the file you will need to restart your application.

Using JasperReportsMultiFormatView

The `JasperReportsMultiFormatView` allows for the report format to be specified at runtime. The actual rendering of the report is delegated to one of the other JasperReports view classes - the

`JasperReportsMultiFormatView` class simply adds a wrapper layer that allows for the exact implementation to be specified at runtime.

The `JasperReportsMultiFormatView` class introduces two concepts: the format key and the discriminator key. The `JasperReportsMultiFormatView` class uses the mapping key to look up the actual view implementation class, and it uses the format key to lookup up the mapping key. From a coding perspective you add an entry to your model with the format key as the key and the mapping key as the value, for example:

```
public ModelAndView handleSimpleReportMulti(HttpServletRequest request,
HttpServletResponse response) throws Exception {

    String uri = request.getRequestURI();
    String format = uri.substring(uri.lastIndexOf(".") + 1);

    Map model = getModel();
    model.put("format", format);

    return new ModelAndView("simpleReportMulti", model);

}
```

In this example, the mapping key is determined from the extension of the request URI and is added to the model under the default format key: `format`. If you wish to use a different format key then you can configure this using the `formatKey` property of the `JasperReportsMultiFormatView` class.

By default the following mapping key mappings are configured in `JasperReportsMultiFormatView`:

Table 18.3. JasperReportsMultiFormatView Default Mapping Key Mappings

Mapping Key	View Class
csv	`JasperReportsCsvView`
html	`JasperReportsHtmlView`
pdf	`JasperReportsPdfView`
xls	`JasperReportsXlsView`

So in the example above a request to URI /foo/myReport.pdf would be mapped to the `JasperReportsPdfView` class. You can override the mapping key to view class mappings using the `formatMappings` property of `JasperReportsMultiFormatView`.

Populating the ModelAndView

In order to render your report correctly in the format you have chosen, you must supply Spring with all of the data needed to populate your report. For JasperReports this means you must pass in all report parameters along with the report datasource. Report parameters are simple name/value pairs and can be added to the `Map` for your model as you would add any name/value pair.

When adding the datasource to the model you have two approaches to choose from. The first approach is to add an instance of `JRDataSource` or a `Collection` type to the model `Map` under any arbitrary key. Spring will then locate this object in the model and treat it as the report datasource. For example, you may populate your model like so:

```
private Map getModel() {
    Map model = new HashMap();
    Collection beanData = getBeanData();
    model.put("myBeanData", beanData);
    return model;
}
```

The second approach is to add the instance of `JRDataSource` or `Collection` under a specific key and then configure this key using the `reportDataKey` property of the view class. In both cases Spring will wrap instances of `Collection` in a `JRBeanCollectionDataSource` instance. For example:

```
private Map getModel() {
    Map model = new HashMap();
    Collection beanData = getBeanData();
    Collection someData = getSomeData();
    model.put("myBeanData", beanData);
    model.put("someData", someData);
    return model;
}
```

Here you can see that two `Collection` instances are being added to the model. To ensure that the correct one is used, we simply modify our view configuration as appropriate:

```
simpleReport.(class)=org.springframework.web.servlet.view.jasperreports.JasperReportsPdfView
simpleReport.url=/WEB-INF/reports/DataSourceReport.jasper
simpleReport.reportDataKey=myBeanData
```

Be aware that when using the first approach, Spring will use the first instance of `JRDataSource` or `Collection` that it encounters. If you need to place multiple instances of `JRDataSource` or `Collection` into the model you need to use the second approach.

Working with Sub-Reports

JasperReports provides support for embedded sub-reports within your master report files. There are a wide variety of mechanisms for including sub-reports in your report files. The easiest way is to hard code the report path and the SQL query for the sub report into your design files. The drawback of this approach is obvious: the values are hard-coded into your report files reducing reusability and making it harder to modify and update report designs. To overcome this you can configure sub-reports declaratively, and you can include additional data for these sub-reports directly from your controllers.

Configuring Sub-Report Files

To control which sub-report files are included in a master report using Spring, your report file must be configured to accept sub-reports from an external source. To do this you declare a parameter in your report file like so:

```
<parameter name="ProductsSubReport" class="net.sf.jasperreports.engine.JasperReport"/>
```

Then, you define your sub-report to use this sub-report parameter:

```
<subreport>
    <reportElement isPrintRepeatedValues="false" x="5" y="25" width="325"
        height="20" isRemoveLineWhenBlank="true" backcolor="#ffcc99"/>
    <subreportParameter name="City">
        <subreportParameterExpression><![CDATA[$F{city}]]></subreportParameterExpression>
    </subreportParameter>
    <dataSourceExpression><![CDATA[$P{SubReportData}]]></dataSourceExpression>
    <subreportExpression class="net.sf.jasperreports.engine.JasperReport">
        <![CDATA[$P{ProductsSubReport}]]></subreportExpression>
</subreport>
```

This defines a master report file that expects the sub-report to be passed in as an instance of `net.sf.jasperreports.engine.JasperReports` under the parameter `ProductsSubReport`. When configuring your Jasper view class, you can instruct Spring to load a report file and pass it into the JasperReports engine as a sub-report using the `subReportUrls` property:

```
<property name="subReportUrls">
    <map>
        <entry key="ProductsSubReport" value="/WEB-INF/reports/subReportChild.jrxml"/>
    </map>
</property>
```

Here, the key of the `Map` corresponds to the name of the sub-report parameter in the report design file, and the entry is the URL of the report file. Spring will load this report file, compiling it if necessary, and pass it into the JasperReports engine under the given key.

Configuring Sub-Report Data Sources

This step is entirely optional when using Spring to configure your sub-reports. If you wish, you can still configure the data source for your sub-reports using static queries. However, if you want Spring to convert data returned in your `ModelAndView` into instances of `JRDataSource` then you need to specify which of the parameters in your `ModelAndView` Spring should convert. To do this, configure the list of parameter names using the `subReportDataKeys` property of your chosen view class:

```
<property name="subReportDataKeys" value="SubReportData"/>
```

Here, the key you supply *must* correspond to both the key used in your `ModelAndView` and the key used in your report design file.

Configuring Exporter Parameters

If you have special requirements for exporter configuration — perhaps you want a specific page size for your PDF report — you can configure these exporter parameters declaratively in your Spring configuration file using the `exporterParameters` property of the view class. The `exporterParameters` property is typed as a `Map`. In your configuration the key of an entry should be the fully-qualified name of a static field that contains the exporter parameter definition, and the value of an entry should be the value you want to assign to the parameter. An example of this is shown below:

```
<bean id="htmlReport" class="org.springframework.web.servlet.view.jasperreports.JasperReportsHtmlView">
    <property name="url" value="/WEB-INF/reports/simpleReport.jrxml"/>
    <property name="exporterParameters">
        <map>
            <entry key="net.sf.jasperreports.engine.export.JRHtmlExporterParameter.HTML_FOOTER">
                <value>Footer by Spring!
                    &lt;/td&gt;&lt;td width="50%"&gt;&amp;nbsp; &lt;/td&gt;&lt;/tr&gt;
                    &lt;/table&gt;&lt;/body&gt;&lt;/html&gt;
                </value>
            </entry>
        </map>
    </property>
</bean>
```

Here you can see that the `JasperReportsHtmlView` is configured with an exporter parameter for `net.sf.jasperreports.engine.export.JRHtmlExporterParameter.HTML_FOOTER` which will output a footer in the resulting HTML.

18.8 Feed Views

Both `AbstractAtomFeedView` and `AbstractRssFeedView` inherit from the base class `AbstractFeedView` and are used to provide Atom and RSS Feed views respectfully. They are based on java.net's ROME project and are located in the package `org.springframework.web.servlet.view.feed`.

`AbstractAtomFeedView` requires you to implement the `buildFeedEntries()` method and optionally override the `buildFeedMetadata()` method (the default implementation is empty), as shown below.

```
public class SampleContentAtomView extends AbstractAtomFeedView {

    @Override
    protected void buildFeedMetadata(Map<String, Object> model,
            Feed feed, HttpServletRequest request) {
        // implementation omitted
    }

    @Override
    protected List<Entry> buildFeedEntries(Map<String, Object> model,
            HttpServletRequest request, HttpServletResponse response) throws Exception {
        // implementation omitted
    }

}
```

Similar requirements apply for implementing `AbstractRssFeedView`, as shown below.

```
public class SampleContentAtomView extends AbstractRssFeedView {

    @Override
    protected void buildFeedMetadata(Map<String, Object> model,
            Channel feed, HttpServletRequest request) {
        // implementation omitted
    }

    @Override
    protected List<Item> buildFeedItems(Map<String, Object> model,
            HttpServletRequest request, HttpServletResponse response) throws Exception {
        // implementation omitted
    }

}
```

The `buildFeedItems()` and `buildFeedEntires()` methods pass in the HTTP request in case you need to access the Locale. The HTTP response is passed in only for the setting of cookies or other HTTP headers. The feed will automatically be written to the response object after the method returns.

For an example of creating an Atom view please refer to Alef Arendsen's Spring Team Blog entry.

18.9 XML Marshalling View

The `MarshallingView` uses an XML `Marshaller` defined in the `org.springframework.oxm` package to render the response content as XML. The object to be marshalled can be set explicitly using `MarhsallingView`'s `modelKey` bean property. Alternatively, the view will iterate over all model properties and marshal the first type that is supported by the `Marshaller`. For more information on the functionality in the `org.springframework.oxm` package refer to the chapter Marshalling XML using O/X Mappers.

18.10 JSON Mapping View

The `MappingJackson2JsonView` uses the Jackson library's `ObjectMapper` to render the response content as JSON. By default, the entire contents of the model map (with the exception of framework-specific classes) will be encoded as JSON. For cases where the contents of the map need to be filtered, users may specify a specific set of model attributes to encode via the `RenderedAttributes` property. The `extractValueFromSingleKeyModel` property may also be used to have the value in single-key models extracted and serialized directly rather than as a map of model attributes.

JSON mapping can be customized as needed through the use of Jackson's provided annotations. When further control is needed, a custom `ObjectMapper` can be injected through the `ObjectMapper` property for cases where custom JSON serializers/deserializers need to be provided for specific types.

JSONP is supported and automatically enabled when the request has a query parameter named `jsonp` or `callback`. The JSONP query parameter name(s) could be customized through the `jsonpParameterNames` property.

18.11 XML Mapping View

The `MappingJackson2XmlView` uses the Jackson XML extension's `XmlMapper` to render the response content as XML. If the model contains multiples entries, the object to be serialized should be set explicitly using `MappingJackson2XmlView`'s `modelKey` bean property. If the model contains a single entry, it will be serialized automatically.

XML mapping can be customized as needed through the use of JAXB or Jackson's provided annotations. When further control is needed, a custom `XmlMapper` can be injected through the `ObjectMapper` property for cases where custom XML serializers/deserializers need to be provided for specific types.

19. Integrating with other web frameworks

19.1 Introduction

Spring Web Flow

Spring Web Flow (SWF) aims to be the best solution for the management of web application page flow.

SWF integrates with existing frameworks like Spring MVC and JSF, in both Servlet and Portlet environments. If you have a business process (or processes) that would benefit from a conversational model as opposed to a purely request model, then SWF may be the solution.

SWF allows you to capture logical page flows as self-contained modules that are reusable in different situations, and as such is ideal for building web application modules that guide the user through controlled navigations that drive business processes.

For more information about SWF, consult the Spring Web Flow website.

This chapter details Spring's integration with third party web frameworks, such as JSF.

One of the core value propositions of the Spring Framework is that of enabling *choice*. In a general sense, Spring does not force one to use or buy into any particular architecture, technology, or methodology (although it certainly recommends some over others). This freedom to pick and choose the architecture, technology, or methodology that is most relevant to a developer and their development team is arguably most evident in the web area, where Spring provides its own web framework (Spring MVC), while at the same time providing integration with a number of popular third party web frameworks. This allows one to continue to leverage any and all of the skills one may have acquired in a particular web framework such as JSF, while at the same time being able to enjoy the benefits afforded by Spring in other areas such as data access, declarative transaction management, and flexible configuration and application assembly.

Having dispensed with the woolly sales patter (c.f. the previous paragraph), the remainder of this chapter will concentrate upon the meaty details of integrating your favorite web framework with Spring. One thing that is often commented upon by developers coming to Java from other languages is the seeming super-abundance of web frameworks available in Java. There are indeed a great number of web frameworks in the Java space; in fact there are far too many to cover with any semblance of detail in a single chapter. This chapter thus picks four of the more popular web frameworks in Java, starting with the Spring configuration that is common to all of the supported web frameworks, and then detailing the specific integration options for each supported web framework.

> **Note**
>
> Please note that this chapter does not attempt to explain how to use any of the supported web frameworks. For example, if you want to use JSF for the presentation layer of your web application, the assumption is that you are already familiar with JSF itself. If you need further details about any of the supported web frameworks themselves, please do consult Section 19.6, "Further Resources" at the end of this chapter.

19.2 Common configuration

Before diving into the integration specifics of each supported web framework, let us first take a look at the Spring configuration that is *not* specific to any one web framework. (This section is equally applicable to Spring's own web framework, Spring MVC.)

One of the concepts (for want of a better word) espoused by (Spring's) lightweight application model is that of a layered architecture. Remember that in a *classic* layered architecture, the web layer is but one of many layers; it serves as one of the entry points into a server side application and it delegates to service objects (facades) defined in a service layer to satisfy business specific (and presentation-technology agnostic) use cases. In Spring, these service objects, any other business-specific objects, data access objects, etc. exist in a distinct *business context*, which contains *no* web or presentation layer objects (presentation objects such as Spring MVC controllers are typically configured in a distinct *presentation context*). This section details how one configures a Spring container (a `WebApplicationContext`) that contains all of the *business beans* in one's application.

On to specifics: all that one need do is to declare a `ContextLoaderListener` in the standard Java EE servlet `web.xml` file of one's web application, and add a `contextConfigLocation`<context-param/> section (in the same file) that defines which set of Spring XML configuration files to load.

Find below the <listener/> configuration:

```
<listener>
    <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
</listener>
```

Find below the <context-param/> configuration:

```
<context-param>
    <param-name>contextConfigLocation</param-name>
    <param-value>/WEB-INF/applicationContext*.xml</param-value>
</context-param>
```

If you don't specify the `contextConfigLocation` context parameter, the `ContextLoaderListener` will look for a file called `/WEB-INF/applicationContext.xml` to load. Once the context files are loaded, Spring creates a `WebApplicationContext` object based on the bean definitions and stores it in the `ServletContext` of the web application.

All Java web frameworks are built on top of the Servlet API, and so one can use the following code snippet to get access to this *business context* `ApplicationContext` created by the `ContextLoaderListener`.

```
WebApplicationContext ctx = WebApplicationContextUtils.getWebApplicationContext(servletContext);
```

The `WebApplicationContextUtils` class is for convenience, so you don't have to remember the name of the `ServletContext` attribute. Its *getWebApplicationContext()* method will return `null` if an object doesn't exist under the `WebApplicationContext.ROOT_WEB_APPLICATION_CONTEXT_ATTRIBUTE` key. Rather than risk getting `NullPointerExceptions` in your application, it's better to use the `getRequiredWebApplicationContext()` method. This method throws an exception when the `ApplicationContext` is missing.

Once you have a reference to the `WebApplicationContext`, you can retrieve beans by their name or type. Most developers retrieve beans by name and then cast them to one of their implemented interfaces.

Fortunately, most of the frameworks in this section have simpler ways of looking up beans. Not only do they make it easy to get beans from a Spring container, but they also allow you to use dependency injection on their controllers. Each web framework section has more detail on its specific integration strategies.

19.3 JavaServer Faces 1.2

JavaServer Faces (JSF) is the JCP's standard component-based, event-driven web user interface framework. As of Java EE 5, it is an official part of the Java EE umbrella.

For a popular JSF runtime as well as for popular JSF component libraries, check out the Apache MyFaces project. The MyFaces project also provides common JSF extensions such as MyFaces Orchestra: a Spring-based JSF extension that provides rich conversation scope support.

> **Note**
>
> Spring Web Flow 2.0 provides rich JSF support through its newly established Spring Faces module, both for JSF-centric usage (as described in this section) and for Spring-centric usage (using JSF views within a Spring MVC dispatcher). Check out the Spring Web Flow website for details!

The key element in Spring's JSF integration is the JSF `ELResolver` mechanism.

SpringBeanFacesELResolver (JSF 1.2+)

`SpringBeanFacesELResolver` is a JSF 1.2 compliant `ELResolver` implementation, integrating with the standard Unified EL as used by JSF 1.2 and JSP 2.1. Like `SpringBeanVariableResolver`, it delegates to the Spring's *business context* `WebApplicationContext` *first*, then to the default resolver of the underlying JSF implementation.

Configuration-wise, simply define `SpringBeanFacesELResolver` in your JSF 1.2 *faces-context.xml* file:

```
<faces-config>
    <application>
        <el-resolver>org.springframework.web.jsf.el.SpringBeanFacesELResolver</el-resolver>
        ...
    </application>
</faces-config>
```

FacesContextUtils

A custom `VariableResolver` works well when mapping one's properties to beans in *faces-config.xml*, but at times one may need to grab a bean explicitly. The `FacesContextUtils` class makes this easy. It is similar to `WebApplicationContextUtils`, except that it takes a `FacesContext` parameter rather than a `ServletContext` parameter.

```
ApplicationContext ctx = FacesContextUtils.getWebApplicationContext(FacesContext.getCurrentInstance());
```

19.4 Apache Struts 2.x

Invented by Craig McClanahan, Struts is an open source project hosted by the Apache Software Foundation. At the time, it greatly simplified the JSP/Servlet programming paradigm and won over many developers who were using proprietary frameworks. It simplified the programming model, it was open

source (and thus free as in beer), and it had a large community, which allowed the project to grow and become popular among Java web developers.

Check out the Struts Spring Plugin for the built-in Spring integration shipped with Struts.

19.5 Tapestry 5.x

From the Tapestry homepage:

Tapestry is a "*Component oriented framework for creating dynamic, robust, highly scalable web applications in Java.*"

While Spring has its own powerful web layer, there are a number of unique advantages to building an enterprise Java application using a combination of Tapestry for the web user interface and the Spring container for the lower layers.

For more information, check out Tapestry's dedicated integration module for Spring.

19.6 Further Resources

Find below links to further resources about the various web frameworks described in this chapter.

- The JSF homepage
- The Struts homepage
- The Tapestry homepage

20. Portlet MVC Framework

20.1 Introduction

JSR-168 The Java Portlet Specification

For more general information about portlet development, please review a whitepaper from Oracle entitled "Introduction to JSR 168", and of course the JSR-168 Specification itself.

In addition to supporting conventional (servlet-based) Web development, Spring also supports JSR-168 Portlet development. As much as possible, the Portlet MVC framework is a mirror image of the Web MVC framework, and also uses the same underlying view abstractions and integration technology. So, be sure to review the chapters entitled Chapter 17, *Web MVC framework* and Chapter 18, *View technologies* before continuing with this chapter.

> **Note**
>
> Bear in mind that while the concepts of Spring MVC are the same in Spring Portlet MVC, there are some notable differences created by the unique workflow of JSR-168 portlets.

The main way in which portlet workflow differs from servlet workflow is that the request to the portlet can have two distinct phases: the action phase and the render phase. The action phase is executed only once and is where any *backend* changes or actions occur, such as making changes in a database. The render phase then produces what is displayed to the user each time the display is refreshed. The critical point here is that for a single overall request, the action phase is executed only once, but the render phase may be executed multiple times. This provides (and requires) a clean separation between the activities that modify the persistent state of your system and the activities that generate what is displayed to the user.

Spring Web Flow

Spring Web Flow (SWF) aims to be the best solution for the management of web application page flow.

SWF integrates with existing frameworks like Spring MVC and JSF, in both Servlet and Portlet environments. If you have a business process (or processes) that would benefit from a conversational model as opposed to a purely request model, then SWF may be the solution.

SWF allows you to capture logical page flows as self-contained modules that are reusable in different situations, and as such is ideal for building web application modules that guide the user through controlled navigations that drive business processes.

For more information about SWF, consult the Spring Web Flow website.

The dual phases of portlet requests are one of the real strengths of the JSR-168 specification. For example, dynamic search results can be updated routinely on the display without the user explicitly rerunning the search. Most other portlet MVC frameworks attempt to completely hide the two phases from the developer and make it look as much like traditional servlet development as possible - we think

this approach removes one of the main benefits of using portlets. So, the separation of the two phases is preserved throughout the Spring Portlet MVC framework. The primary manifestation of this approach is that where the servlet version of the MVC classes will have one method that deals with the request, the portlet version of the MVC classes will have two methods that deal with the request: one for the action phase and one for the render phase. For example, where the servlet version of `AbstractController` has the `handleRequestInternal(..)` method, the portlet version of `AbstractController` has `handleActionRequestInternal(..)` and `handleRenderRequestInternal(..)` methods.

The framework is designed around a `DispatcherPortlet` that dispatches requests to handlers, with configurable handler mappings and view resolution, just as the `DispatcherServlet` in the web framework does. File upload is also supported in the same way.

Locale resolution and theme resolution are not supported in Portlet MVC - these areas are in the purview of the portal/portlet container and are not appropriate at the Spring level. However, all mechanisms in Spring that depend on the locale (such as internationalization of messages) will still function properly because `DispatcherPortlet` exposes the current locale in the same way as `DispatcherServlet`.

Controllers - The C in MVC

The default handler is still a very simple `Controller` interface, offering just two methods:

- `void handleActionRequest(request,response)`
- `ModelAndView handleRenderRequest(request,response)`

The framework also includes most of the same controller implementation hierarchy, such as `AbstractController`, `SimpleFormController`, and so on. Data binding, command object usage, model handling, and view resolution are all the same as in the servlet framework.

Views - The V in MVC

All the view rendering capabilities of the servlet framework are used directly via a special bridge servlet named `ViewRendererServlet`. By using this servlet, the portlet request is converted into a servlet request and the view can be rendered using the entire normal servlet infrastructure. This means all the existing renderers, such as JSP, Velocity, etc., can still be used within the portlet.

Web-scoped beans

Spring Portlet MVC supports beans whose lifecycle is scoped to the current HTTP request or HTTP `Session` (both normal and global). This is not a specific feature of Spring Portlet MVC itself, but rather of the `WebApplicationContext` container(s) that Spring Portlet MVC uses. These bean scopes are described in detail in the section called “Request, session, and global session scopes”

20.2 The DispatcherPortlet

Portlet MVC is a request-driven web MVC framework, designed around a portlet that dispatches requests to controllers and offers other functionality facilitating the development of portlet applications. Spring’s `DispatcherPortlet` however, does more than just that. It is completely integrated with the Spring `ApplicationContext` and allows you to use every other feature Spring has.

Like ordinary portlets, the `DispatcherPortlet` is declared in the `portlet.xml` file of your web application:

```
<portlet>
    <portlet-name>sample</portlet-name>
    <portlet-class>org.springframework.web.portlet.DispatcherPortlet</portlet-class>
    <supports>
        <mime-type>text/html</mime-type>
        <portlet-mode>view</portlet-mode>
    </supports>
    <portlet-info>
        <title>Sample Portlet</title>
    </portlet-info>
</portlet>
```

The `DispatcherPortlet` now needs to be configured.

In the Portlet MVC framework, each `DispatcherPortlet` has its own `WebApplicationContext`, which inherits all the beans already defined in the Root `WebApplicationContext`. These inherited beans can be overridden in the portlet-specific scope, and new scope-specific beans can be defined local to a given portlet instance.

The framework will, on initialization of a `DispatcherPortlet`, look for a file named `[portlet-name]-portlet.xml` in the `WEB-INF` directory of your web application and create the beans defined there (overriding the definitions of any beans defined with the same name in the global scope).

The config location used by the `DispatcherPortlet` can be modified through a portlet initialization parameter (see below for details).

The Spring `DispatcherPortlet` has a few special beans it uses, in order to be able to process requests and render the appropriate views. These beans are included in the Spring framework and can be configured in the `WebApplicationContext`, just as any other bean would be configured. Each of those beans is described in more detail below. Right now, we'll just mention them, just to let you know they exist and to enable us to go on talking about the `DispatcherPortlet`. For most of the beans, defaults are provided so you don't have to worry about configuring them.

Table 20.1. Special beans in the WebApplicationContext

Expression	Explanation
handler mapping(s)	(Section 20.5, "Handler mappings") a list of pre- and post-processors and controllers that will be executed if they match certain criteria (for instance a matching portlet mode specified with the controller)
controller(s)	(Section 20.4, "Controllers") the beans providing the actual functionality (or at least, access to the functionality) as part of the MVC triad
view resolver	(Section 20.6, "Views and resolving them") capable of resolving view names to view definitions
multipart resolver	(Section 20.7, "Multipart (file upload) support") offers functionality to process file uploads from HTML forms
handler exception resolver	(Section 20.8, "Handling exceptions") offers functionality to map exceptions to views or implement other more complex exception handling code

When a `DispatcherPortlet` is setup for use and a request comes in for that specific `DispatcherPortlet`, it starts processing the request. The list below describes the complete process a request goes through if handled by a `DispatcherPortlet`:

1. The locale returned by `PortletRequest.getLocale()` is bound to the request to let elements in the process resolve the locale to use when processing the request (rendering the view, preparing data, etc.).

2. If a multipart resolver is specified and this is an `ActionRequest`, the request is inspected for multiparts and if they are found, it is wrapped in a `MultipartActionRequest` for further processing by other elements in the process. (See Section 20.7, “Multipart (file upload) support” for further information about multipart handling).

3. An appropriate handler is searched for. If a handler is found, the execution chain associated with the handler (pre-processors, post-processors, controllers) will be executed in order to prepare a model.

4. If a model is returned, the view is rendered, using the view resolver that has been configured with the `WebApplicationContext`. If no model is returned (which could be due to a pre- or post-processor intercepting the request, for example, for security reasons), no view is rendered, since the request could already have been fulfilled.

Exceptions that are thrown during processing of the request get picked up by any of the handler exception resolvers that are declared in the `WebApplicationContext`. Using these exception resolvers you can define custom behavior in case such exceptions get thrown.

You can customize Spring’s `DispatcherPortlet` by adding context parameters in the `portlet.xml` file or portlet init-parameters. The possibilities are listed below.

Table 20.2. DispatcherPortlet initialization parameters

Parameter	Explanation
`contextClass`	Class that implements `WebApplicationContext`, which will be used to instantiate the context used by this portlet. If this parameter isn’t specified, the `XmlPortletApplicationContext` will be used.
`contextConfigLocation`	String which is passed to the context instance (specified by `contextClass`) to indicate where context(s) can be found. The String is potentially split up into multiple Strings (using a comma as a delimiter) to support multiple contexts (in case of multiple context locations, for beans that are defined twice, the latest takes precedence).
`namespace`	The namespace of the `WebApplicationContext`. Defaults to `[portlet-name]-portlet`.
`viewRendererUrl`	The URL at which `DispatcherPortlet` can access an instance of `ViewRendererServlet` (see Section 20.3, “The ViewRendererServlet”).

20.3 The ViewRendererServlet

The rendering process in Portlet MVC is a bit more complex than in Web MVC. In order to reuse all the view technologies from Spring Web MVC, we must convert the `PortletRequest` / `PortletResponse` to `HttpServletRequest` / `HttpServletResponse` and then call the `render` method of the `View`. To do this, `DispatcherPortlet` uses a special servlet that exists for just this purpose: the `ViewRendererServlet`.

In order for `DispatcherPortlet` rendering to work, you must declare an instance of the `ViewRendererServlet` in the `web.xml` file for your web application as follows:

```
<servlet>
    <servlet-name>ViewRendererServlet</servlet-name>
    <servlet-class>org.springframework.web.servlet.ViewRendererServlet</servlet-class>
</servlet>

<servlet-mapping>
    <servlet-name>ViewRendererServlet</servlet-name>
    <url-pattern>/WEB-INF/servlet/view</url-pattern>
</servlet-mapping>
```

To perform the actual rendering, `DispatcherPortlet` does the following:

1. Binds the `WebApplicationContext` to the request as an attribute under the same `WEB_APPLICATION_CONTEXT_ATTRIBUTE` key that `DispatcherServlet` uses.

2. Binds the `Model` and `View` objects to the request to make them available to the `ViewRendererServlet`.

3. Constructs a `PortletRequestDispatcher` and performs an `include` using the `/WEB-INF/servlet/view` URL that is mapped to the `ViewRendererServlet`.

The `ViewRendererServlet` is then able to call the `render` method on the `View` with the appropriate arguments.

The actual URL for the `ViewRendererServlet` can be changed using `DispatcherPortlet`'s `viewRendererUrl` configuration parameter.

20.4 Controllers

The controllers in Portlet MVC are very similar to the Web MVC Controllers, and porting code from one to the other should be simple.

The basis for the Portlet MVC controller architecture is the `org.springframework.web.portlet.mvc.Controller` interface, which is listed below.

```
public interface Controller {

    /**
     * Process the render request and return a ModelAndView object which the
     * DispatcherPortlet will render.
     */
    ModelAndView handleRenderRequest(RenderRequest request,
            RenderResponse response) throws Exception;

    /**
     * Process the action request. There is nothing to return.
     */
    void handleActionRequest(ActionRequest request,
            ActionResponse response) throws Exception;

}
```

As you can see, the Portlet `Controller` interface requires two methods that handle the two phases of a portlet request: the action request and the render request. The action phase should be capable of handling an action request, and the render phase should be capable of handling a render request and returning an appropriate model and view. While the `Controller` interface is quite abstract, Spring Portlet MVC offers several controllers that already contain a lot of the functionality you might need; most of these are very similar to controllers from Spring Web MVC. The `Controller` interface just

defines the most common functionality required of every controller: handling an action request, handling a render request, and returning a model and a view.

AbstractController and PortletContentGenerator

Of course, just a `Controller` interface isn't enough. To provide a basic infrastructure, all of Spring Portlet MVC's `Controllers` inherit from `AbstractController`, a class offering access to Spring's `ApplicationContext` and control over caching.

Table 20.3. Features offered by the AbstractController

Parameter	Explanation
`requireSession`	Indicates whether or not this `Controller` requires a session to do its work. This feature is offered to all controllers. If a session is not present when such a controller receives a request, the user is informed using a `SessionRequiredException`.
`synchronizeSessionUse`	Use this if you want handling by this controller to be synchronized on the user's session. To be more specific, the extending controller will override the `handleRenderRequestInternal(..)` and `handleActionRequestInternal(..)` methods, which will be synchronized on the user's session if you specify this variable.
`renderWhenMinimized`	If you want your controller to actually render the view when the portlet is in a minimized state, set this to true. By default, this is set to false so that portlets that are in a minimized state don't display any content.
`cacheSeconds`	When you want a controller to override the default cache expiration defined for the portlet, specify a positive integer here. By default it is set to `-1`, which does not change the default caching. Setting it to `0` will ensure the result is never cached.

The `requireSession` and `cacheSeconds` properties are declared on the `PortletContentGenerator` class, which is the superclass of `AbstractController`) but are included here for completeness.

When using the `AbstractController` as a base class for your controllers (which is not recommended since there are a lot of other controllers that might already do the job for you) you only have to override either the `handleActionRequestInternal(ActionRequest, ActionResponse)` method or the `handleRenderRequestInternal(RenderRequest, RenderResponse)` method (or both), implement your logic, and return a `ModelAndView` object (in the case of `handleRenderRequestInternal`).

The default implementations of both `handleActionRequestInternal(..)` and `handleRenderRequestInternal(..)` throw a `PortletException`. This is consistent with the behavior of `GenericPortlet` from the JSR- 168 Specification API. So you only need to override the method that your controller is intended to handle.

Here is short example consisting of a class and a declaration in the web application context.

```
package samples;

import javax.portlet.RenderRequest;
import javax.portlet.RenderResponse;

import org.springframework.web.portlet.mvc.AbstractController;
import org.springframework.web.portlet.ModelAndView;

public class SampleController extends AbstractController {

    public ModelAndView handleRenderRequestInternal(RenderRequest request, RenderResponse response) {
        ModelAndView mav = new ModelAndView("foo");
        mav.addObject("message", "Hello World!");
        return mav;
    }

}
```

```
<bean id="sampleController" class="samples.SampleController">
    <property name="cacheSeconds" value="120"/>
</bean>
```

The class above and the declaration in the web application context is all you need besides setting up a handler mapping (see Section 20.5, “Handler mappings”) to get this very simple controller working.

Other simple controllers

Although you can extend `AbstractController`, Spring Portlet MVC provides a number of concrete implementations which offer functionality that is commonly used in simple MVC applications.

The `ParameterizableViewController` is basically the same as the example above, except for the fact that you can specify the view name that it will return in the web application context (no need to hard-code the view name).

The `PortletModeNameViewController` uses the current mode of the portlet as the view name. So, if your portlet is in View mode (i.e. `PortletMode.VIEW`) then it uses "view" as the view name.

Command Controllers

Spring Portlet MVC has the exact same hierarchy of *command controllers* as Spring Web MVC. They provide a way to interact with data objects and dynamically bind parameters from the `PortletRequest` to the data object specified. Your data objects don’t have to implement a framework-specific interface, so you can directly manipulate your persistent objects if you desire. Let’s examine what command controllers are available, to get an overview of what you can do with them:

- `AbstractCommandController` - a command controller you can use to create your own command controller, capable of binding request parameters to a data object you specify. This class does not offer form functionality, it does however offer validation features and lets you specify in the controller itself what to do with the command object that has been filled with the parameters from the request.
- `AbstractFormController` - an abstract controller offering form submission support. Using this controller you can model forms and populate them using a command object you retrieve in the controller. After a user has filled the form, `AbstractFormController` binds the fields, validates, and hands the object back to the controller to take appropriate action. Supported features are: invalid form submission (resubmission), validation, and normal form workflow. You implement methods to determine which views are used for form presentation and success. Use this controller if you need forms, but don’t want to specify what views you’re going to show the user in the application context.

- `SimpleFormController` - a concrete `AbstractFormController` that provides even more support when creating a form with a corresponding command object. The `SimpleFormController` lets you specify a command object, a viewname for the form, a viewname for the page you want to show the user when form submission has succeeded, and more.
- `AbstractWizardFormController` — a concrete `AbstractFormController` that provides a wizard-style interface for editing the contents of a command object across multiple display pages. Supports multiple user actions: finish, cancel, or page change, all of which are easily specified in request parameters from the view.

These command controllers are quite powerful, but they do require a detailed understanding of how they operate in order to use them efficiently. Carefully review the javadocs for this entire hierarchy and then look at some sample implementations before you start using them.

PortletWrappingController

Instead of developing new controllers, it is possible to use existing portlets and map requests to them from a `DispatcherPortlet`. Using the `PortletWrappingController`, you can instantiate an existing `Portlet` as a `Controller` as follows:

```
<bean id="myPortlet" class="org.springframework.web.portlet.mvc.PortletWrappingController">
    <property name="portletClass" value="sample.MyPortlet"/>
    <property name="portletName" value="my-portlet"/>
    <property name="initParameters">
        <value>config=/WEB-INF/my-portlet-config.xml</value>
    </property>
</bean>
```

This can be very valuable since you can then use interceptors to pre-process and post-process requests going to these portlets. Since JSR-168 does not support any kind of filter mechanism, this is quite handy. For example, this can be used to wrap the Hibernate `OpenSessionInViewInterceptor` around a MyFaces JSF Portlet.

20.5 Handler mappings

Using a handler mapping you can map incoming portlet requests to appropriate handlers. There are some handler mappings you can use out of the box, for example, the `PortletModeHandlerMapping`, but let's first examine the general concept of a `HandlerMapping`.

Note: We are intentionally using the term "Handler" here instead of "Controller". `DispatcherPortlet` is designed to be used with other ways to process requests than just Spring Portlet MVC's own Controllers. A Handler is any Object that can handle portlet requests. Controllers are an example of Handlers, and they are of course the default. To use some other framework with `DispatcherPortlet`, a corresponding implementation of `HandlerAdapter` is all that is needed.

The functionality a basic `HandlerMapping` provides is the delivering of a `HandlerExecutionChain`, which must contain the handler that matches the incoming request, and may also contain a list of handler interceptors that are applied to the request. When a request comes in, the `DispatcherPortlet` will hand it over to the handler mapping to let it inspect the request and come up with an appropriate `HandlerExecutionChain`. Then the `DispatcherPortlet` will execute the handler and interceptors in the chain (if any). These concepts are all exactly the same as in Spring Web MVC.

The concept of configurable handler mappings that can optionally contain interceptors (executed before or after the actual handler was executed, or both) is extremely powerful. A lot of supporting functionality can be built into a custom `HandlerMapping`. Think of a custom handler mapping that chooses a handler

not only based on the portlet mode of the request coming in, but also on a specific state of the session associated with the request.

In Spring Web MVC, handler mappings are commonly based on URLs. Since there is really no such thing as a URL within a Portlet, we must use other mechanisms to control mappings. The two most common are the portlet mode and a request parameter, but anything available to the portlet request can be used in a custom handler mapping.

The rest of this section describes three of Spring Portlet MVC's most commonly used handler mappings. They all extend `AbstractHandlerMapping` and share the following properties:

- `interceptors`: The list of interceptors to use. `HandlerInterceptors` are discussed in the section called "Adding HandlerInterceptors".
- `defaultHandler`: The default handler to use, when this handler mapping does not result in a matching handler.
- `order`: Based on the value of the order property (see the `org.springframework.core.Ordered` interface), Spring will sort all handler mappings available in the context and apply the first matching handler.
- `lazyInitHandlers`: Allows for lazy initialization of singleton handlers (prototype handlers are always lazily initialized). Default value is false. This property is directly implemented in the three concrete Handlers.

PortletModeHandlerMapping

This is a simple handler mapping that maps incoming requests based on the current mode of the portlet (e.g. *view*, *edit*, *help*). An example:

```
<bean class="org.springframework.web.portlet.handler.PortletModeHandlerMapping">
    <property name="portletModeMap">
        <map>
            <entry key="view" value-ref="viewHandler"/>
            <entry key="edit" value-ref="editHandler"/>
            <entry key="help" value-ref="helpHandler"/>
        </map>
    </property>
</bean>
```

ParameterHandlerMapping

If we need to navigate around to multiple controllers without changing portlet mode, the simplest way to do this is with a request parameter that is used as the key to control the mapping.

`ParameterHandlerMapping` uses the value of a specific request parameter to control the mapping. The default name of the parameter is `'action'`, but can be changed using the `'parameterName'` property.

The bean configuration for this mapping will look something like this:

```
<bean class="org.springframework.web.portlet.handler.ParameterHandlerMapping">
    <property name="parameterMap">
        <map>
            <entry key="add" value-ref="addItemHandler"/>
            <entry key="edit" value-ref="editItemHandler"/>
            <entry key="delete" value-ref="deleteItemHandler"/>
        </map>
    </property>
</bean>
```

PortletModeParameterHandlerMapping

The most powerful built-in handler mapping, `PortletModeParameterHandlerMapping` combines the capabilities of the two previous ones to allow different navigation within each portlet mode.

Again the default name of the parameter is "action", but can be changed using the `parameterName` property.

By default, the same parameter value may not be used in two different portlet modes. This is so that if the portal itself changes the portlet mode, the request will no longer be valid in the mapping. This behavior can be changed by setting the `allowDupParameters` property to true. However, this is not recommended.

The bean configuration for this mapping will look something like this:

```
<bean class="org.springframework.web.portlet.handler.PortletModeParameterHandlerMapping">
    <property name="portletModeParameterMap">
        <map>
            <entry key="view"> <!-- view portlet mode -->
                <map>
                    <entry key="add" value-ref="addItemHandler"/>
                    <entry key="edit" value-ref="editItemHandler"/>
                    <entry key="delete" value-ref="deleteItemHandler"/>
                </map>
            </entry>
            <entry key="edit"> <!-- edit portlet mode -->
                <map>
                    <entry key="prefs" value-ref="prefsHandler"/>
                    <entry key="resetPrefs" value-ref="resetPrefsHandler"/>
                </map>
            </entry>
        </map>
    </property>
</bean>
```

This mapping can be chained ahead of a `PortletModeHandlerMapping`, which can then provide defaults for each mode and an overall default as well.

Adding HandlerInterceptors

Spring's handler mapping mechanism has a notion of handler interceptors, which can be extremely useful when you want to apply specific functionality to certain requests, for example, checking for a principal. Again Spring Portlet MVC implements these concepts in the same way as Web MVC.

Interceptors located in the handler mapping must implement `HandlerInterceptor` from the `org.springframework.web.portlet` package. Just like the servlet version, this interface defines three methods: one that will be called before the actual handler will be executed (`preHandle`), one that will be called after the handler is executed (`postHandle`), and one that is called after the complete request has finished (`afterCompletion`). These three methods should provide enough flexibility to do all kinds of pre- and post- processing.

The `preHandle` method returns a boolean value. You can use this method to break or continue the processing of the execution chain. When this method returns `true`, the handler execution chain will continue. When it returns `false`, the `DispatcherPortlet` assumes the interceptor itself has taken care of requests (and, for example, rendered an appropriate view) and does not continue executing the other interceptors and the actual handler in the execution chain.

The `postHandle` method is only called on a `RenderRequest`. The `preHandle` and `afterCompletion` methods are called on both an `ActionRequest` and a `RenderRequest`. If you

need to execute logic in these methods for just one type of request, be sure to check what kind of request it is before processing it.

HandlerInterceptorAdapter

As with the servlet package, the portlet package has a concrete implementation of `HandlerInterceptor` called `HandlerInterceptorAdapter`. This class has empty versions of all the methods so that you can inherit from this class and implement just one or two methods when that is all you need.

ParameterMappingInterceptor

The portlet package also has a concrete interceptor named `ParameterMappingInterceptor` that is meant to be used directly with `ParameterHandlerMapping` and `PortletModeParameterHandlerMapping`. This interceptor will cause the parameter that is being used to control the mapping to be forwarded from an `ActionRequest` to the subsequent `RenderRequest`. This will help ensure that the `RenderRequest` is mapped to the same Handler as the `ActionRequest`. This is done in the `preHandle` method of the interceptor, so you can still modify the parameter value in your handler to change where the `RenderRequest` will be mapped.

Be aware that this interceptor is calling `setRenderParameter` on the `ActionResponse`, which means that you cannot call `sendRedirect` in your handler when using this interceptor. If you need to do external redirects then you will either need to forward the mapping parameter manually or write a different interceptor to handle this for you.

20.6 Views and resolving them

As mentioned previously, Spring Portlet MVC directly reuses all the view technologies from Spring Web MVC. This includes not only the various `View` implementations themselves, but also the `ViewResolver` implementations. For more information, refer to Chapter 18, *View technologies* and Section 17.5, “Resolving views” respectively.

A few items on using the existing `View` and `ViewResolver` implementations are worth mentioning:

- Most portals expect the result of rendering a portlet to be an HTML fragment. So, things like JSP/JSTL, Velocity, FreeMarker, and XSLT all make sense. But it is unlikely that views that return other document types will make any sense in a portlet context.
- There is no such thing as an HTTP redirect from within a portlet (the `sendRedirect(..)` method of `ActionResponse` cannot be used to stay within the portal). So, `RedirectView` and use of the `'redirect:'` prefix will *not* work correctly from within Portlet MVC.
- It may be possible to use the `'forward:'` prefix from within Portlet MVC. However, remember that since you are in a portlet, you have no idea what the current URL looks like. This means you cannot use a relative URL to access other resources in your web application and that you will have to use an absolute URL.

Also, for JSP development, the new Spring Taglib and the new Spring Form Taglib both work in portlet views in exactly the same way that they work in servlet views.

20.7 Multipart (file upload) support

Spring Portlet MVC has built-in multipart support to handle file uploads in portlet applications, just like Web MVC does. The design for the multipart

support is done with pluggable `PortletMultipartResolver` objects, defined in the `org.springframework.web.portlet.multipart` package. Spring provides a `PortletMultipartResolver` for use with Commons FileUpload. How uploading files is supported will be described in the rest of this section.

By default, no multipart handling will be done by Spring Portlet MVC, as some developers will want to handle multiparts themselves. You will have to enable it yourself by adding a multipart resolver to the web application's context. After you have done that, `DispatcherPortlet` will inspect each request to see if it contains a multipart. If no multipart is found, the request will continue as expected. However, if a multipart is found in the request, the `PortletMultipartResolver` that has been declared in your context will be used. After that, the multipart attribute in your request will be treated like any other attribute.

> **Note**
>
> Any configured `PortletMultipartResolver` bean *must* have the following id (or name): " `portletMultipartResolver`". If you have defined your `PortletMultipartResolver` with any other name, then the `DispatcherPortlet` will *not* find your `PortletMultipartResolver`, and consequently no multipart support will be in effect.

Using the PortletMultipartResolver

The following example shows how to use the `CommonsPortletMultipartResolver`:

```
<bean id="portletMultipartResolver"
        class="org.springframework.web.portlet.multipart.CommonsPortletMultipartResolver">
    <!-- one of the properties available; the maximum file size in bytes -->
    <property name="maxUploadSize" value="100000"/>
</bean>
```

Of course you also need to put the appropriate jars in your classpath for the multipart resolver to work. In the case of the `CommonsMultipartResolver`, you need to use `commons-fileupload.jar`. Be sure to use at least version 1.1 of Commons FileUpload as previous versions do not support JSR-168 Portlet applications.

Now that you have seen how to set Portlet MVC up to handle multipart requests, let's talk about how to actually use it. When `DispatcherPortlet` detects a multipart request, it activates the resolver that has been declared in your context and hands over the request. What the resolver then does is wrap the current `ActionRequest` in a `MultipartActionRequest` that has support for multipart file uploads. Using the `MultipartActionRequest` you can get information about the multiparts contained by this request and actually get access to the multipart files themselves in your controllers.

Note that you can only receive multipart file uploads as part of an `ActionRequest`, not as part of a `RenderRequest`.

Handling a file upload in a form

After the `PortletMultipartResolver` has finished doing its job, the request will be processed like any other. To use the `PortletMultipartResolver`, create a form with an upload field (see example below), then let Spring bind the file onto your form (backing object). To actually let the user upload a file, we have to create a (JSP/HTML) form:

```
<h1>Please upload a file</h1>
<form method="post" action="<portlet:actionURL/>" enctype="multipart/form-data">
    <input type="file" name="file"/>
    <input type="submit"/>
</form>
```

As you can see, we've created a field named "file" that matches the property of the bean that holds the `byte[]` array. Furthermore we've added the encoding attribute (`enctype="multipart/form-data"`), which is necessary to let the browser know how to encode the multipart fields (do not forget this!).

Just as with any other property that's not automagically convertible to a string or primitive type, to be able to put binary data in your objects you have to register a custom editor with the `PortletRequestDataBinder`. There are a couple of editors available for handling files and setting the results on an object. There's a `StringMultipartFileEditor` capable of converting files to Strings (using a user-defined character set), and there is a `ByteArrayMultipartFileEditor` which converts files to byte arrays. They function analogous to the `CustomDateEditor`.

So, to be able to upload files using a form, declare the resolver, a mapping to a controller that will process the bean, and the controller itself.

```
<bean id="portletMultipartResolver"
        class="org.springframework.web.portlet.multipart.CommonsPortletMultipartResolver"/>

<bean class="org.springframework.web.portlet.handler.PortletModeHandlerMapping">
    <property name="portletModeMap">
        <map>
            <entry key="view" value-ref="fileUploadController"/>
        </map>
    </property>
</bean>

<bean id="fileUploadController" class="examples.FileUploadController">
    <property name="commandClass" value="examples.FileUploadBean"/>
    <property name="formView" value="fileuploadform"/>
    <property name="successView" value="confirmation"/>
</bean>
```

After that, create the controller and the actual class to hold the file property.

```
public class FileUploadController extends SimpleFormController {

    public void onSubmitAction(ActionRequest request, ActionResponse response,
            Object command, BindException errors) throws Exception {

        // cast the bean
        FileUploadBean bean = (FileUploadBean) command;

        // let's see if there's content there
        byte[] file = bean.getFile();
        if (file == null) {
            // hmm, that's strange, the user did not upload anything
        }

        // do something with the file here
    }

    protected void initBinder(PortletRequest request,
            PortletRequestDataBinder binder) throws Exception {
        // to actually be able to convert Multipart instance to byte[]
        // we have to register a custom editor
        binder.registerCustomEditor(byte[].class, new ByteArrayMultipartFileEditor());
        // now Spring knows how to handle multipart object and convert
    }

}

public class FileUploadBean {

    private byte[] file;

    public void setFile(byte[] file) {
        this.file = file;
    }

    public byte[] getFile() {
        return file;
    }

}
```

As you can see, the `FileUploadBean` has a property of type `byte[]` that holds the file. The controller registers a custom editor to let Spring know how to actually convert the multipart objects the resolver has found to properties specified by the bean. In this example, nothing is done with the `byte[]` property of the bean itself, but in practice you can do whatever you want (save it in a database, mail it to somebody, etc).

An equivalent example in which a file is bound straight to a String-typed property on a form backing object might look like this:

```
public class FileUploadController extends SimpleFormController {

    public void onSubmitAction(ActionRequest request, ActionResponse response,
            Object command, BindException errors) throws Exception {

        // cast the bean
        FileUploadBean bean = (FileUploadBean) command;

        // let's see if there's content there
        String file = bean.getFile();
        if (file == null) {
            // hmm, that's strange, the user did not upload anything
        }

        // do something with the file here
    }

    protected void initBinder(PortletRequest request,
            PortletRequestDataBinder binder) throws Exception {

        // to actually be able to convert Multipart instance to a String
        // we have to register a custom editor
        binder.registerCustomEditor(String.class, new StringMultipartFileEditor());
        // now Spring knows how to handle multipart objects and convert
    }
}

public class FileUploadBean {

    private String file;

    public void setFile(String file) {
        this.file = file;
    }

    public String getFile() {
        return file;
    }
}
```

Of course, this last example only makes (logical) sense in the context of uploading a plain text file (it wouldn't work so well in the case of uploading an image file).

The third (and final) option is where one binds directly to a `MultipartFile` property declared on the (form backing) object's class. In this case one does not need to register any custom property editor because there is no type conversion to be performed.

```
public class FileUploadController extends SimpleFormController {

    public void onSubmitAction(ActionRequest request, ActionResponse response,
            Object command, BindException errors) throws Exception {

        // cast the bean
        FileUploadBean bean = (FileUploadBean) command;

        // let's see if there's content there
        MultipartFile file = bean.getFile();
        if (file == null) {
            // hmm, that's strange, the user did not upload anything
        }

        // do something with the file here
    }
}

public class FileUploadBean {

    private MultipartFile file;

    public void setFile(MultipartFile file) {
        this.file = file;
    }

    public MultipartFile getFile() {
        return file;
    }

}
```

20.8 Handling exceptions

Just like Servlet MVC, Portlet MVC provides `HandlerExceptionResolvers` to ease the pain of unexpected exceptions that occur while your request is being processed by a handler that matched the request. Portlet MVC also provides a portlet-specific, concrete `SimpleMappingExceptionResolver` that enables you to take the class name of any exception that might be thrown and map it to a view name.

20.9 Annotation-based controller configuration

Spring 2.5 introduced an annotation-based programming model for MVC controllers, using annotations such as `@RequestMapping`, `@RequestParam`, `@ModelAttribute`, etc. This annotation support is available for both Servlet MVC and Portlet MVC. Controllers implemented in this style do not have to extend specific base classes or implement specific interfaces. Furthermore, they do not usually have direct dependencies on Servlet or Portlet API's, although they can easily get access to Servlet or Portlet facilities if desired.

The following sections document these annotations and how they are most commonly used in a Portlet environment.

Setting up the dispatcher for annotation support

`@RequestMapping` will only be processed if a corresponding `HandlerMapping` (for type level annotations) and/or `HandlerAdapter` (for method level annotations) is present in the dispatcher. This is the case by default in both `DispatcherServlet` and `DispatcherPortlet`.

However, if you are defining custom `HandlerMappings` or `HandlerAdapters`, then you need to make sure that a corresponding custom `DefaultAnnotationHandlerMapping` and/

or `AnnotationMethodHandlerAdapter` is defined as well - provided that you intend to use `@RequestMapping`.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean class="org.springframework.web.portlet.mvc.annotation.DefaultAnnotationHandlerMapping"/>

    <bean class="org.springframework.web.portlet.mvc.annotation.AnnotationMethodHandlerAdapter"/>

    // ... (controller bean definitions) ...

</beans>
```

Defining a `DefaultAnnotationHandlerMapping` and/or `AnnotationMethodHandlerAdapter` explicitly also makes sense if you would like to customize the mapping strategy, e.g. specifying a custom `WebBindingInitializer` (see below).

Defining a controller with @Controller

The `@Controller` annotation indicates that a particular class serves the role of a *controller*. There is no need to extend any controller base class or reference the Portlet API. You are of course still able to reference Portlet-specific features if you need to.

The basic purpose of the `@Controller` annotation is to act as a stereotype for the annotated class, indicating its role. The dispatcher will scan such annotated classes for mapped methods, detecting `@RequestMapping` annotations (see the next section).

Annotated controller beans may be defined explicitly, using a standard Spring bean definition in the dispatcher's context. However, the `@Controller` stereotype also allows for autodetection, aligned with Spring 2.5's general support for detecting component classes in the classpath and auto-registering bean definitions for them.

To enable autodetection of such annotated controllers, you have to add component scanning to your configuration. This is easily achieved by using the *spring-context* schema as shown in the following XML snippet:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:p="http://www.springframework.org/schema/p"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
        http://www.springframework.org/schema/context/spring-context.xsd">

    <context:component-scan base-package="org.springframework.samples.petportal.portlet"/>

    // ...

</beans>
```

Mapping requests with @RequestMapping

The `@RequestMapping` annotation is used to map portlet modes like *VIEW*/*EDIT* onto an entire class or a particular handler method. Typically the type-level annotation maps a specific mode (or mode

plus parameter condition) onto a form controller, with additional method-level annotations *narrowing* the primary mapping for specific portlet request parameters.

> **Tip**
>
> `@RequestMapping` at the type level may be used for plain implementations of the `Controller` interface as well. In this case, the request processing code would follow the traditional `handle(Action|Render)Request` signature, while the controller's mapping would be expressed through an `@RequestMapping` annotation. This works for pre-built `Controller` base classes, such as `SimpleFormController`, too.
>
> In the following discussion, we'll focus on controllers that are based on annotated handler methods.

The following is an example of a form controller from the PetPortal sample application using this annotation:

```
@Controller
@RequestMapping("EDIT")
@SessionAttributes("site")
public class PetSitesEditController {

    private Properties petSites;

    public void setPetSites(Properties petSites) {
        this.petSites = petSites;
    }

    @ModelAttribute("petSites")
    public Properties getPetSites() {
        return this.petSites;
    }

    @RequestMapping // default (action=list)
    public String showPetSites() {
        return "petSitesEdit";
    }

    @RequestMapping(params = "action=add") // render phase
    public String showSiteForm(Model model) {
        // Used for the initial form as well as for redisplaying with errors.
        if (!model.containsAttribute("site")) {
            model.addAttribute("site", new PetSite());
        }

        return "petSitesAdd";
    }

    @RequestMapping(params = "action=add") // action phase
    public void populateSite(@ModelAttribute("site") PetSite petSite,
            BindingResult result, SessionStatus status, ActionResponse response) {
        new PetSiteValidator().validate(petSite, result);
        if (!result.hasErrors()) {
            this.petSites.put(petSite.getName(), petSite.getUrl());
            status.setComplete();
            response.setRenderParameter("action", "list");
        }
    }

    @RequestMapping(params = "action=delete")
    public void removeSite(@RequestParam("site") String site, ActionResponse response) {
        this.petSites.remove(site);
        response.setRenderParameter("action", "list");
    }
}
```

Supported handler method arguments

Handler methods which are annotated with `@RequestMapping` are allowed to have very flexible signatures. They may have arguments of the following types, in arbitrary order (except for validation results, which need to follow right after the corresponding command object, if desired):

- Request and/or response objects (Portlet API). You may choose any specific request/response type, e.g. PortletRequest / ActionRequest / RenderRequest. An explicitly declared action/render argument is also used for mapping specific request types onto a handler method (in case of no other information given that differentiates between action and render requests).
- Session object (Portlet API): of type PortletSession. An argument of this type will enforce the presence of a corresponding session. As a consequence, such an argument will never be `null`.
- `org.springframework.web.context.request.WebRequest` or `org.springframework.web.context.request.NativeWebRequest`. Allows for generic request parameter access as well as request/session attribute access, without ties to the native Servlet/Portlet API.
- `java.util.Locale` for the current request locale (the portal locale in a Portlet environment).
- `java.util.TimeZone` / `java.time.ZoneId` for the current request time zone.
- `java.io.InputStream` / `java.io.Reader` for access to the request's content. This will be the raw InputStream/Reader as exposed by the Portlet API.
- `java.io.OutputStream` / `java.io.Writer` for generating the response's content. This will be the raw OutputStream/Writer as exposed by the Portlet API.
- `@RequestParam` annotated parameters for access to specific Portlet request parameters. Parameter values will be converted to the declared method argument type.
- `java.util.Map` / `org.springframework.ui.Model` / `org.springframework.ui.ModelMap` for enriching the implicit model that will be exposed to the web view.
- Command/form objects to bind parameters to: as bean properties or fields, with customizable type conversion, depending on `@InitBinder` methods and/or the HandlerAdapter configuration - see the " `webBindingInitializer`" property on `AnnotationMethodHandlerAdapter`. Such command objects along with their validation results will be exposed as model attributes, by default using the non-qualified command class name in property notation (e.g. "orderAddress" for type "mypackage.OrderAddress"). Specify a parameter-level `ModelAttribute` annotation for declaring a specific model attribute name.
- `org.springframework.validation.Errors` / `org.springframework.validation.BindingResult` validation results for a preceding command/form object (the immediate preceding argument).
- `org.springframework.web.bind.support.SessionStatus` status handle for marking form processing as complete (triggering the cleanup of session attributes that have been indicated by the `@SessionAttributes` annotation at the handler type level).

The following return types are supported for handler methods:

- A `ModelAndView` object, with the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.

- A `Model` object, with the view name implicitly determined through a `RequestToViewNameTranslator` and the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.
- A `Map` object for exposing a model, with the view name implicitly determined through a `RequestToViewNameTranslator` and the model implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.
- A `View` object, with the model implicitly determined through command objects and `@ModelAttribute` annotated reference data accessor methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above).
- A `String` value which is interpreted as view name, with the model implicitly determined through command objects and `@ModelAttribute` annotated reference data accessor methods. The handler method may also programmatically enrich the model by declaring a `Model` argument (see above).
- `void` if the method handles the response itself (e.g. by writing the response content directly).
- Any other return type will be considered a single model attribute to be exposed to the view, using the attribute name specified through `@ModelAttribute` at the method level (or the default attribute name based on the return type's class name otherwise). The model will be implicitly enriched with command objects and the results of `@ModelAttribute` annotated reference data accessor methods.

Binding request parameters to method parameters with @RequestParam

The `@RequestParam` annotation is used to bind request parameters to a method parameter in your controller.

The following code snippet from the PetPortal sample application shows the usage:

```
@Controller
@RequestMapping("EDIT")
@SessionAttributes("site")
public class PetSitesEditController {

    // ...

    public void removeSite(@RequestParam("site") String site, ActionResponse response) {
        this.petSites.remove(site);
        response.setRenderParameter("action", "list");
    }

    // ...

}
```

Parameters using this annotation are required by default, but you can specify that a parameter is optional by setting `@RequestParam`'s `required` attribute to `false` (e.g., `@RequestParam(value="id", required=false)`).

Providing a link to data from the model with @ModelAttribute

`@ModelAttribute` has two usage scenarios in controllers. When placed on a method parameter, `@ModelAttribute` is used to map a model attribute to the specific, annotated method parameter (see the `populateSite()` method below). This is how the controller gets a reference to the object holding the data entered in the form. In addition, the parameter can be declared as the specific type of the form backing object rather than as a generic `java.lang.Object`, thus increasing type safety.

`@ModelAttribute` is also used at the method level to provide *reference data* for the model (see the `getPetSites()` method below). For this usage the method signature can contain the same types as documented above for the `@RequestMapping` annotation.

> **Note**
>
> `@ModelAttribute` annotated methods will be executed *before* the chosen `@RequestMapping` annotated handler method. They effectively pre-populate the implicit model with specific attributes, often loaded from a database. Such an attribute can then already be accessed through `@ModelAttribute` annotated handler method parameters in the chosen handler method, potentially with binding and validation applied to it.

The following code snippet shows these two usages of this annotation:

```
@Controller
@RequestMapping("EDIT")
@SessionAttributes("site")
public class PetSitesEditController {

    // ...

    @ModelAttribute("petSites")
    public Properties getPetSites() {
        return this.petSites;
    }

    @RequestMapping(params = "action=add") // action phase
    public void populateSite( @ModelAttribute("site") PetSite petSite, BindingResult result,
 SessionStatus status, ActionResponse response) {
        new PetSiteValidator().validate(petSite, result);
        if (!result.hasErrors()) {
            this.petSites.put(petSite.getName(), petSite.getUrl());
            status.setComplete();
            response.setRenderParameter("action", "list");
        }
    }
}
```

Specifying attributes to store in a Session with @SessionAttributes

The type-level `@SessionAttributes` annotation declares session attributes used by a specific handler. This will typically list the names of model attributes or types of model attributes which should be transparently stored in the session or some conversational storage, serving as form-backing beans between subsequent requests.

The following code snippet shows the usage of this annotation:

```
@Controller
@RequestMapping("EDIT")
@SessionAttributes("site")
public class PetSitesEditController {
    // ...
}
```

Customizing WebDataBinder initialization

To customize request parameter binding with PropertyEditors, etc. via Spring's `WebDataBinder`, you can either use `@InitBinder`-annotated methods within your controller or externalize your configuration by providing a custom `WebBindingInitializer`.

Customizing data binding with @InitBinder

Annotating controller methods with `@InitBinder` allows you to configure web data binding directly within your controller class. `@InitBinder` identifies methods which initialize the `WebDataBinder` which will be used for populating command and form object arguments of annotated handler methods.

Such init-binder methods support all arguments that `@RequestMapping` supports, except for command/form objects and corresponding validation result objects. Init-binder methods must not have a return value. Thus, they are usually declared as `void`. Typical arguments include `WebDataBinder` in combination with `WebRequest` or `java.util.Locale`, allowing code to register context-specific editors.

The following example demonstrates the use of `@InitBinder` for configuring a `CustomDateEditor` for all `java.util.Date` form properties.

```
@Controller
public class MyFormController {

    @InitBinder
    public void initBinder(WebDataBinder binder) {
    SimpleDateFormat dateFormat = new SimpleDateFormat("yyyy-MM-dd");
        dateFormat.setLenient(false);
        binder.registerCustomEditor(Date.class, new CustomDateEditor(dateFormat, false));
    }

    // ...

}
```

Configuring a custom WebBindingInitializer

To externalize data binding initialization, you can provide a custom implementation of the `WebBindingInitializer` interface, which you then enable by supplying a custom bean configuration for an `AnnotationMethodHandlerAdapter`, thus overriding the default configuration.

20.10 Portlet application deployment

The process of deploying a Spring Portlet MVC application is no different than deploying any JSR-168 Portlet application. However, this area is confusing enough in general that it is worth talking about here briefly.

Generally, the portal/portlet container runs in one webapp in your servlet container and your portlets run in another webapp in your servlet container. In order for the portlet container webapp to make calls into your portlet webapp it must make cross-context calls to a well-known servlet that provides access to the portlet services defined in your `portlet.xml` file.

The JSR-168 specification does not specify exactly how this should happen, so each portlet container has its own mechanism for this, which usually involves some kind of "deployment process" that makes changes to the portlet webapp itself and then registers the portlets within the portlet container.

At a minimum, the `web.xml` file in your portlet webapp is modified to inject the well-known servlet that the portlet container will call. In some cases a single servlet will service all portlets in the webapp, in other cases there will be an instance of the servlet for each portlet.

Some portlet containers will also inject libraries and/or configuration files into the webapp as well. The portlet container must also make its implementation of the Portlet JSP Tag Library available to your webapp.

The bottom line is that it is important to understand the deployment needs of your target portal and make sure they are met (usually by following the automated deployment process it provides). Be sure to carefully review the documentation from your portal for this process.

Once you have deployed your portlet, review the resulting `web.xml` file for sanity. Some older portals have been known to corrupt the definition of the `ViewRendererServlet`, thus breaking the rendering of your portlets.

21. WebSocket Support

This part of the reference documentation covers Spring Framework's support for WebSocket-style messaging in web applications including use of STOMP as an application level WebSocket sub-protocol.

Section 21.1, "Introduction" establishes a frame of mind in which to think about WebSocket, covering adoption challenges, design considerations, and thoughts on when it is a good fit.

Section 21.2, "WebSocket API" reviews the Spring WebSocket API on the server-side while Section 21.3, "SockJS Fallback Options" explains the SockJS protocol and shows how to configure and use it.

the section called "Overview of STOMP" introduces the STOMP messaging protocol. the section called "Enable STOMP over WebSocket" demonstrates how to configure STOMP support in Spring. the section called "Annotation Message Handling" and the following sections explain how to write annotated message handling methods, send messages, choose message broker options, as well as work with the special "user" destinations. Finally, the section called "Testing Annotated Controller Methods" lists three approaches to testing STOMP/WebSocket applications.

21.1 Introduction

The WebSocket protocol RFC 6455 defines an important new capability for web applications: full-duplex, two-way communication between client and server. It is an exciting new capability on the heels of a long history of techniques to make the web more interactive including Java applets, XMLHttpRequest, Adobe Flash, ActiveXObject, various Comet techniques, server-sent events, and others.

A proper introduction of the WebSocket protocol is beyond the scope of this document. At a minimum however it's important to understand that HTTP is used only for the initial handshake, which relies on a mechanism built into HTTP to request a protocol upgrade (or in this case a protocol switch) to which the server can respond with HTTP status 101 (switching protocols) if it agrees. Assuming the handshake succeeds the TCP socket underlying the HTTP upgrade request remains open and both client and server can use it to send messages to each other.

Spring Framework 4 includes a new `spring-websocket` module with comprehensive WebSocket support. It is compatible with the Java WebSocket API standard (JSR-356) and also provides additional value-add as explained in the rest of the introduction.

WebSocket Fallback Options

An important challenge to adoption is the lack of support for WebSocket in some browsers. Notably the first Internet Explorer version to support WebSocket is version 10 (see http://caniuse.com/websockets for support by browser versions). Furthermore, some restrictive proxies may be configured in ways that either preclude the attempt to do HTTP upgrade or otherwise break connection after some time because it has remained opened for too long. A good overview on this topic from Peter Lubbers is available in the InfoQ article "How HTML5 Web Sockets Interact With Proxy Servers".

Therefore to build a WebSocket application today, fallback options are required to simulate the WebSocket API where necessary. Spring Framework provides such transparent fallback options based on the SockJS protocol. These options can be enabled through configuration and do not require modifying the application otherwise.

A Messaging Architecture

Aside from short-to-midterm adoption challenges, using WebSocket brings up important design considerations that are important to recognize early on, especially in contrast to what we know about building web applications today.

Today REST is a widely accepted, understood, and supported architecture for building web applications. It is an architecture that relies on having many URLs (*nouns*), a handful of HTTP methods (*verbs*), and other principles such as using hypermedia (*links*), remaining stateless, etc.

By contrast a WebSocket application may use a single URL only for the initial HTTP handshake. All messages thereafter share and flow on the same TCP connection. This points to an entirely different, asynchronous, event-driven, messaging architecture. One that is much closer to traditional messaging applications (e.g. JMS, AMQP).

Spring Framework 4 includes a new `spring-messaging` module with key abstractions from the Spring Integration project such as `Message`, `MessageChannel`, `MessageHandler` and others that can serve as a foundation for such a messaging architecture. The module also includes a set of annotations for mapping messages to methods, similar to the Spring MVC annotation based programming model.

Sub-Protocol Support in WebSocket

WebSocket does imply a *messaging architecture* but does not mandate the use of any specific *messaging protocol*. It is a very thin layer over TCP that transforms a stream of bytes into a stream of messages (either text or binary) and not much more. It is up to applications to interpret the meaning of a message.

Unlike HTTP, which is an application-level protocol, in the WebSocket protocol there is simply not enough information in an incoming message for a framework or container to know how to route it or process it. Therefore WebSocket is arguably too low level for anything but a very trivial application. It can be done, but it will likely lead to creating a framework on top. This is comparable to how most web applications today are written using a web framework rather than the Servlet API alone.

For this reason the WebSocket RFC defines the use of sub-protocols. During the handshake, client and server can use the header `Sec-WebSocket-Protocol` to agree on a sub-protocol, i.e. a higher, application-level protocol to use. The use of a sub-protocol is not required, but even if not used, applications will still need to choose a message format that both client and server can understand. That format can be custom, framework-specific, or a standard messaging protocol.

Spring Framework provides support for using STOMP — a simple, messaging protocol originally created for use in scripting languages with frames inspired by HTTP. STOMP is widely support and well suited for use over WebSocket and over the web.

Should I Use WebSocket?

With all the design considerations surrounding the use of WebSocket, it is reasonable to ask when is it appropriate to use?

The best fit for WebSocket is in web applications where client and server need to exchange events at high frequency and at low latency. Prime candidates include but are not limited to applications in finance, games, collaboration, and others. Such applications are both very sensitive to time delays and also need to exchange a wide variety of messages at high frequency.

For other application types, however, this may not be the case. For example, a news or social feed that shows breaking news as they become available may be perfectly okay with simple polling once every few minutes. Here latency is important, but it is acceptable if the news takes a few minutes to appear.

Even in cases where latency is crucial, if the volume of messages is relatively low (e.g. monitoring network failures) the use of long polling should be considered as a relatively simple alternative that works reliably and is comparable by efficiency (again assuming the volume of messages is relatively low).

It is the combination of both low latency and high frequency of messages that can make the use of the WebSocket protocol critical. Even in such applications, the choice remains whether all client-server communication should be done through WebSocket messages as opposed to using HTTP and REST? The answer is going to vary by application, however, it is likely that some functionality may be exposed over both WebSocket and as a REST API in order to provide clients with alternatives. Furthermore, a REST API call may need to broadcast a message to interested clients connected via WebSocket.

Spring Framework allows `@Controller` and `@RestController` classes to have both HTTP request handling and WebSocket message handling methods. Furthermore, a Spring MVC request handling method, or any application method for that matter, can easily broadcast a message to all interested WebSocket clients or to a specific user.

21.2 WebSocket API

The Spring Framework provides a WebSocket API designed to adapt to various WebSocket engines. For example, it runs on JSR-356 runtimes such as Tomcat (7.0.47+), GlassFish (4.0+) and WildFly (8.0+) but can also adapt to other WebSocket runtimes such as the Jetty (9.1+) native WebSocket support.

> **Note**
>
> As explained in the introduction, direct use of a WebSocket API is too low level for applications — until assumptions are made about the format of a message there is little a framework can do to interpret messages or route them via annotations. This is why applications should consider using a sub-protocol and Spring's STOMP over WebSocket support.
>
> When using a higher level protocol, the details of the WebSocket API become less relevant, much like the details of TCP communication are not exposed to applications when using HTTP. Nevertheless this section covers the details of using WebSocket directly.

Create and Configure a WebSocketHandler

Creating a WebSocket server is as simple as implementing `WebSocketHandler` or more likely extending either `TextWebSocketHandler` or `BinaryWebSocketHandler`:

```
import org.springframework.web.socket.WebSocketHandler;
import org.springframework.web.socket.WebSocketSession;
import org.springframework.web.socket.TextMessage;

public class MyHandler extends TextWebSocketHandler {

    @Override
    public void handleTextMessage(WebSocketSession session, TextMessage message) {
        // ...
    }

}
```

There is dedicated WebSocket Java-config and XML namespace support for mapping the above WebSocket handler at a specific URL:

```
import org.springframework.web.socket.config.annotation.EnableWebSocket;
import org.springframework.web.socket.config.annotation.WebSocketConfigurer;
import org.springframework.web.socket.config.annotation.WebSocketHandlerRegistry;

@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(myHandler(), "/myHandler");
    }

    @Bean
    public WebSocketHandler myHandler() {
        return new MyHandler();
    }

}
```

XML configuration equivalent:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:handlers>
        <websocket:mapping path="/myHandler" handler="myHandler"/>
    </websocket:handlers>

    <bean id="myHandler" class="org.springframework.samples.MyHandler"/>

</beans>
```

The above is for use in Spring MVC applications and should be included in the configuration of a DispatcherServlet. However, Spring's WebSocket support does not depend on Spring MVC. It is relatively simple to integrate a `WebSocketHandler` into other HTTP serving environments with the help of WebSocketHttpRequestHandler.

Customizing the WebSocket Handshake

The easiest way to customize the initial HTTP WebSocket handshake request is through a `HandshakeInterceptor`, which exposes "before" and "after" the handshake methods. Such an interceptor can be used to preclude the handshake or to make any attributes available to the `WebSocketSession`. For example, there is a built-in interceptor for passing HTTP session attributes to the WebSocket session:

```
@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(new MyHandler(), "/myHandler")
            .addInterceptors(new HttpSessionHandshakeInterceptor());
    }

}
```

And the XML configuration equivalent:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:handlers>
        <websocket:mapping path="/myHandler" handler="myHandler"/>
        <websocket:handshake-interceptors>
            <bean class="org.springframework.web.socket.server.support.HttpSessionHandshakeInterceptor"/
>
        </websocket:handshake-interceptors>
    </websocket:handlers>

    <bean id="myHandler" class="org.springframework.samples.MyHandler"/>

</beans>
```

A more advanced option is to extend the `DefaultHandshakeHandler` that performs the steps of the WebSocket handshake, including validating the client origin, negotiating a sub-protocol, and others. An application may also need to use this option if it needs to configure a custom `RequestUpgradeStrategy` in order to adapt to a WebSocket server engine and version that is not yet supported (also see the section called “Deployment Considerations” for more on this subject). Both the Java-config and XML namespace make it possible to configure a custom `HandshakeHandler`.

WebSocketHandler Decoration

Spring provides a `WebSocketHandlerDecorator` base class that can be used to decorate a `WebSocketHandler` with additional behavior. Logging and exception handling implementations are provided and added by default when using the WebSocket Java-config or XML namespace. The `ExceptionWebSocketHandlerDecorator` catches all uncaught exceptions arising from any WebSocketHandler method and closes the WebSocket session with status `1011` that indicates a server error.

Deployment Considerations

The Spring WebSocket API is easy to integrate into a Spring MVC application where the `DispatcherServlet` serves both HTTP WebSocket handshake as well as other HTTP requests. It is also easy to integrate into other HTTP processing scenarios by invoking `WebSocketHttpRequestHandler`. This is convenient and easy to understand. However, special considerations apply with regards to JSR-356 runtimes.

The Java WebSocket API (JSR-356) provides two deployment mechanisms. The first involves a Servlet container classpath scan (Servlet 3 feature) at startup; and the other is a registration API to use at Servlet

container initialization. Neither of these mechanism make it possible to use a single "front controller" for all HTTP processing — including WebSocket handshake and all other HTTP requests — such as Spring MVC's `DispatcherServlet`.

This is a significant limitation of JSR-356 that Spring's WebSocket support addresses by providing a server-specific `RequestUpgradeStrategy` even when running in a JSR-356 runtime. At present such support is available on Tomcat 7.0.47+, Jetty 9.1+, GlassFish 4.0+, and WildFly 8.0+. Additional support will be added as more WebSocket runtimes become available.

> **Note**
>
> A request to overcome the above limitation in the Java WebSocket API has been created and can be followed at WEBSOCKET_SPEC-211. Also note that Tomcat and Jetty already provide native API alternatives that makes it easy to overcome the limitation. We are hopeful that more servers will follow their example regardless of when it is addressed in the Java WebSocket API.

A secondary consideration is that Servlet containers with JSR-356 support are expected to perform an SCI scan that can slow down application startup, in some cases dramatically. If a significant impact is observed after an upgrade to a Servlet container version with JSR-356 support, it should be possible to selectively enable or disable web fragments (and SCI scanning) through the use of an `<absolute-ordering />` element in `web.xml`:

```
<web-app xmlns="http://java.sun.com/xml/ns/javaee"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://java.sun.com/xml/ns/javaee
        http://java.sun.com/xml/ns/javaee/web-app_3_0.xsd"
    version="3.0">

    <absolute-ordering/>

</web-app>
```

You can then selectively enable web fragments by name, such as Spring's own `SpringServletContainerInitializer` that provides support for the Servlet 3 Java initialization API, if required:

```
<web-app xmlns="http://java.sun.com/xml/ns/javaee"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://java.sun.com/xml/ns/javaee
        http://java.sun.com/xml/ns/javaee/web-app_3_0.xsd"
    version="3.0">

    <absolute-ordering>
        <name>spring_web</name>
    </absolute-ordering>

</web-app>
```

Configuring the WebSocket Engine

Each underlying WebSocket engine exposes configuration properties that control runtime characteristics such as the size of message buffer sizes, idle timeout, and others.

For Tomcat, WildFly, and Glassfish add a `ServletServerContainerFactoryBean` to your WebSocket Java config:

```
@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Bean
    public ServletServerContainerFactoryBean createWebSocketContainer() {
        ServletServerContainerFactoryBean container = new ServletServerContainerFactoryBean();
        container.setMaxTextMessageBufferSize(8192);
        container.setMaxBinaryMessageBufferSize(8192);
        return container;
    }

}
```

or WebSocket XML namespace:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <bean class="org.springframework...ServletServerContainerFactoryBean">
        <property name="maxTextMessageBufferSize" value="8192"/>
        <property name="maxBinaryMessageBufferSize" value="8192"/>
    </bean>

</beans>
```

> **Note**
>
> For client side WebSocket configuration, you should use `WebSocketContainerFactoryBean` (XML) or `ContainerProvider.getWebSocketContainer()` (Java config).

For Jetty, you'll need to supply a pre-configured Jetty `WebSocketServerFactory` and plug that into Spring's `DefaultHandshakeHandler` through your WebSocket Java config:

```
@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(echoWebSocketHandler(),
            "/echo").setHandshakeHandler(handshakeHandler());
    }

    @Bean
    public DefaultHandshakeHandler handshakeHandler() {

        WebSocketPolicy policy = new WebSocketPolicy(WebSocketBehavior.SERVER);
        policy.setInputBufferSize(8192);
        policy.setIdleTimeout(600000);

        return new DefaultHandshakeHandler(
                new JettyRequestUpgradeStrategy(new WebSocketServerFactory(policy)));
    }

}
```

or WebSocket XML namespace:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:handlers>
        <websocket:mapping path="/echo" handler="echoHandler"/>
        <websocket:handshake-handler ref="handshakeHandler"/>
    </websocket:handlers>

    <bean id="handshakeHandler" class="org.springframework...DefaultHandshakeHandler">
        <constructor-arg ref="upgradeStrategy"/>
    </bean>

    <bean id="upgradeStrategy" class="org.springframework...JettyRequestUpgradeStrategy">
        <constructor-arg ref="serverFactory"/>
    </bean>

    <bean id="serverFactory" class="org.eclipse.jetty...WebSocketServerFactory">
        <constructor-arg>
            <bean class="org.eclipse.jetty...WebSocketPolicy">
                <constructor-arg value="SERVER"/>
                <property name="inputBufferSize" value="8092"/>
                <property name="idleTimeout" value="600000"/>
            </bean>
        </constructor-arg>
    </bean>

</beans>
```

21.3 SockJS Fallback Options

As explained in the introduction, WebSocket is not supported in all browsers yet and may be precluded by restrictive network proxies. This is why Spring provides fallback options that emulate the WebSocket API as close as possible based on the SockJS protocol.

Overview of SockJS

The goal of SockJS is to let applications use a WebSocket API but fall back to non-WebSocket alternatives when necessary at runtime, i.e. without the need to change application code.

SockJS consists of:

- The SockJS protocol defined in the form of executable narrated tests.
- The SockJS JavaScript client - a client library for use in browsers.
- SockJS server implementations including one in the Spring Framework `spring-websocket` module.
- As of 4.1 `spring-websocket` also provides a SockJS Java client.

SockJS is designed for use in browsers. It goes to great lengths to support a wide range of browser versions using a variety of techniques. For the full list of SockJS transport types and browsers see the SockJS client page. Transports fall in 3 general categories: WebSocket, HTTP Streaming, and HTTP Long Polling. For an overview of these categories see this blog post.

The SockJS client begins by sending `"GET /info"` to obtain basic information from the server. After that it must decide what transport to use. If possible WebSocket is used. If not, in most browsers there is at least one HTTP streaming option and if not then HTTP (long) polling is used.

All transport requests have the following URL structure:

```
http://host:port/myApp/myEndpoint/{server-id}/{session-id}/{transport}
```

- `{server-id}` - useful for routing requests in a cluster but not used otherwise.
- `{session-id}` - correlates HTTP requests belonging to a SockJS session.
- `{transport}` - indicates the transport type, e.g. "websocket", "xhr-streaming", etc.

The WebSocket transport needs only a single HTTP request to do the WebSocket handshake. All messages thereafter are exchanged on that socket.

HTTP transports require more requests. Ajax/XHR streaming for example relies on one long-running request for server-to-client messages and additional HTTP POST requests for client-to-server messages. Long polling is similar except it ends the current request after each server-to-client send.

SockJS adds minimal message framing. For example the server sends the letter o ("open" frame) initially, messages are sent as `a["message1","message2"]` (JSON-encoded array), the letter h ("heartbeat" frame) if no messages flow for 25 seconds by default, and the letter c ("close" frame) to close the session.

To learn more run an example in a browser and watch HTTP requests. The SockJS client allows fixing the list of transports so it is possible to see each transport one at a time. The SockJS client also provides a debug flag which enables helpful messages in the browser console. On the server side enable TRACE logging for `org.springframework.web.socket`. For even more detail refer to the SockJS protocol narrated test.

Enable SockJS

SockJS is easy to enable through a configuration:

```
@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Override
    public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
        registry.addHandler(myHandler(), "/myHandler").withSockJS();
    }

    @Bean
    public WebSocketHandler myHandler() {
        return new MyHandler();
    }

}
```

and the XML configuration equivalent:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:handlers>
        <websocket:mapping path="/myHandler" handler="myHandler"/>
        <websocket:sockjs/>
    </websocket:handlers>

    <bean id="myHandler" class="org.springframework.samples.MyHandler"/>

</beans>
```

The above is for use in Spring MVC applications and should be included in the configuration of a DispatcherServlet. However, Spring's WebSocket and SockJS support does not depend on Spring MVC. It is relatively simple to integrate into other HTTP serving environments with the help of SockJsHttpRequestHandler.

On the browser side, applications can use the sockjs-client that emulates the W3C WebSocket API and communicates with the server to select the best transport option depending on the browser it's running in. Review the sockjs-client page and the list of transport types supported by browser. The client also provides several configuration options, for example, to specify which transports to include.

HTTP Streaming in IE 8, 9: Ajax/XHR vs IFrame

Internet Explorer 8 and 9 are and will remain common for some time. They are a key reason for having SockJS. This section covers important considerations about running in those browsers.

SockJS client supports Ajax/XHR streaming in IE 8, 9 via Microsoft's XDomainRequest. That works across domains but does not support sending cookies. Cookies are very often essential for Java applications. However since the SockJS client can be used with many server types (not just Java ones), it needs to know whether cookies do matter. If so the SockJS client prefers Ajax/XHR for streaming or otherwise it relies on a iframe-based technique.

The very first `"/info"` request from the SockJS client is a request for information that can influence the client's choice of transports. One of those details is whether the server application relies on cookies, e.g. for authentication purposes or clustering with sticky sessions. Spring's SockJS support includes a property called `sessionCookieNeeded`. It is enabled by default since most Java applications rely on the `JSESSIONID` cookie. If your application does not need it, you can turn off this option and the SockJS client should choose `xdr-streaming` in IE 8 and 9.

If you do use an iframe-based transport, and in any case, it is good to know that browsers can be instructed to block the use of iframes on a given page by setting the HTTP response header `X-Frame-Options` to `DENY`, `SAMEORIGIN`, or `ALLOW-FROM <origin>`. This is used to prevent clickjacking.

> **Note**
>
> Spring Security 3.2+ provides support for setting `X-Frame-Options` on every response. By default the Spring Security Java config sets it to `DENY`. In 3.2 the Spring Security XML namespace does not set that header by default but may be configured to do so, and in the future it may set it by default.

> See Section 7.1. "Default Security Headers" of the Spring Security documentation for details no how to configure the setting of the `X-Frame-Options` header. You may also check or watch SEC-2501 for additional background.

If your application adds the `X-Frame-Options` response header (as it should!) and relies on an iframe-based transport, you will need to set the header value to `SAMEORIGIN` or `ALLOW-FROM <origin>`. Along with that the Spring SockJS support also needs to know the location of the SockJS client because it is loaded from the iframe. By default the iframe is set to download the SockJS client from a CDN location. It is a good idea to configure this option to a URL from the same origin as the application.

In Java config this can be done as shown below. The XML namespace provides a similar option on the `<websocket:sockjs>` element:

```
@Configuration
@EnableWebSocket
public class WebSocketConfig implements WebSocketConfigurer {

    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/portfolio").withSockJS()
                .setClientLibraryUrl("http://localhost:8080/myapp/js/sockjs-client.js");
    }

    // ...

}
```

> **Note**
>
> During initial development, do enable the SockJS client `devel` mode that prevents the browser from caching SockJS requests (like the iframe) that would otherwise be cached. For details on how to enable it see the SockJS client page.

Heartbeat Messages

The SockJS protocol requires servers to send heartbeat messages to preclude proxies from concluding a connection is hung. The Spring SockJS configuiration has a property called `heartbeatTime` that can be used to customize the frequency. By default a heartbeat is sent after 25 seconds assuming no other messages were sent on that connection. This 25 seconds value is in line with the following IETF recommendation for public Internet applications.

> **Note**
>
> When using STOMP over WebSocket/SockJS, if the STOMP client and server negotiate heartbeats to be exchanged, the SockJS heartbeats are disabled.

The Spring SockJS support also allows configuring the `TaskScheduler` to use for scheduling heartbeats tasks. The task scheduler is backed by a thread pool with default settings based on the number of available processors. Applications should consider customizing the settings according to their specific needs.

Servlet 3 Async Requests

HTTP streaming and HTTP long polling SockJS transports require a connection to remain open longer than usual. For an overview of these techniques see this blog post.

In Servlet containers this is done through Servlet 3 async support that allows exiting the Servlet container thread processing a request and continuing to write to the response from another thread.

A specific issue is the Servlet API does not provide notifications for a client that has gone away, see SERVLET_SPEC-44. However, Servlet containers raise an exception on subseqeunt attempts to write to the response. Since Spring's SockJS Service support sever-sent heartbeats (every 25 seconds by default), that means a client disconnect is usually detected within that time period or earlier if a message are sent more frequently.

> **Note**
>
> As a result network IO failures may occur simply because a client has disconnected, which can fill the log with unnecessary stack traces. Spring makes a best effort to identify such network failures that represent client disconnects (specific to each server) and log a more minimal message using the dedicated log category `DISCONNECTED_CLIENT_LOG_CATEGORY` defined in `AbstractSockJsSession`. If you need to see the stack traces, set that log category to TRACE.

CORS Headers for SockJS

The SockJS protocol uses CORS for cross-domain support in the XHR streaming and polling transports. Therefore CORS headers are added automatically unless the presence of CORS headers in the response is detected. So if an application is already configured to provide CORS support, e.g. through a Servlet Filter, Spring's SockJsService will skip this part.

It is also possible to disable the addition of these CORS headers thanks to the `suppressCors` property in Spring's SockJsService.

The following is the list of headers and values expected by SockJS:

- `"Access-Control-Allow-Origin"` - initialized from the value of the "Origin" request header.
- `"Access-Control-Allow-Credentials"` - always set to `true`.
- `"Access-Control-Request-Headers"` - initialized from values from the equivalent request header.
- `"Access-Control-Allow-Methods"` - the HTTP methods a transport supports (see `TransportType` enum).
- `"Access-Control-Max-Age"` - set to 31536000 (1 year).

For the exact implementation see `addCorsHeaders` in `AbstractSockJsService` as well as the `TransportType` enum in the source code.

Alternatively if the CORS configuration allows it consider excluding URLs with the SockJS endpoint prefix thus letting Spring's SockJsService handle it.

SockJS Client

A SockJS Java client is provided in order to connect to remote SockJS endpoints without using a browser. This can be especially useful when there is a need of bidirectional communication between 2 servers over a public network, i.e. where network proxies may preclude the use of the WebSocket protocol. A SockJS Java client is also very useful for testing purposes for example to simulate a large number of concurrent users.

The SockJS Java client supports the "websocket", "xhr-streaming", and "xhr-polling" transports. The remaining ones only make sense for use in a browser.

The `WebSocketTransport` can be configured with:

- `StandardWebSocketClient` in a JSR-356 runtime
- `JettyWebSocketClient` using the Jetty 9+ native WebSocket API
- Any implementation of Spring's `WebSocketClient`

An `XhrTransport` by definition supports both "xhr-streaming" and "xhr-polling" since from a client perspective there is no difference other than in the URL used to connect to the server. At present there are two implementations:

- `RestTemplateXhrTransport` uses the RestTemplate for HTTP requests.
- `JettyXhrTransport` uses Jetty's HttpClient for HTTP requests.

The example below shows how to create a SockJS client and connect to a SockJS endpoint:

```
List<Transport> transports = new ArrayList<>(2);
transports.add(new WebSocketTransport(StandardWebSocketClient()));
transports.add(new RestTemplateXhrTransport());

SockJsClient sockJsClient = new SockJsClient(transports);
sockJsClient.doHandshake(new MyWebSocketHandler(), "ws://example.com:8080/sockjs");
```

> **Note**
>
> SockJS uses JSON formatted arrays for messages. By default Jackson 2 is used and needs to be on the classpath. Alternatively you can configure a custom implementation of `SockJsMessageCodec` and configure it on the SockJsClient.

To use the SockJsClient for simulating a large number of concurrent users you will need to configure the underlying HTTP client (for XHR transports) to allow a sufficient number of connections and threads. For example with Jetty:

```
HttpClient jettyHttpClient = new HttpClient();
jettyHttpClient.setMaxConnectionsPerDestination(1000);
jettyHttpClient.setExecutor(new QueuedThreadPool(1000));
```

Consider also customizing these server-side SockJS related properties (see Javadoc for details):

```
@Configuration
public class WebSocketConfig extends WebSocketMessageBrokerConfigurationSupport {

    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/sockjs").withSockJS()
            .setStreamBytesLimit(512 * 1024)
            .setHttpMessageCacheSize(1000)
            .setDisconnectDelay(30 * 1000);
    }

    // ...

}
```

21.4 STOMP Over WebSocket Messaging Architecture

The WebSocket protocol defines two main types of messages — text and binary — but leaves their content undefined. Instead it's expected that client and server may agree on using a sub-protocol, i.e. a higher-level protocol that defines the message content. Using a sub-protocol is optional but either way client and server both need to understand how to interpret messages.

Overview of STOMP

STOMP is a simple messaging protocol originally created for scripting languages (such as Ruby, Python and Perl) to connect to enterprise message brokers. It is designed to address a subset of commonly used patterns in messaging protocols. STOMP can be used over any reliable 2-way streaming network protocol such as TCP and WebSocket.

STOMP is a frame based protocol with frames modelled on HTTP. This is the structure of a frame:

```
COMMAND
header1:value1
header2:value2

Body^@
```

For example, a client can use the `SEND` command to send a message or the `SUBSCRIBE` command to express interest in receiving messages. Both of these commands require a `"destination"` header that indicates where to send a message to, or likewise what to subscribe to.

Here is an example of a client sending a request to buy stock shares:

```
SEND
destination:/queue/trade
content-type:application/json
content-length:44

{"action":"BUY","ticker":"MMM","shares",44}^@
```

Here is an example of a client subscribing to receive stock quotes:

```
SUBSCRIBE
id:sub-1
destination:/topic/price.stock.*

^@
```

> **Note**
>
> The meaning of a destination is intentionally left opaque in the STOMP spec. It can be any string and it's entirely up to STOMP servers to define the semantics and the syntax of the destinations that they support. It is very common however, for destinations to be path-like strings where `"/topic/.."` implies publish-subscribe (*one-to-many*) and `"/queue/"` to implies point-to-point (*one-to-one*) message exchanges.

STOMP servers can use the `MESSAGE` command to broadcast messages to all subscribers. Here is an example of a server sending a stock quote to a subscribed client:

```
MESSAGE
message-id:nxahklf6-1
subscription:sub-1
destination:/topic/price.stock.MMM

{"ticker":"MMM","price":129.45}^@
```

> **Note**
>
> It's important to know that a server cannot send unsolicited messages. All messages from a server must be in response to a specific client subscription and the `"subscription-id"` header of the server message must match the `"id"` header of the client subscription.

The above overview is intended to provide the most basic understanding of the STOMP protocol. It is recommended to review the protocol specification, which is easy to follow and manageable in terms of size.

The following summarizes the benefits for an application from using STOMP over WebSocket:

- Standard message format
- Application-level protocol with support for common messaging patterns
- Client-side support, e.g. stomp.js, msgs.js
- The ability to interpret, route, and process messages on both client and server-side
- The option to plug a message broker — RabbitMQ, ActiveMQ, many others — to broadcast messages (explained later)

Most importantly the use of STOMP (vs plain WebSocket) enables the Spring Framework to provide a programming model for application-level use in the same way that Spring MVC provides a programming model based on HTTP.

Enable STOMP over WebSocket

The Spring Framework provides support for using STOMP over WebSocket through the `spring-messaging` and `spring-websocket` modules. It's easy to enable it.

Here is an example of configuring a STOMP WebSocket endpoint with SockJS fallback options. The endpoint is available for clients to connect to at URL path `/app/portfolio`:

```
import org.springframework.web.socket.config.annotation.EnableWebSocketMessageBroker;
import org.springframework.web.socket.config.annotation.StompEndpointRegistry;

@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfig implements WebSocketMessageBrokerConfigurer {

    @Override
    public void configureMessageBroker(MessageBrokerRegistry config) {
        config.setApplicationDestinationPrefixes("/app");
        config.enableSimpleBroker("/queue", "/topic");
    }

    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/portfolio").withSockJS();
    }

    // ...

}
```

XML configuration equivalent:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:message-broker application-destination-prefix="/app">
        <websocket:stomp-endpoint path="/portfolio">
            <websocket:sockjs/>
        </websocket:stomp-endpoint>
        <websocket:simple-broker prefix="/queue, /topic"/>
        ...
    </websocket:message-broker>

</beans>
```

On the browser side, a client might connect as follows using stomp.js and the sockjs-client:

```
var socket = new SockJS("/spring-websocket-portfolio/portfolio");
var stompClient = Stomp.over(socket);

stompClient.connect({}, function(frame) {
}
```

Or if connecting via WebSocket (without SockJS):

```
var socket = new WebSocket("/spring-websocket-portfolio/portfolio");
var stompClient = Stomp.over(socket);

stompClient.connect({}, function(frame) {
}
```

Note that the stompClient above does not need to specify a `login` and `passcode` headers. Even if it did, they would be ignored, or rather overridden, on the server side. See the sections the section called “Connections To Full-Featured Broker” and the section called “Authentication” for more information on authentication.

Flow of Messages

When a STOMP endpoint is configured, the Spring application acts as the STOMP broker to connected clients. It handles incoming messages and sends messages back. This section provides a big picture overview of how messages flow inside the application.

The `spring-messaging` module contains a number of abstractions that originated in the Spring Integration project and are intended for use as building blocks in messaging applications:

- Message — represents a message with headers and a payload.
- MessageHandler — a contract for handling a message.
- MessageChannel — a contract for sending a message enabling loose coupling between senders and receivers.
- SubscribableChannel — extends `MessageChannel` and sends messages to registered `MessageHandler` subscribers.
- ExecutorSubscribableChannel — a concrete implementation of `SubscribableChannel` that can deliver messages asynchronously through a thread pool.

The provided STOMP over WebSocket config, both Java and XML, uses the above to assemble a concrete message flow including the following 3 channels:

- `"clientInboundChannel"` — for messages from WebSocket clients. Every incoming WebSocket message carrying a STOMP frame is sent through this channel.
- `"clientOutboundChannel"` — for messages to WebSocket clients. Every outgoing STOMP message from the broker is sent through this channel before getting sent to a client's WebSocket session.
- `"brokerChannel"` — for messages to the broker from within the application. Every message sent from the application to the broker passes through this channel.

Messages on the `"clientInboundChannel"` can flow to annotated methods for application handling (e.g. a stock trade execution request) or can be forwarded to the broker (e.g. client subscribing for stock quotes). The STOMP destination is used for simple prefix-based routing. For example the "/app" prefix could route messages to annotated methods while the "/topic" and "/queue" prefixes could route messages to the broker.

When a message-handling annotated method has a return type, its return value is sent as the payload of a Spring Message to the `"brokerChannel"`. The broker in turn broadcasts the message to clients. Sending a message to a destination can also be done from anywhere in the application with the help of a messaging template. For example a an HTTP POST handling method can broadcast a message to connected clients or a service component may periodically broadcast stock quotes.

Below is a simple example to illustrate the flow of messages:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfig implements WebSocketMessageBrokerConfigurer {

    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/portfolio");
    }

    @Override
    public void configureMessageBroker(MessageBrokerRegistry registry) {
        registry.setApplicationDestinationPrefixes("/app");
        registry.enableSimpleBroker("/topic");
    }

}

@Controller
public class GreetingController {

    @MessageMapping("/greeting") {
    public String handle(String greeting) {
        return "[" + getTimestamp() + ": " + greeting;
    }

}
```

The following explains the message flow for the above exmaple:

- WebSocket clients connect to the WebSocket endpoint at "/portfolio".
- Subscriptions to "/topic/greeting" pass through the "clientInboundChannel" and are forwarded to the broker.
- Greetings sent to "/app/greeting" pass through the "clientInboundChannel" and are forwarded to the `GreetingController`. The controller adds the current time and the return value is passed through the "brokerChannel" as message to "/topic/greeting" (destination is selected based on a convention but can be overridden via `@SendTo`).
- The broker in turn broadcasts messages to subscribers and they pass through the `"clientOutboundChannel"`.

The next section provides more details on annotated methods including the kinds of arguments and return values supported.

Annotation Message Handling

The `@MessageMapping` annotation is supported on methods of `@Controller` classes. It can be used for mapping methods to message destinations and can also be combined with the type-level `@MessageMapping` for expressing shared mappings across all annotated methods within a controller.

By default destination mappings are treated as Ant-style, slash-separated, path patterns, e.g. "/foo*", "/foo/**". etc. They can also contain template variables, e.g. "/foo/{id}" that can then be referenced via `@DestinationVariable`-annotated method arguments.

> **Note**
>
> Applications can also use dot-separated destinations (vs slash). See the section called “Using Dot as Separator in `@MessageMapping` Destinations”.

The following method arguments are supported for `@MessageMapping` methods:

- `Message` method argument to get access to the complete message being processed.
- `@Payload`-annotated argument for access to the payload of a message, converted with a `org.springframework.messaging.converter.MessageConverter`. The presence of the annotation is not required since it is assumed by default. Payload method arguments annotated with Validation annotations (like `@Validated`) will be subject to JSR-303 validation.
- `@Header`-annotated arguments for access to a specific header value along with type conversion using an `org.springframework.core.convert.converter.Converter` if necessary.
- `@Headers`-annotated method argument that must also be assignable to `java.util.Map` for access to all headers in the message.
- `MessageHeaders` method argument for getting access to a map of all headers.
- `MessageHeaderAccessor`, `SimpMessageHeaderAccessor`, or `StompHeaderAccessor` for access to headers via typed accessor methods.
- `@DestinationVariable`-annotated arguments for access to template variables extracted from the message destination. Values will be converted to the declared method argument type as necessary.
- `java.security.Principal` method arguments reflecting the user logged in at the time of the WebSocket HTTP handshake.

The return value from an `@MessageMapping` method is converted with a `org.springframework.messaging.converter.MessageConverter` and used as the body of a new message that is then sent, by default, to the `"brokerChannel"` with the same destination as the client message but using the prefix "/topic" by default. An `@SendTo` message level annotation can be used to specify any other destination instead.

An `@SubscribeMapping` annotation can also be used to map subscription requests to `@Controller` methods. It is supported on the method level, but can also be combined with a type level `@MessageMapping` annotation that expresses shared mappings across all message handling methods within the same controller.

By default the return value from an `@SubscribeMapping` method is sent as a message directly back to the connected client and does not pass through the broker. This is useful for implementing request-reply message interactions; for example, to fetch application data when the application UI is being initialized. Or alternatively an `@SubscribeMapping` method can be annotated with `@SendTo` in which case the resulting message is sent to the `"brokerChannel"` using the specified target destination.

Sending Messages

What if you wanted to send messages to connected clients from any part of the application? Any application component can send messages to the `"brokerChannel"`. The easiest way to do that is to have a `SimpMessagingTemplate` injected, and use it to send messages. Typically it should be easy to have it injected by type, for example:

```
@Controller
public class GreetingController {

    private SimpMessagingTemplate template;

    @Autowired
    public GreetingController(SimpMessagingTemplate template) {
        this.template = template;
    }

    @RequestMapping(value="/greetings", method=POST)
    public void greet(String greeting) {
        String text = "[" + getTimestamp() + "]:" + greeting;
        this.template.convertAndSend("/topic/greetings", text);
    }

}
```

But it can also be qualified by its name "brokerMessagingTemplate" if another bean of the same type exists.

Simple Broker

The built-in, simple, message broker handles subscription requests from clients, stores them in memory, and broadcasts messages to connected clients with matching destinations. The broker supports path-like destinations, including subscriptions to Ant-style destination patterns.

> **Note**
>
> Applications can also use dot-separated destinations (vs slash). See the section called “Using Dot as Separator in `@MessageMapping` Destinations”.

Full-Featured Broker

The simple broker is great for getting started but supports only a subset of STOMP commands (e.g. no acks, receipts, etc), relies on a simple message sending loop, and is not suitable for clustering. Instead, applications can upgrade to using a full-featured message broker.

Check the STOMP documentation for your message broker of choice (e.g. RabbitMQ, ActiveMQ, or other), install and run the broker with STOMP support enabled. Then enable the STOMP broker relay in the Spring configuration instead of the simple broker.

Below is example configuration that enables a full-featured broker:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfig implements WebSocketMessageBrokerConfigurer {

    @Override
    public void registerStompEndpoints(StompEndpointRegistry registry) {
        registry.addEndpoint("/portfolio").withSockJS();
    }

    @Override
    public void configureMessageBroker(MessageBrokerRegistry registry) {
        registry.enableStompBrokerRelay("/topic", "/queue");
        registry.setApplicationDestinationPrefixes("/app");
    }

}
```

XML configuration equivalent:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:message-broker application-destination-prefix="/app">
        <websocket:stomp-endpoint path="/portfolio" />
            <websocket:sockjs/>
        </websocket:stomp-endpoint>
        <websocket:stomp-broker-relay prefix="/topic,/queue" />
    </websocket:message-broker>

</beans>
```

The "STOMP broker relay" in the above configuration is a Spring MessageHandler that handles messages by forwarding them to an external message broker. To do so it establishes TCP connections to the broker, forwards all messages to it, and reversely forwards all messages received from the broker to clients through their WebSocket sessions. Essentially it acts as a "relay" forwarding messages in both directions.

> **Note**
>
> Please add a dependency on `org.projectreactor:reactor-net` for TCP connection management.

Furthermore, application components (e.g. HTTP request handling methods, business services, etc) can also send messages to the broker relay, as described in the section called “Sending Messages”, in order to broadcast messages to subscribed WebSocket clients.

In effect, the broker relay enables robust and scalable message broadcasting.

Connections To Full-Featured Broker

A STOMP broker relay maintains a single "system" TCP connection to the broker. This connection is used for messages originating from the server-side application only, not for receiving messages. You can configure the STOMP credentials for this connection, i.e. the STOMP frame `login` and `passcode` headers. This is exposed in both the XML namespace and the Java config as the `systemLogin`/`systemPasscode` properties with default values `guest`/`guest`.

The STOMP broker relay also creates a separate TCP connection for every connected WebSocket client. You can configure the STOMP credentials to use for all TCP connections created on behalf of clients. This is exposed in both the XML namespace and the Java config as the `clientLogin`/`clientPasscode` properties with default values `guest`/`guest`.

> **Note**
>
> The STOMP broker relay always sets the `login` and `passcode` headers on every CONNECT frame it forwards to the broker on behalf of clients. Therefore WebSocket clients need not set those headers, they will be ignored. As the following section explains instead WebSocket clients should rely on HTTP authentication to protect the WebSocket endpoint and establish the client identity.

The STOMP broker relay also sends and receives heartbeats to and from the message broker over the "system" TCP connection. You can configure the intervals for sending and receiving heartbeats (10 seconds each by default). If connectivity to the broker is lost, the broker relay will continue to try to reconnect, every 5 seconds, until it succeeds.

> **Note**
>
> A Spring bean can implement `ApplicationListener<BrokerAvailabilityEvent>` in order to receive notifications when the "system" connection to the broker is lost and re-established. For example a Stock Quote service broadcasting stock quotes can stop trying to send messages when there is no active "system" connection.

The STOMP broker relay can also be configured with a `virtualHost` property. The value of this property will be set as the `host` header of every CONNECT frame and may be useful for example in a cloud environment where the actual host to which the TCP connection is established is different from the host providing the cloud-based STOMP service.

Using Dot as Separator in `@MessageMapping` Destinations

Although slash-separated path patterns are familiar to web developers, in messaging it is common to use "." as separator for example in the names of topics, queues, exchanges, etc. Applications can also switch to using "." (dot) instead of "/" (slash) as the separator in `@MessageMapping` mappings by configuring a custom `AntPathMatcher`.

In Java config:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebsocketConfig extends AbstractWebSocketMessageBrokerConfigurer {

  // ...

  @Override
  public void configureMessageBroker(MessageBrokerRegistry registry) {
    registry.enableStompBrokerRelay("/queue/", "/topic/");
    registry.setApplicationDestinationPrefixes("/app");
    registry.setPathMatcher(new AntPathMatcher("."));
  }

}
```

In XML config:

```
<beans xmlns="http://www.springframework.org/schema/beans"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:websocket="http://www.springframework.org/schema/websocket"
  xsi:schemaLocation="
    http://www.springframework.org/schema/beans
    http://www.springframework.org/schema/beans/spring-beans.xsd
    http://www.springframework.org/schema/websocket
    http://www.springframework.org/schema/websocket/spring-websocket.xsd">

  <websocket:message-broker application-destination-prefix="/app" path-matcher="pathMatcher">
    <websocket:stomp-endpoint path="/stomp" />
    <websocket:simple-broker prefix="/topic, /queue"/>
  </websocket:message-broker>

  <bean id="pathMatcher" class="org.springframework.util.AntPathMatcher">
    <constructor-arg index="0" value="." />
  </bean>

</beans>
```

And below is a simple example to illustrate a controller with "." separator:

```
@Controller
@MessageMapping("foo")
public class FooController {

  @MessageMapping("bar.{baz}")
  public void handleBaz(@DestinationVariable String baz) {
  }

}
```

If the application prefix is set to "/app" then the foo method is effectively mapped to "/app/foo.bar.{baz}".

Authentication

In a WebSocket-style application it is often useful to know who sent a message. Therefore some form of authentication is needed to establish the user identity and associate it with the current session.

Existing Web applications already use HTTP based authentication. For example Spring Security can secure the HTTP URLs of the application as usual. Since a WebSocket session begins with an HTTP handshake, that means URLs mapped to STOMP/WebSocket are already automatically protected and require authentication. Moreover the page that opens the WebSocket connection is itself likely protected and so by the time of the actual handshake, the user should have been authenticated.

When a WebSocket handshake is made and a new WebSocket session created, Spring's WebSocket support automatically transfers the `java.security.Principal` from the HTTP request to the WebSocket session. After that every message flowing through the application on that WebSocket session is enriched with the user information. It's present in the message as a header. Controller methods can access the current user by adding a method argument of type `javax.security.Principal`.

Note that even though the STOMP `CONNECT` frame has "login" and "passcode" headers that can be used for authentication, Spring's STOMP WebSocket support ignores them and currently expects users to have been authenticated already via HTTP.

In some cases it may be useful to assign an identity to WebSocket session even when the user has not formally authenticated. For example a mobile app might assign some identity to anonymous users, perhaps based on geographical location. The do that currently, an application can sub-class

`DefaultHandshakeHandler` and override the `determineUser` method. The custom handshake handler can then be plugged in (see examples in the section called “Deployment Considerations”).

User Destinations

An application can send messages targeting a specific user. Spring’s STOMP support recognizes destinations prefixed with `"/user/"`. For example, a client might subscribe to the destination `"/user/queue/position-updates"`. This destination will be handled by the `UserDestinationMessageHandler` and transformed into a destination unique to the user session, e.g. `"/queue/position-updates-user123"`. This provides the convenience of subscribing to a generically named destination while at the same time ensuring no collisions with other users subscribing to the same destination so that each user can receive unique stock position updates.

On the sending side messages can be sent to a destination such as `"/user/{username}/queue/position-updates"`, which in turn will be translated by the `UserDestinationMessageHandler` into one or more destinations, one for each session associated with the user. This allows any component within the application to send messages targeting a specific user without necessarily knowing anything more than their name and the generic destination. This is also supported through an annotation as well as a messaging template.

For example message-handling method can send messages to the user associated with the message being handled through the `@SendToUser` annotation:

```
@Controller
public class PortfolioController {

    @MessageMapping("/trade")
    @SendToUser("/queue/position-updates")
    public TradeResult executeTrade(Trade trade, Principal principal) {
        // ...
        return tradeResult;
    }
}
```

If the user has more than one sessions, by default all of the sessions subscribed to the given destination are targeted. However sometimes, it may be necessary to target only the session that sent the message being handled. This can be done by setting the `broadcast` attribute to false, for example:

```
@Controller
public class MyController {

    @MessageMapping("/action")
    public void handleAction() throws Exception{
        // raise MyBusinessException here
    }

    @MessageExceptionHandler
    @SendToUser(value="/queue/errors", broadcast=false)
    public ApplicationError handleException(MyBusinessException exception) {
        // ...
        return appError;
    }
}
```

> **Note**
>
> While user destinations generally imply an authenticated user, it isn’t required strictly. A WebSocket session that is not associated with an authenticated user can subscribe to a user

> destination. In such cases the `@SendToUser` annotation will behave exactly the same as with `broadcast=false`, i.e. targeting only the session that sent the message being handled.

It is also possible to send a message to user destinations from any application component by injecting the `SimpMessageTemplate` created by the Java config or XML namespace, for example (the bean name is "brokerMessagingTemplate` if required for qualification with `@Qualifier`):

```
@Service
public class TradeServiceImpl implements TradeService {

 private final SimpMessageTemplate messagingTemplate;

 @Autowired
 public TradeServiceImpl(SimpMessageTemplate messagingTemplate) {
  this.messagingTemplate = messagingTemplate;
 }

 // ...

 public void afterTradeExecuted(Trade trade) {
  this.messagingTemplate.convertAndSendToUser(
    trade.getUserName(), "/queue/position-updates", trade.getResult());
 }
}
```

> **Note**
>
> When using user destinations with an external message broker, check the broker documentation on how to manage inactive queues, so that when the user session is over, all unique user queues are removed. For example, RabbitMQ creates auto-delete queues when destinations like `/exchange/amq.direct/position-updates` are used. So in that case the client could subscribe to `/user/exchange/amq.direct/position-updates`. ActiveMQ has configuration options for purging inactive destinations.

Listening To ApplicationContext Events and Intercepting Messages

Several `ApplicationContext` events (listed below) are published and can be received by implementing Spring's `ApplicationListener` interface.

- `BrokerAvailabilityEvent` — indicates when the broker becomes available/unavailable. While the "simple" broker becomes available immediately on startup and remains so while the application is running, the STOMP "broker relay" may lose its connection to the full featured broker for example if the broker is restarted. The broker relay has reconnect logic and will re-establish the "system" connection to the broker when it comes back, hence this event is published whenever the state changes from connected to disconnected and vice versa. Components using the `SimpMessagingTemplate` should subscribe to this event and avoid sending messages at times when the broker is not available. In any case they should be prepared to handle `MessageDeliveryException` when sending a message.

- `SessionConnectEvent` — published when a new STOMP CONNECT is received indicating the start of a new client session. The event contains the message representing the connect including the session id, user information (if any), and any custom headers the client may have sent. This is useful for tracking client sessions. Components subscribed to this event can wrap the contained message using `SimpMessageHeaderAccessor` or `StompMessageHeaderAccessor`.

- `SessionConnectedEvent` — published shortly after a `SessionConnectEvent` when the broker has sent a STOMP CONNECTED frame in response to the CONNECT. At this point the STOMP session can be considered fully established.
- `SessionSubscribeEvent` — published when a new STOMP SUBSCRIBE is received.
- `SessionUnsubscribeEvent` — published when a new STOMP UNSUBSCRIBE is received.
- `SessionDisconnectEvent` — published when a STOMP session ends. The DISCONNECT may have been sent from the client or it may also be automatically generated when the WebSocket session is closed. In some cases this event may be published more than once per session. Components should be idempotent to multiple disconnect events.

> **Note**
>
> When using a full-featured broker, the STOMP "broker relay" automatically reconnects the "system" connection should the broker become temporarily unavailable. Client connections however are not automatically reconnected. Assuming heartbeats are enabled, the client will typically notice the broker is not responding within 10 seconds. Clients need to implement their own reconnect logic.

Furthermore, an application can directly intercept every incoming and outgoing message by registering a `ChannelInterceptor` on the respective message channel. For example to intercept inbound messages:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebsocketConfig extends AbstractWebSocketMessageBrokerConfigurer {

  @Override
  public void configureClientInboundChannel(ChannelRegistration registration) {
    registration.setInterceptors(new MyChannelInterceptor());
  }
}
```

A custom `ChannelInterceptor` can extend the empty method base class `ChannelInterceptorAdapter` and use `StompHeaderAccessor` or `SimpMessageHeaderAccessor` to access information about the message.

```
public class MyChannelInterceptor extends ChannelInterceptorAdapter {

  @Override
  public Message<?> preSend(Message<?> message, MessageChannel channel) {
    StompHeaderAccessor accessor = StompHeaderAccessor.wrap(message);
    StompCommand command = accessor.getStompCommand();
    // ...
    return message;
  }
}
```

WebSocket Scope

Each WebSocket session has a map of attributes. The map is attached as a header to inbound client messages and may be accessed from a controller method, for example:

```
@Controller
public class MyController {

    @MessageMapping("/action")
    public void handle(SimpMessageHeaderAccessor headerAccessor) {
        Map<String, Object> attrs = headerAccessor.getSessionAttributes();
        // ...
    }
}
```

It is also possible to declare a Spring-managed bean in the `"websocket"` scope. WebSocket-scoped beans can be injected into controllers and any channel interceptors registered on the "clientInboundChannel". Those are typically singletons and live longer than any individual WebSocket session. Therefore you will need to use a scope proxy mode for WebSocket-scoped beans:

```
@Component
@Scope(value="websocket", proxyMode = ScopedProxyMode.TARGET_CLASS)
public class MyBean {

    @PostConstruct
    public void init() {
        // Invoked after dependencies injected
    }

    // ...

    @PreDestroy
    public void destroy() {
        // Invoked when the WebSocket session ends
    }
}

@Controller
public class MyController {

    private final MyBean myBean;

    @Autowired
    public MyController(MyBean myBean) {
        this.myBean = myBean;
    }

    @MessageMapping("/action")
    public void handle() {
        // this.myBean from the current WebSocket session
    }
}
```

As with any custom scope, Spring initializes a new MyBean instance the first time it is accessed from the controller and stores the instance in the WebSocket session attributes. The same instance is returned subsequently until the session ends. WebSocket-scoped beans will have all Spring lifecycle methods invoked as shown in the examples above.

Configuration and Performance

There is no silver bullet when it comes to performance. Many factors may affect it including the size of messages, the volume, whether application methods perform work that requires blocking, as well as external factors such as network speed and others. The goal of this section is to provide an overview of the available configuration options along with some thoughts on how to reason about scaling.

In a messaging application messages are passed through channels for asynchronous executions backed by thread pools. Configuring such an application requires good knowledge of the channels and the flow of messages. Therefore it is recommended to review the section called “Flow of Messages”.

The obvious place to start is to configure the thread pools backing the `"clientInboundChannel"` and the `"clientOutboundChannel"`. By default both are configured at twice the number of available processors.

If the handling of messages in annotated methods is mainly CPU bound then the number of threads for the `"clientInboundChannel"` should remain close to the number of processors. If the work they do is more IO bound and requires blocking or waiting on a database or other external system then the thread pool size will need to be increased.

> **Note**
>
> `ThreadPoolExecutor` has 3 important properties. Those are the core and the max thread pool size as well as the capacity for the queue to store tasks for which there are no available threads.
>
> A common point of confusion is that configuring the core pool size (e.g. 10) and max pool size (e.g. 20) results in a thread pool with 10 to 20 threads. In fact if the capacity is left at its default value of Integer.MAX_VALUE then the thread pool will never increase beyond the core pool size since all additional tasks will be queued.
>
> Please review the Javadoc of `ThreadPoolExecutor` to learn how these properties work and understand the various queuing strategies.

On the `"clientOutboundChannel"` side it is all about sending messages to WebSocket clients. If clients are on a fast network then the number of threads should remain close to the number of available processors. If they are slow or on low bandwidth they will take longer to consume messages and put a burden on the thread pool. Therefore increasing the thread pool size will be necessary.

While the workload for the "clientInboundChannel" is possible to predict — after all it is based on what the application does — how to configure the "clientOutboundChannel" is harder as it is based on factors beyond the control of the application. For this reason there are two additional properties related to the sending of messages. Those are the `"sendTimeLimit"` and the `"sendBufferSizeLimit"`. Those are used to configure how long a send is allowed to take and how much data can be buffered when sending messages to a client.

The general idea is that at any given time only a single thread may be used to send to a client. All additional messages meanwhile get buffered and you can use these properties to decide how long sending a message is allowed to take and how much data can be buffered in the mean time. Please review the Javadoc of XML schema for this configuration for important additional details.

Here is example configuration:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfig implements WebSocketMessageBrokerConfigurer {

    @Override
    public void configureWebSocketTransport(WebSocketTransportRegistration registration) {
        registration.setSendTimeLimit(15 * 1000).setSendBufferSizeLimit(512 * 1024);
    }

    // ...

}
```

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:message-broker>
        <websocket:transport send-timeout="15000" send-buffer-size="524288" />
        <!-- ... -->
    </websocket:message-broker>

</beans>
```

The WebSocket transport configuration shown above can also be used to configure the maximum allowed size for incoming STOMP messages. Although in theory a WebSocket message can be almost unlimited in size, in pracitce WebSocket servers impose limits. For example 8K on Tomcat and 64K on Jetty. For this reason STOMP clients such as stomp.js split larger STOMP messages at 16K boundaries and send them as multiple WebSocket messages thus requiring the server to buffer and re-assemble.

Spring's STOMP over WebSocket support does this so applications can configure the maximum size for STOMP messages irrespective of WebSocket server specific message sizes. Do keep in mind that the WebSocket message size will be automatically adjusted if necessary to ensure they can carry 16K WebSocket messages at a minimum.

Here is example configuration:

```
@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfig implements WebSocketMessageBrokerConfigurer {

    @Override
    public void configureWebSocketTransport(WebSocketTransportRegistration registration) {
        registration.setMessageSizeLimit(128 * 1024);
    }

    // ...

}
```

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:websocket="http://www.springframework.org/schema/websocket"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/websocket
        http://www.springframework.org/schema/websocket/spring-websocket.xsd">

    <websocket:message-broker>
        <websocket:transport message-size="131072" />
        <!-- ... -->
    </websocket:message-broker>

</beans>
```

An important point about scaling is using multiple application instances. Currently it is not possible to do that with the simple broker. However when using a full-featured broker such as RabbitMQ, each application instance connects to the broker and messages broadcast from one application instance can be broadcast through the broker to WebSocket clients connected through any other application instances.

Runtime Monitoring

When using `@EnableWebSocketMessageBroker` or `<websocket:message-broker>` key infrastructure components automatically gather stats and counters that provide important insight into the internal state of the application. The configuration also declares a bean of type `WebSocketMessageBrokerStats` that gathers all available information in one place and by default logs it at INFO once every 30 minutes. This bean can be exported to JMX through Spring's `MBeanExporter` for viewing at runtime for example through JDK's jconsole. Below is a summary of the available information.

Client WebSocket Sessions

Current
: indicates how many client sessions there are currently with the count further broken down by WebSocket vs HTTP streaming and polling SockJS sessions.

Total
: indicates how many total sessions have been established.

Abnormally Closed

Connect Failures
: these are sessions that got established but were closed after not having received any messages within 60 seconds. This is usually an indication of proxy or network issues.

Send Limit Exceeded
: sessions closed after exceeding the configured send timeout or the send buffer limits which can occur with slow clients (see previous section).

Transport Errors
: sessions closed after a transport error such as failure to read or write to a WebSocket connection or HTTP request/response.

STOMP Frames
: the total number of CONNECT, CONNECTED, and DISCONNECT frames processed indicating how many clients connected on the STOMP level. Note that the DISCONNECT count may be lower when sessions get closed abnormally or when clients close without sending a DISCONNECT frame.

STOMP Broker Relay

TCP Connections
: indicates how many TCP connections on behalf of client WebSocket sessions are established to the broker. This should be equal to the number of client WebSocket sessions + 1 additional shared "system" connection for sending messages from within the application.

STOMP Frames
: the total number of CONNECT, CONNECTED, and DISCONNECT frames forwarded to or received from the broker on behalf of clients. Note that a DISCONNECT frame is sent to the broker regardless of how the client WebSocket session was closed. Therefore a lower DISCONNECT frame count is an indication that the broker is pro-actively closing connections, may be because of a heartbeat that didn't arrive in time, an invalid input frame, or other.

Client Inbound Channel
: stats from thread pool backing the "clientInboundChannel" providing insight into the health of incoming message processing. Tasks queueing up here is an indication the application may be too slow to handle messages. If there I/O bound tasks (e.g. slow database query, HTTP request to 3rd party REST API, etc) consider increasing the thread pool size.

Client Outbound Channel
: stats from the thread pool backing the "clientOutboundChannel" providing insight into the health of broadcasting messages to clients. Tasks queueing up here is an indication clients are too slow to consume messages. One way to address this is to increase the thread pool size to accommodate the number of concurrent slow clients expected. Another option is to reduce the send timeout and send buffer size limits (see the previous section).

SockJS Task Scheduler
: stats from thread pool of the SockJS task scheduler which is used to send heartbeats. Note that when heartbeats are negotiated on the STOMP level the SockJS heartbeats are disabled.

Testing Annotated Controller Methods

There are two main approaches to testing applications using Spring's STOMP over WebSocket support. The first is to write server-side tests verifying the functionality of controllers and their annotated message handling methods. The second is to write full end-to-end tests that involve running a client and a server.

The two approaches are not mutually exclusive. On the contrary each has a place in an overall test strategy. Server-side tests are more focused and easier to write and maintain. End-to-end integration tests on the other hand are more complete and test much more but they're also more involved to write and maintain.

The simplest form of server-side tests is to write controller unit tests. However this is not useful enough since much of what a controller does depends on its annotations. Pure unit tests simply can't test that.

Ideally controllers under test should be invoked as they are at runtime, much like the approach to testing controllers handling HTTP requests using the Spring MVC Test framework. i.e. without running a Servlet container but relying on the Spring Framework to invoke the annotated controllers. Just like with Spring MVC Test here there are two two possible alternatives, either using a "context-based" or "standalone" setup:

1. Load the actual Spring configuration with the help of the Spring TestContext framework, inject "clientInboundChannel" as a test field, and use it to send messages to be handled by controller methods.

2. Manually set up the minimum Spring framework infrastructure required to invoke controllers (namely the `SimpAnnotationMethodMessageHandler`) and pass messages for controllers directly to it.

Both of these setup scenarios are demonstrated in the tests for the stock portfolio sample application.

The second approach is to create end-to-end integration tests. For that you will need to run a WebSocket server in embedded mode and connect to it as a WebSocket client sending WebSocket messages containing STOMP frames. The tests for the stock portfolio sample application also demonstrate this approach using Tomcat as the embedded WebSocket server and a simple STOMP client for test purposes.

Part VI. Integration

This part of the reference documentation covers the Spring Framework's integration with a number of Java EE (and related) technologies.

- Chapter 22, *Remoting and web services using Spring*
- Chapter 23, *Enterprise JavaBeans (EJB) integration*
- Chapter 24, *JMS (Java Message Service)*
- Chapter 25, *JMX*
- Chapter 26, *JCA CCI*
- Chapter 27, *Email*
- Chapter 28, *Task Execution and Scheduling*
- Chapter 29, *Dynamic language support*
- Chapter 30, *Cache Abstraction*

22. Remoting and web services using Spring

22.1 Introduction

Spring features integration classes for remoting support using various technologies. The remoting support eases the development of remote-enabled services, implemented by your usual (Spring) POJOs. Currently, Spring supports the following remoting technologies:

- *Remote Method Invocation (RMI)*. Through the use of the `RmiProxyFactoryBean` and the `RmiServiceExporter` Spring supports both traditional RMI (with `java.rmi.Remote` interfaces and `java.rmi.RemoteException`) and transparent remoting via RMI invokers (with any Java interface).
- *Spring's HTTP invoker*. Spring provides a special remoting strategy which allows for Java serialization via HTTP, supporting any Java interface (just like the RMI invoker). The corresponding support classes are `HttpInvokerProxyFactoryBean` and `HttpInvokerServiceExporter`.
- *Hessian*. By using Spring's `HessianProxyFactoryBean` and the `HessianServiceExporter` you can transparently expose your services using the lightweight binary HTTP-based protocol provided by Caucho.
- *Burlap*. Burlap is Caucho's XML-based alternative to Hessian. Spring provides support classes such as `BurlapProxyFactoryBean` and `BurlapServiceExporter`.
- *JAX-WS*. Spring provides remoting support for web services via JAX-WS (the successor of JAX-RPC, as introduced in Java EE 5 and Java 6).
- *JMS*. Remoting using JMS as the underlying protocol is supported via the `JmsInvokerServiceExporter` and `JmsInvokerProxyFactoryBean` classes.
- *AMQP*. Remoting using AMQP as the underlying protocol is supported by the Spring AMQP project.

While discussing the remoting capabilities of Spring, we'll use the following domain model and corresponding services:

```
public class Account implements Serializable{

    private String name;

    public String getName(){
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

}
```

```
public interface AccountService {

    public void insertAccount(Account account);

    public List<Account> getAccounts(String name);

}
```

```
public interface RemoteAccountService extends Remote {

    public void insertAccount(Account account) throws RemoteException;

    public List<Account> getAccounts(String name) throws RemoteException;

}
```

```
// the implementation doing nothing at the moment
public class AccountServiceImpl implements AccountService {

    public void insertAccount(Account acc) {
        // do something...
    }

    public List<Account> getAccounts(String name) {
        // do something...
    }

}
```

We will start exposing the service to a remote client by using RMI and talk a bit about the drawbacks of using RMI. We'll then continue to show an example using Hessian as the protocol.

22.2 Exposing services using RMI

Using Spring's support for RMI, you can transparently expose your services through the RMI infrastructure. After having this set up, you basically have a configuration similar to remote EJBs, except for the fact that there is no standard support for security context propagation or remote transaction propagation. Spring does provide hooks for such additional invocation context when using the RMI invoker, so you can for example plug in security frameworks or custom security credentials here.

Exporting the service using the RmiServiceExporter

Using the `RmiServiceExporter`, we can expose the interface of our AccountService object as RMI object. The interface can be accessed by using `RmiProxyFactoryBean`, or via plain RMI in case of a traditional RMI service. The `RmiServiceExporter` explicitly supports the exposing of any non-RMI services via RMI invokers.

Of course, we first have to set up our service in the Spring container:

```
<bean id="accountService" class="example.AccountServiceImpl">
    <!-- any additional properties, maybe a DAO? -->
</bean>
```

Next we'll have to expose our service using the `RmiServiceExporter`:

```
<bean class="org.springframework.remoting.rmi.RmiServiceExporter">
    <!-- does not necessarily have to be the same name as the bean to be exported -->
    <property name="serviceName" value="AccountService"/>
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
    <!-- defaults to 1099 -->
    <property name="registryPort" value="1199"/>
</bean>
```

As you can see, we're overriding the port for the RMI registry. Often, your application server also maintains an RMI registry and it is wise to not interfere with that one. Furthermore, the service name is used to bind the service under. So right now, the service will be bound at `'rmi://HOST:1199/AccountService'`. We'll use the URL later on to link in the service at the client side.

> **Note**
>
> The `servicePort` property has been omitted (it defaults to 0). This means that an anonymous port will be used to communicate with the service.

Linking in the service at the client

Our client is a simple object using the `AccountService` to manage accounts:

```
public class SimpleObject {

    private AccountService accountService;

    public void setAccountService(AccountService accountService) {
        this.accountService = accountService;
    }

    // additional methods using the accountService

}
```

To link in the service on the client, we'll create a separate Spring container, containing the simple object and the service linking configuration bits:

```
<bean class="example.SimpleObject">
    <property name="accountService" ref="accountService"/>
</bean>

<bean id="accountService" class="org.springframework.remoting.rmi.RmiProxyFactoryBean">
    <property name="serviceUrl" value="rmi://HOST:1199/AccountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

That's all we need to do to support the remote account service on the client. Spring will transparently create an invoker and remotely enable the account service through the `RmiServiceExporter`. At the client we're linking it in using the `RmiProxyFactoryBean`.

22.3 Using Hessian or Burlap to remotely call services via HTTP

Hessian offers a binary HTTP-based remoting protocol. It is developed by Caucho and more information about Hessian itself can be found at http://www.caucho.com.

Wiring up the DispatcherServlet for Hessian and co.

Hessian communicates via HTTP and does so using a custom servlet. Using Spring's `DispatcherServlet` principles, as known from Spring Web MVC usage, you can easily wire up such a servlet exposing your services. First we'll have to create a new servlet in your application (this is an excerpt from `'web.xml'`):

```
<servlet>
    <servlet-name>remoting</servlet-name>
    <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
    <load-on-startup>1</load-on-startup>
</servlet>

<servlet-mapping>
    <servlet-name>remoting</servlet-name>
    <url-pattern>/remoting/*</url-pattern>
</servlet-mapping>
```

You're probably familiar with Spring's `DispatcherServlet` principles and if so, you know that now you'll have to create a Spring container configuration resource named `'remoting-servlet.xml'` (after the name of your servlet) in the `'WEB-INF'` directory. The application context will be used in the next section.

Alternatively, consider the use of Spring's simpler `HttpRequestHandlerServlet`. This allows you to embed the remote exporter definitions in your root application context (by default in `'WEB-INF/applicationContext.xml'`), with individual servlet definitions pointing to specific exporter beans. Each servlet name needs to match the bean name of its target exporter in this case.

Exposing your beans by using the HessianServiceExporter

In the newly created application context called `remoting-servlet.xml`, we'll create a `HessianServiceExporter` exporting your services:

```
<bean id="accountService" class="example.AccountServiceImpl">
    <!-- any additional properties, maybe a DAO? -->
</bean>

<bean name="/AccountService" class="org.springframework.remoting.caucho.HessianServiceExporter">
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

Now we're ready to link in the service at the client. No explicit handler mapping is specified, mapping request URLs onto services, so `BeanNameUrlHandlerMapping` will be used: Hence, the service will be exported at the URL indicated through its bean name within the containing `DispatcherServlet`'s mapping (as defined above): `'http://HOST:8080/remoting/AccountService'`.

Alternatively, create a `HessianServiceExporter` in your root application context (e.g. in `'WEB-INF/applicationContext.xml'`):

```
<bean name="accountExporter" class="org.springframework.remoting.caucho.HessianServiceExporter">
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

In the latter case, define a corresponding servlet for this exporter in `'web.xml'`, with the same end result: The exporter getting mapped to the request path `/remoting/AccountService`. Note that the servlet name needs to match the bean name of the target exporter.

```
<servlet>
    <servlet-name>accountExporter</servlet-name>
    <servlet-class>org.springframework.web.context.support.HttpRequestHandlerServlet</servlet-class>
</servlet>

<servlet-mapping>
    <servlet-name>accountExporter</servlet-name>
    <url-pattern>/remoting/AccountService</url-pattern>
</servlet-mapping>
```

Linking in the service on the client

Using the `HessianProxyFactoryBean` we can link in the service at the client. The same principles apply as with the RMI example. We'll create a separate bean factory or application context and mention the following beans where the `SimpleObject` is using the `AccountService` to manage accounts:

```
<bean class="example.SimpleObject">
    <property name="accountService" ref="accountService"/>
</bean>

<bean id="accountService" class="org.springframework.remoting.caucho.HessianProxyFactoryBean">
    <property name="serviceUrl" value="http://remotehost:8080/remoting/AccountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

Using Burlap

We won't discuss Burlap, the XML-based equivalent of Hessian, in detail here, since it is configured and set up in exactly the same way as the Hessian variant explained above. Just replace the word `Hessian` with `Burlap` and you're all set to go.

Applying HTTP basic authentication to a service exposed through Hessian or Burlap

One of the advantages of Hessian and Burlap is that we can easily apply HTTP basic authentication, because both protocols are HTTP-based. Your normal HTTP server security mechanism can easily be applied through using the `web.xml` security features, for example. Usually, you don't use per-user security credentials here, but rather shared credentials defined at the `Hessian/BurlapProxyFactoryBean` level (similar to a JDBC `DataSource`).

```
<bean class="org.springframework.web.servlet.handler.BeanNameUrlHandlerMapping">
    <property name="interceptors" ref="authorizationInterceptor"/>
</bean>

<bean id="authorizationInterceptor"
        class="org.springframework.web.servlet.handler.UserRoleAuthorizationInterceptor">
    <property name="authorizedRoles" value="administrator,operator"/>
</bean>
```

This is an example where we explicitly mention the `BeanNameUrlHandlerMapping` and set an interceptor allowing only administrators and operators to call the beans mentioned in this application context.

> **Note**
>
> Of course, this example doesn't show a flexible kind of security infrastructure. For more options as far as security is concerned, have a look at the Spring Security project at http://projects.spring.io/spring-security/.

22.4 Exposing services using HTTP invokers

As opposed to Burlap and Hessian, which are both lightweight protocols using their own slim serialization mechanisms, Spring HTTP invokers use the standard Java serialization mechanism to expose services through HTTP. This has a huge advantage if your arguments and return types are complex types that cannot be serialized using the serialization mechanisms Hessian and Burlap use (refer to the next section for more considerations when choosing a remoting technology).

Under the hood, Spring uses either the standard facilities provided by the JDK or Apache `HttpComponents` to perform HTTP calls. Use the latter if you need more advanced and easier-to-use functionality. Refer to hc.apache.org/httpcomponents-client-ga/ for more information.

Exposing the service object

Setting up the HTTP invoker infrastructure for a service object resembles closely the way you would do the same using Hessian or Burlap. Just as Hessian support provides the `HessianServiceExporter`, Spring's HttpInvoker support provides the `org.springframework.remoting.httpinvoker.HttpInvokerServiceExporter`.

To expose the `AccountService` (mentioned above) within a Spring Web MVC `DispatcherServlet`, the following configuration needs to be in place in the dispatcher's application context:

```
<bean name="/
AccountService" class="org.springframework.remoting.httpinvoker.HttpInvokerServiceExporter">
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

Such an exporter definition will be exposed through the `DispatcherServlet`'s standard mapping facilities, as explained in the section on Hessian.

Alternatively, create an `HttpInvokerServiceExporter` in your root application context (e.g. in `'WEB-INF/applicationContext.xml'`):

```
<bean name="accountExporter" class="org.springframework.remoting.httpinvoker.HttpInvokerServiceExporter">
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

In addition, define a corresponding servlet for this exporter in `'web.xml'`, with the servlet name matching the bean name of the target exporter:

```
<servlet>
    <servlet-name>accountExporter</servlet-name>
    <servlet-class>org.springframework.web.context.support.HttpRequestHandlerServlet</servlet-class>
</servlet>

<servlet-mapping>
    <servlet-name>accountExporter</servlet-name>
    <url-pattern>/remoting/AccountService</url-pattern>
</servlet-mapping>
```

If you are running outside of a servlet container and are using Oracle's Java 6, then you can use the built-in HTTP server implementation. You can configure the `SimpleHttpServerFactoryBean` together with a `SimpleHttpInvokerServiceExporter` as is shown in this example:

```
<bean name="accountExporter"
        class="org.springframework.remoting.httpinvoker.SimpleHttpInvokerServiceExporter">
    <property name="service" ref="accountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>

<bean id="httpServer"
        class="org.springframework.remoting.support.SimpleHttpServerFactoryBean">
    <property name="contexts">
        <util:map>
            <entry key="/remoting/AccountService" value-ref="accountExporter"/>
        </util:map>
    </property>
    <property name="port" value="8080" />
</bean>
```

Linking in the service at the client

Again, linking in the service from the client much resembles the way you would do it when using Hessian or Burlap. Using a proxy, Spring will be able to translate your calls to HTTP POST requests to the URL pointing to the exported service.

```
<bean id="httpInvokerProxy" class="org.springframework.remoting.httpinvoker.HttpInvokerProxyFactoryBean">
    <property name="serviceUrl" value="http://remotehost:8080/remoting/AccountService"/>
    <property name="serviceInterface" value="example.AccountService"/>
</bean>
```

As mentioned before, you can choose what HTTP client you want to use. By default, the `HttpInvokerProxy` uses the JDK's HTTP functionality, but you can also use the Apache `HttpComponents` client by setting the `httpInvokerRequestExecutor` property:

```
<property name="httpInvokerRequestExecutor">
    <bean class="org.springframework.remoting.httpinvoker.HttpComponentsHttpInvokerRequestExecutor"/>
</property>
```

22.5 Web services

Spring provides full support for standard Java web services APIs:

- Exposing web services using JAX-WS
- Accessing web services using JAX-WS

In addition to stock support for JAX-WS in Spring Core, the Spring portfolio also features Spring Web Services, a solution for contract-first, document-driven web services - highly recommended for building modern, future-proof web services.

Exposing servlet-based web services using JAX-WS

Spring provides a convenient base class for JAX-WS servlet endpoint implementations - `SpringBeanAutowiringSupport`. To expose our `AccountService` we extend Spring's `SpringBeanAutowiringSupport` class and implement our business logic here, usually delegating the call to the business layer. We'll simply use Spring's `@Autowired` annotation for expressing such dependencies on Spring-managed beans.

```
/**
 * JAX-WS compliant AccountService implementation that simply delegates
 * to the AccountService implementation in the root web application context.
 *
 * This wrapper class is necessary because JAX-WS requires working with dedicated
 * endpoint classes. If an existing service needs to be exported, a wrapper that
 * extends SpringBeanAutowiringSupport for simple Spring bean autowiring (through
 * the @Autowired annotation) is the simplest JAX-WS compliant way.
 *
 * This is the class registered with the server-side JAX-WS implementation.
 * In the case of a Java EE 5 server, this would simply be defined as a servlet
 * in web.xml, with the server detecting that this is a JAX-WS endpoint and reacting
 * accordingly. The servlet name usually needs to match the specified WS service name.
 *
 * The web service engine manages the lifecycle of instances of this class.
 * Spring bean references will just be wired in here.
 */
import org.springframework.web.context.support.SpringBeanAutowiringSupport;

@WebService(serviceName="AccountService")
public class AccountServiceEndpoint extends SpringBeanAutowiringSupport {

    @Autowired
    private AccountService biz;

    @WebMethod
    public void insertAccount(Account acc) {
        biz.insertAccount(acc);
    }

    @WebMethod
    public Account[] getAccounts(String name) {
        return biz.getAccounts(name);
    }

}
```

Our `AccountServletEndpoint` needs to run in the same web application as the Spring context to allow for access to Spring's facilities. This is the case by default in Java EE 5 environments, using the standard contract for JAX-WS servlet endpoint deployment. See Java EE 5 web service tutorials for details.

Exporting standalone web services using JAX-WS

The built-in JAX-WS provider that comes with Oracle's JDK 1.6 supports exposure of web services using the built-in HTTP server that's included in JDK 1.6 as well. Spring's `SimpleJaxWsServiceExporter` detects all `@WebService` annotated beans in the Spring application context, exporting them through the default JAX-WS server (the JDK 1.6 HTTP server).

In this scenario, the endpoint instances are defined and managed as Spring beans themselves; they will be registered with the JAX-WS engine but their lifecycle will be up to the Spring application context. This means that Spring functionality like explicit dependency injection may be applied to the endpoint instances. Of course, annotation-driven injection through `@Autowired` will work as well.

```
<bean class="org.springframework.remoting.jaxws.SimpleJaxWsServiceExporter">
    <property name="baseAddress" value="http://localhost:8080/"/>
</bean>

<bean id="accountServiceEndpoint" class="example.AccountServiceEndpoint">
    ...
</bean>

...
```

The `AccountServiceEndpoint` may derive from Spring's `SpringBeanAutowiringSupport` but doesn't have to since the endpoint is a fully Spring-managed bean here. This means that the endpoint implementation may look like as follows, without any superclass declared - and Spring's `@Autowired` configuration annotation still being honored:

```
@WebService(serviceName="AccountService")
public class AccountServiceEndpoint {

    @Autowired
    private AccountService biz;

    @WebMethod
    public void insertAccount(Account acc) {
        biz.insertAccount(acc);
    }

    @WebMethod
    public List<Account> getAccounts(String name) {
        return biz.getAccounts(name);
    }

}
```

Exporting web services using the JAX-WS RI's Spring support

Oracle's JAX-WS RI, developed as part of the GlassFish project, ships Spring support as part of its JAX-WS Commons project. This allows for defining JAX-WS endpoints as Spring-managed beans, similar to the standalone mode discussed in the previous section - but this time in a Servlet environment. *Note that this is not portable in a Java EE 5 environment; it is mainly intended for non-EE environments such as Tomcat, embedding the JAX-WS RI as part of the web application.*

The difference to the standard style of exporting servlet-based endpoints is that the lifecycle of the endpoint instances themselves will be managed by Spring here, and that there will be only one JAX-WS servlet defined in `web.xml`. With the standard Java EE 5 style (as illustrated above), you'll have one servlet definition per service endpoint, with each endpoint typically delegating to Spring beans (through the use of `@Autowired`, as shown above).

Check out https://jax-ws-commons.java.net/spring/ for details on setup and usage style.

Accessing web services using JAX-WS

Spring provides two factory beans to create JAX-WS web service proxies, namely `LocalJaxWsServiceFactoryBean` and `JaxWsPortProxyFactoryBean`. The former can only return a JAX-WS service class for us to work with. The latter is the full-fledged version that can return a proxy that implements our business service interface. In this example we use the latter to create a proxy for the `AccountService` endpoint (again):

```
<bean id="accountWebService" class="org.springframework.remoting.jaxws.JaxWsPortProxyFactoryBean">
    <property name="serviceInterface" value="example.AccountService"/>
    <property name="wsdlDocumentUrl" value="http://localhost:8888/AccountServiceEndpoint?WSDL"/>
    <property name="namespaceUri" value="http://example/"/>
    <property name="serviceName" value="AccountService"/>
    <property name="portName" value="AccountServiceEndpointPort"/>
</bean>
```

Where `serviceInterface` is our business interface the clients will use. `wsdlDocumentUrl` is the URL for the WSDL file. Spring needs this a startup time to create the JAX-WS Service. `namespaceUri` corresponds to the targetNamespace in the .wsdl file. `serviceName` corresponds to the service name in the .wsdl file. `portName` corresponds to the port name in the .wsdl file.

Accessing the web service is now very easy as we have a bean factory for it that will expose it as `AccountService` interface. We can wire this up in Spring:

```
<bean id="client" class="example.AccountClientImpl">
    ...
    <property name="service" ref="accountWebService"/>
</bean>
```

From the client code we can access the web service just as if it was a normal class:

```
public class AccountClientImpl {

    private AccountService service;

    public void setService(AccountService service) {
        this.service = service;
    }

    public void foo() {
        service.insertAccount(...);
    }
}
```

> **Note**
>
> The above is slightly simplified in that JAX-WS requires endpoint interfaces and implementation classes to be annotated with `@WebService`, `@SOAPBinding` etc annotations. This means that you cannot (easily) use plain Java interfaces and implementation classes as JAX-WS endpoint artifacts; you need to annotate them accordingly first. Check the JAX-WS documentation for details on those requirements.

22.6 JMS

It is also possible to expose services transparently using JMS as the underlying communication protocol. The JMS remoting support in the Spring Framework is pretty basic - it sends and receives on the `same thread` and in the *same non-transactional* `Session`, and as such throughput will be very implementation dependent. Note that these single-threaded and non-transactional constraints apply only to Spring's JMS *remoting* support. See Chapter 24, *JMS (Java Message Service)* for information on Spring's rich support for JMS-based *messaging*.

The following interface is used on both the server and the client side.

```
package com.foo;

public interface CheckingAccountService {

    public void cancelAccount(Long accountId);

}
```

The following simple implementation of the above interface is used on the server-side.

```
package com.foo;

public class SimpleCheckingAccountService implements CheckingAccountService {

    public void cancelAccount(Long accountId) {
        System.out.println("Cancelling account [" + accountId + "]");
    }

}
```

This configuration file contains the JMS-infrastructure beans that are shared on both the client and server.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="connectionFactory" class="org.apache.activemq.ActiveMQConnectionFactory">
        <property name="brokerURL" value="tcp://ep-t43:61616"/>
    </bean>

    <bean id="queue" class="org.apache.activemq.command.ActiveMQQueue">
        <constructor-arg value="mmm"/>
    </bean>

</beans>
```

Server-side configuration

On the server, you just need to expose the service object using the `JmsInvokerServiceExporter`.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="checkingAccountService"
            class="org.springframework.jms.remoting.JmsInvokerServiceExporter">
        <property name="serviceInterface" value="com.foo.CheckingAccountService"/>
        <property name="service">
            <bean class="com.foo.SimpleCheckingAccountService"/>
        </property>
    </bean>

    <bean class="org.springframework.jms.listener.SimpleMessageListenerContainer">
        <property name="connectionFactory" ref="connectionFactory"/>
        <property name="destination" ref="queue"/>
        <property name="concurrentConsumers" value="3"/>
        <property name="messageListener" ref="checkingAccountService"/>
    </bean>

</beans>
```

```
package com.foo;

import org.springframework.context.support.ClassPathXmlApplicationContext;

public class Server {

    public static void main(String[] args) throws Exception {
        new ClassPathXmlApplicationContext(new String[]{"com/foo/server.xml", "com/foo/jms.xml"});
    }

}
```

Client-side configuration

The client merely needs to create a client-side proxy that will implement the agreed upon interface (`CheckingAccountService`). The resulting object created off the back of the following bean definition can be injected into other client side objects, and the proxy will take care of forwarding the call to the server-side object via JMS.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="checkingAccountService"
            class="org.springframework.jms.remoting.JmsInvokerProxyFactoryBean">
        <property name="serviceInterface" value="com.foo.CheckingAccountService"/>
        <property name="connectionFactory" ref="connectionFactory"/>
        <property name="queue" ref="queue"/>
    </bean>

</beans>
```

```
package com.foo;

import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;

public class Client {

    public static void main(String[] args) throws Exception {
        ApplicationContext ctx = new ClassPathXmlApplicationContext(
                new String[] {"com/foo/client.xml", "com/foo/jms.xml"});
        CheckingAccountService service = (CheckingAccountService) ctx.getBean("checkingAccountService");
        service.cancelAccount(new Long(10));
    }

}
```

You may also wish to investigate the support provided by the Lingo project, which (to quote the homepage blurb) "*… is a lightweight POJO based remoting and messaging library based on the Spring Framework's remoting libraries which extends it to support JMS.*"

22.7 AMQP

Refer to the Spring AMQP Reference Document *Spring Remoting with AMQP* section for more information.

22.8 Auto-detection is not implemented for remote interfaces

The main reason why auto-detection of implemented interfaces does not occur for remote interfaces is to avoid opening too many doors to remote callers. The target object might implement internal callback interfaces like `InitializingBean` or `DisposableBean` which one would not want to expose to callers.

Offering a proxy with all interfaces implemented by the target usually does not matter in the local case. But when exporting a remote service, you should expose a specific service interface, with specific operations intended for remote usage. Besides internal callback interfaces, the target might implement multiple business interfaces, with just one of them intended for remote exposure. For these reasons, we *require* such a service interface to be specified.

This is a trade-off between configuration convenience and the risk of accidental exposure of internal methods. Always specifying a service interface is not too much effort, and puts you on the safe side regarding controlled exposure of specific methods.

22.9 Considerations when choosing a technology

Each and every technology presented here has its drawbacks. You should carefully consider your needs, the services you are exposing and the objects you'll be sending over the wire when choosing a technology.

When using RMI, it's not possible to access the objects through the HTTP protocol, unless you're tunneling the RMI traffic. RMI is a fairly heavy-weight protocol in that it supports full-object serialization which is important when using a complex data model that needs serialization over the wire. However, RMI-JRMP is tied to Java clients: It is a Java-to-Java remoting solution.

Spring's HTTP invoker is a good choice if you need HTTP-based remoting but also rely on Java serialization. It shares the basic infrastructure with RMI invokers, just using HTTP as transport. Note that HTTP invokers are not only limited to Java-to-Java remoting but also to Spring on both the client and server side. (The latter also applies to Spring's RMI invoker for non-RMI interfaces.)

Hessian and/or Burlap might provide significant value when operating in a heterogeneous environment, because they explicitly allow for non-Java clients. However, non-Java support is still limited. Known issues include the serialization of Hibernate objects in combination with lazily-initialized collections. If you have such a data model, consider using RMI or HTTP invokers instead of Hessian.

JMS can be useful for providing clusters of services and allowing the JMS broker to take care of load balancing, discovery and auto-failover. By default: Java serialization is used when using JMS remoting but the JMS provider could use a different mechanism for the wire formatting, such as XStream to allow servers to be implemented in other technologies.

Last but not least, EJB has an advantage over RMI in that it supports standard role-based authentication and authorization and remote transaction propagation. It is possible to get RMI invokers or HTTP invokers to support security context propagation as well, although this is not provided by core Spring: There are just appropriate hooks for plugging in third-party or custom solutions here.

22.10 Accessing RESTful services on the Client

The `RestTemplate` is the core class for client-side access to RESTful services. It is conceptually similar to other template classes in Spring, such as `JdbcTemplate` and `JmsTemplate` and other template classes found in other Spring portfolio projects. `RestTemplate`'s behavior is customized by providing callback methods and configuring the `HttpMessageConverter` used to marshal objects into the HTTP request body and to unmarshal any response back into an object. As it is common to use XML as a message format, Spring provides a `MarshallingHttpMessageConverter` that uses the Object-to-XML framework that is part of the `org.springframework.oxm` package. This gives you a wide range of choices of XML to Object mapping technologies to choose from.

This section describes how to use the `RestTemplate` and its associated `HttpMessageConverters`.

RestTemplate

Invoking RESTful services in Java is typically done using a helper class such as Apache HttpComponents `HttpClient`. For common REST operations this approach is too low level as shown below.

```
String uri = "http://example.com/hotels/1/bookings";

PostMethod post = new PostMethod(uri);
String request = // create booking request content
post.setRequestEntity(new StringRequestEntity(request));

httpClient.executeMethod(post);

if (HttpStatus.SC_CREATED == post.getStatusCode()) {
    Header location = post.getRequestHeader("Location");
    if (location != null) {
        System.out.println("Created new booking at :" + location.getValue());
    }
}
```

RestTemplate provides higher level methods that correspond to each of the six main HTTP methods that make invoking many RESTful services a one-liner and enforce REST best practices.

> **Note**
>
> RestTemplate has an asynchronous counter-part: see the section called “Async RestTemplate”.

Table 22.1. Overview of RestTemplate methods

HTTP Method	RestTemplate Method
DELETE	delete
GET	getForObject getForEntity
HEAD	headForHeaders(String url, String… urlVariables)
OPTIONS	optionsForAllow(String url, String… urlVariables)
POST	postForLocation(String url, Object request, String… urlVariables) postForObject(String url, Object request, Class<T> responseType, String… uriVariables)
PUT	put(String url, Object request, String…urlVariables)
PATCH and others	exchange execute

The names of `RestTemplate` methods follow a naming convention, the first part indicates what HTTP method is being invoked and the second part indicates what is returned. For example, the method `getForObject()` will perform a GET, convert the HTTP response into an object type of your choice and return that object. The method `postForLocation()` will do a POST, converting the given object into a HTTP request and return the response HTTP Location header where the newly created object can be found. In case of an exception processing the HTTP request, an exception of the type `RestClientException` will be thrown; this behavior can be changed by plugging in another `ResponseErrorHandler` implementation into the `RestTemplate`.

The `exchange` and `execute` methods are generalized versions of the more specific methods listed above them and can support additional combinations and methods, like HTTP PATCH. However, note that the underlying HTTP library must also support the desired combination. The JDK `HttpURLConnection` does not support the `PATCH` method, but Apache HttpComponents HttpClient version 4.2 or later does. They also enable `RestTemplate` to read an HTTP response to a generic type (e.g. `List<Account>`), using a `ParameterizedTypeReference`, a new class that enables capturing and passing generic type info.

Objects passed to and returned from these methods are converted to and from HTTP messages by `HttpMessageConverter` instances. Converters for the main mime types are registered by default, but you can also write your own converter and register it via the `messageConverters()` bean property. The default converter instances registered with the template are `ByteArrayHttpMessageConverter`, `StringHttpMessageConverter`, `FormHttpMessageConverter` and `SourceHttpMessageConverter`. You can override these defaults using the `messageConverters()` bean property as would be required if using the `MarshallingHttpMessageConverter` or `MappingJackson2HttpMessageConverter`.

Each method takes URI template arguments in two forms, either as a `String` variable length argument or a `Map<String,String>`. For example,

```
String result = restTemplate.getForObject(
        "http://example.com/hotels/{hotel}/bookings/{booking}", String.class,"42", "21");
```

using variable length arguments and

```
Map<String, String> vars = Collections.singletonMap("hotel", "42");
String result = restTemplate.getForObject(
        "http://example.com/hotels/{hotel}/rooms/{hotel}", String.class, vars);
```

using a `Map<String,String>`.

To create an instance of `RestTemplate` you can simply call the default no-arg constructor. This will use standard Java classes from the `java.net` package as the underlying implementation to create HTTP requests. This can be overridden by specifying an implementation of `ClientHttpRequestFactory`. Spring provides the implementation `HttpComponentsClientHttpRequestFactory` that uses the Apache HttpComponents `HttpClient` to create requests. `HttpComponentsClientHttpRequestFactory` is configured using an instance of `org.apache.http.client.HttpClient` which can in turn be configured with credentials information or connection pooling functionality.

> **Tip**
>
> Note that the `java.net` implementation for HTTP requests may raise an exception when accessing the status of a response that represents an error (e.g. 401). If this is an issue, switch to `HttpComponentsClientHttpRequestFactory` instead.

The previous example using Apache HttpComponents `HttpClient` directly rewritten to use the `RestTemplate` is shown below

```
uri = "http://example.com/hotels/{id}/bookings";

RestTemplate template = new RestTemplate();

Booking booking = // create booking object

URI location = template.postForLocation(uri, booking, "1");
```

To use Apache HttpComponents instead of the native `java.net` functionality, construct the `RestTemplate` as follows:

```
RestTemplate template = new RestTemplate(new HttpComponentsClientHttpRequestFactory());
```

> **Tip**
>
> Apache HttpClient supports gzip encoding. To use it, construct a `HttpComponentsClientHttpRequestFactory` like so:
>
> ```
> HttpClient httpClient = HttpClientBuilder.create().build();
> ClientHttpRequestFactory requestFactory = new HttpComponentsClientHttpRequestFactory(httpClient);
> RestTemplate restTemplate = new RestTemplate(requestFactory);
> ```

The general callback interface is `RequestCallback` and is called when the execute method is invoked.

```
public <T> T execute(String url, HttpMethod method, RequestCallback requestCallback,
        ResponseExtractor<T> responseExtractor, String... urlVariables)

// also has an overload with urlVariables as a Map<String, String>.
```

The `RequestCallback` interface is defined as

```
public interface RequestCallback {
 void doWithRequest(ClientHttpRequest request) throws IOException;
}
```

and allows you to manipulate the request headers and write to the request body. When using the execute method you do not have to worry about any resource management, the template will always close the request and handle any errors. Refer to the API documentation for more information on using the execute method and the meaning of its other method arguments.

Working with the URI

For each of the main HTTP methods, the `RestTemplate` provides variants that either take a String URI or `java.net.URI` as the first argument.

The String URI variants accept template arguments as a String variable length argument or as a `Map<String,String>`. They also assume the URL String is not encoded and needs to be encoded. For example the following:

```
restTemplate.getForObject("http://example.com/hotel list", String.class);
```

will perform a GET on `http://example.com/hotel%20list`. That means if the input URL String is already encoded, it will be encoded twice — i.e. `http://example.com/hotel%20list` will become `http://example.com/hotel%2520list`. If this is not the intended effect, use the `java.net.URI` method variant, which assumes the URL is already encoded is also generally useful if you want to reuse a single (fully expanded) `URI` multiple times.

The `UriComponentsBuilder` class can be used to build and encode the `URI` including support for URI templates. For example you can start with a URL String:

```
UriComponents uriComponents = UriComponentsBuilder.fromUriString(
        "http://example.com/hotels/{hotel}/bookings/{booking}").build()
        .expand("42", "21")
        .encode();

URI uri = uriComponents.toUri();
```

Or specify each URI component individually:

```
UriComponents uriComponents = UriComponentsBuilder.newInstance()
        .scheme("http").host("example.com").path("/hotels/{hotel}/bookings/{booking}").build()
        .expand("42", "21")
        .encode();

URI uri = uriComponents.toUri();
```

Dealing with request and response headers

Besides the methods described above, the `RestTemplate` also has the `exchange()` method, which can be used for arbitrary HTTP method execution based on the `HttpEntity` class.

Perhaps most importantly, the `exchange()` method can be used to add request headers and read response headers. For example:

```
HttpHeaders requestHeaders = new HttpHeaders();
requestHeaders.set("MyRequestHeader", "MyValue");
HttpEntity<?> requestEntity = new HttpEntity(requestHeaders);

HttpEntity<String> response = template.exchange(
        "http://example.com/hotels/{hotel}",
        HttpMethod.GET, requestEntity, String.class, "42");

String responseHeader = response.getHeaders().getFirst("MyResponseHeader");
String body = response.getBody();
```

In the above example, we first prepare a request entity that contains the `MyRequestHeader` header. We then retrieve the response, and read the `MyResponseHeader` and body.

Jackson JSON Views support

It is possible to specify a Jackson JSON View to serialize only a subset of the object properties. For example:

```
JacksonSerializationValue jsv = new JacksonSerializationValue(new User("eric", "7!jd#h23"),
    User.WithoutPasswordView.class);
HttpEntity<JacksonSerializationValue> entity = new HttpEntity<JacksonSerializationValue>(jsv);
String s = template.postForObject("http://example.com/user", entity, String.class);
```

HTTP Message Conversion

Objects passed to and returned from the methods `getForObject()`, `postForLocation()`, and `put()` are converted to HTTP requests and from HTTP responses by `HttpMessageConverters`. The `HttpMessageConverter` interface is shown below to give you a better feel for its functionality

```
public interface HttpMessageConverter<T> {

    // Indicate whether the given class and media type can be read by this converter.
    boolean canRead(Class<?> clazz, MediaType mediaType);

    // Indicate whether the given class and media type can be written by this converter.
    boolean canWrite(Class<?> clazz, MediaType mediaType);

    // Return the list of MediaType objects supported by this converter.
    List<MediaType> getSupportedMediaTypes();

    // Read an object of the given type from the given input message, and returns it.
    T read(Class<T> clazz, HttpInputMessage inputMessage) throws IOException,
 HttpMessageNotReadableException;

    // Write an given object to the given output message.
    void write(T t, HttpOutputMessage outputMessage) throws IOException,
 HttpMessageNotWritableException;

}
```

Concrete implementations for the main media (mime) types are provided in the framework and are registered by default with the `RestTemplate` on the client-side and with `AnnotationMethodHandlerAdapter` on the server-side.

The implementations of `HttpMessageConverters` are described in the following sections. For all converters a default media type is used but can be overridden by setting the `supportedMediaTypes` bean property

StringHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write Strings from the HTTP request and response. By default, this converter supports all text media types (`text/*`), and writes with a `Content-Type` of `text/plain`.

FormHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write form data from the HTTP request and response. By default, this converter reads and writes the media type `application/x-www-form-urlencoded`. Form data is read from and written into a `MultiValueMap<String, String>`.

ByteArrayHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write byte arrays from the HTTP request and response. By default, this converter supports all media types (`*/*`), and writes with a `Content-Type` of `application/octet-stream`. This can be overridden by setting the `supportedMediaTypes` property, and overriding `getContentType(byte[])`.

MarshallingHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write XML using Spring's `Marshaller` and `Unmarshaller` abstractions from the `org.springframework.oxm` package. This converter requires a `Marshaller` and `Unmarshaller` before it can be used. These can be injected via constructor or bean properties. By default this converter supports (`text/xml`) and (`application/xml`).

MappingJackson2HttpMessageConverter

An `HttpMessageConverter` implementation that can read and write JSON using Jackson's `ObjectMapper`. JSON mapping can be customized as needed through the use of Jackson's provided

annotations. When further control is needed, a custom `ObjectMapper` can be injected through the `ObjectMapper` property for cases where custom JSON serializers/deserializers need to be provided for specific types. By default this converter supports (`application/json`).

MappingJackson2XmlHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write XML using Jackson XML extension's `XmlMapper`. XML mapping can be customized as needed through the use of JAXB or Jackson's provided annotations. When further control is needed, a custom `XmlMapper` can be injected through the `ObjectMapper` property for cases where custom XML serializers/deserializers need to be provided for specific types. By default this converter supports (`application/xml`).

SourceHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write `javax.xml.transform.Source` from the HTTP request and response. Only `DOMSource`, `SAXSource`, and `StreamSource` are supported. By default, this converter supports (`text/xml`) and (`application/xml`).

BufferedImageHttpMessageConverter

An `HttpMessageConverter` implementation that can read and write `java.awt.image.BufferedImage` from the HTTP request and response. This converter reads and writes the media type supported by the Java I/O API.

Async RestTemplate

Web applications often need to query external REST services those days. The very nature of HTTP and synchronous calls can lead up to challenges when scaling applications for those needs: multiple threads may be blocked, waiting for remote HTTP responses.

`AsyncRestTemplate` and the section called "RestTemplate"'s APIs are very similar; see Table 22.1, "Overview of RestTemplate methods". The main difference between those APIs is that `AsyncRestTemplate` returns `ListenableFuture` wrappers as opposed to concrete results.

The previous `RestTemplate` example translates to:

```
// async call
Future<ResponseEntity<String>> futureEntity = template.getForEntity(
    "http://example.com/hotels/{hotel}/bookings/{booking}", String.class, "42", "21");

// get the concrete result - synchronous call
ResponseEntity<String> entity = futureEntity.get();
```

`ListenableFuture` accepts completion callbacks:

```
ListenableFuture<ResponseEntity<String>> futureEntity = template.getForEntity(
    "http://example.com/hotels/{hotel}/bookings/{booking}", String.class, "42", "21");

// register a callback
futureEntity.addCallback(new ListenableFutureCallback<ResponseEntity<String>>() {
    @Override
    public void onSuccess(ResponseEntity<String> entity) {
        //...
    }

    @Override
    public void onFailure(Throwable t) {
        //...
    }
});
```

Note

The default `AsyncRestTemplate` constructor registers a `SimpleAsyncTaskExecutor` for executing HTTP requests. When dealing with a large number of short-lived requests, a thread-pooling TaskExecutor implementation like `ThreadPoolTaskExecutor` may be a good choice.

See the `ListenableFuture` javadocs and `AsyncRestTemplate` javadocs for more details.

23. Enterprise JavaBeans (EJB) integration

23.1 Introduction

As a lightweight container, Spring is often considered an EJB replacement. We do believe that for many if not most applications and use cases, Spring as a container, combined with its rich supporting functionality in the area of transactions, ORM and JDBC access, is a better choice than implementing equivalent functionality via an EJB container and EJBs.

However, it is important to note that using Spring does not prevent you from using EJBs. In fact, Spring makes it much easier to access EJBs and implement EJBs and functionality within them. Additionally, using Spring to access services provided by EJBs allows the implementation of those services to later transparently be switched between local EJB, remote EJB, or POJO (plain old Java object) variants, without the client code having to be changed.

In this chapter, we look at how Spring can help you access and implement EJBs. Spring provides particular value when accessing stateless session beans (SLSBs), so we'll begin by discussing this.

23.2 Accessing EJBs

Concepts

To invoke a method on a local or remote stateless session bean, client code must normally perform a JNDI lookup to obtain the (local or remote) EJB Home object, then use a *create* method call on that object to obtain the actual (local or remote) EJB object. One or more methods are then invoked on the EJB.

To avoid repeated low-level code, many EJB applications use the Service Locator and Business Delegate patterns. These are better than spraying JNDI lookups throughout client code, but their usual implementations have significant disadvantages. For example:

- Typically code using EJBs depends on Service Locator or Business Delegate singletons, making it hard to test.
- In the case of the Service Locator pattern used without a Business Delegate, application code still ends up having to invoke the create() method on an EJB home, and deal with the resulting exceptions. Thus it remains tied to the EJB API and the complexity of the EJB programming model.
- Implementing the Business Delegate pattern typically results in significant code duplication, where we have to write numerous methods that simply call the same method on the EJB.

The Spring approach is to allow the creation and use of proxy objects, normally configured inside a Spring container, which act as codeless business delegates. You do not need to write another Service Locator, another JNDI lookup, or duplicate methods in a hand-coded Business Delegate unless you are actually adding real value in such code.

Accessing local SLSBs

Assume that we have a web controller that needs to use a local EJB. We'll follow best practice and use the EJB Business Methods Interface pattern, so that the EJB's local interface extends a non EJB-specific business methods interface. Let's call this business methods interface `MyComponent`.

```
public interface MyComponent {
    ...
}
```

One of the main reasons to use the Business Methods Interface pattern is to ensure that synchronization between method signatures in local interface and bean implementation class is automatic. Another reason is that it later makes it much easier for us to switch to a POJO (plain old Java object) implementation of the service if it makes sense to do so. Of course we'll also need to implement the local home interface and provide an implementation class that implements `SessionBean` and the `MyComponent` business methods interface. Now the only Java coding we'll need to do to hook up our web tier controller to the EJB implementation is to expose a setter method of type `MyComponent` on the controller. This will save the reference as an instance variable in the controller:

```
private MyComponent myComponent;

public void setMyComponent(MyComponent myComponent) {
    this.myComponent = myComponent;
}
```

We can subsequently use this instance variable in any business method in the controller. Now assuming we are obtaining our controller object out of a Spring container, we can (in the same context) configure a `LocalStatelessSessionProxyFactoryBean` instance, which will be the EJB proxy object. The configuration of the proxy, and setting of the `myComponent` property of the controller is done with a configuration entry such as:

```
<bean id="myComponent"
        class="org.springframework.ejb.access.LocalStatelessSessionProxyFactoryBean">
    <property name="jndiName" value="ejb/myBean"/>
    <property name="businessInterface" value="com.mycom.MyComponent"/>
</bean>

<bean id="myController" class="com.mycom.myController">
    <property name="myComponent" ref="myComponent"/>
</bean>
```

There's a lot of work happening behind the scenes, courtesy of the Spring AOP framework, although you aren't forced to work with AOP concepts to enjoy the results. The `myComponent` bean definition creates a proxy for the EJB, which implements the business method interface. The EJB local home is cached on startup, so there's only a single JNDI lookup. Each time the EJB is invoked, the proxy invokes the `classname` method on the local EJB and invokes the corresponding business method on the EJB.

The `myController` bean definition sets the `myComponent` property of the controller class to the EJB proxy.

Alternatively (and preferably in case of many such proxy definitions), consider using the `<jee:local-slsb>` configuration element in Spring's "jee" namespace:

```
<jee:local-slsb id="myComponent" jndi-name="ejb/myBean"
        business-interface="com.mycom.MyComponent"/>

<bean id="myController" class="com.mycom.myController">
    <property name="myComponent" ref="myComponent"/>
</bean>
```

This EJB access mechanism delivers huge simplification of application code: the web tier code (or other EJB client code) has no dependence on the use of EJB. If we want to replace this EJB reference with a POJO or a mock object or other test stub, we could simply change the `myComponent` bean definition without changing a line of Java code. Additionally, we haven't had to write a single line of JNDI lookup or other EJB plumbing code as part of our application.

Benchmarks and experience in real applications indicate that the performance overhead of this approach (which involves reflective invocation of the target EJB) is minimal, and is typically undetectable in

typical use. Remember that we don't want to make fine-grained calls to EJBs anyway, as there's a cost associated with the EJB infrastructure in the application server.

There is one caveat with regards to the JNDI lookup. In a bean container, this class is normally best used as a singleton (there simply is no reason to make it a prototype). However, if that bean container pre-instantiates singletons (as do the various XML `ApplicationContext` variants) you may have a problem if the bean container is loaded before the EJB container loads the target EJB. That is because the JNDI lookup will be performed in the `init()` method of this class and then cached, but the EJB will not have been bound at the target location yet. The solution is to not pre-instantiate this factory object, but allow it to be created on first use. In the XML containers, this is controlled via the `lazy-init` attribute.

Although this will not be of interest to the majority of Spring users, those doing programmatic AOP work with EJBs may want to look at `LocalSlsbInvokerInterceptor`.

Accessing remote SLSBs

Accessing remote EJBs is essentially identical to accessing local EJBs, except that the `SimpleRemoteStatelessSessionProxyFactoryBean` or `<jee:remote-slsb>` configuration element is used. Of course, with or without Spring, remote invocation semantics apply; a call to a method on an object in another VM in another computer does sometimes have to be treated differently in terms of usage scenarios and failure handling.

Spring's EJB client support adds one more advantage over the non-Spring approach. Normally it is problematic for EJB client code to be easily switched back and forth between calling EJBs locally or remotely. This is because the remote interface methods must declare that they throw `RemoteException`, and client code must deal with this, while the local interface methods don't. Client code written for local EJBs which needs to be moved to remote EJBs typically has to be modified to add handling for the remote exceptions, and client code written for remote EJBs which needs to be moved to local EJBs, can either stay the same but do a lot of unnecessary handling of remote exceptions, or needs to be modified to remove that code. With the Spring remote EJB proxy, you can instead not declare any thrown `RemoteException` in your Business Method Interface and implementing EJB code, have a remote interface which is identical except that it does throw `RemoteException`, and rely on the proxy to dynamically treat the two interfaces as if they were the same. That is, client code does not have to deal with the checked `RemoteException` class. Any actual `RemoteException` that is thrown during the EJB invocation will be re-thrown as the non-checked `RemoteAccessException` class, which is a subclass of `RuntimeException`. The target service can then be switched at will between a local EJB or remote EJB (or even plain Java object) implementation, without the client code knowing or caring. Of course, this is optional; there is nothing stopping you from declaring `RemoteExceptions` in your business interface.

Accessing EJB 2.x SLSBs versus EJB 3 SLSBs

Accessing EJB 2.x Session Beans and EJB 3 Session Beans via Spring is largely transparent. Spring's EJB accessors, including the `<jee:local-slsb>` and `<jee:remote-slsb>` facilities, transparently adapt to the actual component at runtime. They handle a home interface if found (EJB 2.x style), or perform straight component invocations if no home interface is available (EJB 3 style).

Note: For EJB 3 Session Beans, you could effectively use a `JndiObjectFactoryBean` / `<jee:jndi-lookup>` as well, since fully usable component references are exposed for plain JNDI lookups there. Defining explicit `<jee:local-slsb>` / `<jee:remote-slsb>` lookups simply provides consistent and more explicit EJB access configuration.

23.3 Using Spring's EJB implementation support classes

EJB 3 injection interceptor

For EJB 3 Session Beans and Message-Driven Beans, Spring provides a convenient interceptor that resolves Spring's `@Autowired` annotation in the EJB component class: `org.springframework.ejb.interceptor.SpringBeanAutowiringInterceptor`. This interceptor can be applied through an `@Interceptors` annotation in the EJB component class, or through an `interceptor-binding` XML element in the EJB deployment descriptor.

```
@Stateless
@Interceptors(SpringBeanAutowiringInterceptor.class)
public class MyFacadeEJB implements MyFacadeLocal {

    // automatically injected with a matching Spring bean
    @Autowired
    private MyComponent myComp;

    // for business method, delegate to POJO service impl.
    public String myFacadeMethod(...) {
        return myComp.myMethod(...);
    }

    ...

}
```

`SpringBeanAutowiringInterceptor` by default obtains target beans from a `ContextSingletonBeanFactoryLocator`, with the context defined in a bean definition file named `beanRefContext.xml`. By default, a single context definition is expected, which is obtained by type rather than by name. However, if you need to choose between multiple context definitions, a specific locator key is required. The locator key (i.e. the name of the context definition in `beanRefContext.xml`) can be explicitly specified either through overriding the `getBeanFactoryLocatorKey` method in a custom `SpringBeanAutowiringInterceptor` subclass.

Alternatively, consider overriding `SpringBeanAutowiringInterceptor`'s `getBeanFactory` method, e.g. obtaining a shared `ApplicationContext` from a custom holder class.

24. JMS (Java Message Service)

24.1 Introduction

Spring provides a JMS integration framework that simplifies the use of the JMS API much like Spring's integration does for the JDBC API.

JMS can be roughly divided into two areas of functionality, namely the production and consumption of messages. The `JmsTemplate` class is used for message production and synchronous message reception. For asynchronous reception similar to Java EE's message-driven bean style, Spring provides a number of message listener containers that are used to create Message-Driven POJOs (MDPs). Spring also provides a declarative way of creating message listeners.

The package `org.springframework.jms.core` provides the core functionality for using JMS. It contains JMS template classes that simplify the use of the JMS by handling the creation and release of resources, much like the `JdbcTemplate` does for JDBC. The design principle common to Spring template classes is to provide helper methods to perform common operations and for more sophisticated usage, delegate the essence of the processing task to user implemented callback interfaces. The JMS template follows the same design. The classes offer various convenience methods for the sending of messages, consuming a message synchronously, and exposing the JMS session and message producer to the user.

The package `org.springframework.jms.support` provides `JMSException` translation functionality. The translation converts the checked `JMSException` hierarchy to a mirrored hierarchy of unchecked exceptions. If there are any provider specific subclasses of the checked `javax.jms.JMSException`, this exception is wrapped in the unchecked `UncategorizedJmsException`.

The package `org.springframework.jms.support.converter` provides a `MessageConverter` abstraction to convert between Java objects and JMS messages.

The package `org.springframework.jms.support.destination` provides various strategies for managing JMS destinations, such as providing a service locator for destinations stored in JNDI.

The package `org.springframework.jms.annotation` provides the necessary infrastructure to support annotation-driven listener endpoints using `@JmsListener`.

The package `org.springframework.jms.config` provides the parser implementation for the `jms` namespace as well the java config support to configure listener containers and create listener endpoints.

Finally, the package `org.springframework.jms.connection` provides an implementation of the `ConnectionFactory` suitable for use in standalone applications. It also contains an implementation of Spring's `PlatformTransactionManager` for JMS (the cunningly named `JmsTransactionManager`). This allows for seamless integration of JMS as a transactional resource into Spring's transaction management mechanisms.

24.2 Using Spring JMS

JmsTemplate

The `JmsTemplate` class is the central class in the JMS core package. It simplifies the use of JMS since it handles the creation and release of resources when sending or synchronously receiving messages.

Code that uses the `JmsTemplate` only needs to implement callback interfaces giving them a clearly defined high level contract. The `MessageCreator` callback interface creates a message given a `Session` provided by the calling code in `JmsTemplate`. In order to allow for more complex usage of the JMS API, the callback `SessionCallback` provides the user with the JMS session and the callback `ProducerCallback` exposes a `Session` and `MessageProducer` pair.

The JMS API exposes two types of send methods, one that takes delivery mode, priority, and time-to-live as Quality of Service (QOS) parameters and one that takes no QOS parameters which uses default values. Since there are many send methods in `JmsTemplate`, the setting of the QOS parameters have been exposed as bean properties to avoid duplication in the number of send methods. Similarly, the timeout value for synchronous receive calls is set using the property `setReceiveTimeout`.

Some JMS providers allow the setting of default QOS values administratively through the configuration of the `ConnectionFactory`. This has the effect that a call to `MessageProducer`'s send method `send(Destination destination, Message message)` will use different QOS default values than those specified in the JMS specification. In order to provide consistent management of QOS values, the `JmsTemplate` must therefore be specifically enabled to use its own QOS values by setting the boolean property `isExplicitQosEnabled` to `true`.

For convenience, `JmsTemplate` also exposes a basic request-reply operation that allows to send a message and wait for a reply on a temporary queue that is created as part of the operation.

> **Note**
>
> Instances of the `JmsTemplate` class are *thread-safe once configured*. This is important because it means that you can configure a single instance of a `JmsTemplate` and then safely inject this *shared* reference into multiple collaborators. To be clear, the `JmsTemplate` is stateful, in that it maintains a reference to a `ConnectionFactory`, but this state is *not* conversational state.

As of Spring Framework 4.1, `JmsMessagingTemplate` is built on top of `JmsTemplate` and provides an integration with the messaging abstraction, i.e. `org.springframework.messaging.Message`. This allows you to create the message to send in generic manner.

Connections

The `JmsTemplate` requires a reference to a `ConnectionFactory`. The `ConnectionFactory` is part of the JMS specification and serves as the entry point for working with JMS. It is used by the client application as a factory to create connections with the JMS provider and encapsulates various configuration parameters, many of which are vendor specific such as SSL configuration options.

When using JMS inside an EJB, the vendor provides implementations of the JMS interfaces so that they can participate in declarative transaction management and perform pooling of connections and sessions. In order to use this implementation, Java EE containers typically require that you declare a JMS connection factory as a `resource-ref` inside the EJB or servlet deployment descriptors. To ensure the use of these features with the `JmsTemplate` inside an EJB, the client application should ensure that it references the managed implementation of the `ConnectionFactory`.

Caching Messaging Resources

The standard API involves creating many intermediate objects. To send a message the following *API* walk is performed

```
ConnectionFactory->Connection->Session->MessageProducer->send
```

Between the ConnectionFactory and the Send operation there are three intermediate objects that are created and destroyed. To optimise the resource usage and increase performance two implementations of `ConnectionFactory` are provided.

SingleConnectionFactory

Spring provides an implementation of the `ConnectionFactory` interface, `SingleConnectionFactory`, that will return the same `Connection` on all `createConnection()` calls and ignore calls to `close()`. This is useful for testing and standalone environments so that the same connection can be used for multiple `JmsTemplate` calls that may span any number of transactions. `SingleConnectionFactory` takes a reference to a standard `ConnectionFactory` that would typically come from JNDI.

CachingConnectionFactory

The `CachingConnectionFactory` extends the functionality of `SingleConnectionFactory` and adds the caching of Sessions, MessageProducers, and MessageConsumers. The initial cache size is set to 1, use the property `SessionCacheSize` to increase the number of cached sessions. Note that the number of actual cached sessions will be more than that number as sessions are cached based on their acknowledgment mode, so there can be up to 4 cached session instances when `SessionCacheSize` is set to one, one for each `AcknowledgementMode`. MessageProducers and MessageConsumers are cached within their owning session and also take into account the unique properties of the producers and consumers when caching. MessageProducers are cached based on their destination. MessageConsumers are cached based on a key composed of the destination, selector, noLocal delivery flag, and the durable subscription name (if creating durable consumers).

Destination Management

Destinations, like ConnectionFactories, are JMS administered objects that can be stored and retrieved in JNDI. When configuring a Spring application context you can use the JNDI factory class `JndiObjectFactoryBean` / `<jee:jndi-lookup>` to perform dependency injection on your object's references to JMS destinations. However, often this strategy is cumbersome if there are a large number of destinations in the application or if there are advanced destination management features unique to the JMS provider. Examples of such advanced destination management would be the creation of dynamic destinations or support for a hierarchical namespace of destinations. The `JmsTemplate` delegates the resolution of a destination name to a JMS destination object to an implementation of the interface `DestinationResolver`. `DynamicDestinationResolver` is the default implementation used by `JmsTemplate` and accommodates resolving dynamic destinations. A `JndiDestinationResolver` is also provided that acts as a service locator for destinations contained in JNDI and optionally falls back to the behavior contained in `DynamicDestinationResolver`.

Quite often the destinations used in a JMS application are only known at runtime and therefore cannot be administratively created when the application is deployed. This is often because there is shared application logic between interacting system components that create destinations at runtime according to a well-known naming convention. Even though the creation of dynamic destinations is not part of the JMS specification, most vendors have provided this functionality. Dynamic destinations are created with a name defined by the user which differentiates them from temporary destinations and are often not registered in JNDI. The API used to create dynamic destinations varies from provider to provider since the properties associated with the destination are vendor specific. However, a simple implementation

choice that is sometimes made by vendors is to disregard the warnings in the JMS specification and to use the `TopicSession` method `createTopic(String topicName)` or the `QueueSession` method `createQueue(String queueName)` to create a new destination with default destination properties. Depending on the vendor implementation, `DynamicDestinationResolver` may then also create a physical destination instead of only resolving one.

The boolean property `pubSubDomain` is used to configure the `JmsTemplate` with knowledge of what JMS domain is being used. By default the value of this property is false, indicating that the point-to-point domain, Queues, will be used. This property used by `JmsTemplate` determines the behavior of dynamic destination resolution via implementations of the `DestinationResolver` interface.

You can also configure the `JmsTemplate` with a default destination via the property `defaultDestination`. The default destination will be used with send and receive operations that do not refer to a specific destination.

Message Listener Containers

One of the most common uses of JMS messages in the EJB world is to drive message-driven beans (MDBs). Spring offers a solution to create message-driven POJOs (MDPs) in a way that does not tie a user to an EJB container. (See the section called “Asynchronous Reception - Message-Driven POJOs” for detailed coverage of Spring’s MDP support.) As from Spring Framework 4.1, endpoint methods can be simply annotated using `@JmsListener` see Section 24.6, “Annotation-driven listener endpoints” for more details.

A message listener container is used to receive messages from a JMS message queue and drive the `MessageListener` that is injected into it. The listener container is responsible for all threading of message reception and dispatches into the listener for processing. A message listener container is the intermediary between an MDP and a messaging provider, and takes care of registering to receive messages, participating in transactions, resource acquisition and release, exception conversion and suchlike. This allows you as an application developer to write the (possibly complex) business logic associated with receiving a message (and possibly responding to it), and delegates boilerplate JMS infrastructure concerns to the framework.

There are two standard JMS message listener containers packaged with Spring, each with its specialised feature set.

SimpleMessageListenerContainer

This message listener container is the simpler of the two standard flavors. It creates a fixed number of JMS sessions and consumers at startup, registers the listener using the standard JMS `MessageConsumer.setMessageListener()` method, and leaves it up the JMS provider to perform listener callbacks. This variant does not allow for dynamic adaption to runtime demands or for participation in externally managed transactions. Compatibility-wise, it stays very close to the spirit of the standalone JMS specification - but is generally not compatible with Java EE’s JMS restrictions.

DefaultMessageListenerContainer

This message listener container is the one used in most cases. In contrast to `SimpleMessageListenerContainer`, this container variant does allow for dynamic adaption to runtime demands and is able to participate in externally managed transactions. Each received message is registered with an XA transaction when configured with a `JtaTransactionManager`; so processing may take advantage of XA transaction semantics. This listener container strikes a good balance between

low requirements on the JMS provider, advanced functionality such as transaction participation, and compatibility with Java EE environments.

The cache level of the container can be customized. Note that when no caching is enabled, a new connection and a new session is created for each message reception. Combining this with a non durable subscription with high loads may lead to message lost. Make sure to use a proper cache level in such case.

This container also has recoverable capabilities when the broker goes down. By default, a simple `BackOff` implementation retries every 5 seconds. It is possible to specify a custom `BackOff` implementation for more fine-grained recovery options, see `ExponentialBackOff` for an example.

Transaction management

Spring provides a `JmsTransactionManager` that manages transactions for a single JMS `ConnectionFactory`. This allows JMS applications to leverage the managed transaction features of Spring as described in Chapter 12, *Transaction Management*. The `JmsTransactionManager` performs local resource transactions, binding a JMS Connection/Session pair from the specified `ConnectionFactory` to the thread. `JmsTemplate` automatically detects such transactional resources and operates on them accordingly.

In a Java EE environment, the `ConnectionFactory` will pool Connections and Sessions, so those resources are efficiently reused across transactions. In a standalone environment, using Spring's `SingleConnectionFactory` will result in a shared JMS `Connection`, with each transaction having its own independent `Session`. Alternatively, consider the use of a provider-specific pooling adapter such as ActiveMQ's `PooledConnectionFactory` class.

`JmsTemplate` can also be used with the `JtaTransactionManager` and an XA-capable JMS `ConnectionFactory` for performing distributed transactions. Note that this requires the use of a JTA transaction manager as well as a properly XA-configured ConnectionFactory! (Check your Java EE server's / JMS provider's documentation.)

Reusing code across a managed and unmanaged transactional environment can be confusing when using the JMS API to create a `Session` from a `Connection`. This is because the JMS API has only one factory method to create a `Session` and it requires values for the transaction and acknowledgement modes. In a managed environment, setting these values is the responsibility of the environment's transactional infrastructure, so these values are ignored by the vendor's wrapper to the JMS Connection. When using the `JmsTemplate` in an unmanaged environment you can specify these values through the use of the properties `sessionTransacted` and `sessionAcknowledgeMode`. When using a `PlatformTransactionManager` with `JmsTemplate`, the template will always be given a transactional JMS `Session`.

24.3 Sending a Message

The `JmsTemplate` contains many convenience methods to send a message. There are send methods that specify the destination using a `javax.jms.Destination` object and those that specify the destination using a string for use in a JNDI lookup. The send method that takes no destination argument uses the default destination.

```
import javax.jms.ConnectionFactory;
import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.Queue;
import javax.jms.Session;

import org.springframework.jms.core.MessageCreator;
import org.springframework.jms.core.JmsTemplate;

public class JmsQueueSender {

    private JmsTemplate jmsTemplate;
    private Queue queue;

    public void setConnectionFactory(ConnectionFactory cf) {
        this.jmsTemplate = new JmsTemplate(cf);
    }

    public void setQueue(Queue queue) {
        this.queue = queue;
    }

    public void simpleSend() {
        this.jmsTemplate.send(this.queue, new MessageCreator() {
            public Message createMessage(Session session) throws JMSException {
                return session.createTextMessage("hello queue world");
            }
        });
    }
}
```

This example uses the `MessageCreator` callback to create a text message from the supplied `Session` object. The `JmsTemplate` is constructed by passing a reference to a `ConnectionFactory`. As an alternative, a zero argument constructor and `connectionFactory` is provided and can be used for constructing the instance in JavaBean style (using a BeanFactory or plain Java code). Alternatively, consider deriving from Spring's `JmsGatewaySupport` convenience base class, which provides pre-built bean properties for JMS configuration.

The method `send(String destinationName, MessageCreator creator)` lets you send a message using the string name of the destination. If these names are registered in JNDI, you should set the `destinationResolver` property of the template to an instance of `JndiDestinationResolver`.

If you created the `JmsTemplate` and specified a default destination, the `send(MessageCreator c)` sends a message to that destination.

Using Message Converters

In order to facilitate the sending of domain model objects, the `JmsTemplate` has various send methods that take a Java object as an argument for a message's data content. The overloaded methods `convertAndSend()` and `receiveAndConvert()` in `JmsTemplate` delegate the conversion process to an instance of the `MessageConverter` interface. This interface defines a simple contract to convert between Java objects and JMS messages. The default implementation `SimpleMessageConverter` supports conversion between `String` and `TextMessage`, `byte[]` and `BytesMesssage`, and `java.util.Map` and `MapMessage`. By using the converter, you and your application code can focus on the business object that is being sent or received via JMS and not be concerned with the details of how it is represented as a JMS message.

The sandbox currently includes a `MapMessageConverter` which uses reflection to convert between a JavaBean and a `MapMessage`. Other popular implementation choices you might implement yourself

are Converters that use an existing XML marshalling package, such as JAXB, Castor, XMLBeans, or XStream, to create a `TextMessage` representing the object.

To accommodate the setting of a message's properties, headers, and body that can not be generically encapsulated inside a converter class, the `MessagePostProcessor` interface gives you access to the message after it has been converted, but before it is sent. The example below demonstrates how to modify a message header and a property after a `java.util.Map` is converted to a message.

```
public void sendWithConversion() {
    Map map = new HashMap();
    map.put("Name", "Mark");
    map.put("Age", new Integer(47));
    jmsTemplate.convertAndSend("testQueue", map, new MessagePostProcessor() {
        public Message postProcessMessage(Message message) throws JMSException {
            message.setIntProperty("AccountID", 1234);
            message.setJMSCorrelationID("123-00001");
            return message;
        }
    });
}
```

This results in a message of the form:

```
MapMessage={
 Header={
  ... standard headers ...
  CorrelationID={123-00001}
 }
 Properties={
  AccountID={Integer:1234}
 }
 Fields={
  Name={String:Mark}
  Age={Integer:47}
 }
}
```

SessionCallback and ProducerCallback

While the send operations cover many common usage scenarios, there are cases when you want to perform multiple operations on a JMS `Session` or `MessageProducer`. The `SessionCallback` and `ProducerCallback` expose the JMS `Session` and `Session` / `MessageProducer` pair respectively. The `execute()` methods on `JmsTemplate` execute these callback methods.

24.4 Receiving a message

Synchronous Reception

While JMS is typically associated with asynchronous processing, it is possible to consume messages synchronously. The overloaded `receive(..)` methods provide this functionality. During a synchronous receive, the calling thread blocks until a message becomes available. This can be a dangerous operation since the calling thread can potentially be blocked indefinitely. The property `receiveTimeout` specifies how long the receiver should wait before giving up waiting for a message.

Asynchronous Reception - Message-Driven POJOs

> **Note**
>
> Spring also supports annotated-listener endpoints through the use of the `@JmsListener` annotation and provides an open infrastructure to register endpoints programmatically. This is by

> far the most convenient way to setup an asynchronous receiver, see the section called “Enable listener endpoint annotations” for more details.

In a fashion similar to a Message-Driven Bean (MDB) in the EJB world, the Message-Driven POJO (MDP) acts as a receiver for JMS messages. The one restriction (but see also below for the discussion of the `MessageListenerAdapter` class) on an MDP is that it must implement the `javax.jms.MessageListener` interface. Please also be aware that in the case where your POJO will be receiving messages on multiple threads, it is important to ensure that your implementation is thread-safe.

Below is a simple implementation of an MDP:

```
import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.TextMessage;

public class ExampleListener implements MessageListener {

    public void onMessage(Message message) {
        if (message instanceof TextMessage) {
            try {
                System.out.println(((TextMessage) message).getText());
            }
            catch (JMSException ex) {
                throw new RuntimeException(ex);
            }
        }
        else {
            throw new IllegalArgumentException("Message must be of type TextMessage");
        }
    }

}
```

Once you’ve implemented your `MessageListener`, it’s time to create a message listener container.

Find below an example of how to define and configure one of the message listener containers that ships with Spring (in this case the `DefaultMessageListenerContainer`).

```
<!-- this is the Message Driven POJO (MDP) -->
<bean id="messageListener" class="jmsexample.ExampleListener" />

<!-- and this is the message listener container -->
<bean id="jmsContainer" class="org.springframework.jms.listener.DefaultMessageListenerContainer">
    <property name="connectionFactory" ref="connectionFactory"/>
    <property name="destination" ref="destination"/>
    <property name="messageListener" ref="messageListener" />
</bean>
```

Please refer to the Spring javadocs of the various message listener containers for a full description of the features supported by each implementation.

the SessionAwareMessageListener interface

The `SessionAwareMessageListener` interface is a Spring-specific interface that provides a similar contract to the JMS `MessageListener` interface, but also provides the message handling method with access to the JMS `Session` from which the `Message` was received.

```
package org.springframework.jms.listener;

public interface SessionAwareMessageListener {

    void onMessage(Message message, Session session) throws JMSException;

}
```

You can choose to have your MDPs implement this interface (in preference to the standard JMS `MessageListener` interface) if you want your MDPs to be able to respond to any received messages (using the `Session` supplied in the `onMessage(Message, Session)` method). All of the message listener container implementations that ship with Spring have support for MDPs that implement either the `MessageListener` or `SessionAwareMessageListener` interface. Classes that implement the `SessionAwareMessageListener` come with the caveat that they are then tied to Spring through the interface. The choice of whether or not to use it is left entirely up to you as an application developer or architect.

Please note that the `'onMessage(..)'` method of the `SessionAwareMessageListener` interface throws `JMSException`. In contrast to the standard JMS `MessageListener` interface, when using the `SessionAwareMessageListener` interface, it is the responsibility of the client code to handle any exceptions thrown.

the MessageListenerAdapter

The `MessageListenerAdapter` class is the final component in Spring's asynchronous messaging support: in a nutshell, it allows you to expose almost *any* class as a MDP (there are of course some constraints).

Consider the following interface definition. Notice that although the interface extends neither the `MessageListener` nor `SessionAwareMessageListener` interfaces, it can still be used as a MDP via the use of the `MessageListenerAdapter` class. Notice also how the various message handling methods are strongly typed according to the *contents* of the various `Message` types that they can receive and handle.

```
public interface MessageDelegate {

    void handleMessage(String message);

    void handleMessage(Map message);

    void handleMessage(byte[] message);

    void handleMessage(Serializable message);

}
```

```
public class DefaultMessageDelegate implements MessageDelegate {
    // implementation elided for clarity...
}
```

In particular, note how the above implementation of the `MessageDelegate` interface (the above `DefaultMessageDelegate` class) has *no* JMS dependencies at all. It truly is a POJO that we will make into an MDP via the following configuration.

```
<!-- this is the Message Driven POJO (MDP) -->
<bean id="messageListener" class="org.springframework.jms.listener.adapter.MessageListenerAdapter">
    <constructor-arg>
        <bean class="jmsexample.DefaultMessageDelegate"/>
    </constructor-arg>
</bean>

<!-- and this is the message listener container... -->
<bean id="jmsContainer" class="org.springframework.jms.listener.DefaultMessageListenerContainer">
    <property name="connectionFactory" ref="connectionFactory"/>
    <property name="destination" ref="destination"/>
    <property name="messageListener" ref="messageListener" />
</bean>
```

Below is an example of another MDP that can only handle the receiving of JMS `TextMessage` messages. Notice how the message handling method is actually called `'receive'` (the name of the message handling method in a `MessageListenerAdapter` defaults to `'handleMessage'`), but it is configurable (as you will see below). Notice also how the `'receive(..)'` method is strongly typed to receive and respond only to JMS `TextMessage` messages.

```
public interface TextMessageDelegate {

    void receive(TextMessage message);

}
```

```
public class DefaultTextMessageDelegate implements TextMessageDelegate {
    // implementation elided for clarity...
}
```

The configuration of the attendant `MessageListenerAdapter` would look like this:

```
<bean id="messageListener" class="org.springframework.jms.listener.adapter.MessageListenerAdapter">
    <constructor-arg>
        <bean class="jmsexample.DefaultTextMessageDelegate"/>
    </constructor-arg>
    <property name="defaultListenerMethod" value="receive"/>
    <!-- we don't want automatic message context extraction -->
    <property name="messageConverter">
        <null/>
    </property>
</bean>
```

Please note that if the above `'messageListener'` receives a JMS `Message` of a type other than `TextMessage`, an `IllegalStateException` will be thrown (and subsequently swallowed). Another of the capabilities of the `MessageListenerAdapter` class is the ability to automatically send back a response `Message` if a handler method returns a non-void value. Consider the interface and class:

```
public interface ResponsiveTextMessageDelegate {

    // notice the return type...
    String receive(TextMessage message);

}
```

```
public class DefaultResponsiveTextMessageDelegate implements ResponsiveTextMessageDelegate {
    // implementation elided for clarity...
}
```

If the above `DefaultResponsiveTextMessageDelegate` is used in conjunction with a `MessageListenerAdapter` then any non-null value that is returned from the execution of the `'receive(..)'` method will (in the default configuration) be converted into a `TextMessage`.

The resulting `TextMessage` will then be sent to the `Destination` (if one exists) defined in the JMS Reply-To property of the original `Message`, or the default `Destination` set on the `MessageListenerAdapter` (if one has been configured); if no `Destination` is found then an `InvalidDestinationException` will be thrown (and please note that this exception *will not* be swallowed and *will* propagate up the call stack).

Processing messages within transactions

Invoking a message listener within a transaction only requires reconfiguration of the listener container.

Local resource transactions can simply be activated through the `sessionTransacted` flag on the listener container definition. Each message listener invocation will then operate within an active JMS transaction, with message reception rolled back in case of listener execution failure. Sending a response message (via `SessionAwareMessageListener`) will be part of the same local transaction, but any other resource operations (such as database access) will operate independently. This usually requires duplicate message detection in the listener implementation, covering the case where database processing has committed but message processing failed to commit.

```
<bean id="jmsContainer" class="org.springframework.jms.listener.DefaultMessageListenerContainer">
    <property name="connectionFactory" ref="connectionFactory"/>
    <property name="destination" ref="destination"/>
    <property name="messageListener" ref="messageListener"/>
    <property name="sessionTransacted" value="true"/>
</bean>
```

For participating in an externally managed transaction, you will need to configure a transaction manager and use a listener container which supports externally managed transactions: typically `DefaultMessageListenerContainer`.

To configure a message listener container for XA transaction participation, you'll want to configure a `JtaTransactionManager` (which, by default, delegates to the Java EE server's transaction subsystem). Note that the underlying JMS ConnectionFactory needs to be XA-capable and properly registered with your JTA transaction coordinator! (Check your Java EE server's configuration of JNDI resources.) This allows message reception as well as e.g. database access to be part of the same transaction (with unified commit semantics, at the expense of XA transaction log overhead).

```
<bean id="transactionManager" class="org.springframework.transaction.jta.JtaTransactionManager"/>
```

Then you just need to add it to our earlier container configuration. The container will take care of the rest.

```
<bean id="jmsContainer" class="org.springframework.jms.listener.DefaultMessageListenerContainer">
    <property name="connectionFactory" ref="connectionFactory"/>
    <property name="destination" ref="destination"/>
    <property name="messageListener" ref="messageListener"/>
    <property name="transactionManager" ref="transactionManager"/>
</bean>
```

24.5 Support for JCA Message Endpoints

Beginning with version 2.5, Spring also provides support for a JCA-based `MessageListener` container. The `JmsMessageEndpointManager` will attempt to automatically determine the `ActivationSpec` class name from the provider's `ResourceAdapter` class name. Therefore, it is typically possible to just provide Spring's generic `JmsActivationSpecConfig` as shown in the following example.

```
<bean class="org.springframework.jms.listener.endpoint.JmsMessageEndpointManager">
    <property name="resourceAdapter" ref="resourceAdapter"/>
    <property name="activationSpecConfig">
        <bean class="org.springframework.jms.listener.endpoint.JmsActivationSpecConfig">
            <property name="destinationName" value="myQueue"/>
        </bean>
    </property>
    <property name="messageListener" ref="myMessageListener"/>
</bean>
```

Alternatively, you may set up a `JmsMessageEndpointManager` with a given `ActivationSpec` object. The `ActivationSpec` object may also come from a JNDI lookup (using `<jee:jndi-lookup>`).

```
<bean class="org.springframework.jms.listener.endpoint.JmsMessageEndpointManager">
    <property name="resourceAdapter" ref="resourceAdapter"/>
    <property name="activationSpec">
        <bean class="org.apache.activemq.ra.ActiveMQActivationSpec">
            <property name="destination" value="myQueue"/>
            <property name="destinationType" value="javax.jms.Queue"/>
        </bean>
    </property>
    <property name="messageListener" ref="myMessageListener"/>
</bean>
```

Using Spring's `ResourceAdapterFactoryBean`, the target `ResourceAdapter` may be configured locally as depicted in the following example.

```
<bean id="resourceAdapter" class="org.springframework.jca.support.ResourceAdapterFactoryBean">
    <property name="resourceAdapter">
        <bean class="org.apache.activemq.ra.ActiveMQResourceAdapter">
            <property name="serverUrl" value="tcp://localhost:61616"/>
        </bean>
    </property>
    <property name="workManager">
        <bean class="org.springframework.jca.work.SimpleTaskWorkManager"/>
    </property>
</bean>
```

The specified `WorkManager` may also point to an environment-specific thread pool - typically through `SimpleTaskWorkManager's` "asyncTaskExecutor" property. Consider defining a shared thread pool for all your `ResourceAdapter` instances if you happen to use multiple adapters.

In some environments (e.g. WebLogic 9 or above), the entire `ResourceAdapter` object may be obtained from JNDI instead (using `<jee:jndi-lookup>`). The Spring-based message listeners can then interact with the server-hosted `ResourceAdapter`, also using the server's built-in `WorkManager`.

Please consult the JavaDoc for `JmsMessageEndpointManager`, `JmsActivationSpecConfig`, and `ResourceAdapterFactoryBean` for more details.

Spring also provides a generic JCA message endpoint manager which is not tied to JMS: `org.springframework.jca.endpoint.GenericMessageEndpointManager`. This component allows for using any message listener type (e.g. a CCI MessageListener) and any provider-specific ActivationSpec object. Check out your JCA provider's documentation to find out about the actual capabilities of your connector, and consult `GenericMessageEndpointManager`'s JavaDoc for the Spring-specific configuration details.

> **Note**
>
> JCA-based message endpoint management is very analogous to EJB 2.1 Message-Driven Beans; it uses the same underlying resource provider contract. Like with EJB 2.1 MDBs, any message

> listener interface supported by your JCA provider can be used in the Spring context as well. Spring nevertheless provides explicit *convenience* support for JMS, simply because JMS is the most common endpoint API used with the JCA endpoint management contract.

24.6 Annotation-driven listener endpoints

The easiest way to receive a message asynchronously is to use the annotated listener endpoint infrastructure. In a nutshell, it allows you to expose a method of a managed bean as a JMS listener endpoint.

```
@Component
public class MyService {

    @JmsListener(destination = "myDestination")
    public void processOrder(String data) { ... }
}
```

The idea of the example above is that whenever a message is available on the `javax.jms.Destination` "myDestination", the `processOrder` method is invoked accordingly (in this case, with the content of the JMS message similarly to what the `MessageListenerAdapter` provides).

The annotated endpoint infrastructure creates a message listener container behind the scenes for each annotated method, using a `JmsListenerContainerFactory`.

Enable listener endpoint annotations

To enable support for `@JmsListener` annotations add `@EnableJms` to one of your `@Configuration` classes.

```
@Configuration
@EnableJms
public class AppConfig {

    @Bean
    public DefaultJmsListenerContainerFactory jmsListenerContainerFactory() {
        DefaultJmsListenerContainerFactory factory =
                new DefaultJmsListenerContainerFactory();
        factory.setConnectionFactory(connectionFactory());
        factory.setDestinationResolver(destinationResolver());
        factory.setConcurrency("3-10");
        return factory;
    }
}
```

By default, the infrastructure looks for a bean named `jmsListenerContainerFactory` as the source for the factory to use to create message listener containers. In this case, and ignoring the JMS infrastructure setup, the `processOrder` method can be invoked with a core poll size of 3 threads and a maximum pool size of 10 threads.

It is possible to customize the listener container factory to use per annotation or an explicit default can be configured by implementing the `JmsListenerConfigurer` interface. The default is only required if at least one endpoint is registered without a specific container factory. See the javadoc for full details and examples.

If you prefer XML configuration use the `<jms:annotation-driven>` element.

```
<jms:annotation-driven/>

<bean id="jmsListenerContainerFactory"
        class="org.springframework.jms.config.DefaultJmsListenerContainerFactory">
    <property name="connectionFactory" ref="connectionFactory"/>
    <property name="destinationResolver" ref="destinationResolver"/>
    <property name="concurrency" value="3-10"/>
</bean>
```

Programmatic endpoints registration

`JmsListenerEndpoint` provides a model of an JMS endpoint and is responsible for configuring the container for that model. The infrastructure allows you to configure endpoints programmatically in addition to the ones that are detected by the `JmsListener` annotation.

```
@Configuration
@EnableJms
public class AppConfig implements JmsListenerConfigurer {

    @Override
    public void configureJmsListeners(JmsListenerEndpointRegistrar registrar) {
        SimpleJmsListenerEndpoint endpoint = new SimpleJmsListenerEndpoint();
        endpoint.setDestination("anotherQueue");
        endpoint.setMessageListener(message -> {
            // processing
        });
        registrar.registerEndpoint(endpoint);
    }
}
```

In the example above, we used `SimpleJmsListenerEndpoint` which provides the actual `MessageListener` to invoke but you could just as well build your own endpoint variant describing a custom invocation mechanism.

It should be noted that you could just as well skip the use of `@JmsListener` altogether and only register your endpoints programmatically through `JmsListenerConfigurer`.

Annotated endpoint method signature

So far, we have been injecting a simple `String` in our endpoint but it can actually have a very flexible method signature. Let's rewrite it to inject the `Order` with a custom header:

```
@Component
public class MyService {

    @JmsListener(destination = "myDestination")
    public void processOrder(Order order, @Header("order_type") String orderType) {
        ...
    }
}
```

These are the main elements you can inject in JMS listener endpoints:

- The raw `javax.jms.Message` or any of its subclasses (provided of course that it matches the incoming message type).
- The `javax.jms.Session` for optional access to the native JMS API e.g. for sending a custom reply.
- The `org.springframework.messaging.Message` representing the incoming JMS message. Note that this message holds both the custom and the standard headers (as defined by `JmsHeaders`).

- `@Header`-annotated method arguments to extract a specific header value, including standard JMS headers.
- `@Headers`-annotated argument that must also be assignable to `java.util.Map` for getting access to all headers.
- A non-annotated element that is not one of the supported types (i.e. `Message` and `Session`) is considered to be the payload. You can make that explicit by annotating the parameter with `@Payload`. You can also turn on validation by adding an extra `@Valid`.

The ability to inject Spring's `Message` abstraction is particularly useful to benefit from all the information stored in the transport-specific message without relying on transport-specific API.

```
@JmsListener(destination = "myDestination")
public void processOrder(Message<Order> order) { ... }
```

Handling of method arguments is provided by `DefaultMessageHandlerMethodFactory` which can be further customized to support additional method arguments. The conversion and validation support can be customized there as well.

For instance, if we want to make sure our `Order` is valid before processing it, we can annotate the payload with `@Valid` and configure the necessary validator as follows:

```
@Configuration
@EnableJms
public class AppConfig implements JmsListenerConfigurer {

    @Override
    public void configureJmsListeners(JmsListenerEndpointRegistrar registrar) {
        registrar.setMessageHandlerMethodFactory(myJmsHandlerMethodFactory());
    }

    @Bean
    public DefaultMessageHandlerMethodFactory myHandlerMethodFactory() {
        DefaultMessageHandlerMethodFactory factory = new DefaultMessageHandlerMethodFactory();
        factory.setValidator(myValidator());
        return factory;
    }
}
```

Reply management

The existing support in MessageListenerAdapter already allows your method to have a non-`void` return type. When that's the case, the result of the invocation is encapsulated in a `javax.jms.Message` sent either in the destination specified in the `JMSReplyTo` header of the original message or in the default destination configured on the listener. That default destination can now be set using the `@SendTo` annotation of the messaging abstraction.

Assuming our `processOrder` method should now return an `OrderStatus`, it is possible to write it as follow to automatically send a reply:

```
@JmsListener(destination = "myDestination")
@SendTo("status")
public OrderStatus processOrder(Order order) {
    // order processing
    return status;
}
```

If you need to set additional headers in a transport-independent manner, you could return a `Message` instead, something like:

```
@JmsListener(destination = "myDestination")
@SendTo("status")
public Message<OrderStatus> processOrder(Order order) {
    // order processing
    return MessageBuilder
            .withPayload(status)
            .setHeader("code", 1234)
            .build();
}
```

24.7 JMS Namespace Support

Spring provides an XML namespace for simplifying JMS configuration. To use the JMS namespace elements you will need to reference the JMS schema:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:jms="http://www.springframework.org/schema/jms"
        xsi:schemaLocation="
            http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/
spring-beans.xsd
            http://www.springframework.org/schema/jms http://www.springframework.org/schema/jms/spring-
jms.xsd">

    <!-- bean definitions here -->

</beans>
```

The namespace consists of three top-level elements: `<annotation-driven/>`, `<listener-container/>` and `<jca-listener-container/>`. `<annotation-driven` enables the use of annotation-driven listener endpoints. `<listener-container/>` and `<jca-listener-container/>` defines shared listener container configuration and may contain `<listener/>` child elements. Here is an example of a basic configuration for two listeners.

```
<jms:listener-container>

    <jms:listener destination="queue.orders" ref="orderService" method="placeOrder"/>

    <jms:listener destination="queue.confirmations" ref="confirmationLogger" method="log"/>

</jms:listener-container>
```

The example above is equivalent to creating two distinct listener container bean definitions and two distinct `MessageListenerAdapter` bean definitions as demonstrated in the section called “the MessageListenerAdapter”. In addition to the attributes shown above, the `listener` element may contain several optional ones. The following table describes all available attributes:

Table 24.1. Attributes of the JMS <listener> element

Attribute	Description
id	A bean name for the hosting listener container. If not specified, a bean name will be automatically generated.
destination *(required)*	The destination name for this listener, resolved through the `DestinationResolver` strategy.
ref *(required)*	The bean name of the handler object.

Attribute	Description
method	The name of the handler method to invoke. If the `ref` points to a `MessageListener` or Spring `SessionAwareMessageListener`, this attribute may be omitted.
response-destination	The name of the default response destination to send response messages to. This will be applied in case of a request message that does not carry a "JMSReplyTo" field. The type of this destination will be determined by the listener-container's "destination-type" attribute. Note: This only applies to a listener method with a return value, for which each result object will be converted into a response message.
subscription	The name of the durable subscription, if any.
selector	An optional message selector for this listener.
concurrency	The number of concurrent sessions/consumers to start for this listener. Can either be a simple number indicating the maximum number (e.g. "5") or a range indicating the lower as well as the upper limit (e.g. "3-5"). Note that a specified minimum is just a hint and might be ignored at runtime. Default is the value provided by the container

The `<listener-container/>` element also accepts several optional attributes. This allows for customization of the various strategies (for example, `taskExecutor` and `destinationResolver`) as well as basic JMS settings and resource references. Using these attributes, it is possible to define highly-customized listener containers while still benefiting from the convenience of the namespace.

Such settings can be automatically exposed as a `JmsListenerContainerFactory` by specifying the id of the bean to expose through the `factory-id` attribute.

```
<jms:listener-container connection-factory="myConnectionFactory"
        task-executor="myTaskExecutor"
        destination-resolver="myDestinationResolver"
        transaction-manager="myTransactionManager"
        concurrency="10">

    <jms:listener destination="queue.orders" ref="orderService" method="placeOrder"/>

    <jms:listener destination="queue.confirmations" ref="confirmationLogger" method="log"/>

</jms:listener-container>
```

The following table describes all available attributes. Consult the class-level javadocs of the `AbstractMessageListenerContainer` and its concrete subclasses for more details on the individual properties. The javadocs also provide a discussion of transaction choices and message redelivery scenarios.

Table 24.2. Attributes of the JMS <listener-container> element

Attribute	Description
container-type	The type of this listener container. Available options are: `default`, `simple`, `default102`, or `simple102` (the default value is `'default'`).
container-class	A custom listener container implementation class as fully qualified class name. Default is Spring's standard `DefaultMessageListenerContainer` or `SimpleMessageListenerContainer`, according to the "container-type" attribute.

Attribute	Description
factory-id	Exposes the settings defined by this element as a `JmsListenerContainerFactory` with the specified id so that they can be reused with other endpoints.
connection-factory	A reference to the JMS `ConnectionFactory` bean (the default bean name is `'connectionFactory'`).
task-executor	A reference to the Spring `TaskExecutor` for the JMS listener invokers.
destination-resolver	A reference to the `DestinationResolver` strategy for resolving JMS `Destinations`.
message-converter	A reference to the `MessageConverter` strategy for converting JMS Messages to listener method arguments. Default is a `SimpleMessageConverter`.
error-handler	A reference to an `ErrorHandler` strategy for handling any uncaught Exceptions that may occur during the execution of the `MessageListener`.
destination-type	The JMS destination type for this listener: `queue`, `topic`, `durableTopic`, `sharedTopic` or `sharedDurableTopic`. This enables potentially the `pubSubDomain`, `subscriptionDurable` and `subscriptionShared` properties of the container. The default is `queue` (i.e. disabling those 3 properties).
client-id	The JMS client id for this listener container. Needs to be specified when using durable subscriptions.
cache	The cache level for JMS resources: `none`, `connection`, `session`, `consumer` or `auto`. By default (`auto`), the cache level will effectively be "consumer", unless an external transaction manager has been specified - in which case the effective default will be `none` (assuming Java EE-style transaction management where the given ConnectionFactory is an XA-aware pool).
acknowledge	The native JMS acknowledge mode: `auto`, `client`, `dups-ok` or `transacted`. A value of `transacted` activates a locally transacted `Session`. As an alternative, specify the `transaction-manager` attribute described below. Default is `auto`.
transaction-manager	A reference to an external `PlatformTransactionManager` (typically an XA-based transaction coordinator, e.g. Spring's `JtaTransactionManager`). If not specified, native acknowledging will be used (see "acknowledge" attribute).
concurrency	The number of concurrent sessions/consumers to start for each listener. Can either be a simple number indicating the maximum number (e.g. "5") or a range indicating the lower as well as the upper limit (e.g. "3-5"). Note that a specified minimum is just a hint and might be ignored at runtime. Default is 1; keep concurrency limited to 1 in case of a topic listener or if queue ordering is important; consider raising it for general queues.
prefetch	The maximum number of messages to load into a single session. Note that raising this number might lead to starvation of concurrent consumers!
receive-timeout	The timeout to use for receive calls (in milliseconds). The default is `1000` ms (1 sec); `-1` indicates no timeout at all.

Attribute	Description
back-off	Specify the `BackOff` instance to use to compute the interval between recovery attempts. If the `BackOffExecution` implementation returns `BackOffExecution#STOP`, the listener container will not further attempt to recover. The `recovery-interval` value is ignored when this property is set. The default is a `FixedBackOff` with an interval of 5000 ms, that is 5 seconds.
recovery-interval	Specify the interval between recovery attempts, in milliseconds. Convenience way to create a `FixedBackOff` with the specified interval. For more recovery options, consider specifying a BackOff instance instead. The default is 5000 ms, that is 5 seconds.
phase	The lifecycle phase within which this container should start and stop. The lower the value the earlier this container will start and the later it will stop. The default is `Integer.MAX_VALUE` meaning the container will start as late as possible and stop as soon as possible.

Configuring a JCA-based listener container with the "jms" schema support is very similar.

```
<jms:jca-listener-container resource-adapter="myResourceAdapter"
        destination-resolver="myDestinationResolver"
        transaction-manager="myTransactionManager"
        concurrency="10">

    <jms:listener destination="queue.orders" ref="myMessageListener"/>

</jms:jca-listener-container>
```

The available configuration options for the JCA variant are described in the following table:

Table 24.3. Attributes of the JMS <jca-listener-container/> element

Attribute	Description
factory-id	Exposes the settings defined by this element as a `JmsListenerContainerFactory` with the specified id so that they can be reused with other endpoints.
resource-adapter	A reference to the JCA `ResourceAdapter` bean (the default bean name is `'resourceAdapter'`).
activation-spec-factory	A reference to the `JmsActivationSpecFactory`. The default is to autodetect the JMS provider and its `ActivationSpec` class (see `DefaultJmsActivationSpecFactory`)
destination-resolver	A reference to the `DestinationResolver` strategy for resolving JMS `Destinations`.
message-converter	A reference to the `MessageConverter` strategy for converting JMS Messages to listener method arguments. Default is a `SimpleMessageConverter`.
destination-type	The JMS destination type for this listener: `queue`, `topic`, `durableTopic`, `sharedTopic` or `sharedDurableTopic`. This enables potentially the `pubSubDomain`, `subscriptionDurable` and `subscriptionShared` properties of the container. The default is `queue` (i.e. disabling those 3 properties).

Attribute	Description
client-id	The JMS client id for this listener container. Needs to be specified when using durable subscriptions.
acknowledge	The native JMS acknowledge mode: `auto`, `client`, `dups-ok` or `transacted`. A value of `transacted` activates a locally transacted `Session`. As an alternative, specify the `transaction-manager` attribute described below. Default is `auto`.
transaction-manager	A reference to a Spring `JtaTransactionManager` or a `javax.transaction.TransactionManager` for kicking off an XA transaction for each incoming message. If not specified, native acknowledging will be used (see the "acknowledge" attribute).
concurrency	The number of concurrent sessions/consumers to start for each listener. Can either be a simple number indicating the maximum number (e.g. "5") or a range indicating the lower as well as the upper limit (e.g. "3-5"). Note that a specified minimum is just a hint and will typically be ignored at runtime when using a JCA listener container. Default is 1.
prefetch	The maximum number of messages to load into a single session. Note that raising this number might lead to starvation of concurrent consumers!

25. JMX

25.1 Introduction

The JMX support in Spring provides you with the features to easily and transparently integrate your Spring application into a JMX infrastructure.

> **JMX?**
>
> This chapter is not an introduction to JMX… it doesn't try to explain the motivations of why one might want to use JMX (or indeed what the letters JMX actually stand for). If you are new to JMX, check out Section 25.8, "Further Resources" at the end of this chapter.

Specifically, Spring's JMX support provides four core features:

- The automatic registration of *any* Spring bean as a JMX MBean
- A flexible mechanism for controlling the management interface of your beans
- The declarative exposure of MBeans over remote, JSR-160 connectors
- The simple proxying of both local and remote MBean resources

These features are designed to work without coupling your application components to either Spring or JMX interfaces and classes. Indeed, for the most part your application classes need not be aware of either Spring or JMX in order to take advantage of the Spring JMX features.

25.2 Exporting your beans to JMX

The core class in Spring's JMX framework is the `MBeanExporter`. This class is responsible for taking your Spring beans and registering them with a JMX `MBeanServer`. For example, consider the following class:

```
package org.springframework.jmx;

public class JmxTestBean implements IJmxTestBean {

    private String name;
    private int age;
    private boolean isSuperman;

    public int getAge() {
        return age;
    }

    public void setAge(int age) {
        this.age = age;
    }

    public void setName(String name) {
        this.name = name;
    }

    public String getName() {
        return name;
    }

    public int add(int x, int y) {
        return x + y;
    }

    public void dontExposeMe() {
        throw new RuntimeException();
    }
}
```

To expose the properties and methods of this bean as attributes and operations of an MBean you simply configure an instance of the `MBeanExporter` class in your configuration file and pass in the bean as shown below:

```
<beans>
    <!-- this bean must not be lazily initialized if the exporting is to happen -->
    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter" lazy-init="false">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
    </bean>
    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>
</beans>
```

The pertinent bean definition from the above configuration snippet is the `exporter` bean. The `beans` property tells the `MBeanExporter` exactly which of your beans must be exported to the JMX `MBeanServer`. In the default configuration, the key of each entry in the `beans Map` is used as the `ObjectName` for the bean referenced by the corresponding entry value. This behavior can be changed as described in Section 25.4, “Controlling the ObjectNames for your beans”.

With this configuration the `testBean` bean is exposed as an MBean under the `ObjectName` `bean:name=testBean1`. By default, all *public* properties of the bean are exposed as attributes and all *public* methods (bar those inherited from the `Object` class) are exposed as operations.

> **Note**
>
> `MBeanExporter` is a `Lifecycle` bean (see the section called “Startup and shutdown callbacks”) and MBeans are exported as late as possible during the application lifecycle by default. It is possible to configure the `phase` at which the export happens or disable automatic registration by setting the `autoStartup` flag.

Creating an MBeanServer

The above configuration assumes that the application is running in an environment that has one (and only one) `MBeanServer` already running. In this case, Spring will attempt to locate the running `MBeanServer` and register your beans with that server (if any). This behavior is useful when your application is running inside a container such as Tomcat or IBM WebSphere that has its own `MBeanServer`.

However, this approach is of no use in a standalone environment, or when running inside a container that does not provide an `MBeanServer`. To address this you can create an `MBeanServer` instance declaratively by adding an instance of the `org.springframework.jmx.support.MBeanServerFactoryBean` class to your configuration. You can also ensure that a specific `MBeanServer` is used by setting the value of the `MBeanExporter`'s `server` property to the `MBeanServer` value returned by an `MBeanServerFactoryBean`; for example:

```
<beans>

    <bean id="mbeanServer" class="org.springframework.jmx.support.MBeanServerFactoryBean"/>

    <!--
    this bean needs to be eagerly pre-instantiated in order for the exporting to occur;
    this means that it must not be marked as lazily initialized
    -->
    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
        <property name="server" ref="mbeanServer"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

</beans>
```

Here an instance of `MBeanServer` is created by the `MBeanServerFactoryBean` and is supplied to the `MBeanExporter` via the server property. When you supply your own `MBeanServer` instance, the `MBeanExporter` will not attempt to locate a running `MBeanServer` and will use the supplied `MBeanServer` instance. For this to work correctly, you must (of course) have a JMX implementation on your classpath.

Reusing an existing MBeanServer

If no server is specified, the `MBeanExporter` tries to automatically detect a running `MBeanServer`. This works in most environment where only one `MBeanServer` instance is used, however when multiple instances exist, the exporter might pick the wrong server. In such cases, one should use the `MBeanServer` `agentId` to indicate which instance to be used:

```
<beans>
    <bean id="mbeanServer" class="org.springframework.jmx.support.MBeanServerFactoryBean">
        <!-- indicate to first look for a server -->
        <property name="locateExistingServerIfPossible" value="true"/>
        <!-- search for the MBeanServer instance with the given agentId -->
        <property name="agentId" value="MBeanServer_instance_agentId>"/>
    </bean>
    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="server" ref="mbeanServer"/>
        ...
    </bean>
</beans>
```

For platforms/cases where the existing `MBeanServer` has a dynamic (or unknown) `agentId` which is retrieved through lookup methods, one should use factory-method:

```
<beans>
    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="server">
            <!-- Custom MBeanServerLocator -->
            <bean class="platform.package.MBeanServerLocator" factory-method="locateMBeanServer"/>
        </property>
    </bean>

    <!-- other beans here -->

</beans>
```

Lazy-initialized MBeans

If you configure a bean with the `MBeanExporter` that is also configured for lazy initialization, then the `MBeanExporter` will *not* break this contract and will avoid instantiating the bean. Instead, it will register a proxy with the `MBeanServer` and will defer obtaining the bean from the container until the first invocation on the proxy occurs.

Automatic registration of MBeans

Any beans that are exported through the `MBeanExporter` and are already valid MBeans are registered as-is with the `MBeanServer` without further intervention from Spring. MBeans can be automatically detected by the `MBeanExporter` by setting the `autodetect` property to `true`:

```
<bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
    <property name="autodetect" value="true"/>
</bean>

<bean name="spring:mbean=true" class="org.springframework.jmx.export.TestDynamicMBean"/>
```

Here, the bean called `spring:mbean=true` is already a valid JMX MBean and will be automatically registered by Spring. By default, beans that are autodetected for JMX registration have their bean name used as the `ObjectName`. This behavior can be overridden as detailed in Section 25.4, “Controlling the ObjectNames for your beans”.

Controlling the registration behavior

Consider the scenario where a Spring `MBeanExporter` attempts to register an `MBean` with an `MBeanServer` using the `ObjectName` `'bean:name=testBean1'`. If an `MBean` instance has already been registered under that same `ObjectName`, the default behavior is to fail (and throw an `InstanceAlreadyExistsException`).

It is possible to control the behavior of exactly what happens when an `MBean` is registered with an `MBeanServer`. Spring's JMX support allows for three different registration behaviors to control the registration behavior when the registration process finds that an `MBean` has already been registered under the same `ObjectName`; these registration behaviors are summarized on the following table:

Table 25.1. Registration Behaviors

Registration behavior	Explanation
`REGISTRATION_FAIL_ON_EXISTING`	This is the default registration behavior. If an `MBean` instance has already been registered under the same `ObjectName`, the `MBean` that is being registered will not be registered and an `InstanceAlreadyExistsException` will be thrown. The existing `MBean` is unaffected.
`REGISTRATION_IGNORE_EXISTING`	If an `MBean` instance has already been registered under the same `ObjectName`, the `MBean` that is being registered will *not* be registered. The existing `MBean` is unaffected, and no `Exception` will be thrown. This is useful in settings where multiple applications want to share a common `MBean` in a shared `MBeanServer`.
`REGISTRATION_REPLACE_EXISTING`	If an `MBean` instance has already been registered under the same `ObjectName`, the existing `MBean` that was previously registered will be unregistered and the new `MBean` will be registered in its place (the new `MBean` effectively replaces the previous instance).

The above values are defined as constants on the `MBeanRegistrationSupport` class (the `MBeanExporter` class derives from this superclass). If you want to change the default registration behavior, you simply need to set the value of the `registrationBehaviorName` property on your `MBeanExporter` definition to one of those values.

The following example illustrates how to effect a change from the default registration behavior to the `REGISTRATION_REPLACE_EXISTING` behavior:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
        <property name="registrationBehaviorName" value="REGISTRATION_REPLACE_EXISTING"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

</beans>
```

25.3 Controlling the management interface of your beans

In the previous example, you had little control over the management interface of your bean; *all* of the *public* properties and methods of each exported bean was exposed as JMX attributes and operations respectively. To exercise finer-grained control over exactly which properties and methods

of your exported beans are actually exposed as JMX attributes and operations, Spring JMX provides a comprehensive and extensible mechanism for controlling the management interfaces of your beans.

the MBeanInfoAssembler Interface

Behind the scenes, the `MBeanExporter` delegates to an implementation of the `org.springframework.jmx.export.assembler.MBeanInfoAssembler` interface which is responsible for defining the management interface of each bean that is being exposed. The default implementation, `org.springframework.jmx.export.assembler.SimpleReflectiveMBeanInfoAssembler`, simply defines a management interface that exposes all public properties and methods (as you saw in the previous examples). Spring provides two additional implementations of the `MBeanInfoAssembler` interface that allow you to control the generated management interface using either source-level metadata or any arbitrary interface.

Using Source-Level Metadata (Java annotations)

Using the `MetadataMBeanInfoAssembler` you can define the management interfaces for your beans using source level metadata. The reading of metadata is encapsulated by the `org.springframework.jmx.export.metadata.JmxAttributeSource` interface. Spring JMX provides a default implementation which uses Java annotations, namely `org.springframework.jmx.export.annotation.AnnotationJmxAttributeSource`. The `MetadataMBeanInfoAssembler` *must* be configured with an implementation instance of the `JmxAttributeSource` interface for it to function correctly (there is *no* default).

To mark a bean for export to JMX, you should annotate the bean class with the `ManagedResource` annotation. Each method you wish to expose as an operation must be marked with the `ManagedOperation` annotation and each property you wish to expose must be marked with the `ManagedAttribute` annotation. When marking properties you can omit either the annotation of the getter or the setter to create a write-only or read-only attribute respectively.

The example below shows the annotated version of the `JmxTestBean` class that you saw earlier:

```
package org.springframework.jmx;

import org.springframework.jmx.export.annotation.ManagedResource;
import org.springframework.jmx.export.annotation.ManagedOperation;
import org.springframework.jmx.export.annotation.ManagedAttribute;

@ManagedResource(
        objectName="bean:name=testBean4",
        description="My Managed Bean",
        log=true,
        logFile="jmx.log",
        currencyTimeLimit=15,
        persistPolicy="OnUpdate",
        persistPeriod=200,
        persistLocation="foo",
        persistName="bar")
public class AnnotationTestBean implements IJmxTestBean {

    private String name;
    private int age;

    @ManagedAttribute(description="The Age Attribute", currencyTimeLimit=15)
    public int getAge() {
        return age;
    }

    public void setAge(int age) {
        this.age = age;
    }

    @ManagedAttribute(description="The Name Attribute",
            currencyTimeLimit=20,
            defaultValue="bar",
            persistPolicy="OnUpdate")
    public void setName(String name) {
        this.name = name;
    }

    @ManagedAttribute(defaultValue="foo", persistPeriod=300)
    public String getName() {
        return name;
    }

    @ManagedOperation(description="Add two numbers")
    @ManagedOperationParameters({
        @ManagedOperationParameter(name = "x", description = "The first number"),
        @ManagedOperationParameter(name = "y", description = "The second number")})
    public int add(int x, int y) {
        return x + y;
    }

    public void dontExposeMe() {
        throw new RuntimeException();
    }

}
```

Here you can see that the `JmxTestBean` class is marked with the `ManagedResource` annotation and that this `ManagedResource` annotation is configured with a set of properties. These properties can be used to configure various aspects of the MBean that is generated by the `MBeanExporter`, and are explained in greater detail later in section entitled the section called “Source-Level Metadata Types”.

You will also notice that both the `age` and `name` properties are annotated with the `ManagedAttribute` annotation, but in the case of the `age` property, only the getter is marked. This will cause both of these properties to be included in the management interface as attributes, but the `age` attribute will be read-only.

Finally, you will notice that the `add(int, int)` method is marked with the `ManagedOperation` attribute whereas the `dontExposeMe()` method is not. This will cause the management interface to contain only one operation, `add(int, int)`, when using the `MetadataMBeanInfoAssembler`.

The configuration below shows how you configure the `MBeanExporter` to use the `MetadataMBeanInfoAssembler`:

```
<beans>
    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="assembler" ref="assembler"/>
        <property name="namingStrategy" ref="namingStrategy"/>
        <property name="autodetect" value="true"/>
    </bean>

    <bean id="jmxAttributeSource"
            class="org.springframework.jmx.export.annotation.AnnotationJmxAttributeSource"/>

    <!-- will create management interface using annotation metadata -->
    <bean id="assembler"
            class="org.springframework.jmx.export.assembler.MetadataMBeanInfoAssembler">
        <property name="attributeSource" ref="jmxAttributeSource"/>
    </bean>

    <!-- will pick up the ObjectName from the annotation -->
    <bean id="namingStrategy"
            class="org.springframework.jmx.export.naming.MetadataNamingStrategy">
        <property name="attributeSource" ref="jmxAttributeSource"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.AnnotationTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>
</beans>
```

Here you can see that an `MetadataMBeanInfoAssembler` bean has been configured with an instance of the `AnnotationJmxAttributeSource` class and passed to the `MBeanExporter` through the assembler property. This is all that is required to take advantage of metadata-driven management interfaces for your Spring-exposed MBeans.

Source-Level Metadata Types

The following source level metadata types are available for use in Spring JMX:

Table 25.2. Source-Level Metadata Types

Purpose	Annotation	Annotation Type
Mark all instances of a `Class` as JMX managed resources	`@ManagedResource`	Class
Mark a method as a JMX operation	`@ManagedOperation`	Method
Mark a getter or setter as one half of a JMX attribute	`@ManagedAttribute`	Method (only getters and setters)
Define descriptions for operation parameters	`@ManagedOperationParameter` and `@ManagedOperationParameters`	Method

The following configuration parameters are available for use on these source-level metadata types:

Table 25.3. Source-Level Metadata Parameters

Parameter	Description	Applies to
`ObjectName`	Used by `MetadataNamingStrategy` to determine the `ObjectName` of a managed resource	`ManagedResource`
`description`	Sets the friendly description of the resource, attribute or operation	`ManagedResource`, `ManagedAttribute`, `ManagedOperation`, `ManagedOperationParameter`
`currencyTimeLimit`	Sets the value of the `currencyTimeLimit` descriptor field	`ManagedResource`, `ManagedAttribute`
`defaultValue`	Sets the value of the `defaultValue` descriptor field	`ManagedAttribute`
`log`	Sets the value of the `log` descriptor field	`ManagedResource`
`logFile`	Sets the value of the `logFile` descriptor field	`ManagedResource`
`persistPolicy`	Sets the value of the `persistPolicy` descriptor field	`ManagedResource`
`persistPeriod`	Sets the value of the `persistPeriod` descriptor field	`ManagedResource`
`persistLocation`	Sets the value of the `persistLocation` descriptor field	`ManagedResource`
`persistName`	Sets the value of the `persistName` descriptor field	`ManagedResource`
`name`	Sets the display name of an operation parameter	`ManagedOperationParameter`
`index`	Sets the index of an operation parameter	`ManagedOperationParameter`

the AutodetectCapableMBeanInfoAssembler interface

To simplify configuration even further, Spring introduces the `AutodetectCapableMBeanInfoAssembler` interface which extends the `MBeanInfoAssembler` interface to add support for autodetection of MBean resources. If you configure the `MBeanExporter` with an instance of `AutodetectCapableMBeanInfoAssembler` then it is allowed to "vote" on the inclusion of beans for exposure to JMX.

Out of the box, the only implementation of the `AutodetectCapableMBeanInfo` interface is the `MetadataMBeanInfoAssembler` which will vote to include any bean which is marked with the `ManagedResource` attribute. The default approach in this case is to use the bean name as the `ObjectName` which results in a configuration like this:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <!-- notice how no beans are explicitly configured here -->
        <property name="autodetect" value="true"/>
        <property name="assembler" ref="assembler"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

    <bean id="assembler" class="org.springframework.jmx.export.assembler.MetadataMBeanInfoAssembler">
        <property name="attributeSource">
            <bean class="org.springframework.jmx.export.annotation.AnnotationJmxAttributeSource"/>
        </property>
    </bean>

</beans>
```

Notice that in this configuration no beans are passed to the `MBeanExporter`; however, the `JmxTestBean` will still be registered since it is marked with the `ManagedResource` attribute and the `MetadataMBeanInfoAssembler` detects this and votes to include it. The only problem with this approach is that the name of the `JmxTestBean` now has business meaning. You can address this issue by changing the default behavior for `ObjectName` creation as defined in Section 25.4, “Controlling the ObjectNames for your beans”.

Defining management interfaces using Java interfaces

In addition to the `MetadataMBeanInfoAssembler`, Spring also includes the `InterfaceBasedMBeanInfoAssembler` which allows you to constrain the methods and properties that are exposed based on the set of methods defined in a collection of interfaces.

Although the standard mechanism for exposing MBeans is to use interfaces and a simple naming scheme, the `InterfaceBasedMBeanInfoAssembler` extends this functionality by removing the need for naming conventions, allowing you to use more than one interface and removing the need for your beans to implement the MBean interfaces.

Consider this interface that is used to define a management interface for the `JmxTestBean` class that you saw earlier:

```
public interface IJmxTestBean {

    public int add(int x, int y);

    public long myOperation();

    public int getAge();

    public void setAge(int age);

    public void setName(String name);

    public String getName();

}
```

This interface defines the methods and properties that will be exposed as operations and attributes on the JMX MBean. The code below shows how to configure Spring JMX to use this interface as the definition for the management interface:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean5" value-ref="testBean"/>
            </map>
        </property>
        <property name="assembler">
            <bean class="org.springframework.jmx.export.assembler.InterfaceBasedMBeanInfoAssembler">
                <property name="managedInterfaces">
                    <value>org.springframework.jmx.IJmxTestBean</value>
                </property>
            </bean>
        </property>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
      </bean>

</beans>
```

Here you can see that the `InterfaceBasedMBeanInfoAssembler` is configured to use the `IJmxTestBean` interface when constructing the management interface for any bean. It is important to understand that beans processed by the `InterfaceBasedMBeanInfoAssembler` are *not* required to implement the interface used to generate the JMX management interface.

In the case above, the `IJmxTestBean` interface is used to construct all management interfaces for all beans. In many cases this is not the desired behavior and you may want to use different interfaces for different beans. In this case, you can pass `InterfaceBasedMBeanInfoAssembler` a `Properties` instance via the `interfaceMappings` property, where the key of each entry is the bean name and the value of each entry is a comma-separated list of interface names to use for that bean.

If no management interface is specified through either the `managedInterfaces` or `interfaceMappings` properties, then the `InterfaceBasedMBeanInfoAssembler` will reflect on the bean and use all of the interfaces implemented by that bean to create the management interface.

Using MethodNameBasedMBeanInfoAssembler

The `MethodNameBasedMBeanInfoAssembler` allows you to specify a list of method names that will be exposed to JMX as attributes and operations. The code below shows a sample configuration for this:

```
<bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
    <property name="beans">
        <map>
            <entry key="bean:name=testBean5" value-ref="testBean"/>
        </map>
    </property>
    <property name="assembler">
        <bean class="org.springframework.jmx.export.assembler.MethodNameBasedMBeanInfoAssembler">
            <property name="managedMethods">
                <value>add,myOperation,getName,setName,getAge</value>
            </property>
        </bean>
    </property>
</bean>
```

Here you can see that the methods `add` and `myOperation` will be exposed as JMX operations and `getName()`, `setName(String)` and `getAge()` will be exposed as the appropriate half of a JMX attribute. In the code above, the method mappings apply to beans that are exposed to

JMX. To control method exposure on a bean-by-bean basis, use the `methodMappings` property of `MethodNameMBeanInfoAssembler` to map bean names to lists of method names.

25.4 Controlling the ObjectNames for your beans

Behind the scenes, the `MBeanExporter` delegates to an implementation of the `ObjectNamingStrategy` to obtain `ObjectNames` for each of the beans it is registering. The default implementation, `KeyNamingStrategy`, will, by default, use the key of the `beans Map` as the `ObjectName`. In addition, the `KeyNamingStrategy` can map the key of the `beans Map` to an entry in a `Properties` file (or files) to resolve the `ObjectName`. In addition to the `KeyNamingStrategy`, Spring provides two additional `ObjectNamingStrategy` implementations: the `IdentityNamingStrategy` that builds an `ObjectName` based on the JVM identity of the bean and the `MetadataNamingStrategy` that uses source level metadata to obtain the `ObjectName`.

Reading ObjectNames from Properties

You can configure your own `KeyNamingStrategy` instance and configure it to read `ObjectNames` from a `Properties` instance rather than use bean key. The `KeyNamingStrategy` will attempt to locate an entry in the `Properties` with a key corresponding to the bean key. If no entry is found or if the `Properties` instance is `null` then the bean key itself is used.

The code below shows a sample configuration for the `KeyNamingStrategy`:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="testBean" value-ref="testBean"/>
            </map>
        </property>
        <property name="namingStrategy" ref="namingStrategy"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

    <bean id="namingStrategy" class="org.springframework.jmx.export.naming.KeyNamingStrategy">
        <property name="mappings">
            <props>
                <prop key="testBean">bean:name=testBean1</prop>
            </props>
        </property>
        <property name="mappingLocations">
            <value>names1.properties,names2.properties</value>
        </property>
    </bean>

</beans>
```

Here an instance of `KeyNamingStrategy` is configured with a `Properties` instance that is merged from the `Properties` instance defined by the mapping property and the properties files located in the paths defined by the mappings property. In this configuration, the `testBean` bean will be given the `ObjectName bean:name=testBean1` since this is the entry in the `Properties` instance that has a key corresponding to the bean key.

If no entry in the `Properties` instance can be found then the bean key name is used as the `ObjectName`.

Using the MetadataNamingStrategy

The `MetadataNamingStrategy` uses the `objectName` property of the `ManagedResource` attribute on each bean to create the `ObjectName`. The code below shows the configuration for the `MetadataNamingStrategy`:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="testBean" value-ref="testBean"/>
            </map>
        </property>
        <property name="namingStrategy" ref="namingStrategy"/>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

    <bean id="namingStrategy" class="org.springframework.jmx.export.naming.MetadataNamingStrategy">
        <property name="attributeSource" ref="attributeSource"/>
    </bean>

    <bean id="attributeSource"
            class="org.springframework.jmx.export.annotation.AnnotationJmxAttributeSource"/>

</beans>
```

If no `objectName` has been provided for the `ManagedResource` attribute, then an `ObjectName` will be created with the following format:*[fully-qualified-package-name]:type=[short-classname],name=[bean-name]*. For example, the generated `ObjectName` for the following bean would be: *com.foo:type=MyClass,name=myBean*.

```
<bean id="myBean" class="com.foo.MyClass"/>
```

Configuring annotation based MBean export

If you prefer using the annotation based approach to define your management interfaces, then a convenience subclass of `MBeanExporter` is available: `AnnotationMBeanExporter`. When defining an instance of this subclass, the `namingStrategy`, `assembler`, and `attributeSource` configuration is no longer needed, since it will always use standard Java annotation-based metadata (autodetection is always enabled as well). In fact, rather than defining an `MBeanExporter` bean, an even simpler syntax is supported by the `@EnableMBeanExport` `@Configuration` annotation.

```
@Configuration
@EnableMBeanExport
public class AppConfig {

}
```

If you prefer XML based configuration the `'context:mbean-export'` element serves the same purpose.

```
<context:mbean-export/>
```

You can provide a reference to a particular MBean `server` if necessary, and the `defaultDomain` attribute (a property of `AnnotationMBeanExporter`) accepts an alternate value for the generated

MBean `ObjectNames`' domains. This would be used in place of the fully qualified package name as described in the previous section on `MetadataNamingStrategy`.

```
@EnableMBeanExport(server="myMBeanServer", defaultDomain="myDomain")
@Configuration
ContextConfiguration {

}
```

```
<context:mbean-export server="myMBeanServer" default-domain="myDomain"/>
```

> **Note**
>
> Do not use interface-based AOP proxies in combination with autodetection of JMX annotations in your bean classes. Interface-based proxies *hide* the target class, which also hides the JMX managed resource annotations. Hence, use target-class proxies in that case: through setting the *proxy-target-class* flag on `<aop:config/>`, `<tx:annotation-driven/>`, etc. Otherwise, your JMX beans might be silently ignored at startup…

25.5 JSR-160 Connectors

For remote access, Spring JMX module offers two `FactoryBean` implementations inside the `org.springframework.jmx.support` package for creating both server- and client-side connectors.

Server-side Connectors

To have Spring JMX create, start and expose a JSR-160 `JMXConnectorServer` use the following configuration:

```
<bean id="serverConnector" class="org.springframework.jmx.support.ConnectorServerFactoryBean"/>
```

By default `ConnectorServerFactoryBean` creates a `JMXConnectorServer` bound to `"service:jmx:jmxmp://localhost:9875"`. The `serverConnector` bean thus exposes the local `MBeanServer` to clients through the JMXMP protocol on localhost, port 9875. Note that the JMXMP protocol is marked as optional by the JSR 160 specification: currently, the main open-source JMX implementation, MX4J, and the one provided with the JDK do *not* support JMXMP.

To specify another URL and register the `JMXConnectorServer` itself with the `MBeanServer` use the `serviceUrl` and `ObjectName` properties respectively:

```
<bean id="serverConnector"
        class="org.springframework.jmx.support.ConnectorServerFactoryBean">
    <property name="objectName" value="connector:name=rmi"/>
    <property name="serviceUrl"
            value="service:jmx:rmi://localhost/jndi/rmi://localhost:1099/myconnector"/>
</bean>
```

If the `ObjectName` property is set Spring will automatically register your connector with the `MBeanServer` under that `ObjectName`. The example below shows the full set of parameters which you can pass to the `ConnectorServerFactoryBean` when creating a JMXConnector:

```
<bean id="serverConnector"
        class="org.springframework.jmx.support.ConnectorServerFactoryBean">
    <property name="objectName" value="connector:name=iiop"/>
    <property name="serviceUrl"
        value="service:jmx:iiop://localhost/jndi/iiop://localhost:900/myconnector"/>
    <property name="threaded" value="true"/>
    <property name="daemon" value="true"/>
    <property name="environment">
        <map>
            <entry key="someKey" value="someValue"/>
        </map>
    </property>
</bean>
```

Note that when using a RMI-based connector you need the lookup service (tnameserv or rmiregistry) to be started in order for the name registration to complete. If you are using Spring to export remote services for you via RMI, then Spring will already have constructed an RMI registry. If not, you can easily start a registry using the following snippet of configuration:

```
<bean id="registry" class="org.springframework.remoting.rmi.RmiRegistryFactoryBean">
    <property name="port" value="1099"/>
</bean>
```

Client-side Connectors

To create an `MBeanServerConnection` to a remote JSR-160 enabled `MBeanServer` use the `MBeanServerConnectionFactoryBean` as shown below:

```
<bean id="clientConnector" class="org.springframework.jmx.support.MBeanServerConnectionFactoryBean">
    <property name="serviceUrl" value="service:jmx:rmi://localhost/jndi/rmi://localhost:1099/jmxrmi"/>
</bean>
```

JMX over Burlap/Hessian/SOAP

JSR-160 permits extensions to the way in which communication is done between the client and the server. The examples above are using the mandatory RMI-based implementation required by the JSR-160 specification (IIOP and JRMP) and the (optional) JMXMP. By using other providers or JMX implementations (such as MX4J) you can take advantage of protocols like SOAP, Hessian, Burlap over simple HTTP or SSL and others:

```
<bean id="serverConnector" class="org.springframework.jmx.support.ConnectorServerFactoryBean">
    <property name="objectName" value="connector:name=burlap"/>
    <property name="serviceUrl" value="service:jmx:burlap://localhost:9874"/>
</bean>
```

In the case of the above example, MX4J 3.0.0 was used; see the official MX4J documentation for more information.

25.6 Accessing MBeans via Proxies

Spring JMX allows you to create proxies that re-route calls to MBeans registered in a local or remote `MBeanServer`. These proxies provide you with a standard Java interface through which you can interact with your MBeans. The code below shows how to configure a proxy for an MBean running in a local `MBeanServer`:

```
<bean id="proxy" class="org.springframework.jmx.access.MBeanProxyFactoryBean">
    <property name="objectName" value="bean:name=testBean"/>
    <property name="proxyInterface" value="org.springframework.jmx.IJmxTestBean"/>
</bean>
```

Here you can see that a proxy is created for the MBean registered under the `ObjectName`: `bean:name=testBean`. The set of interfaces that the proxy will implement is controlled by the `proxyInterfaces` property and the rules for mapping methods and properties on these interfaces to operations and attributes on the MBean are the same rules used by the `InterfaceBasedMBeanInfoAssembler`.

The `MBeanProxyFactoryBean` can create a proxy to any MBean that is accessible via an `MBeanServerConnection`. By default, the local `MBeanServer` is located and used, but you can override this and provide an `MBeanServerConnection` pointing to a remote `MBeanServer` to cater for proxies pointing to remote MBeans:

```
<bean id="clientConnector"
        class="org.springframework.jmx.support.MBeanServerConnectionFactoryBean">
    <property name="serviceUrl" value="service:jmx:rmi://remotehost:9875"/>
</bean>

<bean id="proxy" class="org.springframework.jmx.access.MBeanProxyFactoryBean">
    <property name="objectName" value="bean:name=testBean"/>
    <property name="proxyInterface" value="org.springframework.jmx.IJmxTestBean"/>
    <property name="server" ref="clientConnector"/>
</bean>
```

Here you can see that we create an `MBeanServerConnection` pointing to a remote machine using the `MBeanServerConnectionFactoryBean`. This `MBeanServerConnection` is then passed to the `MBeanProxyFactoryBean` via the `server` property. The proxy that is created will forward all invocations to the `MBeanServer` via this `MBeanServerConnection`.

25.7 Notifications

Spring's JMX offering includes comprehensive support for JMX notifications.

Registering Listeners for Notifications

Spring's JMX support makes it very easy to register any number of `NotificationListeners` with any number of MBeans (this includes MBeans exported by Spring's `MBeanExporter` and MBeans registered via some other mechanism). By way of an example, consider the scenario where one would like to be informed (via a `Notification`) each and every time an attribute of a target MBean changes.

```
package com.example;

import javax.management.AttributeChangeNotification;
import javax.management.Notification;
import javax.management.NotificationFilter;
import javax.management.NotificationListener;

public class ConsoleLoggingNotificationListener
        implements NotificationListener, NotificationFilter {

    public void handleNotification(Notification notification, Object handback) {
        System.out.println(notification);
        System.out.println(handback);
    }

    public boolean isNotificationEnabled(Notification notification) {
        return AttributeChangeNotification.class.isAssignableFrom(notification.getClass());
    }

}
```

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
        <property name="notificationListenerMappings">
            <map>
                <entry key="bean:name=testBean1">
                    <bean class="com.example.ConsoleLoggingNotificationListener"/>
                </entry>
            </map>
        </property>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

</beans>
```

With the above configuration in place, every time a JMX `Notification` is broadcast from the target MBean (`bean:name=testBean1`), the `ConsoleLoggingNotificationListener` bean that was registered as a listener via the `notificationListenerMappings` property will be notified. The `ConsoleLoggingNotificationListener` bean can then take whatever action it deems appropriate in response to the `Notification`.

You can also use straight bean names as the link between exported beans and listeners:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
        <property name="notificationListenerMappings">
            <map>
                <entry key="testBean">
                    <bean class="com.example.ConsoleLoggingNotificationListener"/>
                </entry>
            </map>
        </property>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

</beans>
```

If one wants to register a single `NotificationListener` instance for all of the beans that the enclosing `MBeanExporter` is exporting, one can use the special wildcard `'*'` (sans quotes) as the key for an entry in the `notificationListenerMappings` property map; for example:

```
<property name="notificationListenerMappings">
    <map>
        <entry key="*">
            <bean class="com.example.ConsoleLoggingNotificationListener"/>
        </entry>
    </map>
</property>
```

If one needs to do the inverse (that is, register a number of distinct listeners against an MBean), then one has to use the `notificationListeners` list property instead (and in preference to the `notificationListenerMappings` property). This time, instead of configuring simply a `NotificationListener` for a single MBean, one configures `NotificationListenerBean` instances... a `NotificationListenerBean` encapsulates a `NotificationListener` and the `ObjectName` (or `ObjectNames`) that it is to be registered against in an `MBeanServer`. The `NotificationListenerBean` also encapsulates a number of other properties such as a `NotificationFilter` and an arbitrary handback object that can be used in advanced JMX notification scenarios.

The configuration when using `NotificationListenerBean` instances is not wildly different to what was presented previously:

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean"/>
            </map>
        </property>
        <property name="notificationListeners">
            <list>
                <bean class="org.springframework.jmx.export.NotificationListenerBean">
                    <constructor-arg>
                        <bean class="com.example.ConsoleLoggingNotificationListener"/>
                    </constructor-arg>
                    <property name="mappedObjectNames">
                        <list>
                            <value>bean:name=testBean1</value>
                        </list>
                    </property>
                </bean>
            </list>
        </property>
    </bean>

    <bean id="testBean" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

</beans>
```

The above example is equivalent to the first notification example. Lets assume then that we want to be given a handback object every time a `Notification` is raised, and that additionally we want to filter out extraneous `Notifications` by supplying a `NotificationFilter`. (For a full discussion of just what a handback object is, and indeed what a `NotificationFilter` is, please do consult that section of the JMX specification (1.2) entitled *The JMX Notification Model*.)

```
<beans>

    <bean id="exporter" class="org.springframework.jmx.export.MBeanExporter">
        <property name="beans">
            <map>
                <entry key="bean:name=testBean1" value-ref="testBean1"/>
                <entry key="bean:name=testBean2" value-ref="testBean2"/>
            </map>
        </property>
        <property name="notificationListeners">
            <list>
                <bean class="org.springframework.jmx.export.NotificationListenerBean">
                    <constructor-arg ref="customerNotificationListener"/>
                    <property name="mappedObjectNames">
                        <list>
                            <!-- handles notifications from two distinct MBeans -->
                            <value>bean:name=testBean1</value>
                            <value>bean:name=testBean2</value>
                        </list>
                    </property>
                    <property name="handback">
                        <bean class="java.lang.String">
                            <constructor-arg value="This could be anything..."/>
                        </bean>
                    </property>
                    <property name="notificationFilter" ref="customerNotificationListener"/>
                </bean>
            </list>
        </property>
    </bean>

    <!-- implements both the NotificationListener and NotificationFilter interfaces -->
    <bean id="customerNotificationListener" class="com.example.ConsoleLoggingNotificationListener"/>

    <bean id="testBean1" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="TEST"/>
        <property name="age" value="100"/>
    </bean>

    <bean id="testBean2" class="org.springframework.jmx.JmxTestBean">
        <property name="name" value="ANOTHER TEST"/>
        <property name="age" value="200"/>
    </bean>

</beans>
```

Publishing Notifications

Spring provides support not just for registering to receive `Notifications`, but also for publishing `Notifications`.

> **Note**
>
> Please note that this section is really only relevant to Spring managed beans that have been exposed as MBeans via an `MBeanExporter`; any existing, user-defined MBeans should use the standard JMX APIs for notification publication.

The key interface in Spring's JMX notification publication support is the `NotificationPublisher` interface (defined in the `org.springframework.jmx.export.notification` package). Any bean that is going to be exported as an MBean via an `MBeanExporter` instance can implement the related `NotificationPublisherAware` interface to gain access to a `NotificationPublisher` instance. The `NotificationPublisherAware` interface simply supplies an instance of a

`NotificationPublisher` to the implementing bean via a simple setter method, which the bean can then use to publish `Notifications`.

As stated in the javadocs of the `NotificationPublisher` class, managed beans that are publishing events via the `NotificationPublisher` mechanism are *not* responsible for the state management of any notification listeners and the like … Spring's JMX support will take care of handling all the JMX infrastructure issues. All one need do as an application developer is implement the `NotificationPublisherAware` interface and start publishing events using the supplied `NotificationPublisher` instance. Note that the `NotificationPublisher` will be set *after* the managed bean has been registered with an `MBeanServer`.

Using a `NotificationPublisher` instance is quite straightforward… one simply creates a JMX `Notification` instance (or an instance of an appropriate `Notification` subclass), populates the notification with the data pertinent to the event that is to be published, and one then invokes the `sendNotification(Notification)` on the `NotificationPublisher` instance, passing in the `Notification`.

Find below a simple example… in this scenario, exported instances of the `JmxTestBean` are going to publish a `NotificationEvent` every time the `add(int, int)` operation is invoked.

```
package org.springframework.jmx;

import org.springframework.jmx.export.notification.NotificationPublisherAware;
import org.springframework.jmx.export.notification.NotificationPublisher;
import javax.management.Notification;

public class JmxTestBean implements IJmxTestBean, NotificationPublisherAware {

    private String name;
    private int age;
    private boolean isSuperman;
    private NotificationPublisher publisher;

    // other getters and setters omitted for clarity

    public int add(int x, int y) {
        int answer = x + y;
        this.publisher.sendNotification(new Notification("add", this, 0));
        return answer;
    }

    public void dontExposeMe() {
        throw new RuntimeException();
    }

    public void setNotificationPublisher(NotificationPublisher notificationPublisher) {
        this.publisher = notificationPublisher;
    }

}
```

The `NotificationPublisher` interface and the machinery to get it all working is one of the nicer features of Spring's JMX support. It does however come with the price tag of coupling your classes to both Spring and JMX; as always, the advice here is to be pragmatic… if you need the functionality offered by the `NotificationPublisher` and you can accept the coupling to both Spring and JMX, then do so.

25.8 Further Resources

This section contains links to further resources about JMX.

- The JMX homepage at Oracle
- The JMX specification (JSR-000003)
- The JMX Remote API specification (JSR-000160)
- The MX4J homepage (an Open Source implementation of various JMX specs)

26. JCA CCI

26.1 Introduction

Java EE provides a specification to standardize access to enterprise information systems (EIS): the JCA (Java EE Connector Architecture). This specification is divided into several different parts:

- SPI (Service provider interfaces) that the connector provider must implement. These interfaces constitute a resource adapter which can be deployed on a Java EE application server. In such a scenario, the server manages connection pooling, transaction and security (managed mode). The application server is also responsible for managing the configuration, which is held outside the client application. A connector can be used without an application server as well; in this case, the application must configure it directly (non-managed mode).
- CCI (Common Client Interface) that an application can use to interact with the connector and thus communicate with an EIS. An API for local transaction demarcation is provided as well.

The aim of the Spring CCI support is to provide classes to access a CCI connector in typical Spring style, leveraging the Spring Framework's general resource and transaction management facilities.

> **Note**
>
> The client side of connectors doesn't alway use CCI. Some connectors expose their own APIs, only providing JCA resource adapter to use the system contracts of a Java EE container (connection pooling, global transactions, security). Spring does not offer special support for such connector-specific APIs.

26.2 Configuring CCI

Connector configuration

The base resource to use JCA CCI is the `ConnectionFactory` interface. The connector used must provide an implementation of this interface.

To use your connector, you can deploy it on your application server and fetch the `ConnectionFactory` from the server's JNDI environment (managed mode). The connector must be packaged as a RAR file (resource adapter archive) and contain a `ra.xml` file to describe its deployment characteristics. The actual name of the resource is specified when you deploy it. To access it within Spring, simply use Spring's `JndiObjectFactoryBean` / `<jee:jndi-lookup>` fetch the factory by its JNDI name.

Another way to use a connector is to embed it in your application (non-managed mode), not using an application server to deploy and configure it. Spring offers the possibility to configure a connector as a bean, through a provided `FactoryBean` (`LocalConnectionFactoryBean`). In this manner, you only need the connector library in the classpath (no RAR file and no `ra.xml` descriptor needed). The library must be extracted from the connector's RAR file, if necessary.

Once you have got access to your `ConnectionFactory` instance, you can inject it into your components. These components can either be coded against the plain CCI API or leverage Spring's support classes for CCI access (e.g. `CciTemplate`).

> **Note**
>
> When you use a connector in non-managed mode, you can't use global transactions because the resource is never enlisted / delisted in the current global transaction of the current thread. The resource is simply not aware of any global Java EE transactions that might be running.

ConnectionFactory configuration in Spring

In order to make connections to the EIS, you need to obtain a `ConnectionFactory` from the application server if you are in a managed mode, or directly from Spring if you are in a non-managed mode.

In a managed mode, you access a `ConnectionFactory` from JNDI; its properties will be configured in the application server.

```
<jee:jndi-lookup id="eciConnectionFactory" jndi-name="eis/cicseci"/>
```

In non-managed mode, you must configure the `ConnectionFactory` you want to use in the configuration of Spring as a JavaBean. The `LocalConnectionFactoryBean` class offers this setup style, passing in the `ManagedConnectionFactory` implementation of your connector, exposing the application-level CCI `ConnectionFactory`.

```
<bean id="eciManagedConnectionFactory" class="com.ibm.connector2.cics.ECIManagedConnectionFactory">
    <property name="serverName" value="TXSERIES"/>
    <property name="connectionURL" value="tcp://localhost/"/>
    <property name="portNumber" value="2006"/>
</bean>

<bean id="eciConnectionFactory" class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="eciManagedConnectionFactory"/>
</bean>
```

> **Note**
>
> You can't directly instantiate a specific `ConnectionFactory`. You need to go through the corresponding implementation of the `ManagedConnectionFactory` interface for your connector. This interface is part of the JCA SPI specification.

Configuring CCI connections

JCA CCI allow the developer to configure the connections to the EIS using the `ConnectionSpec` implementation of your connector. In order to configure its properties, you need to wrap the target connection factory with a dedicated adapter, `ConnectionSpecConnectionFactoryAdapter`. So, the dedicated `ConnectionSpec` can be configured with the property `connectionSpec` (as an inner bean).

This property is not mandatory because the CCI `ConnectionFactory` interface defines two different methods to obtain a CCI connection. Some of the `ConnectionSpec` properties can often be configured in the application server (in managed mode) or on the corresponding local `ManagedConnectionFactory` implementation.

```
public interface ConnectionFactory implements Serializable, Referenceable {
    ...
    Connection getConnection() throws ResourceException;
    Connection getConnection(ConnectionSpec connectionSpec) throws ResourceException;
    ...
}
```

Spring provides a `ConnectionSpecConnectionFactoryAdapter` that allows for specifying a `ConnectionSpec` instance to use for all operations on a given factory. If the adapter's `connectionSpec` property is specified, the adapter uses the `getConnection` variant with the `ConnectionSpec` argument, otherwise the variant without argument.

```
<bean id="managedConnectionFactory"
        class="com.sun.connector.cciblackbox.CciLocalTxManagedConnectionFactory">
    <property name="connectionURL" value="jdbc:hsqldb:hsql://localhost:9001"/>
    <property name="driverName" value="org.hsqldb.jdbcDriver"/>
</bean>

<bean id="targetConnectionFactory"
        class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="managedConnectionFactory"/>
</bean>

<bean id="connectionFactory"
        class="org.springframework.jca.cci.connection.ConnectionSpecConnectionFactoryAdapter">
    <property name="targetConnectionFactory" ref="targetConnectionFactory"/>
    <property name="connectionSpec">
        <bean class="com.sun.connector.cciblackbox.CciConnectionSpec">
            <property name="user" value="sa"/>
            <property name="password" value=""/>
        </bean>
    </property>
</bean>
```

Using a single CCI connection

If you want to use a single CCI connection, Spring provides a further `ConnectionFactory` adapter to manage this. The `SingleConnectionFactory` adapter class will open a single connection lazily and close it when this bean is destroyed at application shutdown. This class will expose special `Connection` proxies that behave accordingly, all sharing the same underlying physical connection.

```
<bean id="eciManagedConnectionFactory"
        class="com.ibm.connector2.cics.ECIManagedConnectionFactory">
    <property name="serverName" value="TEST"/>
    <property name="connectionURL" value="tcp://localhost/"/>
    <property name="portNumber" value="2006"/>
</bean>

<bean id="targetEciConnectionFactory"
        class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="eciManagedConnectionFactory"/>
</bean>

<bean id="eciConnectionFactory"
        class="org.springframework.jca.cci.connection.SingleConnectionFactory">
    <property name="targetConnectionFactory" ref="targetEciConnectionFactory"/>
</bean>
```

> **Note**
>
> This `ConnectionFactory` adapter cannot directly be configured with a `ConnectionSpec`. Use an intermediary `ConnectionSpecConnectionFactoryAdapter` that the `SingleConnectionFactory` talks to if you require a single connection for a specific `ConnectionSpec`.

26.3 Using Spring's CCI access support

Record conversion

One of the aims of the JCA CCI support is to provide convenient facilities for manipulating CCI records. The developer can specify the strategy to create records and extract datas from records, for use with Spring's `CciTemplate`. The following interfaces will configure the strategy to use input and output records if you don't want to work with records directly in your application.

In order to create an input `Record`, the developer can use a dedicated implementation of the `RecordCreator` interface.

```
public interface RecordCreator {

    Record createRecord(RecordFactory recordFactory) throws ResourceException, DataAccessException;

}
```

As you can see, the `createRecord(..)` method receives a `RecordFactory` instance as parameter, which corresponds to the `RecordFactory` of the `ConnectionFactory` used. This reference can be used to create `IndexedRecord` or `MappedRecord` instances. The following sample shows how to use the `RecordCreator` interface and indexed/mapped records.

```
public class MyRecordCreator implements RecordCreator {

    public Record createRecord(RecordFactory recordFactory) throws ResourceException {
        IndexedRecord input = recordFactory.createIndexedRecord("input");
        input.add(new Integer(id));
        return input;
    }

}
```

An output `Record` can be used to receive data back from the EIS. Hence, a specific implementation of the `RecordExtractor` interface can be passed to Spring's `CciTemplate` for extracting data from the output `Record`.

```
public interface RecordExtractor {

    Object extractData(Record record) throws ResourceException, SQLException, DataAccessException;

}
```

The following sample shows how to use the `RecordExtractor` interface.

```
public class MyRecordExtractor implements RecordExtractor {

    public Object extractData(Record record) throws ResourceException {
        CommAreaRecord commAreaRecord = (CommAreaRecord) record;
        String str = new String(commAreaRecord.toByteArray());
        String field1 = string.substring(0,6);
        String field2 = string.substring(6,1);
        return new OutputObject(Long.parseLong(field1), field2);
    }

}
```

the CciTemplate

The `CciTemplate` is the central class of the core CCI support package (`org.springframework.jca.cci.core`). It simplifies the use of CCI since it handles the creation

and release of resources. This helps to avoid common errors like forgetting to always close the connection. It cares for the lifecycle of connection and interaction objects, letting application code focus on generating input records from application data and extracting application data from output records.

The JCA CCI specification defines two distinct methods to call operations on an EIS. The CCI `Interaction` interface provides two execute method signatures:

```
public interface javax.resource.cci.Interaction {

    ...

    boolean execute(InteractionSpec spec, Record input, Record output) throws ResourceException;

    Record execute(InteractionSpec spec, Record input) throws ResourceException;

    ...

}
```

Depending on the template method called, `CciTemplate` will know which `execute` method to call on the interaction. In any case, a correctly initialized `InteractionSpec` instance is mandatory.

`CciTemplate.execute(..)` can be used in two ways:

- With direct `Record` arguments. In this case, you simply need to pass the CCI input record in, and the returned object be the corresponding CCI output record.
- With application objects, using record mapping. In this case, you need to provide corresponding `RecordCreator` and `RecordExtractor` instances.

With the first approach, the following methods of the template will be used. These methods directly correspond to those on the `Interaction` interface.

```
public class CciTemplate implements CciOperations {

    public Record execute(InteractionSpec spec, Record inputRecord)
            throws DataAccessException { ... }

    public void execute(InteractionSpec spec, Record inputRecord, Record outputRecord)
            throws DataAccessException { ... }

}
```

With the second approach, we need to specify the record creation and record extraction strategies as arguments. The interfaces used are those describe in the previous section on record conversion. The corresponding `CciTemplate` methods are the following:

```
public class CciTemplate implements CciOperations {

    public Record execute(InteractionSpec spec,
            RecordCreator inputCreator) throws DataAccessException {
        // ...
    }

    public Object execute(InteractionSpec spec, Record inputRecord,
            RecordExtractor outputExtractor) throws DataAccessException {
        // ...
    }

    public Object execute(InteractionSpec spec, RecordCreator creator,
            RecordExtractor extractor) throws DataAccessException {
        // ...
    }

}
```

Unless the `outputRecordCreator` property is set on the template (see the following section), every method will call the corresponding `execute` method of the CCI `Interaction` with two parameters: `InteractionSpec` and input `Record`, receiving an output `Record` as return value.

`CciTemplate` also provides methods to create `IndexRecord` and `MappedRecord` outside a `RecordCreator` implementation, through its `createIndexRecord(..)` and `createMappedRecord(..)` methods. This can be used within DAO implementations to create `Record` instances to pass into corresponding `CciTemplate.execute(..)` methods.

```
public class CciTemplate implements CciOperations {

    public IndexedRecord createIndexedRecord(String name) throws DataAccessException { ... }

    public MappedRecord createMappedRecord(String name) throws DataAccessException { ... }

}
```

DAO support

Spring's CCI support provides a abstract class for DAOs, supporting injection of a `ConnectionFactory` or a `CciTemplate` instances. The name of the class is `CciDaoSupport`: It provides simple `setConnectionFactory` and `setCciTemplate` methods. Internally, this class will create a `CciTemplate` instance for a passed-in `ConnectionFactory`, exposing it to concrete data access implementations in subclasses.

```
public abstract class CciDaoSupport {

    public void setConnectionFactory(ConnectionFactory connectionFactory) {
        // ...
    }

    public ConnectionFactory getConnectionFactory() {
        // ...
    }

    public void setCciTemplate(CciTemplate cciTemplate) {
        // ...
    }

    public CciTemplate getCciTemplate() {
        // ...
    }

}
```

Automatic output record generation

If the connector used only supports the `Interaction.execute(..)` method with input and output records as parameters (that is, it requires the desired output record to be passed in instead of returning an appropriate output record), you can set the `outputRecordCreator` property of the `CciTemplate` to automatically generate an output record to be filled by the JCA connector when the response is received. This record will be then returned to the caller of the template.

This property simply holds an implementation of the `RecordCreator` interface, used for that purpose. The `RecordCreator` interface has already been discussed in the section called “Record conversion”. The `outputRecordCreator` property must be directly specified on the `CciTemplate`. This could be done in the application code like so:

```
cciTemplate.setOutputRecordCreator(new EciOutputRecordCreator());
```

Or (recommended) in the Spring configuration, if the `CciTemplate` is configured as a dedicated bean instance:

```
<bean id="eciOutputRecordCreator" class="eci.EciOutputRecordCreator"/>

<bean id="cciTemplate" class="org.springframework.jca.cci.core.CciTemplate">
    <property name="connectionFactory" ref="eciConnectionFactory"/>
    <property name="outputRecordCreator" ref="eciOutputRecordCreator"/>
</bean>
```

> **Note**
>
> As the `CciTemplate` class is thread-safe, it will usually be configured as a shared instance.

Summary

The following table summarizes the mechanisms of the `CciTemplate` class and the corresponding methods called on the CCI `Interaction` interface:

Table 26.1. Usage of Interaction execute methods

CciTemplate method signature	CciTemplate outputRecordCreator property	execute method called on the CCI Interaction
Record execute(InteractionSpec, Record)	not set	Record execute(InteractionSpec, Record)
Record execute(InteractionSpec, Record)	set	boolean execute(InteractionSpec, Record, Record)
void execute(InteractionSpec, Record, Record)	not set	void execute(InteractionSpec, Record, Record)
void execute(InteractionSpec, Record, Record)	set	void execute(InteractionSpec, Record, Record)
Record execute(InteractionSpec, RecordCreator)	not set	Record execute(InteractionSpec, Record)
Record execute(InteractionSpec, RecordCreator)	set	void execute(InteractionSpec, Record, Record)

CciTemplate method signature	CciTemplate outputRecordCreation property	execute method called on the CCI Interaction
Record execute(InteractionSpec, Record, RecordExtractor)	not set	Record execute(InteractionSpec, Record)
Record execute(InteractionSpec, Record, RecordExtractor)	set	void execute(InteractionSpec, Record, Record)
Record execute(InteractionSpec, RecordCreator, RecordExtractor)	not set	Record execute(InteractionSpec, Record)
Record execute(InteractionSpec, RecordCreator, RecordExtractor)	set	void execute(InteractionSpec, Record, Record)

Using a CCI Connection and Interaction directly

`CciTemplate` also offers the possibility to work directly with CCI connections and interactions, in the same manner as `JdbcTemplate` and `JmsTemplate`. This is useful when you want to perform multiple operations on a CCI connection or interaction, for example.

The interface `ConnectionCallback` provides a CCI `Connection` as argument, in order to perform custom operations on it, plus the CCI `ConnectionFactory` which the `Connection` was created with. The latter can be useful for example to get an associated `RecordFactory` instance and create indexed/mapped records, for example.

```
public interface ConnectionCallback {

    Object doInConnection(Connection connection, ConnectionFactory connectionFactory)
            throws ResourceException, SQLException, DataAccessException;

}
```

The interface `InteractionCallback` provides the CCI `Interaction`, in order to perform custom operations on it, plus the corresponding CCI `ConnectionFactory`.

```
public interface InteractionCallback {

    Object doInInteraction(Interaction interaction, ConnectionFactory connectionFactory)
        throws ResourceException, SQLException, DataAccessException;

}
```

> **Note**
>
> `InteractionSpec` objects can either be shared across multiple template calls or newly created inside every callback method. This is completely up to the DAO implementation.

Example for CciTemplate usage

In this section, the usage of the `CciTemplate` will be shown to acces to a CICS with ECI mode, with the IBM CICS ECI connector.

Firstly, some initializations on the CCI `InteractionSpec` must be done to specify which CICS program to access and how to interact with it.

```
ECIInteractionSpec interactionSpec = new ECIInteractionSpec();
interactionSpec.setFunctionName("MYPROG");
interactionSpec.setInteractionVerb(ECIInteractionSpec.SYNC_SEND_RECEIVE);
```

Then the program can use CCI via Spring's template and specify mappings between custom objects and CCI `Records`.

```
public class MyDaoImpl extends CciDaoSupport implements MyDao {

    public OutputObject getData(InputObject input) {
        ECIInteractionSpec interactionSpec = ...;

    OutputObject output = (ObjectOutput) getCciTemplate().execute(interactionSpec,
        new RecordCreator() {
            public Record createRecord(RecordFactory recordFactory) throws ResourceException {
                return new CommAreaRecord(input.toString().getBytes());
            }
        },
        new RecordExtractor() {
            public Object extractData(Record record) throws ResourceException {
                CommAreaRecord commAreaRecord = (CommAreaRecord)record;
                String str = new String(commAreaRecord.toByteArray());
                String field1 = string.substring(0,6);
                String field2 = string.substring(6,1);
                return new OutputObject(Long.parseLong(field1), field2);
            }
        });

        return output;
    }
}
```

As discussed previously, callbacks can be used to work directly on CCI connections or interactions.

```
public class MyDaoImpl extends CciDaoSupport implements MyDao {

    public OutputObject getData(InputObject input) {
        ObjectOutput output = (ObjectOutput) getCciTemplate().execute(
            new ConnectionCallback() {
                public Object doInConnection(Connection connection,
                        ConnectionFactory factory) throws ResourceException {

                    // do something...

                }
            });
        }
        return output;
    }

}
```

> **Note**
>
> With a `ConnectionCallback`, the `Connection` used will be managed and closed by the `CciTemplate`, but any interactions created on the connection must be managed by the callback implementation.

For a more specific callback, you can implement an `InteractionCallback`. The passed-in `Interaction` will be managed and closed by the `CciTemplate` in this case.

```
public class MyDaoImpl extends CciDaoSupport implements MyDao {

    public String getData(String input) {
        ECIInteractionSpec interactionSpec = ...;
        String output = (String) getCciTemplate().execute(interactionSpec,
            new InteractionCallback() {
                public Object doInInteraction(Interaction interaction,
                        ConnectionFactory factory) throws ResourceException {
                    Record input = new CommAreaRecord(inputString.getBytes());
                    Record output = new CommAreaRecord();
                    interaction.execute(holder.getInteractionSpec(), input, output);
                    return new String(output.toByteArray());
                }
            });
        return output;
    }

}
```

For the examples above, the corresponding configuration of the involved Spring beans could look like this in non-managed mode:

```
<bean id="managedConnectionFactory" class="com.ibm.connector2.cics.ECIManagedConnectionFactory">
    <property name="serverName" value="TXSERIES"/>
    <property name="connectionURL" value="local:"/>
    <property name="userName" value="CICSUSER"/>
    <property name="password" value="CICS"/>
</bean>

<bean id="connectionFactory" class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="managedConnectionFactory"/>
</bean>

<bean id="component" class="mypackage.MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

In managed mode (that is, in a Java EE environment), the configuration could look as follows:

```
<jee:jndi-lookup id="connectionFactory" jndi-name="eis/cicseci"/>

<bean id="component" class="MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

26.4 Modeling CCI access as operation objects

The `org.springframework.jca.cci.object` package contains support classes that allow you to access the EIS in a different style: through reusable operation objects, analogous to Spring's JDBC operation objects (see JDBC chapter). This will usually encapsulate the CCI API: an application-level input object will be passed to the operation object, so it can construct the input record and then convert the received record data to an application-level output object and return it.

> **Note**
>
> This approach is internally based on the `CciTemplate` class and the `RecordCreator` / `RecordExtractor` interfaces, reusing the machinery of Spring's core CCI support.

MappingRecordOperation

`MappingRecordOperation` essentially performs the same work as `CciTemplate`, but represents a specific, pre-configured operation as an object. It provides two template methods to specify how to

convert an input object to a input record, and how to convert an output record to an output object (record mapping):

- `createInputRecord(..)` to specify how to convert an input object to an input `Record`
- `extractOutputData(..)` to specify how to extract an output object from an output `Record`

Here are the signatures of these methods:

```
public abstract class MappingRecordOperation extends EisOperation {

    ...

    protected abstract Record createInputRecord(RecordFactory recordFactory,
            Object inputObject) throws ResourceException, DataAccessException {
        // ...
    }

    protected abstract Object extractOutputData(Record outputRecord)
            throws ResourceException, SQLException, DataAccessException {
        // ...
    }

    ...

}
```

Thereafter, in order to execute an EIS operation, you need to use a single execute method, passing in an application-level input object and receiving an application-level output object as result:

```
public abstract class MappingRecordOperation extends EisOperation {

    ...

    public Object execute(Object inputObject) throws DataAccessException {
    }

    ...
}
```

As you can see, contrary to the `CciTemplate` class, this `execute(..)` method does not have an `InteractionSpec` as argument. Instead, the `InteractionSpec` is global to the operation. The following constructor must be used to instantiate an operation object with a specific `InteractionSpec`:

```
InteractionSpec spec = ...;
MyMappingRecordOperation eisOperation = new MyMappingRecordOperation(getConnectionFactory(), spec);
...
```

MappingCommAreaOperation

Some connectors use records based on a COMMAREA which represents an array of bytes containing parameters to send to the EIS and data returned by it. Spring provides a special operation class for working directly on COMMAREA rather than on records. The `MappingCommAreaOperation` class extends the `MappingRecordOperation` class to provide such special COMMAREA support. It implicitly uses the `CommAreaRecord` class as input and output record type, and provides two new methods to convert an input object into an input COMMAREA and the output COMMAREA into an output object.

```
public abstract class MappingCommAreaOperation extends MappingRecordOperation {

    ...

    protected abstract byte[] objectToBytes(Object inObject)
            throws IOException, DataAccessException;

    protected abstract Object bytesToObject(byte[] bytes)
        throws IOException, DataAccessException;

    ...

}
```

Automatic output record generation

As every `MappingRecordOperation` subclass is based on CciTemplate internally, the same way to automatically generate output records as with `CciTemplate` is available. Every operation object provides a corresponding `setOutputRecordCreator(..)` method. For further information, see the section called “Automatic output record generation”.

Summary

The operation object approach uses records in the same manner as the `CciTemplate` class.

Table 26.2. Usage of Interaction execute methods

MappingRecordOperation method signature	MappingRecordOperation outputRecordCreator property	execute method called on the CCI Interaction
Object execute(Object)	not set	Record execute(InteractionSpec, Record)
Object execute(Object)	set	boolean execute(InteractionSpec, Record, Record)

Example for MappingRecordOperation usage

In this section, the usage of the `MappingRecordOperation` will be shown to access a database with the Blackbox CCI connector.

> **Note**
>
> The original version of this connector is provided by the Java EE SDK (version 1.3), available from Oracle.

Firstly, some initializations on the CCI `InteractionSpec` must be done to specify which SQL request to execute. In this sample, we directly define the way to convert the parameters of the request to a CCI record and the way to convert the CCI result record to an instance of the `Person` class.

```
public class PersonMappingOperation extends MappingRecordOperation {

    public PersonMappingOperation(ConnectionFactory connectionFactory) {
        setConnectionFactory(connectionFactory);
        CciInteractionSpec interactionSpec = new CciConnectionSpec();
        interactionSpec.setSql("select * from person where person_id=?");
        setInteractionSpec(interactionSpec);
    }

    protected Record createInputRecord(RecordFactory recordFactory,
            Object inputObject) throws ResourceException {
        Integer id = (Integer) inputObject;
        IndexedRecord input = recordFactory.createIndexedRecord("input");
        input.add(new Integer(id));
        return input;
    }

    protected Object extractOutputData(Record outputRecord)
            throws ResourceException, SQLException {
        ResultSet rs = (ResultSet) outputRecord;
        Person person = null;
        if (rs.next()) {
            Person person = new Person();
            person.setId(rs.getInt("person_id"));
            person.setLastName(rs.getString("person_last_name"));
            person.setFirstName(rs.getString("person_first_name"));
        }
        return person;
    }
}
```

Then the application can execute the operation object, with the person identifier as argument. Note that operation object could be set up as shared instance, as it is thread-safe.

```
public class MyDaoImpl extends CciDaoSupport implements MyDao {

    public Person getPerson(int id) {
        PersonMappingOperation query = new PersonMappingOperation(getConnectionFactory());
        Person person = (Person) query.execute(new Integer(id));
        return person;
    }
}
```

The corresponding configuration of Spring beans could look as follows in non-managed mode:

```
<bean id="managedConnectionFactory"
        class="com.sun.connector.cciblackbox.CciLocalTxManagedConnectionFactory">
    <property name="connectionURL" value="jdbc:hsqldb:hsql://localhost:9001"/>
    <property name="driverName" value="org.hsqldb.jdbcDriver"/>
</bean>

<bean id="targetConnectionFactory"
        class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="managedConnectionFactory"/>
</bean>

<bean id="connectionFactory"
        class="org.springframework.jca.cci.connection.ConnectionSpecConnectionFactoryAdapter">
    <property name="targetConnectionFactory" ref="targetConnectionFactory"/>
    <property name="connectionSpec">
        <bean class="com.sun.connector.cciblackbox.CciConnectionSpec">
            <property name="user" value="sa"/>
            <property name="password" value=""/>
        </bean>
    </property>
</bean>

<bean id="component" class="MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

In managed mode (that is, in a Java EE environment), the configuration could look as follows:

```
<jee:jndi-lookup id="targetConnectionFactory" jndi-name="eis/blackbox"/>

<bean id="connectionFactory"
        class="org.springframework.jca.cci.connection.ConnectionSpecConnectionFactoryAdapter">
    <property name="targetConnectionFactory" ref="targetConnectionFactory"/>
    <property name="connectionSpec">
        <bean class="com.sun.connector.cciblackbox.CciConnectionSpec">
            <property name="user" value="sa"/>
            <property name="password" value=""/>
        </bean>
    </property>
</bean>

<bean id="component" class="MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

Example for MappingCommAreaOperation usage

In this section, the usage of the `MappingCommAreaOperation` will be shown: accessing a CICS with ECI mode with the IBM CICS ECI connector.

Firstly, the CCI `InteractionSpec` needs to be initialized to specify which CICS program to access and how to interact with it.

```
public abstract class EciMappingOperation extends MappingCommAreaOperation {

    public EciMappingOperation(ConnectionFactory connectionFactory, String programName) {
        setConnectionFactory(connectionFactory);
        ECIInteractionSpec interactionSpec = new ECIInteractionSpec(),
        interactionSpec.setFunctionName(programName);
        interactionSpec.setInteractionVerb(ECIInteractionSpec.SYNC_SEND_RECEIVE);
        interactionSpec.setCommareaLength(30);
        setInteractionSpec(interactionSpec);
        setOutputRecordCreator(new EciOutputRecordCreator());
    }

    private static class EciOutputRecordCreator implements RecordCreator {
        public Record createRecord(RecordFactory recordFactory) throws ResourceException {
            return new CommAreaRecord();
        }
    }

}
```

The abstract `EciMappingOperation` class can then be subclassed to specify mappings between custom objects and `Records`.

```
public class MyDaoImpl extends CciDaoSupport implements MyDao {

    public OutputObject getData(Integer id) {
        EciMappingOperation query = new EciMappingOperation(getConnectionFactory(), "MYPROG") {

            protected abstract byte[] objectToBytes(Object inObject) throws IOException {
                Integer id = (Integer) inObject;
                return String.valueOf(id);
            }

            protected abstract Object bytesToObject(byte[] bytes) throws IOException;
                String str = new String(bytes);
                String field1 = str.substring(0,6);
                String field2 = str.substring(6,1);
                String field3 = str.substring(7,1);
                return new OutputObject(field1, field2, field3);
            }
        });

        return (OutputObject) query.execute(new Integer(id));
    }

}
```

The corresponding configuration of Spring beans could look as follows in non-managed mode:

```
<bean id="managedConnectionFactory" class="com.ibm.connector2.cics.ECIManagedConnectionFactory">
    <property name="serverName" value="TXSERIES"/>
    <property name="connectionURL" value="local:"/>
    <property name="userName" value="CICSUSER"/>
    <property name="password" value="CICS"/>
</bean>

<bean id="connectionFactory" class="org.springframework.jca.support.LocalConnectionFactoryBean">
    <property name="managedConnectionFactory" ref="managedConnectionFactory"/>
</bean>

<bean id="component" class="MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

In managed mode (that is, in a Java EE environment), the configuration could look as follows:

```
<jee:jndi-lookup id="connectionFactory" jndi-name="eis/cicseci"/>

<bean id="component" class="MyDaoImpl">
    <property name="connectionFactory" ref="connectionFactory"/>
</bean>
```

26.5 Transactions

JCA specifies several levels of transaction support for resource adapters. The kind of transactions that your resource adapter supports is specified in its `ra.xml` file. There are essentially three options: none (for example with CICS EPI connector), local transactions (for example with a CICS ECI connector), global transactions (for example with an IMS connector).

```
<connector>
    <resourceadapter>
        <!-- <transaction-support>NoTransaction</transaction-support> -->
        <!-- <transaction-support>LocalTransaction</transaction-support> -->
        <transaction-support>XATransaction</transaction-support>
    <resourceadapter>
<connector>
```

For global transactions, you can use Spring's generic transaction infrastructure to demarcate transactions, with `JtaTransactionManager` as backend (delegating to the Java EE server's distributed transaction coordinator underneath).

For local transactions on a single CCI `ConnectionFactory`, Spring provides a specific transaction management strategy for CCI, analogous to the `DataSourceTransactionManager` for JDBC. The CCI API defines a local transaction object and corresponding local transaction demarcation methods. Spring's `CciLocalTransactionManager` executes such local CCI transactions, fully compliant with Spring's generic `PlatformTransactionManager` abstraction.

```
<jee:jndi-lookup id="eciConnectionFactory" jndi-name="eis/cicseci"/>

<bean id="eciTransactionManager"
        class="org.springframework.jca.cci.connection.CciLocalTransactionManager">
    <property name="connectionFactory" ref="eciConnectionFactory"/>
</bean>
```

Both transaction strategies can be used with any of Spring's transaction demarcation facilities, be it declarative or programmatic. This is a consequence of Spring's generic `PlatformTransactionManager` abstraction, which decouples transaction demarcation from the actual execution strategy. Simply switch between `JtaTransactionManager` and `CciLocalTransactionManager` as needed, keeping your transaction demarcation as-is.

For more information on Spring's transaction facilities, see the chapter entitled Chapter 12, *Transaction Management*.

27. Email

27.1 Introduction

Library dependencies

The following additional jars to be on the classpath of your application in order to be able to use the Spring Framework's email library.

- The JavaMail `mail.jar` library
- The JAF `activation.jar` library

All of these libraries are freely available on the web.

The Spring Framework provides a helpful utility library for sending email that shields the user from the specifics of the underlying mailing system and is responsible for low level resource handling on behalf of the client.

The `org.springframework.mail` package is the root level package for the Spring Framework's email support. The central interface for sending emails is the `MailSender` interface; a simple value object encapsulating the properties of a simple mail such as *from* and *to* (plus many others) is the `SimpleMailMessage` class. This package also contains a hierarchy of checked exceptions which provide a higher level of abstraction over the lower level mail system exceptions with the root exception being `MailException`. Please refer to the javadocs for more information on the rich mail exception hierarchy.

The `org.springframework.mail.javamail.JavaMailSender` interface adds specialized *JavaMail* features such as MIME message support to the `MailSender` interface (from which it inherits). `JavaMailSender` also provides a callback interface for preparation of JavaMail MIME messages, called `org.springframework.mail.javamail.MimeMessagePreparator`

27.2 Usage

Let's assume there is a business interface called `OrderManager`:

```
public interface OrderManager {

    void placeOrder(Order order);

}
```

Let us also assume that there is a requirement stating that an email message with an order number needs to be generated and sent to a customer placing the relevant order.

Basic MailSender and SimpleMailMessage usage

```
import org.springframework.mail.MailException;
import org.springframework.mail.MailSender;
import org.springframework.mail.SimpleMailMessage;

public class SimpleOrderManager implements OrderManager {

    private MailSender mailSender;
    private SimpleMailMessage templateMessage;

    public void setMailSender(MailSender mailSender) {
        this.mailSender = mailSender;
    }

    public void setTemplateMessage(SimpleMailMessage templateMessage) {
        this.templateMessage = templateMessage;
    }

    public void placeOrder(Order order) {

        // Do the business calculations...

        // Call the collaborators to persist the order...

        // Create a thread safe "copy" of the template message and customize it
        SimpleMailMessage msg = new SimpleMailMessage(this.templateMessage);
        msg.setTo(order.getCustomer().getEmailAddress());
        msg.setText(
            "Dear " + order.getCustomer().getFirstName()
                + order.getCustomer().getLastName()
                + ", thank you for placing order. Your order number is "
                + order.getOrderNumber());
        try{
            this.mailSender.send(msg);
        }
        catch (MailException ex) {
            // simply log it and go on...
            System.err.println(ex.getMessage());
        }
    }

}
```

Find below the bean definitions for the above code:

```
<bean id="mailSender" class="org.springframework.mail.javamail.JavaMailSenderImpl">
    <property name="host" value="mail.mycompany.com"/>
</bean>

<!-- this is a template message that we can pre-load with default state -->
<bean id="templateMessage" class="org.springframework.mail.SimpleMailMessage">
    <property name="from" value="customerservice@mycompany.com"/>
    <property name="subject" value="Your order"/>
</bean>

<bean id="orderManager" class="com.mycompany.businessapp.support.SimpleOrderManager">
    <property name="mailSender" ref="mailSender"/>
    <property name="templateMessage" ref="templateMessage"/>
</bean>
```

Using the JavaMailSender and the MimeMessagePreparator

Here is another implementation of `OrderManager` using the `MimeMessagePreparator` callback interface. Please note in this case that the `mailSender` property is of type `JavaMailSender` so that we are able to use the JavaMail `MimeMessage` class:

```
import javax.mail.Message;
import javax.mail.MessagingException;
import javax.mail.internet.InternetAddress;
import javax.mail.internet.MimeMessage;

import javax.mail.internet.MimeMessage;
import org.springframework.mail.MailException;
import org.springframework.mail.javamail.JavaMailSender;
import org.springframework.mail.javamail.MimeMessagePreparator;

public class SimpleOrderManager implements OrderManager {

    private JavaMailSender mailSender;

    public void setMailSender(JavaMailSender mailSender) {
        this.mailSender = mailSender;
    }

    public void placeOrder(final Order order) {

        // Do the business calculations...

        // Call the collaborators to persist the order...

        MimeMessagePreparator preparator = new MimeMessagePreparator() {

            public void prepare(MimeMessage mimeMessage) throws Exception {

                mimeMessage.setRecipient(Message.RecipientType.TO,
                        new InternetAddress(order.getCustomer().getEmailAddress()));
                mimeMessage.setFrom(new InternetAddress("mail@mycompany.com"));
                mimeMessage.setText(
                        "Dear " + order.getCustomer().getFirstName() + " "
                            + order.getCustomer().getLastName()
                            + ", thank you for placing order. Your order number is "
                            + order.getOrderNumber());
            }
        };

        try {
            this.mailSender.send(preparator);
        }
        catch (MailException ex) {
            // simply log it and go on...
            System.err.println(ex.getMessage());
        }
    }

}
```

> **Note**
>
> The mail code is a crosscutting concern and could well be a candidate for refactoring into a custom Spring AOP aspect, which then could be executed at appropriate joinpoints on the `OrderManager` target.

The Spring Framework's mail support ships with the standard JavaMail implementation. Please refer to the relevant javadocs for more information.

27.3 Using the JavaMail MimeMessageHelper

A class that comes in pretty handy when dealing with JavaMail messages is the `org.springframework.mail.javamail.MimeMessageHelper` class, which shields you from

having to use the verbose JavaMail API. Using the `MimeMessageHelper` it is pretty easy to create a `MimeMessage`:

```
// of course you would use DI in any real-world cases
JavaMailSenderImpl sender = new JavaMailSenderImpl();
sender.setHost("mail.host.com");

MimeMessage message = sender.createMimeMessage();
MimeMessageHelper helper = new MimeMessageHelper(message);
helper.setTo("test@host.com");
helper.setText("Thank you for ordering!");

sender.send(message);
```

Sending attachments and inline resources

Multipart email messages allow for both attachments and inline resources. Examples of inline resources would be images or a stylesheet you want to use in your message, but that you don't want displayed as an attachment.

Attachments

The following example shows you how to use the `MimeMessageHelper` to send an email along with a single JPEG image attachment.

```
JavaMailSenderImpl sender = new JavaMailSenderImpl();
sender.setHost("mail.host.com");

MimeMessage message = sender.createMimeMessage();

// use the true flag to indicate you need a multipart message
MimeMessageHelper helper = new MimeMessageHelper(message, true);
helper.setTo("test@host.com");

helper.setText("Check out this image!");

// let's attach the infamous windows Sample file (this time copied to c:/)
FileSystemResource file = new FileSystemResource(new File("c:/Sample.jpg"));
helper.addAttachment("CoolImage.jpg", file);

sender.send(message);
```

Inline resources

The following example shows you how to use the `MimeMessageHelper` to send an email along with an inline image.

```
JavaMailSenderImpl sender = new JavaMailSenderImpl();
sender.setHost("mail.host.com");

MimeMessage message = sender.createMimeMessage();

// use the true flag to indicate you need a multipart message
MimeMessageHelper helper = new MimeMessageHelper(message, true);
helper.setTo("test@host.com");

// use the true flag to indicate the text included is HTML
helper.setText("<html><body><img src='cid:identifier1234'></body></html>", true);

// let's include the infamous windows Sample file (this time copied to c:/)
FileSystemResource res = new FileSystemResource(new File("c:/Sample.jpg"));
helper.addInline("identifier1234", res);

sender.send(message);
```

> **Warning**
>
> Inline resources are added to the mime message using the specified `Content-ID` (`identifier1234` in the above example). The order in which you are adding the text and the resource are *very* important. Be sure to *first add the text* and after that the resources. If you are doing it the other way around, it won't work!

Creating email content using a templating library

The code in the previous examples explicitly created the content of the email message, using methods calls such as `message.setText(..)`. This is fine for simple cases, and it is okay in the context of the aforementioned examples, where the intent was to show you the very basics of the API.

In your typical enterprise application though, you are not going to create the content of your emails using the above approach for a number of reasons.

- Creating HTML-based email content in Java code is tedious and error prone
- There is no clear separation between display logic and business logic
- Changing the display structure of the email content requires writing Java code, recompiling, redeploying…

Typically the approach taken to address these issues is to use a template library such as FreeMarker or Velocity to define the display structure of email content. This leaves your code tasked only with creating the data that is to be rendered in the email template and sending the email. It is definitely a best practice for when the content of your emails becomes even moderately complex, and with the Spring Framework's support classes for FreeMarker and Velocity becomes quite easy to do. Find below an example of using the Velocity template library to create email content.

A Velocity-based example

To use Velocity to create your email template(s), you will need to have the Velocity libraries available on your classpath. You will also need to create one or more Velocity templates for the email content that your application needs. Find below the Velocity template that this example will be using. As you can see it is HTML-based, and since it is plain text it can be created using your favorite HTML or text editor.

```
# in the com/foo/package
<html>
    <body>
        <h3>Hi ${user.userName}, welcome to the Chipping Sodbury On-the-Hill message boards!</h3>

        <div>
            Your email address is <a href="mailto:${user.emailAddress}">${user.emailAddress}</a>.
        </div>
    </body>
</html>
```

Find below some simple code and Spring XML configuration that makes use of the above Velocity template to create email content and send email(s).

```
package com.foo;

import org.apache.velocity.app.VelocityEngine;
import org.springframework.mail.javamail.JavaMailSender;
import org.springframework.mail.javamail.MimeMessageHelper;
import org.springframework.mail.javamail.MimeMessagePreparator;
import org.springframework.ui.velocity.VelocityEngineUtils;

import javax.mail.internet.MimeMessage;
import java.util.HashMap;
import java.util.Map;

public class SimpleRegistrationService implements RegistrationService {

    private JavaMailSender mailSender;
    private VelocityEngine velocityEngine;

    public void setMailSender(JavaMailSender mailSender) {
        this.mailSender = mailSender;
    }

    public void setVelocityEngine(VelocityEngine velocityEngine) {
        this.velocityEngine = velocityEngine;
    }

    public void register(User user) {

        // Do the registration logic...

        sendConfirmationEmail(user);
    }

    private void sendConfirmationEmail(final User user) {
        MimeMessagePreparator preparator = new MimeMessagePreparator() {
            public void prepare(MimeMessage mimeMessage) throws Exception {
                MimeMessageHelper message = new MimeMessageHelper(mimeMessage);
                message.setTo(user.getEmailAddress());
                message.setFrom("webmaster@csonth.gov.uk"); // could be parameterized...
                Map model = new HashMap();
                model.put("user", user);
                String text = VelocityEngineUtils.mergeTemplateIntoString(
                        velocityEngine, "com/dns/registration-confirmation.vm", model);
                message.setText(text, true);
            }
        };
        this.mailSender.send(preparator);
    }

}
```

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="mailSender" class="org.springframework.mail.javamail.JavaMailSenderImpl">
        <property name="host" value="mail.csonth.gov.uk"/>
    </bean>

    <bean id="registrationService" class="com.foo.SimpleRegistrationService">
        <property name="mailSender" ref="mailSender"/>
        <property name="velocityEngine" ref="velocityEngine"/>
    </bean>

    <bean id="velocityEngine" class="org.springframework.ui.velocity.VelocityEngineFactoryBean">
        <property name="velocityProperties">
            <value>
                resource.loader=class

 class.resource.loader.class=org.apache.velocity.runtime.resource.loader.ClasspathResourceLoader
            </value>
        </property>
    </bean>

</beans>
```

28. Task Execution and Scheduling

28.1 Introduction

The Spring Framework provides abstractions for asynchronous execution and scheduling of tasks with the `TaskExecutor` and `TaskScheduler` interfaces, respectively. Spring also features implementations of those interfaces that support thread pools or delegation to CommonJ within an application server environment. Ultimately the use of these implementations behind the common interfaces abstracts away the differences between Java SE 5, Java SE 6 and Java EE environments.

Spring also features integration classes for supporting scheduling with the `Timer`, part of the JDK since 1.3, and the Quartz Scheduler (http://quartz-scheduler.org). Both of those schedulers are set up using a `FactoryBean` with optional references to `Timer` or `Trigger` instances, respectively. Furthermore, a convenience class for both the Quartz Scheduler and the `Timer` is available that allows you to invoke a method of an existing target object (analogous to the normal `MethodInvokingFactoryBean` operation).

28.2 The Spring TaskExecutor abstraction

Spring 2.0 introduces a new abstraction for dealing with executors. Executors are the Java 5 name for the concept of thread pools. The "executor" naming is due to the fact that there is no guarantee that the underlying implementation is actually a pool; an executor may be single-threaded or even synchronous. Spring's abstraction hides implementation details between Java SE 1.4, Java SE 5 and Java EE environments.

Spring's `TaskExecutor` interface is identical to the `java.util.concurrent.Executor` interface. In fact, its primary reason for existence was to abstract away the need for Java 5 when using thread pools. The interface has a single method `execute(Runnable task)` that accepts a task for execution based on the semantics and configuration of the thread pool.

The `TaskExecutor` was originally created to give other Spring components an abstraction for thread pooling where needed. Components such as the `ApplicationEventMulticaster`, JMS's `AbstractMessageListenerContainer`, and Quartz integration all use the `TaskExecutor` abstraction to pool threads. However, if your beans need thread pooling behavior, it is possible to use this abstraction for your own needs.

TaskExecutor types

There are a number of pre-built implementations of `TaskExecutor` included with the Spring distribution. In all likelihood, you shouldn't ever need to implement your own.

- `SimpleAsyncTaskExecutor` This implementation does not reuse any threads, rather it starts up a new thread for each invocation. However, it does support a concurrency limit which will block any invocations that are over the limit until a slot has been freed up. If you re looking for true pooling, keep scrolling further down the page.
- `SyncTaskExecutor` This implementation doesn't execute invocations asynchronously. Instead, each invocation takes place in the calling thread. It is primarily used in situations where multi-threading isn't necessary such as simple test cases.
- `ConcurrentTaskExecutor` This implementation is an adapter for a `java.util.concurrent.Executor` object. There is an alternative,

`ThreadPoolTaskExecutor, that exposes the `Executor configuration parameters as bean properties. It is rare to need to use the `ConcurrentTaskExecutor` but if the `ThreadPoolTaskExecutor` isn't flexible enough for your needs, the `ConcurrentTaskExecutor` is an alternative.

- `SimpleThreadPoolTaskExecutor` This implementation is actually a subclass of Quartz's `SimpleThreadPool` which listens to Spring's lifecycle callbacks. This is typically used when you have a thread pool that may need to be shared by both Quartz and non-Quartz components.
- `ThreadPoolTaskExecutor` This implementation is the most commonly used one. It exposes bean properties for configuring a java.util.concurrent.ThreadPoolExecutor` and wraps it in a `TaskExecutor`. If you need to adapt to a different kind of `java.util.concurrent.Executor`, it is recommended that you use a `ConcurrentTaskExecutor` instead.
- `WorkManagerTaskExecutor`

> CommonJ is a set of specifications jointly developed between BEA and IBM. These specifications are not Java EE standards, but are standard across BEA's and IBM's Application Server implementations.

This implementation uses the CommonJ WorkManager as its backing implementation and is the central convenience class for setting up a CommonJ WorkManager reference in a Spring context. Similar to the `SimpleThreadPoolTaskExecutor`, this class implements the WorkManager interface and therefore can be used directly as a WorkManager as well.

Using a TaskExecutor

Spring's `TaskExecutor` implementations are used as simple JavaBeans. In the example below, we define a bean that uses the `ThreadPoolTaskExecutor` to asynchronously print out a set of messages.

```
import org.springframework.core.task.TaskExecutor;

public class TaskExecutorExample {

    private class MessagePrinterTask implements Runnable {

        private String message;

        public MessagePrinterTask(String message) {
            this.message = message;
        }

        public void run() {
            System.out.println(message);
        }

    }

    private TaskExecutor taskExecutor;

    public TaskExecutorExample(TaskExecutor taskExecutor) {
        this.taskExecutor = taskExecutor;
    }

    public void printMessages() {
        for(int i = 0; i < 25; i++) {
            taskExecutor.execute(new MessagePrinterTask("Message" + i));
        }
    }

}
```

As you can see, rather than retrieving a thread from the pool and executing yourself, you add your `Runnable` to the queue and the `TaskExecutor` uses its internal rules to decide when the task gets executed.

To configure the rules that the `TaskExecutor` will use, simple bean properties have been exposed.

```
<bean id="taskExecutor" class="org.springframework.scheduling.concurrent.ThreadPoolTaskExecutor">
    <property name="corePoolSize" value="5" />
    <property name="maxPoolSize" value="10" />
    <property name="queueCapacity" value="25" />
</bean>

<bean id="taskExecutorExample" class="TaskExecutorExample">
    <constructor-arg ref="taskExecutor" />
</bean>
```

28.3 The Spring TaskScheduler abstraction

In addition to the `TaskExecutor` abstraction, Spring 3.0 introduces a `TaskScheduler` with a variety of methods for scheduling tasks to run at some point in the future.

```
public interface TaskScheduler {

    ScheduledFuture schedule(Runnable task, Trigger trigger);

    ScheduledFuture schedule(Runnable task, Date startTime);

    ScheduledFuture scheduleAtFixedRate(Runnable task, Date startTime, long period);

    ScheduledFuture scheduleAtFixedRate(Runnable task, long period);

    ScheduledFuture scheduleWithFixedDelay(Runnable task, Date startTime, long delay);

    ScheduledFuture scheduleWithFixedDelay(Runnable task, long delay);

}
```

The simplest method is the one named *schedule* that takes a `Runnable` and `Date` only. That will cause the task to run once after the specified time. All of the other methods are capable of scheduling tasks to run repeatedly. The fixed-rate and fixed-delay methods are for simple, periodic execution, but the method that accepts a Trigger is much more flexible.

the Trigger interface

The `Trigger` interface is essentially inspired by JSR-236, which, as of Spring 3.0, has not yet been officially implemented. The basic idea of the `Trigger` is that execution times may be determined based on past execution outcomes or even arbitrary conditions. If these determinations do take into account the outcome of the preceding execution, that information is available within a `TriggerContext`. The `Trigger` interface itself is quite simple:

```
public interface Trigger {

    Date nextExecutionTime(TriggerContext triggerContext);

}
```

As you can see, the `TriggerContext` is the most important part. It encapsulates all of the relevant data, and is open for extension in the future if necessary. The `TriggerContext` is an interface (a `SimpleTriggerContext` implementation is used by default). Here you can see what methods are available for `Trigger` implementations.

```
public interface TriggerContext {

    Date lastScheduledExecutionTime();

    Date lastActualExecutionTime();

    Date lastCompletionTime();

}
```

Trigger implementations

Spring provides two implementations of the `Trigger` interface. The most interesting one is the `CronTrigger`. It enables the scheduling of tasks based on cron expressions. For example the following task is being scheduled to run 15 minutes past each hour but only during the 9-to-5 "business hours" on weekdays.

```
scheduler.schedule(task, new CronTrigger("* 15 9-17 * * MON-FRI"));
```

The other out-of-the-box implementation is a `PeriodicTrigger` that accepts a fixed period, an optional initial delay value, and a boolean to indicate whether the period should be interpreted as a fixed-rate or a fixed-delay. Since the `TaskScheduler` interface already defines methods for scheduling tasks at a fixed-rate or with a fixed-delay, those methods should be used directly whenever possible. The value of the `PeriodicTrigger` implementation is that it can be used within components that rely on the `Trigger` abstraction. For example, it may be convenient to allow periodic triggers, cron-based triggers, and even custom trigger implementations to be used interchangeably. Such a component could take advantage of dependency injection so that such `Triggers` could be configured externally.

TaskScheduler implementations

As with Spring's `TaskExecutor` abstraction, the primary benefit of the `TaskScheduler` is that code relying on scheduling behavior need not be coupled to a particular scheduler implementation. The flexibility this provides is particularly relevant when running within Application Server environments where threads should not be created directly by the application itself. For such cases, Spring provides a `TimerManagerTaskScheduler` that delegates to a CommonJ TimerManager instance, typically configured with a JNDI-lookup.

A simpler alternative, the `ThreadPoolTaskScheduler`, can be used whenever external thread management is not a requirement. Internally, it delegates to a `ScheduledExecutorService` instance. `ThreadPoolTaskScheduler` actually implements Spring's `TaskExecutor` interface as well, so that a single instance can be used for asynchronous execution *as soon as possible* as well as scheduled, and potentially recurring, executions.

28.4 Annotation Support for Scheduling and Asynchronous Execution

Spring provides annotation support for both task scheduling and asynchronous method execution.

Enable scheduling annotations

To enable support for `@Scheduled` and `@Async` annotations add `@EnableScheduling` and `@EnableAsync` to one of your `@Configuration` classes:

```
@Configuration
@EnableAsync
@EnableScheduling
public class AppConfig {
}
```

You are free to pick and choose the relevant annotations for your application. For example, if you only need support for `@Scheduled`, simply omit `@EnableAsync`. For more fine-grained control you can additionally implement the `SchedulingConfigurer` and/or `AsyncConfigurer` interfaces. See the javadocs for full details.

If you prefer XML configuration use the `<task:annotation-driven>` element.

```
<task:annotation-driven executor="myExecutor" scheduler="myScheduler"/>
<task:executor id="myExecutor" pool-size="5"/>
<task:scheduler id="myScheduler" pool-size="10"/>
```

Notice with the above XML that an executor reference is provided for handling those tasks that correspond to methods with the `@Async` annotation, and the scheduler reference is provided for managing those methods annotated with `@Scheduled`.

The @Scheduled Annotation

The @Scheduled annotation can be added to a method along with trigger metadata. For example, the following method would be invoked every 5 seconds with a fixed delay, meaning that the period will be measured from the completion time of each preceding invocation.

```
@Scheduled(fixedDelay=5000)
public void doSomething() {
    // something that should execute periodically
}
```

If a fixed rate execution is desired, simply change the property name specified within the annotation. The following would be executed every 5 seconds measured between the successive start times of each invocation.

```
@Scheduled(fixedRate=5000)
public void doSomething() {
    // something that should execute periodically
}
```

For fixed-delay and fixed-rate tasks, an initial delay may be specified indicating the number of milliseconds to wait before the first execution of the method.

```
@Scheduled(initialDelay=1000, fixedRate=5000)
public void doSomething() {
    // something that should execute periodically
}
```

If simple periodic scheduling is not expressive enough, then a cron expression may be provided. For example, the following will only execute on weekdays.

```
@Scheduled(cron="*/5 * * * * MON-FRI")
public void doSomething() {
    // something that should execute on weekdays only
}
```

> **Tip**
>
> You can additionally use the `zone` attribute to specify the time zone in which the cron expression will be resolved.

Notice that the methods to be scheduled must have void returns and must not expect any arguments. If the method needs to interact with other objects from the Application Context, then those would typically have been provided through dependency injection.

> **Note**
>
> Make sure that you are not initializing multiple instances of the same @Scheduled annotation class at runtime, unless you do want to schedule callbacks to each such instance. Related to this, make sure that you do not use @Configurable on bean classes which are annotated with @Scheduled and registered as regular Spring beans with the container: You would get double initialization otherwise, once through the container and once through the @Configurable aspect, with the consequence of each @Scheduled method being invoked twice.

The @Async Annotation

The `@Async` annotation can be provided on a method so that invocation of that method will occur asynchronously. In other words, the caller will return immediately upon invocation and the actual execution of the method will occur in a task that has been submitted to a Spring `TaskExecutor`. In the simplest case, the annotation may be applied to a `void`-returning method.

```
@Async
void doSomething() {
    // this will be executed asynchronously
}
```

Unlike the methods annotated with the `@Scheduled` annotation, these methods can expect arguments, because they will be invoked in the "normal" way by callers at runtime rather than from a scheduled task being managed by the container. For example, the following is a legitimate application of the `@Async` annotation.

```
@Async
void doSomething(String s) {
    // this will be executed asynchronously
}
```

Even methods that return a value can be invoked asynchronously. However, such methods are required to have a `Future` typed return value. This still provides the benefit of asynchronous execution so that the caller can perform other tasks prior to calling `get()` on that Future.

```
@Async
Future<String> returnSomething(int i) {
    // this will be executed asynchronously
}
```

`@Async` can not be used in conjunction with lifecycle callbacks such as `@PostConstruct`. To asynchronously initialize Spring beans you currently have to use a separate initializing Spring bean that invokes the `@Async` annotated method on the target then.

```
public class SampleBeanImpl implements SampleBean {

    @Async
    void doSomething() {
        // ...
    }

}

public class SampleBeanInititalizer {

    private final SampleBean bean;

    public SampleBeanInitializer(SampleBean bean) {
        this.bean = bean;
    }

    @PostConstruct
    public void initialize() {
        bean.doSomething();
    }

}
```

Executor qualification with @Async

By default when specifying `@Async` on a method, the executor that will be used is the one supplied to the *annotation-driven* element as described above. However, the `value` attribute of the `@Async` annotation can be used when needing to indicate that an executor other than the default should be used when executing a given method.

```
@Async("otherExecutor")
void doSomething(String s) {
    // this will be executed asynchronously by "otherExecutor"
}
```

In this case, "otherExecutor" may be the name of any `Executor` bean in the Spring container, or may be the name of a *qualifier* associated with any `Executor`, e.g. as specified with the `<qualifier>` element or Spring's `@Qualifier` annotation.

Exception management with @Async

When an `@Async` method has a `Future` typed return value, it is easy to manage an exception that was thrown during the method execution as this exception will be thrown when calling `get` on the `Future` result. With a void return type however, the exception is uncaught and cannot be transmitted. For those cases, an `AsyncUncaughtExceptionHandler` can be provided to handle such exceptions.

```
public class MyAsyncUncaughtExceptionHandler implements AsyncUncaughtExceptionHandler {

    @Override
    public void handleUncaughtException(Throwable ex, Method method, Object... params) {
        // handle exception
    }
}
```

By default, the exception is simply logged. A custom `AsyncUncaughtExceptionHandler` can be defined *via* `AsyncConfigurer` or the `task:annotation-driven` XML element.

28.5 The Task Namespace

Beginning with Spring 3.0, there is an XML namespace for configuring `TaskExecutor` and `TaskScheduler` instances. It also provides a convenient way to configure tasks to be scheduled with a trigger.

The *scheduler* element

The following element will create a `ThreadPoolTaskScheduler` instance with the specified thread pool size.

```
<task:scheduler id="scheduler" pool-size="10"/>
```

The value provided for the *id* attribute will be used as the prefix for thread names within the pool. The *scheduler* element is relatively straightforward. If you do not provide a *pool-size* attribute, the default thread pool will only have a single thread. There are no other configuration options for the scheduler.

The *executor* element

The following will create a `ThreadPoolTaskExecutor` instance:

```
<task:executor id="executor" pool-size="10"/>
```

As with the scheduler above, the value provided for the *id* attribute will be used as the prefix for thread names within the pool. As far as the pool size is concerned, the *executor* element supports more configuration options than the *scheduler* element. For one thing, the thread pool for a `ThreadPoolTaskExecutor` is itself more configurable. Rather than just a single size, an executor's thread pool may have different values for the *core* and the *max* size. If a single value is provided then the executor will have a fixed-size thread pool (the core and max sizes are the same). However, the *executor* element's *pool-size* attribute also accepts a range in the form of "min-max".

```
<task:executor
        id="executorWithPoolSizeRange"
        pool-size="5-25"
        queue-capacity="100"/>
```

As you can see from that configuration, a *queue-capacity* value has also been provided. The configuration of the thread pool should also be considered in light of the executor's queue capacity. For the full description of the relationship between pool size and queue capacity, consult the documentation for ThreadPoolExecutor. The main idea is that when a task is submitted, the executor will first try to use a free thread if the number of active threads is currently less than the core size. If the core size has been reached, then the task will be added to the queue as long as its capacity has not yet been reached. Only then, if the queue's capacity *has* been reached, will the executor create a new thread beyond the core size. If the max size has also been reached, then the executor will reject the task.

By default, the queue is *unbounded*, but this is rarely the desired configuration, because it can lead to `OutOfMemoryErrors` if enough tasks are added to that queue while all pool threads are busy. Furthermore, if the queue is unbounded, then the max size has no effect at all. Since the executor will always try the queue before creating a new thread beyond the core size, a queue must have a finite capacity for the thread pool to grow beyond the core size (this is why a *fixed size* pool is the only sensible case when using an unbounded queue).

In a moment, we will review the effects of the keep-alive setting which adds yet another factor to consider when providing a pool size configuration. First, let's consider the case, as mentioned above, when a task is rejected. By default, when a task is rejected, a thread pool executor will throw a `TaskRejectedException`. However, the rejection policy is actually configurable. The exception is thrown when using the default rejection policy which is the `AbortPolicy` implementation. For applications where some tasks can be skipped under heavy load, either the `DiscardPolicy` or `DiscardOldestPolicy` may be configured instead. Another option that works well for applications that need to throttle the submitted tasks under heavy load is the `CallerRunsPolicy`. Instead of throwing an exception or discarding tasks, that policy will simply force the thread that is calling the submit method to run the task itself. The idea is that such a caller will be busy while running that task and not able to submit other tasks immediately. Therefore it provides a simple way to throttle the incoming load while maintaining the limits of the thread pool and queue. Typically this allows the executor to "catch up" on the tasks it is handling and thereby frees up some capacity on the queue, in the pool, or both. Any of these options can be chosen from an enumeration of values available for the *rejection-policy* attribute on the *executor* element.

```
<task:executor
        id="executorWithCallerRunsPolicy"
        pool-size="5-25"
        queue-capacity="100"
        rejection-policy="CALLER_RUNS"/>
```

Finally, the `keep-alive` setting determines the time limit (in seconds) for which threads may remain idle before being terminated. If there are more than the core number of threads currently in the pool, after waiting this amount of time without processing a task, excess threads will get terminated. A time value

of zero will cause excess threads to terminate immediately after executing a task without remaining follow-up work in the task queue.

```
<task:executor
        id="executorWithKeepAlive"
        pool-size="5-25"
        keep-alive="120"/>
```

The *scheduled-tasks* element

The most powerful feature of Spring's task namespace is the support for configuring tasks to be scheduled within a Spring Application Context. This follows an approach similar to other "method-invokers" in Spring, such as that provided by the JMS namespace for configuring Message-driven POJOs. Basically a "ref" attribute can point to any Spring-managed object, and the "method" attribute provides the name of a method to be invoked on that object. Here is a simple example.

```
<task:scheduled-tasks scheduler="myScheduler">
    <task:scheduled ref="beanA" method="methodA" fixed-delay="5000"/>
</task:scheduled-tasks>

<task:scheduler id="myScheduler" pool-size="10"/>
```

As you can see, the scheduler is referenced by the outer element, and each individual task includes the configuration of its trigger metadata. In the preceding example, that metadata defines a periodic trigger with a fixed delay indicating the number of milliseconds to wait after each task execution has completed. Another option is *fixed-rate*, indicating how often the method should be executed regardless of how long any previous execution takes. Additionally, for both fixed-delay and fixed-rate tasks an *initial-delay* parameter may be specified indicating the number of milliseconds to wait before the first execution of the method. For more control, a "cron" attribute may be provided instead. Here is an example demonstrating these other options.

```
<task:scheduled-tasks scheduler="myScheduler">
    <task:scheduled ref="beanA" method="methodA" fixed-delay="5000" initial-delay="1000"/>
    <task:scheduled ref="beanB" method="methodB" fixed-rate="5000"/>
    <task:scheduled ref="beanC" method="methodC" cron="*/5 * * * * MON-FRI"/>
</task:scheduled-tasks>

<task:scheduler id="myScheduler" pool-size="10"/>
```

28.6 Using the Quartz Scheduler

Quartz uses `Trigger`, `Job` and `JobDetail` objects to realize scheduling of all kinds of jobs. For the basic concepts behind Quartz, have a look at http://quartz-scheduler.org. For convenience purposes, Spring offers a couple of classes that simplify the usage of Quartz within Spring-based applications.

Using the JobDetailFactoryBean

Quartz `JobDetail` objects contain all information needed to run a job. Spring provides a `JobDetailFactoryBean` which provides bean-style properties for XML configuration purposes. Let's have a look at an example:

```
<bean name="exampleJob" class="org.springframework.scheduling.quartz.JobDetailFactoryBean">
    <property name="jobClass" value="example.ExampleJob"/>
    <property name="jobDataAsMap">
        <map>
            <entry key="timeout" value="5"/>
        </map>
    </property>
</bean>
```

The job detail configuration has all information it needs to run the job (`ExampleJob`). The timeout is specified in the job data map. The job data map is available through the `JobExecutionContext` (passed to you at execution time), but the `JobDetail` also gets its properties from the job data mapped to properties of the job instance. So in this case, if the `ExampleJob` contains a bean property named `timeout`, the `JobDetail` will have it applied automatically:

```
package example;

public class ExampleJob extends QuartzJobBean {

    private int timeout;

    /**
     * Setter called after the ExampleJob is instantiated
     * with the value from the JobDetailFactoryBean (5)
     */
    public void setTimeout(int timeout) {
        this.timeout = timeout;
    }

    protected void executeInternal(JobExecutionContext ctx) throws JobExecutionException {
        // do the actual work
    }

}
```

All additional properties from the job data map are of course available to you as well.

> **Note**
>
> Using the `name` and `group` properties, you can modify the name and the group of the job, respectively. By default, the name of the job matches the bean name of the `JobDetailFactoryBean` (in the example above, this is `exampleJob`).

Using the MethodInvokingJobDetailFactoryBean

Often you just need to invoke a method on a specific object. Using the `MethodInvokingJobDetailFactoryBean` you can do exactly this:

```
<bean id="jobDetail" class="org.springframework.scheduling.quartz.MethodInvokingJobDetailFactoryBean">
    <property name="targetObject" ref="exampleBusinessObject"/>
    <property name="targetMethod" value="doIt"/>
</bean>
```

The above example will result in the `doIt` method being called on the `exampleBusinessObject` method (see below):

```
public class ExampleBusinessObject {

    // properties and collaborators

    public void doIt() {
        // do the actual work
    }
}
```

```
<bean id="exampleBusinessObject" class="examples.ExampleBusinessObject"/>
```

Using the `MethodInvokingJobDetailFactoryBean`, you don't need to create one-line jobs that just invoke a method, and you only need to create the actual business object and wire up the detail object.

By default, Quartz Jobs are stateless, resulting in the possibility of jobs interfering with each other. If you specify two triggers for the same `JobDetail`, it might be possible that before the first job has finished, the second one will start. If `JobDetail` classes implement the `Stateful` interface, this won't happen. The second job will not start before the first one has finished. To make jobs resulting from the `MethodInvokingJobDetailFactoryBean` non-concurrent, set the `concurrent` flag to `false`.

```
<bean id="jobDetail" class="org.springframework.scheduling.quartz.MethodInvokingJobDetailFactoryBean">
    <property name="targetObject" ref="exampleBusinessObject"/>
    <property name="targetMethod" value="doIt"/>
    <property name="concurrent" value="false"/>
</bean>
```

> **Note**
>
> By default, jobs will run in a concurrent fashion.

Wiring up jobs using triggers and the SchedulerFactoryBean

We've created job details and jobs. We've also reviewed the convenience bean that allows you to invoke a method on a specific object. Of course, we still need to schedule the jobs themselves. This is done using triggers and a `SchedulerFactoryBean`. Several triggers are available within Quartz and Spring offers two Quartz `FactoryBean` implementations with convenient defaults: `CronTriggerFactoryBean` and `SimpleTriggerFactoryBean`.

Triggers need to be scheduled. Spring offers a `SchedulerFactoryBean` that exposes triggers to be set as properties. `SchedulerFactoryBean` schedules the actual jobs with those triggers.

Find below a couple of examples:

```
<bean id="simpleTrigger" class="org.springframework.scheduling.quartz.SimpleTriggerFactoryBean">
    <!-- see the example of method invoking job above -->
    <property name="jobDetail" ref="jobDetail"/>
    <!-- 10 seconds -->
    <property name="startDelay" value="10000"/>
    <!-- repeat every 50 seconds -->
    <property name="repeatInterval" value="50000"/>
</bean>

<bean id="cronTrigger" class="org.springframework.scheduling.quartz.CronTriggerFactoryBean">
    <property name="jobDetail" ref="exampleJob"/>
    <!-- run every morning at 6 AM -->
    <property name="cronExpression" value="0 0 6 * * ?"/>
</bean>
```

Now we've set up two triggers, one running every 50 seconds with a starting delay of 10 seconds and one every morning at 6 AM. To finalize everything, we need to set up the `SchedulerFactoryBean`:

```
<bean class="org.springframework.scheduling.quartz.SchedulerFactoryBean">
    <property name="triggers">
        <list>
            <ref bean="cronTrigger"/>
            <ref bean="simpleTrigger"/>
        </list>
    </property>
</bean>
```

More properties are available for the `SchedulerFactoryBean` for you to set, such as the calendars used by the job details, properties to customize Quartz with, etc. Have a look at the `SchedulerFactoryBean` javadocs for more information.

29. Dynamic language support

29.1 Introduction

Spring 2.0 introduces comprehensive support for using classes and objects that have been defined using a dynamic language (such as JRuby) with Spring. This support allows you to write any number of classes in a supported dynamic language, and have the Spring container transparently instantiate, configure and dependency inject the resulting objects.

The dynamic languages currently supported are:

- JRuby 1.5+
- Groovy 1.8+
- BeanShell 2.0

> **Why only these languages?**
>
> The supported languages were chosen because *a)* the languages have a lot of traction in the Java enterprise community, *b)* no requests were made for other languages at the time that this support was added, and *c)* the Spring developers were most familiar with them.

Fully working examples of where this dynamic language support can be immediately useful are described in Section 29.4, “Scenarios”.

29.2 A first example

This bulk of this chapter is concerned with describing the dynamic language support in detail. Before diving into all of the ins and outs of the dynamic language support, let’s look at a quick example of a bean defined in a dynamic language. The dynamic language for this first bean is Groovy (the basis of this example was taken from the Spring test suite, so if you want to see equivalent examples in any of the other supported languages, take a look at the source code).

Find below the `Messenger` interface that the Groovy bean is going to be implementing, and note that this interface is defined in plain Java. Dependent objects that are injected with a reference to the `Messenger` won’t know that the underlying implementation is a Groovy script.

```
package org.springframework.scripting;

public interface Messenger {

    String getMessage();

}
```

Here is the definition of a class that has a dependency on the `Messenger` interface.

```
package org.springframework.scripting;

public class DefaultBookingService implements BookingService {

    private Messenger messenger;

    public void setMessenger(Messenger messenger) {
        this.messenger = messenger;
    }

    public void processBooking() {
        // use the injected Messenger object...
    }

}
```

Here is an implementation of the `Messenger` interface in Groovy.

```
// from the file Messenger.groovy
package org.springframework.scripting.groovy;

// import the Messenger interface (written in Java) that is to be implemented
import org.springframework.scripting.Messenger

// define the implementation in Groovy
class GroovyMessenger implements Messenger {

    String message

}
```

Finally, here are the bean definitions that will effect the injection of the Groovy-defined `Messenger` implementation into an instance of the `DefaultBookingService` class.

> **Note**
>
> To use the custom dynamic language tags to define dynamic-language-backed beans, you need to have the XML Schema preamble at the top of your Spring XML configuration file. You also need to be using a Spring `ApplicationContext` implementation as your IoC container. Using the dynamic-language-backed beans with a plain `BeanFactory` implementation is supported, but you have to manage the plumbing of the Spring internals to do so.
>
> For more information on schema-based configuration, see Chapter 34, *XML Schema-based configuration*.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"
    xmlns:lang="http://www.springframework.org/schema/lang"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/lang http://www.springframework.org/schema/lang/spring-
lang.xsd">

    <!-- this is the bean definition for the Groovy-backed Messenger implementation -->
    <lang:groovy id="messenger" script-source="classpath:Messenger.groovy">
        <lang:property name="message" value="I Can Do The Frug" />
    </lang:groovy>

    <!-- an otherwise normal bean that will be injected by the Groovy-backed Messenger -->
    <bean id="bookingService" class="x.y.DefaultBookingService">
        <property name="messenger" ref="messenger" />
    </bean>

</beans>
```

The `bookingService` bean (a `DefaultBookingService`) can now use its private `messenger` member variable as normal because the `Messenger` instance that was injected into it *is* a `Messenger` instance. There is nothing special going on here, just plain Java and plain Groovy.

Hopefully the above XML snippet is self-explanatory, but don't worry unduly if it isn't. Keep reading for the in-depth detail on the whys and wherefores of the above configuration.

29.3 Defining beans that are backed by dynamic languages

This section describes exactly how you define Spring managed beans in any of the supported dynamic languages.

Please note that this chapter does not attempt to explain the syntax and idioms of the supported dynamic languages. For example, if you want to use Groovy to write certain of the classes in your application, then the assumption is that you already know Groovy. If you need further details about the dynamic languages themselves, please consult Section 29.6, "Further Resources" at the end of this chapter.

Common concepts

The steps involved in using dynamic-language-backed beans are as follows:

- Write the test for the dynamic language source code (naturally)
- *Then* write the dynamic language source code itself :)
- Define your dynamic-language-backed beans using the appropriate `<lang:language/>` element in the XML configuration (you can of course define such beans programmatically using the Spring API - although you will have to consult the source code for directions on how to do this as this type of advanced configuration is not covered in this chapter). Note this is an iterative step. You will need at least one bean definition per dynamic language source file (although the same dynamic language source file can of course be referenced by multiple bean definitions).

The first two steps (testing and writing your dynamic language source files) are beyond the scope of this chapter. Refer to the language specification and / or reference manual for your chosen dynamic language and crack on with developing your dynamic language source files. You *will* first want to read the

rest of this chapter though, as Spring's dynamic language support does make some (small) assumptions about the contents of your dynamic language source files.

The <lang:language/> element

The final step involves defining dynamic-language-backed bean definitions, one for each bean that you want to configure (this is no different from normal JavaBean configuration). However, instead of specifying the fully qualified classname of the class that is to be instantiated and configured by the container, you use the `<lang:language/>` element to define the dynamic language-backed bean.

Each of the supported languages has a corresponding `<lang:language/>` element:

- `<lang:jruby/>` (JRuby)
- `<lang:groovy/>` (Groovy)
- `<lang:bsh/>` (BeanShell)

The exact attributes and child elements that are available for configuration depends on exactly which language the bean has been defined in (the language-specific sections below provide the full lowdown on this).

Refreshable beans

One of the (if not *the*) most compelling value adds of the dynamic language support in Spring is the*'refreshable bean'* feature.

A refreshable bean is a dynamic-language-backed bean that with a small amount of configuration, a dynamic-language-backed bean can monitor changes in its underlying source file resource, and then reload itself when the dynamic language source file is changed (for example when a developer edits and saves changes to the file on the filesystem).

This allows a developer to deploy any number of dynamic language source files as part of an application, configure the Spring container to create beans backed by dynamic language source files (using the mechanisms described in this chapter), and then later, as requirements change or some other external factor comes into play, simply edit a dynamic language source file and have any change they make reflected in the bean that is backed by the changed dynamic language source file. There is no need to shut down a running application (or redeploy in the case of a web application). The dynamic-language-backed bean so amended will pick up the new state and logic from the changed dynamic language source file.

> **Note**
>
> Please note that this feature is *off* by default.

Let's take a look at an example to see just how easy it is to start using refreshable beans. To *turn on* the refreshable beans feature, you simply have to specify exactly *one* additional attribute on the `<lang:language/>` element of your bean definition. So if we stick with the example from earlier in this chapter, here's what we would change in the Spring XML configuration to effect refreshable beans:

```
<beans>

    <!-- this bean is now refreshable due to the presence of the refresh-check-delay attribute -->
    <lang:groovy id="messenger"
            refresh-check-delay="5000" <!-- switches refreshing on with 5 seconds between checks -->
            script-source="classpath:Messenger.groovy">
        <lang:property name="message" value="I Can Do The Frug" />
    </lang:groovy>

    <bean id="bookingService" class="x.y.DefaultBookingService">
        <property name="messenger" ref="messenger" />
    </bean>

</beans>
```

That really is all you have to do. The `'refresh-check-delay'` attribute defined on the `'messenger'` bean definition is the number of milliseconds after which the bean will be refreshed with any changes made to the underlying dynamic language source file. You can turn off the refresh behavior by assigning a negative value to the `'refresh-check-delay'` attribute. Remember that, by default, the refresh behavior is disabled. If you don't want the refresh behavior, then simply don't define the attribute.

If we then run the following application we can exercise the refreshable feature; please do excuse the *'jumping-through-hoops-to-pause-the-execution'* shenanigans in this next slice of code. The `System.in.read()` call is only there so that the execution of the program pauses while I (the author) go off and edit the underlying dynamic language source file so that the refresh will trigger on the dynamic-language-backed bean when the program resumes execution.

```
import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;
import org.springframework.scripting.Messenger;

public final class Boot {

    public static void main(final String[] args) throws Exception {
        ApplicationContext ctx = new ClassPathXmlApplicationContext("beans.xml");
        Messenger messenger = (Messenger) ctx.getBean("messenger");
        System.out.println(messenger.getMessage());
        // pause execution while I go off and make changes to the source file...
        System.in.read();
        System.out.println(messenger.getMessage());
    }
}
```

Let's assume then, for the purposes of this example, that all calls to the `getMessage()` method of `Messenger` implementations have to be changed such that the message is surrounded by quotes. Below are the changes that I (the author) make to the `Messenger.groovy` source file when the execution of the program is paused.

```
package org.springframework.scripting

class GroovyMessenger implements Messenger {

    private String message = "Bingo"

    public String getMessage() {
        // change the implementation to surround the message in quotes
        return "'" + this.message + "'"
    }

    public void setMessage(String message) {
        this.message = message
    }
}
```

When the program executes, the output before the input pause will be *I Can Do The Frug*. After the change to the source file is made and saved, and the program resumes execution, the result of calling the `getMessage()` method on the dynamic-language-backed `Messenger` implementation will be *'I Can Do The Frug'* (notice the inclusion of the additional quotes).

It is important to understand that changes to a script will *not* trigger a refresh if the changes occur within the window of the `'refresh-check-delay'` value. It is equally important to understand that changes to the script are *not* actually *picked up* until a method is called on the dynamic-language-backed bean. It is only when a method is called on a dynamic-language-backed bean that it checks to see if its underlying script source has changed. Any exceptions relating to refreshing the script (such as encountering a compilation error, or finding that the script file has been deleted) will result in a *fatal* exception being propagated to the calling code.

The refreshable bean behavior described above does *not* apply to dynamic language source files defined using the `<lang:inline-script/>` element notation (see the section called “Inline dynamic language source files”). Additionally, it *only* applies to beans where changes to the underlying source file can actually be detected; for example, by code that checks the last modified date of a dynamic language source file that exists on the filesystem.

Inline dynamic language source files

The dynamic language support can also cater for dynamic language source files that are embedded directly in Spring bean definitions. More specifically, the `<lang:inline-script/>` element allows you to define dynamic language source immediately inside a Spring configuration file. An example will perhaps make the inline script feature crystal clear:

```
<lang:groovy id="messenger">
    <lang:inline-script>

package org.springframework.scripting.groovy;

import org.springframework.scripting.Messenger

class GroovyMessenger implements Messenger {
    String message
}

    </lang:inline-script>
    <lang:property name="message" value="I Can Do The Frug" />
</lang:groovy>
```

If we put to one side the issues surrounding whether it is good practice to define dynamic language source inside a Spring configuration file, the `<lang:inline-script/>` element can be useful in some scenarios. For instance, we might want to quickly add a Spring `Validator` implementation to a Spring MVC `Controller`. This is but a moment’s work using inline source. (See the section called “Scripted Validators” for such an example.)

Find below an example of defining the source for a JRuby-based bean directly in a Spring XML configuration file using the `inline:` notation. (Notice the use of the < characters to denote a `'<'` character. In such a case surrounding the inline source in a `<![CDATA[]]>` region might be better.)

```
<lang:jruby id="messenger" script-interfaces="org.springframework.scripting.Messenger">
    <lang:inline-script>

require java

include_class org.springframework.scripting.Messenger

class RubyMessenger &lt; Messenger

    def setMessage(message)
        @@message = message
    end

    def getMessage
        @@message
    end

end

        </lang:inline-script>
    <lang:property name="message" value="Hello World!" />
</lang:jruby>
```

Understanding Constructor Injection in the context of dynamic-language-backed beans

There is one *very* important thing to be aware of with regard to Spring's dynamic language support. Namely, it is not (currently) possible to supply constructor arguments to dynamic-language-backed beans (and hence constructor-injection is not available for dynamic-language-backed beans). In the interests of making this special handling of constructors and properties 100% clear, the following mixture of code and configuration will *not* work.

```
// from the file Messenger.groovy
package org.springframework.scripting.groovy;

import org.springframework.scripting.Messenger

class GroovyMessenger implements Messenger {

    GroovyMessenger() {}

    // this constructor is not available for Constructor Injection
    GroovyMessenger(String message) {
        this.message = message;
    }

    String message

    String anotherMessage

}
```

```
<lang:groovy id="badMessenger"
    script-source="classpath:Messenger.groovy">
    <!-- this next constructor argument will not be injected into the GroovyMessenger -->
    <!-- in fact, this isn't even allowed according to the schema -->
    <constructor-arg value="This will not work" />

    <!-- only property values are injected into the dynamic-language-backed object -->
    <lang:property name="anotherMessage" value="Passed straight through to the dynamic-language-backed
 object" />

</lang>
```

In practice this limitation is not as significant as it first appears since setter injection is the injection style favored by the overwhelming majority of developers anyway (let's leave the discussion as to whether that is a good thing to another day).

JRuby beans

The JRuby library dependencies

The JRuby scripting support in Spring requires the following libraries to be on the classpath of your application.

- `jruby.jar`

From the JRuby homepage…

"*JRuby is an 100% pure-Java implementation of the Ruby programming language.*"

In keeping with the Spring philosophy of offering choice, Spring's dynamic language support also supports beans defined in the JRuby language. The JRuby language is based on the quite intuitive Ruby language, and has support for inline regular expressions, blocks (closures), and a whole host of other features that do make solutions for some domain problems a whole lot easier to develop.

The implementation of the JRuby dynamic language support in Spring is interesting in that what happens is this: Spring creates a JDK dynamic proxy implementing all of the interfaces that are specified in the `'script-interfaces'` attribute value of the `<lang:ruby>` element (this is why you *must* supply at least one interface in the value of the attribute, and (accordingly) program to interfaces when using JRuby-backed beans).

Let us look at a fully working example of using a JRuby-based bean. Here is the JRuby implementation of the `Messenger` interface that was defined earlier in this chapter (for your convenience it is repeated below).

```
package org.springframework.scripting;

public interface Messenger {

    String getMessage();

}
```

```
require java

class RubyMessenger
    include org.springframework.scripting.Messenger

    def setMessage(message)
        @@message = message
    end

    def getMessage
        @@message
    end
end

# this last line is not essential (but see below)
RubyMessenger.new
```

And here is the Spring XML that defines an instance of the `RubyMessenger` JRuby bean.

```
<lang:jruby id="messageService"
        script-interfaces="org.springframework.scripting.Messenger"
        script-source="classpath:RubyMessenger.rb">

    <lang:property name="message" value="Hello World!" />

</lang:jruby>
```

Take note of the last line of that JRuby source (`'RubyMessenger.new'`). When using JRuby in the context of Spring's dynamic language support, you are encouraged to instantiate and return a new instance of the JRuby class that you want to use as a dynamic-language-backed bean as the result of the execution of your JRuby source. You can achieve this by simply instantiating a new instance of your JRuby class on the last line of the source file like so:

```
require java

include_class org.springframework.scripting.Messenger

# class definition same as above...

# instantiate and return a new instance of the RubyMessenger class
RubyMessenger.new
```

If you forget to do this, it is not the end of the world; this will however result in Spring having to trawl (reflectively) through the type representation of your JRuby class looking for a class to instantiate. In the grand scheme of things this will be so fast that you'll never notice it, but it is something that can be avoided by simply having a line such as the one above as the last line of your JRuby script. If you don't supply such a line, or if Spring cannot find a JRuby class in your script to instantiate then an opaque `ScriptCompilationException` will be thrown immediately after the source is executed by the JRuby interpreter. The key text that identifies this as the root cause of an exception can be found immediately below (so if your Spring container throws the following exception when creating your dynamic-language-backed bean and the following text is there in the corresponding stacktrace, this will hopefully allow you to identify and then easily rectify the issue):

```
org.springframework.scripting.ScriptCompilationException: Compilation of JRuby script returned ''
```

To rectify this, simply instantiate a new instance of whichever class you want to expose as a JRuby-dynamic-language-backed bean (as shown above). Please also note that you can actually define as many classes and objects as you want in your JRuby script; what is important is that the source file as a whole must return an object (for Spring to configure).

See Section 29.4, "Scenarios" for some scenarios where you might want to use JRuby-based beans.

Groovy beans

The Groovy library dependencies

The Groovy scripting support in Spring requires the following libraries to be on the classpath of your application.

- `groovy-1.8.jar`
- `asm-3.2.jar`
- `antlr-2.7.7.jar`

From the Groovy homepage…

"*Groovy is an agile dynamic language for the Java 2 Platform that has many of the features that people like so much in languages like Python, Ruby and Smalltalk, making them available to Java developers using a Java-like syntax.* "

If you have read this chapter straight from the top, you will already have seen an example of a Groovy-dynamic-language-backed bean. Let's look at another example (again using an example from the Spring test suite).

```
package org.springframework.scripting;

public interface Calculator {

    int add(int x, int y);

}
```

Here is an implementation of the `Calculator` interface in Groovy.

```
// from the file calculator.groovy
package org.springframework.scripting.groovy

class GroovyCalculator implements Calculator {

    int add(int x, int y) {
        x + y
    }

}
```

```
<-- from the file beans.xml -->
<beans>
    <lang:groovy id="calculator" script-source="classpath:calculator.groovy"/>
</beans>
```

Lastly, here is a small application to exercise the above configuration.

```
package org.springframework.scripting;

import org.springframework.context.ApplicationContext;
import org.springframework.context.support.ClassPathXmlApplicationContext;

public class Main {

    public static void Main(String[] args) {
        ApplicationContext ctx = new ClassPathXmlApplicationContext("beans.xml");
        Calculator calc = (Calculator) ctx.getBean("calculator");
        System.out.println(calc.add(2, 8));
    }
}
```

The resulting output from running the above program will be (unsurprisingly) *10*. (Exciting example, huh? Remember that the intent is to illustrate the concept. Please consult the dynamic language showcase project for a more complex example, or indeed Section 29.4, "Scenarios" later in this chapter).

It is important that you *do not* define more than one class per Groovy source file. While this is perfectly legal in Groovy, it is (arguably) a bad practice: in the interests of a consistent approach, you should (in the opinion of this author) respect the standard Java conventions of one (public) class per source file.

Customizing Groovy objects via a callback

The `GroovyObjectCustomizer` interface is a callback that allows you to hook additional creation logic into the process of creating a Groovy-backed bean. For example, implementations of this interface

could invoke any required initialization method(s), or set some default property values, or specify a custom `MetaClass`.

```
public interface GroovyObjectCustomizer {

    void customize(GroovyObject goo);

}
```

The Spring Framework will instantiate an instance of your Groovy-backed bean, and will then pass the created `GroovyObject` to the specified `GroovyObjectCustomizer` if one has been defined. You can do whatever you like with the supplied `GroovyObject` reference: it is expected that the setting of a custom `MetaClass` is what most folks will want to do with this callback, and you can see an example of doing that below.

```
public final class SimpleMethodTracingCustomizer implements GroovyObjectCustomizer {

    public void customize(GroovyObject goo) {
        DelegatingMetaClass metaClass = new DelegatingMetaClass(goo.getMetaClass()) {

            public Object invokeMethod(Object object, String methodName, Object[] arguments) {
                System.out.println("Invoking '" + methodName + "'.");
                return super.invokeMethod(object, methodName, arguments);
            }
        };
        metaClass.initialize();
        goo.setMetaClass(metaClass);
    }

}
```

A full discussion of meta-programming in Groovy is beyond the scope of the Spring reference manual. Consult the relevant section of the Groovy reference manual, or do a search online: there are plenty of articles concerning this topic. Actually making use of a `GroovyObjectCustomizer` is easy if you are using the Spring namespace support.

```
<!-- define the GroovyObjectCustomizer just like any other bean -->
<bean id="tracingCustomizer" class="example.SimpleMethodTracingCustomizer" />

    <!-- ... and plug it into the desired Groovy bean via the customizer-ref attribute -->
    <lang:groovy id="calculator"
        script-source="classpath:org/springframework/scripting/groovy/Calculator.groovy"
        customizer-ref="tracingCustomizer" />
```

If you are not using the Spring namespace support, you can still use the `GroovyObjectCustomizer` functionality.

```
<bean id="calculator" class="org.springframework.scripting.groovy.GroovyScriptFactory">
    <constructor-arg value="classpath:org/springframework/scripting/groovy/Calculator.groovy"/>
    <!-- define the GroovyObjectCustomizer (as an inner bean) -->
    <constructor-arg>
        <bean id="tracingCustomizer" class="example.SimpleMethodTracingCustomizer" />
    </constructor-arg>
</bean>

<bean class="org.springframework.scripting.support.ScriptFactoryPostProcessor"/>
```

BeanShell beans

The BeanShell library dependencies

The BeanShell scripting support in Spring requires the following libraries to be on the classpath of your application.

- `bsh-2.0b4.jar`

From the BeanShell homepage…

"*BeanShell is a small, free, embeddable Java source interpreter with dynamic language features, written in Java. BeanShell dynamically executes standard Java syntax and extends it with common scripting conveniences such as loose types, commands, and method closures like those in Perl and JavaScript.*"

In contrast to Groovy, BeanShell-backed bean definitions require some (small) additional configuration. The implementation of the BeanShell dynamic language support in Spring is interesting in that what happens is this: Spring creates a JDK dynamic proxy implementing all of the interfaces that are specified in the `'script-interfaces'` attribute value of the `<lang:bsh>` element (this is why you *must* supply at least one interface in the value of the attribute, and (accordingly) program to interfaces when using BeanShell-backed beans). This means that every method call on a BeanShell-backed object is going through the JDK dynamic proxy invocation mechanism.

Let's look at a fully working example of using a BeanShell-based bean that implements the `Messenger` interface that was defined earlier in this chapter (repeated below for your convenience).

```
package org.springframework.scripting;

public interface Messenger {

    String getMessage();

}
```

Here is the BeanShell *implementation* (the term is used loosely here) of the `Messenger` interface.

```
String message;

String getMessage() {
    return message;
}

void setMessage(String aMessage) {
    message = aMessage;
}
```

And here is the Spring XML that defines an *instance* of the above *class* (again, the term is used very loosely here).

```
<lang:bsh id="messageService" script-source="classpath:BshMessenger.bsh"
    script-interfaces="org.springframework.scripting.Messenger">

    <lang:property name="message" value="Hello World!" />
</lang:bsh>
```

See Section 29.4, "Scenarios" for some scenarios where you might want to use BeanShell-based beans.

29.4 Scenarios

The possible scenarios where defining Spring managed beans in a scripting language would be beneficial are, of course, many and varied. This section describes two possible use cases for the dynamic language support in Spring.

Scripted Spring MVC Controllers

One group of classes that may benefit from using dynamic-language-backed beans is that of Spring MVC controllers. In pure Spring MVC applications, the navigational flow through a web application is to a large extent determined by code encapsulated within your Spring MVC controllers. As the navigational flow and other presentation layer logic of a web application needs to be updated to respond to support issues or changing business requirements, it may well be easier to effect any such required changes by editing one or more dynamic language source files and seeing those changes being immediately reflected in the state of a running application.

Remember that in the lightweight architectural model espoused by projects such as Spring, you are typically aiming to have a really *thin* presentation layer, with all the meaty business logic of an application being contained in the domain and service layer classes. Developing Spring MVC controllers as dynamic-language-backed beans allows you to change presentation layer logic by simply editing and saving text files; any changes to such dynamic language source files will (depending on the configuration) automatically be reflected in the beans that are backed by dynamic language source files.

> **Note**
>
> In order to effect this automatic *pickup* of any changes to dynamic-language-backed beans, you will have had to enable the *refreshable beans* functionality. See the section called “Refreshable beans” for a full treatment of this feature.

Find below an example of an `org.springframework.web.servlet.mvc.Controller` implemented using the Groovy dynamic language.

```
// from the file /WEB-INF/groovy/FortuneController.groovy
package org.springframework.showcase.fortune.web

import org.springframework.showcase.fortune.service.FortuneService
import org.springframework.showcase.fortune.domain.Fortune
import org.springframework.web.servlet.ModelAndView
import org.springframework.web.servlet.mvc.Controller

import javax.servlet.http.HttpServletRequest
import javax.servlet.http.HttpServletResponse

class FortuneController implements Controller {

    @Property FortuneService fortuneService

    ModelAndView handleRequest(HttpServletRequest request,
            HttpServletResponse httpServletResponse) {
        return new ModelAndView("tell", "fortune", this.fortuneService.tellFortune())
    }

}
```

```
<lang:groovy id="fortune"
        refresh-check-delay="3000"
        script-source="/WEB-INF/groovy/FortuneController.groovy">
    <lang:property name="fortuneService" ref="fortuneService"/>
</lang:groovy>
```

Scripted Validators

Another area of application development with Spring that may benefit from the flexibility afforded by dynamic-language-backed beans is that of validation. It *may* be easier to express complex validation logic using a loosely typed dynamic language (that may also have support for inline regular expressions) as opposed to regular Java.

Again, developing validators as dynamic-language-backed beans allows you to change validation logic by simply editing and saving a simple text file; any such changes will (depending on the configuration) automatically be reflected in the execution of a running application and would not require the restart of an application.

> **Note**
>
> Please note that in order to effect the automatic *pickup* of any changes to dynamic-language-backed beans, you will have had to enable the *refreshable beans* feature. See the section called “Refreshable beans” for a full and detailed treatment of this feature.

Find below an example of a Spring `org.springframework.validation.Validator` implemented using the Groovy dynamic language. (See Section 7.2, “Validation using Spring’s Validator interface” for a discussion of the `Validator` interface.)

```
import org.springframework.validation.Validator
import org.springframework.validation.Errors
import org.springframework.beans.TestBean

class TestBeanValidator implements Validator {

    boolean supports(Class clazz) {
        return TestBean.class.isAssignableFrom(clazz)
    }

    void validate(Object bean, Errors errors) {
        if(bean.name?.trim()?.size() > 0) {
            return
        }
        errors.reject("whitespace", "Cannot be composed wholly of whitespace.")
    }

}
```

29.5 Bits and bobs

This last section contains some bits and bobs related to the dynamic language support.

AOP - advising scripted beans

It is possible to use the Spring AOP framework to advise scripted beans. The Spring AOP framework actually is unaware that a bean that is being advised might be a scripted bean, so all of the AOP use cases and functionality that you may be using or aim to use will work with scripted beans. There is just one (small) thing that you need to be aware of when advising scripted beans… you cannot use class-based proxies, you must use interface-based proxies.

You are of course not just limited to advising scripted beans… you can also write aspects themselves in a supported dynamic language and use such beans to advise other Spring beans. This really would be an advanced use of the dynamic language support though.

Scoping

In case it is not immediately obvious, scripted beans can of course be scoped just like any other bean. The `scope` attribute on the various `<lang:language/>` elements allows you to control the scope of the underlying scripted bean, just as it does with a regular bean. (The default scope is singleton, just as it is with *regular* beans.)

Find below an example of using the `scope` attribute to define a Groovy bean scoped as a prototype.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"
    xmlns:lang="http://www.springframework.org/schema/lang"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/lang http://www.springframework.org/schema/lang/spring-
lang.xsd">

    <lang:groovy id="messenger" script-source="classpath:Messenger.groovy" scope="prototype">
        <lang:property name="message" value="I Can Do The RoboCop" />
    </lang:groovy>

    <bean id="bookingService" class="x.y.DefaultBookingService">
        <property name="messenger" ref="messenger" />
    </bean>

</beans>
```

See Section 5.5, “Bean scopes” in Chapter 5, *The IoC container* for a fuller discussion of the scoping support in the Spring Framework.

29.6 Further Resources

Find below links to further resources about the various dynamic languages described in this chapter.

- The JRuby homepage
- The Groovy homepage
- The BeanShell homepage

Some of the more active members of the Spring community have also added support for a number of additional dynamic languages above and beyond the ones covered in this chapter. While it is possible that such third party contributions may be added to the list of languages supported by the main Spring distribution, your best bet for seeing if your favorite scripting language is supported is the Spring Modules project.

30. Cache Abstraction

30.1 Introduction

Since version 3.1, Spring Framework provides support for transparently adding caching into an existing Spring application. Similar to the transaction support, the caching abstraction allows consistent use of various caching solutions with minimal impact on the code.

As from Spring 4.1, the cache abstraction has been significantly improved with the support of JSR-107 annotations and more customization options.

30.2 Understanding the cache abstraction

Cache vs Buffer

The terms "buffer" and "cache" tend to be used interchangeably; note however they represent different things. A buffer is used traditionally as an intermediate temporary store for data between a fast and a slow entity. As one party would have to *wait* for the other affecting performance, the buffer alleviates this by allowing entire blocks of data to move at once rather then in small chunks. The data is written and read only once from the buffer. Furthermore, the buffers are *visible* to at least one party which is aware of it.

A cache on the other hand by definition is hidden and neither party is aware that caching occurs.It as well improves performance but does that by allowing the same data to be read multiple times in a fast fashion.

A further explanation of the differences between two can be found here.

At its core, the abstraction applies caching to Java methods, reducing thus the number of executions based on the information available in the cache. That is, each time a *targeted* method is invoked, the abstraction will apply a caching behavior checking whether the method has been already executed for the given arguments. If it has, then the cached result is returned without having to execute the actual method; if it has not, then method is executed, the result cached and returned to the user so that, the next time the method is invoked, the cached result is returned. This way, expensive methods (whether CPU or IO bound) can be executed only once for a given set of parameters and the result reused without having to actually execute the method again. The caching logic is applied transparently without any interference to the invoker.

> **Important**
>
> Obviously this approach works only for methods that are guaranteed to return the same output (result) for a given input (or arguments) no matter how many times it is being executed.

Other cache-related operations are provided by the abstraction such as the ability to update the content of the cache or remove one of all entries. These are useful if the cache deals with data that can change during the course of the application.

Just like other services in the Spring Framework, the caching service is an abstraction (not a cache implementation) and requires the use of an actual storage to store the cache data - that is, the abstraction frees the developer from having to write the caching logic but does not provide the

actual stores. This abstraction is materialized by the `org.springframework.cache.Cache` and `org.springframework.cache.CacheManager` interfaces.

There are a few implementations of that abstraction available out of the box: JDK `java.util.concurrent.ConcurrentMap` based caches, EhCache, Gemfire cache, Guava caches and JSR-107 compliant caches. See Section 30.7, “Plugging-in different back-end caches” for more information on plugging in other cache stores/providers.

> **Important**
>
> The caching abstraction has no special handling of multi-threaded and multi-process environments as such features are handled by the cache implementation. .

If you have a multi-process environment (i.e. an application deployed on several nodes), you will need to configure your cache provider accordingly. Depending on your use cases, a copy of the same data on several nodes may be enough but if you change the data during the course of the application, you may need to enable other propagation mechanisms.

Caching a particular item is a direct equivalent of the typical get-if-not-found-then- proceed-and-put-eventually code blocks found with programmatic cache interaction: no locks are applied and several threads may try to load the same item concurrently. The same applies to eviction: if several threads are trying to update or evict data concurrently, you may use stale data. Certain cache providers offer advanced features in that area, refer to the documentation of the cache provider that you are using for more details.

To use the cache abstraction, the developer needs to take care of two aspects:

- caching declaration - identify the methods that need to be cached and their policy
- cache configuration - the backing cache where the data is stored and read from

30.3 Declarative annotation-based caching

For caching declaration, the abstraction provides a set of Java annotations:

- `@Cacheable` triggers cache population
- `@CacheEvict` triggers cache eviction
- `@CachePut` updates the cache without interfering with the method execution
- `@Caching` regroups multiple cache operations to be applied on a method
- `@CacheConfig` shares some common cache-related settings at class-level

Let us take a closer look at each annotation:

@Cacheable annotation

As the name implies, `@Cacheable` is used to demarcate methods that are cacheable - that is, methods for whom the result is stored into the cache so on subsequent invocations (with the same arguments), the value in the cache is returned without having to actually execute the method. In its simplest form, the annotation declaration requires the name of the cache associated with the annotated method:

```
@Cacheable("books")
public Book findBook(ISBN isbn) {...}
```

In the snippet above, the method `findBook` is associated with the cache named `books`. Each time the method is called, the cache is checked to see whether the invocation has been already executed and does not have to be repeated. While in most cases, only one cache is declared, the annotation allows multiple names to be specified so that more than one cache are being used. In this case, each of the caches will be checked before executing the method - if at least one cache is hit, then the associated value will be returned:

> **Note**
>
> All the other caches that do not contain the value will be updated as well even though the cached method was not actually executed.

```
@Cacheable({"books", "isbns"})
public Book findBook(ISBN isbn) {...}
```

Default Key Generation

Since caches are essentially key-value stores, each invocation of a cached method needs to be translated into a suitable key for cache access. Out of the box, the caching abstraction uses a simple `KeyGenerator` based on the following algorithm:

- If no params are given, return `SimpleKey.EMPTY`.
- If only one param is given, return that instance.
- If more the one param is given, return a `SimpleKey` containing all parameters.

This approach works well for most use-cases; As long as parameters have *natural keys* and implement valid `hashCode()` and `equals()` methods. If that is not the case then the strategy needs to be changed.

To provide a different *default* key generator, one needs to implement the `org.springframework.cache.interceptor.KeyGenerator` interface.

> **Note**
>
> The default key generation strategy changed with the release of Spring 4.0. Earlier versions of Spring used a key generation strategy that, for multiple key parameters, only considered the `hashCode()` of parameters and not `equals()`; this could cause unexpected key collisions (see SPR-10237 for background). The new *SimpleKeyGenerator* uses a compound key for such scenarios.
>
> If you want to keep using the previous key strategy, you can configure the deprecated `org.springframework.cache.interceptor.DefaultKeyGenerator` class or create a custom hash-based *KeyGenerator* implementation.

Custom Key Generation Declaration

Since caching is generic, it is quite likely the target methods have various signatures that cannot be simply mapped on top of the cache structure. This tends to become obvious when the target method has multiple arguments out of which only some are suitable for caching (while the rest are used only by the method logic). For example:

```
@Cacheable("books")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

At first glance, while the two `boolean` arguments influence the way the book is found, they are no use for the cache. Further more what if only one of the two is important while the other is not?

For such cases, the `@Cacheable` annotation allows the user to specify how the key is generated through its `key` attribute. The developer can use SpEL to pick the arguments of interest (or their nested properties), perform operations or even invoke arbitrary methods without having to write any code or implement any interface. This is the recommended approach over the default generator since methods tend to be quite different in signatures as the code base grows; while the default strategy might work for some methods, it rarely does for all methods.

Below are some examples of various SpEL declarations - if you are not familiar with it, do yourself a favor and read Chapter 8, *Spring Expression Language (SpEL)*:

```
@Cacheable(value="books", key="#isbn")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)

@Cacheable(value="books", key="#isbn.rawNumber")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)

@Cacheable(value="books", key="T(someType).hash(#isbn)")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

The snippets above show how easy it is to select a certain argument, one of its properties or even an arbitrary (static) method.

If the algorithm responsible to generate the key is too specific or if it needs to be shared, you may define a custom `keyGenerator` on the operation. To do this, specify the name of the `KeyGenerator` bean implementation to use:

```
@Cacheable(value="books", keyGenerator="myKeyGenerator")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

> **Note**
>
> The `key` and `keyGenerator` parameters are mutually exclusive and an operation specifying both will result in an exception.

Default Cache Resolution

Out of the box, the caching abstraction uses a simple `CacheResolver` that retrieves the cache(s) defined at the operation level using the configured `CacheManager`.

To provide a different *default* cache resolver, one needs to implement the `org.springframework.cache.interceptor.CacheResolver` interface.

Custom cache resolution

The default cache resolution fits well for applications working with a single `CacheManager` and with no complex cache resolution requirements.

For applications working with several cache managers, it is possible to set the `cacheManager` to use per operation:

```
@Cacheable(value="books", cacheManager="anotherCacheManager")
public Book findBook(ISBN isbn) {...}
```

It is also possible to replace the `CacheResolver` entirely in a similar fashion as for key generation. The resolution is requested for every cache operation, giving a chance to the implementation to actually resolve the cache(s) to use based on runtime arguments:

```
@Cacheable(cacheResolver="runtimeCacheResolver")
public Book findBook(ISBN isbn) {...}
```

> **Note**
>
> Since Spring 4.1, the `value` attribute of the cache annotations are no longer mandatory since this particular information can be provided by the `CacheResolver` regardless of the content of the annotation.
>
> Similarly to `key` and `keyGenerator`, the `cacheManager` and `cacheResolver` parameters are mutually exclusive and an operation specifying both will result in an exception as a custom `CacheManager` will be ignored by the `CacheResolver` implementation. This is probably not what you expect.

Conditional caching

Sometimes, a method might not be suitable for caching all the time (for example, it might depend on the given arguments). The cache annotations support such functionality through the `condition` parameter which takes a `SpEL` expression that is evaluated to either `true` or `false`. If `true`, the method is cached - if not, it behaves as if the method is not cached, that is executed every since time no matter what values are in the cache or what arguments are used. A quick example - the following method will be cached only if the argument `name` has a length shorter than 32:

```
@Cacheable(value="book", condition="#name.length < 32")
public Book findBook(String name)
```

In addition the `condition` parameter, the `unless` parameter can be used to veto the adding of a value to the cache. Unlike `condition`, `unless` expressions are evaluated *after* the method has been called. Expanding on the previous example - perhaps we only want to cache paperback books:

```
@Cacheable(value="book", condition="#name.length < 32", unless="#result.hardback")
public Book findBook(String name)
```

Available caching SpEL evaluation context

Each `SpEL` expression evaluates again a dedicated `context`. In addition to the build in parameters, the framework provides dedicated caching related metadata such as the argument names. The next table lists the items made available to the context so one can use them for key and conditional computations:

Table 30.1. Cache SpEL available metadata

Name	Location	Description	Example
methodName	root object	The name of the method being invoked	`#root.methodName`
method	root object	The method being invoked	`#root.method.name`
target	root object	The target object being invoked	`#root.target`

Name	Location	Description	Example
targetClass	root object	The class of the target being invoked	`#root.targetClass`
args	root object	The arguments (as array) used for invoking the target	`#root.args[0]`
caches	root object	Collection of caches against which the current method is executed	`#root.caches[0].name`
argument name	evaluation context	Name of any of the method argument. If for some reason the names are not available (ex: no debug information), the argument names are also available under the `a<#arg>` where *#arg* stands for the argument index (starting from 0).	`iban` or `a0` (one can also use `p0` or `p<#arg>` notation as an alias).
result	evaluation context	The result of the method call (the value to be cached). Only available in `unless` expressions, `cache put` expressions (to compute the `key`), or `cache evict` expressions (when `beforeInvocation` is `false`).	`#result`

@CachePut annotation

For cases where the cache needs to be updated without interfering with the method execution, one can use the `@CachePut` annotation. That is, the method will always be executed and its result placed into the cache (according to the `@CachePut` options). It supports the same options as `@Cacheable` and should be used for cache population rather than method flow optimization:

```
@CachePut(value="book", key="#isbn")
public Book updateBook(ISBN isbn, BookDescriptor descriptor)
```

> **Important**
>
> Note that using `@CachePut` and `@Cacheable` annotations on the same method is generally strongly discouraged because they have different behaviors. While the latter causes the method

> execution to be skipped by using the cache, the former forces the execution in order to execute a cache update. This leads to unexpected behavior and with the exception of specific corner-cases (such as annotations having conditions that exclude them from each other), such declaration should be avoided. Note also that such condition should not rely on the result object (i.e. the `#result` variable) as these are validated upfront to confirm the exclusion.

@CacheEvict annotation

The cache abstraction allows not just population of a cache store but also eviction. This process is useful for removing stale or unused data from the cache. Opposed to `@Cacheable`, annotation `@CacheEvict` demarcates methods that perform cache *eviction*, that is methods that act as triggers for removing data from the cache. Just like its sibling, `@CacheEvict` requires specifying one (or multiple) caches that are affected by the action, allows a custom cache and key resolution or a condition to be specified but in addition, features an extra parameter `allEntries` which indicates whether a cache-wide eviction needs to be performed rather then just an entry one (based on the key):

```
@CacheEvict(value="books", allEntries=true)
public void loadBooks(InputStream batch)
```

This option comes in handy when an entire cache region needs to be cleared out - rather then evicting each entry (which would take a long time since it is inefficient), all the entries are removed in one operation as shown above. Note that the framework will ignore any key specified in this scenario as it does not apply (the entire cache is evicted not just one entry).

One can also indicate whether the eviction should occur after (the default) or before the method executes through the `beforeInvocation` attribute. The former provides the same semantics as the rest of the annotations - once the method completes successfully, an action (in this case eviction) on the cache is executed. If the method does not execute (as it might be cached) or an exception is thrown, the eviction does not occur. The latter (`beforeInvocation=true`) causes the eviction to occur always, before the method is invoked - this is useful in cases where the eviction does not need to be tied to the method outcome.

It is important to note that void methods can be used with `@CacheEvict` - as the methods act as triggers, the return values are ignored (as they don't interact with the cache) - this is not the case with `@Cacheable` which adds/updates data into the cache and thus requires a result.

@Caching annotation

There are cases when multiple annotations of the same type, such as `@CacheEvict` or `@CachePut` need to be specified, for example because the condition or the key expression is different between different caches. Unfortunately Java does not support such declarations however there is a workaround - using an *enclosing* annotation, in this case, `@Caching`. `@Caching` allows multiple nested `@Cacheable`, `@CachePut` and `@CacheEvict` to be used on the same method:

```
@Caching(evict = { @CacheEvict("primary"), @CacheEvict(value="secondary", key="#p0") })
public Book importBooks(String deposit, Date date)
```

@CacheConfig annotation

So far we have seen that caching operations offered many customization options and these can be set on an operation basis. However, some of the customization options can be tedious to configure if they apply to all operations of the class. For instance, specifying the name of the cache to use for

every cache operation of the class could be replaced by a single class-level definition. This is where `@CacheConfig` comes into play.

```
@CacheConfig("books")
public class BookRepositoryImpl implements BookRepository {

    @Cacheable
    public Book findBook(ISBN isbn) {...}
}
```

`@CacheConfig` is a class-level annotation that allows to share the cache names, the custom `KeyGenerator`, the custom `CacheManager` and finally the custom `CacheResolver`. Placing this annotation on the class does not turn on any caching operation.

An operation-level customization will always override a customization set on `@CacheConfig`. This gives therefore three levels of customizations per cache operation:

- Globally configured, available for `CacheManager`, `KeyGenerator`
- At class level, using `@CacheConfig`
- At the operation level

Enable caching annotations

It is important to note that even though declaring the cache annotations does not automatically trigger their actions - like many things in Spring, the feature has to be declaratively enabled (which means if you ever suspect caching is to blame, you can disable it by removing only one configuration line rather than all the annotations in your code).

To enable caching annotations add the annotation `@EnableCaching` to one of your `@Configuration` classes:

```
@Configuration
@EnableCaching
public class AppConfig {
}
```

Alternatively for XML configuration use the `cache:annotation-driven` element:

```
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:cache="http://www.springframework.org/schema/cache"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/cache http://www.springframework.org/schema/cache/spring-
cache.xsd">

        <cache:annotation-driven />

</beans>
```

Both the `cache:annotation-driven` element and `@EnableCaching` annotation allow various options to be specified that influence the way the caching behavior is added to the application through AOP. The configuration is intentionally similar with that of `@Transactional`:

Table 30.2. Cache annotation settings

XML Attribute	Annotation Attribute	Default	Description
`cache-manager`	N/A (See `CachingConfigurer` javadocs)	cacheManager	Name of cache manager to use. A default `CacheResolver` will be initialized behind the scenes with this cache manager (or `cacheManager`if not set). For more fine-grained management of the cache resolution, consider setting the *cache-resolver* attribute.
`cache-resolver`	N/A (See `CachingConfigurer` javadocs)	A `SimpleCacheResolver` using the configured `cacheManager`.	The bean name of the CacheResolver that is to be used to resolve the backing caches. This attribute is not required, and only needs to be specified as an alternative to the *cache-manager* attribute.
`key-generator`	N/A (See `CachingConfigurer` javadocs)	`SimpleKeyGenerator`	Name of the custom key generator to use.
`error-handler`	N/A (See `CachingConfigurer` javadocs)	`SimpleCacheErrorHandler`	Name of the custom cache error handler to use. By default, any exception throw during a cache related operations are thrown back at the client.
`mode`	`mode`	proxy	The default mode "proxy" processes annotated beans to be proxied using Spring's AOP framework (following proxy semantics, as discussed above, applying to method calls coming in through the proxy only). The alternative mode "aspectj" instead weaves the affected classes with Spring's AspectJ caching aspect, modifying the target class byte code to apply to any kind of method call. AspectJ weaving requires spring-aspects.jar in the classpath as well as load-time weaving (or compile-time weaving) enabled. (See the section called "Spring configuration" for details on how to set up load-time weaving.)
`proxy-target-class`	`proxyTargetClass`	false	Applies to proxy mode only. Controls what type of caching proxies are created for classes annotated with the `@Cacheable` or `@CacheEvict` annotations. If the `proxy-target-class` attribute is set to `true`, then class-based proxies are created. If `proxy-target-class` is `false` or if the attribute is omitted, then standard JDK interface-based proxies are created. (See Section 9.6, "Proxying mechanisms" for a detailed examination of the different proxy types.)

XML Attribute	Annotation Attribute	Default	Description
`order`	`order`	Ordered.LOWEST_PRECEDENCE	Defines the order of the cache advice that is applied to beans annotated with `@Cacheable` or `@CacheEvict`. (For more information about the rules related to ordering of AOP advice, see the section called “Advice ordering”.) No specified ordering means that the AOP subsystem determines the order of the advice.

Note

`<cache:annotation-driven/>` only looks for `@Cacheable/@CachePut/@CacheEvict/@Caching` on beans in the same application context it is defined in. This means that, if you put `<cache:annotation-driven/>` in a `WebApplicationContext` for a `DispatcherServlet`, it only checks for beans in your controllers, and not your services. See Section 17.2, “The DispatcherServlet” for more information.

Method visibility and cache annotations

When using proxies, you should apply the cache annotations only to methods with *public* visibility. If you do annotate protected, private or package-visible methods with these annotations, no error is raised, but the annotated method does not exhibit the configured caching settings. Consider the use of AspectJ (see below) if you need to annotate non-public methods as it changes the bytecode itself.

Tip

Spring recommends that you only annotate concrete classes (and methods of concrete classes) with the `@Cache*` annotation, as opposed to annotating interfaces. You certainly can place the `@Cache*` annotation on an interface (or an interface method), but this works only as you would expect it to if you are using interface-based proxies. The fact that Java annotations are *not inherited from interfaces* means that if you are using class-based proxies (`proxy-target-class="true"`) or the weaving-based aspect (`mode="aspectj"`), then the caching settings are not recognized by the proxying and weaving infrastructure, and the object will not be wrapped in a caching proxy, which would be decidedly *bad*.

Note

In proxy mode (which is the default), only external method calls coming in through the proxy are intercepted. This means that self-invocation, in effect, a method within the target object calling another method of the target object, will not lead to an actual caching at runtime even if the invoked method is marked with `@Cacheable` - considering using the aspectj mode in this case.

Using custom annotations

> **Custom annotation and AspectJ**
>
> This feature only works out-of-the-box with the proxy-based approach but can be enabled with a bit of extra effort using AspectJ.
>
> The `spring-aspects` module defines an aspect for the standard annotations only. If you have defined your own annotations, you also need to define an aspect for those. Check `AnnotationCacheAspect` for an example.

The caching abstraction allows you to use your own annotations to identify what method triggers cache population or eviction. This is quite handy as a template mechanism as it eliminates the need to duplicate cache annotation declarations (especially useful if the key or condition are specified) or if the foreign imports (`org.springframework`) are not allowed in your code base. Similar to the rest of the stereotype annotations, `@Cacheable`, `@CachePut`, `@CacheEvict` and `@CacheConfig` can be used as meta-annotations, that is annotations that can annotate other annotations. To wit, let us replace a common `@Cacheable` declaration with our own, custom annotation:

```
@Retention(RetentionPolicy.RUNTIME)
@Target({ElementType.METHOD})
@Cacheable(value="books", key="#isbn")
public @interface SlowService {
}
```

Above, we have defined our own `SlowService` annotation which itself is annotated with `@Cacheable` - now we can replace the following code:

```
@Cacheable(value="books", key="#isbn")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

with:

```
@SlowService
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

Even though `@SlowService` is not a Spring annotation, the container automatically picks up its declaration at runtime and understands its meaning. Note that as mentioned above, the annotation-driven behavior needs to be enabled.

30.4 JCache (JSR-107) annotations

Since the Spring Framework 4.1, the caching abstraction fully supports the JCache standard annotations: these are `@CacheResult`, `@CacheEvict`, `@CacheRemove` and `@CacheRemoveAll` as well as the `@CacheDefaults`, `@CacheKey` and `@CacheValue` companions. These annotations can be used right the way without migrating your cache store to JSR-107: the internal implementation uses Spring's caching abstraction and provides default `CacheResolver` and `KeyGenerator` implementations that are compliant with the specification. In other words, if you are already using Spring's caching abstraction, you can switch to these standard annotations without changing your cache storage (or configuration, for that matter).

Features summary

For those who are familiar with Spring's caching annotations, the following table describes the main differences between the Spring annotations and the JSR-107 counterpart:

Table 30.3. Spring vs. JSR-107 caching annotations

Spring	JSR-107	Remark
`@Cacheable`	`@CacheResult`	Fairly similar. `@CacheResult` can cache specific exceptions and force the execution of the method regardless of the content of the cache.
`@CachePut`	`@CachePut`	While Spring updates the cache with the result of the method invocation, JCache requires to pass it as an argument that is annotated with `@CacheValue`. Due to this difference, JCache allows to update the cache before or after the actual method invocation.
`@CacheEvict`	`@CacheRemove`	Fairly similar. `@CacheRemove` supports a conditional evict in case the method invocation results in an exception.
`@CacheEvict(allEntries=true)`	`@CacheRemoveAll`	See `@CacheRemove`.
`@CacheConfig`	`@CacheDefaults`	Allows to configure the same concepts, in a similar fashion.

JCache has the notion of `javax.cache.annotation.CacheResolver` that is identical to the Spring's `CacheResolver` interface, except that JCache only supports a single cache. By default, a simple implementation retrieves the cache to use based on the name declared on the annotation. It should be noted that if no cache name is specified on the annotation, a default is automatically generated, check the javadoc of `@CacheResult#cacheName()` for more information.

`CacheResolver` instances are retrieved by a `CacheResolverFactory`. It is possible to customize the factory per cache operation:

```
@CacheResult(value="books", cacheResolverFactory=MyCacheResolverFactory.class)
public Book findBook(ISBN isbn)
```

> **Note**
>
> For all referenced *classes*, Spring tries to locate a bean with the given type. If more than one match exists, a new instance is created and can use the regular bean lifecycle callbacks such as dependency injection.

Keys are generated by a `javax.cache.annotation.CacheKeyGenerator` that serves the same purpose as Spring's `KeyGenerator`. By default, all method arguments are taken into account unless at least one parameter is annotated with `@CacheKey`. This is similar to Spring's custom key generation declaration. For instance these are identical operations, one using Spring's abstraction and the other with JCache:

```
@Cacheable(value="books", key="#isbn")
public Book findBook(ISBN isbn, boolean checkWarehouse, boolean includeUsed)

@CacheResult(cacheName="books")
public Book findBook(@CacheKey ISBN isbn, boolean checkWarehouse, boolean includeUsed)
```

The `CacheKeyResolver` to use can also be specified on the operation, in a similar fashion as the `CacheResolverFactory`.

JCache can manage exceptions thrown by annotated methods: this can prevent an update of the cache but it can also cache the exception as an indicator of the failure instead of calling the method again.

Let's assume that `InvalidIsbnNotFoundException` is thrown if the structure of the ISBN is invalid. This is a permanent failure, no book could ever be retrieved with such parameter. The following caches the exception so that further calls with the same, invalid ISBN, throws the cached exception directly instead of invoking the method again.

```
@CacheResult(cacheName="books", exceptionCacheName="failures"
             cachedExceptions = InvalidIsbnNotFoundException.class)
public Book findBook(ISBN isbn)
```

Enabling JSR-107 support

Nothing specific needs to be done to enable the JSR-107 support alongside Spring's declarative annotation support. Both `@EnableCaching` and the `cache:annotation-driven` element will enable automatically the JCache support if both the JSR-107 API and the `spring-context-support` module are present in the classpath.

> **Note**
>
> Depending of your use case, the choice is basically yours. You can even mix and match services using the JSR-107 API and others using Spring's own annotations. Be aware however that if these services are impacting the same caches, a consistent and identical key generation implementation should be used.

30.5 Declarative XML-based caching

If annotations are not an option (no access to the sources or no external code), one can use XML for declarative caching. So instead of annotating the methods for caching, one specifies the target method and the caching directives externally (similar to the declarative transaction management advice). The previous example can be translated into:

```
<!-- the service we want to make cacheable -->
<bean id="bookService" class="x.y.service.DefaultBookService"/>

<!-- cache definitions -->
<cache:advice id="cacheAdvice" cache-manager="cacheManager">
    <cache:caching cache="books">
        <cache:cacheable method="findBook" key="#isbn"/>
        <cache:cache-evict method="loadBooks" all-entries="true"/>
    </cache:caching>
</cache:advice>

<!-- apply the cacheable behavior to all BookService interfaces -->
<aop:config>
    <aop:advisor advice-ref="cacheAdvice" pointcut="execution(* x.y.BookService.*(..))"/>
</aop:config>

<!-- cache manager definition omitted -->
```

In the configuration above, the `bookService` is made cacheable. The caching semantics to apply are encapsulated in the `cache:advice` definition which instructs method `findBooks` to be used for putting data into the cache while method `loadBooks` for evicting data. Both definitions are working against the `books` cache.

The `aop:config` definition applies the cache advice to the appropriate points in the program by using the AspectJ pointcut expression (more information is available in Chapter 9, *Aspect Oriented Programming with Spring*). In the example above, all methods from the `BookService` are considered and the cache advice applied to them.

The declarative XML caching supports all of the annotation-based model so moving between the two should be fairly easy - further more both can be used inside the same application. The XML based approach does not touch the target code however it is inherently more verbose; when dealing with classes with overloaded methods that are targeted for caching, identifying the proper methods does take an extra effort since the `method` argument is not a good discriminator - in these cases, the AspectJ pointcut can be used to cherry pick the target methods and apply the appropriate caching functionality. However through XML, it is easier to apply a package/group/interface-wide caching (again due to the AspectJ pointcut) and to create template-like definitions (as we did in the example above by defining the target cache through the `cache:definitions cache` attribute).

30.6 Configuring the cache storage

Out of the box, the cache abstraction provides several storages integration. To use them, one needs to simply declare an appropriate `CacheManager` - an entity that controls and manages `Caches` and can be used to retrieve these for storage.

JDK ConcurrentMap-based Cache

The JDK-based `Cache` implementation resides under `org.springframework.cache.concurrent` package. It allows one to use `ConcurrentHashMap` as a backing `Cache` store.

```
<!-- simple cache manager -->
<bean id="cacheManager" class="org.springframework.cache.support.SimpleCacheManager">
    <property name="caches">
        <set>

  <bean class="org.springframework.cache.concurrent.ConcurrentMapCacheFactoryBean" p:name="default"/>

  <bean class="org.springframework.cache.concurrent.ConcurrentMapCacheFactoryBean" p:name="books"/>
        </set>
    </property>
</bean>
```

The snippet above uses the `SimpleCacheManager` to create a `CacheManager` for the two nested `ConcurrentMapCache` instances named *default* and *books*. Note that the names are configured directly for each cache.

As the cache is created by the application, it is bound to its lifecycle, making it suitable for basic use cases, tests or simple applications. The cache scales well and is very fast but it does not provide any management or persistence capabilities nor eviction contracts.

EhCache-based Cache

The EhCache implementation is located under `org.springframework.cache.ehcache` package. Again, to use it, one simply needs to declare the appropriate `CacheManager`:

```
<bean id="cacheManager"
      class="org.springframework.cache.ehcache.EhCacheCacheManager" p:cache-manager-ref="ehcache"/>

<!-- EhCache library setup -->
<bean id="ehcache"
      class="org.springframework.cache.ehcache.EhCacheManagerFactoryBean" p:config-
location="ehcache.xml"/>
```

This setup bootstraps the ehcache library inside Spring IoC (through the `ehcache` bean) which is then wired into the dedicated `CacheManager` implementation. Note the entire ehcache-specific configuration is read from `ehcache.xml`.

Guava Cache

The Guava implementation is located under `org.springframework.cache.guava` package and provides access to several features of Guava.

Configuring a `CacheManager` that creates the cache on demand is straightforward:

```
<bean id="cacheManager"
      class="org.springframework.cache.guava.GuavaCacheManager"/>
```

It is also possible to provide the caches to use explicitly. In that case, only those will be made available by the manager:

```
<bean id="cacheManager" class="org.springframework.cache.guava.GuavaCacheManager">
    <property name="caches">
        <set>
            <value>default</value>
            <value>books</value>
        </set>
    </property>
</bean>
```

The Guava `CacheManager` also supports customs `CacheBuilder` and `CacheLoader`. See the Guava documentation for more information about those.

GemFire-based Cache

GemFire is a memory-oriented/disk-backed, elastically scalable, continuously available, active (with built-in pattern-based subscription notifications), globally replicated database and provides fully-featured edge caching. For further information on how to use GemFire as a CacheManager (and more), please refer to the Spring Data GemFire reference documentation.

JSR-107 Cache

JSR-107 compliant caches can also be used by Spring's caching abstraction. The JCache implementation is located under `org.springframework.cache.jcache` package.

Again, to use it, one simply needs to declare the appropriate `CacheManager`:

```
<bean id="cacheManager"
      class="org.springframework.cache.jcache.JCacheCacheManager"
      p:cache-manager-ref="jCacheManager"/>

<!-- JSR-107 cache manager setup  -->
<bean id="jCacheManager" .../>
```

Dealing with caches without a backing store

Sometimes when switching environments or doing testing, one might have cache declarations without an actual backing cache configured. As this is an invalid configuration, at runtime an exception will be thrown since the caching infrastructure is unable to find a suitable store. In situations like this, rather then removing the cache declarations (which can prove tedious), one can wire in a simple, dummy cache that performs no caching - that is, forces the cached methods to be executed every time:

```
<bean id="cacheManager" class="org.springframework.cache.support.CompositeCacheManager">
    <property name="cacheManagers">
        <list>
            <ref bean="jdkCache"/>
            <ref bean="gemfireCache"/>
        </list>
    </property>
    <property name="fallbackToNoOpCache" value="true"/>
</bean>
```

The `CompositeCacheManager` above chains multiple `CacheManagers` and additionally, through the `fallbackToNoOpCache` flag, adds a *no op* cache that for all the definitions not handled by the configured cache managers. That is, every cache definition not found in either `jdkCache` or `gemfireCache` (configured above) will be handled by the no op cache, which will not store any information causing the target method to be executed every time.

30.7 Plugging-in different back-end caches

Clearly there are plenty of caching products out there that can be used as a backing store. To plug them in, one needs to provide a `CacheManager` and `Cache` implementation since unfortunately there is no available standard that we can use instead. This may sound harder than it is since in practice, the classes tend to be simple adapters that map the caching abstraction framework on top of the storage API as the `ehcache` classes can show. Most `CacheManager` classes can use the classes in `org.springframework.cache.support` package, such as `AbstractCacheManager` which takes care of the boiler-plate code leaving only the actual *mapping* to be completed. We hope that in time, the libraries that provide integration with Spring can fill in this small configuration gap.

30.8 How can I set the TTL/TTI/Eviction policy/XXX feature?

Directly through your cache provider. The cache abstraction is… well, an abstraction not a cache implementation. The solution you are using might support various data policies and different topologies which other solutions do not (take for example the JDK `ConcurrentHashMap`) - exposing that in the cache abstraction would be useless simply because there would no backing support. Such functionality should be controlled directly through the backing cache, when configuring it or through its native API.

Part VII. Appendices

31. Migrating to Spring Framework 4.0

Migration guides for upgrading from previous releases of the Spring Framework are now provided as a Wiki page. For details please refer to https://github.com/spring-projects/spring-framework/wiki/Migrating-from-earlier-versions-of-the-spring-framework

32. Classic Spring Usage

This appendix discusses some classic Spring usage patterns as a reference for developers maintaining legacy Spring applications. These usage patterns no longer reflect the recommended way of using these features and the current recommended usage is covered in the respective sections of the reference manual.

32.1 Classic ORM usage

This section documents the classic usage patterns that you might encounter in a legacy Spring application. For the currently recommended usage patterns, please refer to the Chapter 15, *Object Relational Mapping (ORM) Data Access* chapter.

Hibernate

For the currently recommended usage patterns for Hibernate see Section 15.3, “Hibernate”

the HibernateTemplate

The basic programming model for templating looks as follows, for methods that can be part of any custom data access object or business service. There are no restrictions on the implementation of the surrounding object at all, it just needs to provide a Hibernate `SessionFactory`. It can get the latter from anywhere, but preferably as bean reference from a Spring IoC container - via a simple `setSessionFactory(..)` bean property setter. The following snippets show a DAO definition in a Spring container, referencing the above defined `SessionFactory`, and an example for a DAO method implementation.

```
<beans>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="sessionFactory" ref="mySessionFactory"/>
    </bean>

</beans>
```

```
public class ProductDaoImpl implements ProductDao {

    private HibernateTemplate hibernateTemplate;

    public void setSessionFactory(SessionFactory sessionFactory) {
        this.hibernateTemplate = new HibernateTemplate(sessionFactory);
    }

    public Collection loadProductsByCategory(String category) throws DataAccessException {
        return this.hibernateTemplate.find("from test.Product product where product.category=?",
 category);
    }
}
```

The `HibernateTemplate` class provides many methods that mirror the methods exposed on the Hibernate `Session` interface, in addition to a number of convenience methods such as the one shown above. If you need access to the `Session` to invoke methods that are not exposed on the `HibernateTemplate`, you can always drop down to a callback-based approach like so.

```
public class ProductDaoImpl implements ProductDao {

    private HibernateTemplate hibernateTemplate;

    public void setSessionFactory(SessionFactory sessionFactory) {
        this.hibernateTemplate = new HibernateTemplate(sessionFactory);
    }

    public Collection loadProductsByCategory(final String category) throws DataAccessException {
        return this.hibernateTemplate.execute(new HibernateCallback() {
            public Object doInHibernate(Session session) {
                Criteria criteria = session.createCriteria(Product.class);
                criteria.add(Expression.eq("category", category));
                criteria.setMaxResults(6);
                return criteria.list();
            }
        };
    }

}
```

A callback implementation effectively can be used for any Hibernate data access. `HibernateTemplate` will ensure that `Session` instances are properly opened and closed, and automatically participate in transactions. The template instances are thread-safe and reusable, they can thus be kept as instance variables of the surrounding class. For simple single step actions like a single find, load, saveOrUpdate, or delete call, `HibernateTemplate` offers alternative convenience methods that can replace such one line callback implementations. Furthermore, Spring provides a convenient `HibernateDaoSupport` base class that provides a `setSessionFactory(..)` method for receiving a `SessionFactory`, and `getSessionFactory()` and `getHibernateTemplate()` for use by subclasses. In combination, this allows for very simple DAO implementations for typical requirements:

```
public class ProductDaoImpl extends HibernateDaoSupport implements ProductDao {

    public Collection loadProductsByCategory(String category) throws DataAccessException {
        return this.getHibernateTemplate().find(
            "from test.Product product where product.category=?", category);
    }

}
```

Implementing Spring-based DAOs without callbacks

As alternative to using Spring's `HibernateTemplate` to implement DAOs, data access code can also be written in a more traditional fashion, without wrapping the Hibernate access code in a callback, while still respecting and participating in Spring's generic `DataAccessException` hierarchy. The `HibernateDaoSupport` base class offers methods to access the current transactional `Session` and to convert exceptions in such a scenario; similar methods are also available as static helpers on the `SessionFactoryUtils` class. Note that such code will usually pass `false` as the value of the `getSession(..)` methods `allowCreate` argument, to enforce running within a transaction (which avoids the need to close the returned `Session`, as its lifecycle is managed by the transaction).

```
public class HibernateProductDao extends HibernateDaoSupport implements ProductDao {

    public Collection loadProductsByCategory(String category) throws DataAccessException, MyException {
        Session session = getSession(false);
        try {
            Query query = session.createQuery("from test.Product product where product.category=?");
            query.setString(0, category);
            List result = query.list();
            if (result == null) {
                throw new MyException("No search results.");
            }
            return result;
        }
        catch (HibernateException ex) {
            throw convertHibernateAccessException(ex);
        }
    }
}
```

The advantage of such direct Hibernate access code is that it allows *any* checked application exception to be thrown within the data access code; contrast this to the `HibernateTemplate` class which is restricted to throwing only unchecked exceptions within the callback. Note that you can often defer the corresponding checks and the throwing of application exceptions to after the callback, which still allows working with `HibernateTemplate`. In general, the `HibernateTemplate` class' convenience methods are simpler and more convenient for many scenarios.

JDO

For the currently recommended usage patterns for JDO see Section 15.4, “JDO”

JdoTemplate and `JdoDaoSupport`

Each JDO-based DAO will then receive the `PersistenceManagerFactory` through dependency injection. Such a DAO could be coded against plain JDO API, working with the given `PersistenceManagerFactory`, but will usually rather be used with the Spring Framework’s `JdoTemplate`:

```
<beans>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="persistenceManagerFactory" ref="myPmf"/>
    </bean>

</beans>
```

```
public class ProductDaoImpl implements ProductDao {

    private JdoTemplate jdoTemplate;

    public void setPersistenceManagerFactory(PersistenceManagerFactory pmf) {
        this.jdoTemplate = new JdoTemplate(pmf);
    }

    public Collection loadProductsByCategory(final String category) throws DataAccessException {
        return (Collection) this.jdoTemplate.execute(new JdoCallback() {
            public Object doInJdo(PersistenceManager pm) throws JDOException {
                Query query = pm.newQuery(Product.class, "category = pCategory");
                query.declareParameters("String pCategory");
                List result = query.execute(category);
                // do some further stuff with the result list
                return result;
            }
        });
    }

}
```

A callback implementation can effectively be used for any JDO data access. `JdoTemplate` will ensure that `PersistenceManager` s are properly opened and closed, and automatically participate in transactions. The template instances are thread-safe and reusable, they can thus be kept as instance variables of the surrounding class. For simple single-step actions such as a single `find`, `load`, `makePersistent`, or `delete` call, `JdoTemplate` offers alternative convenience methods that can replace such one line callback implementations. Furthermore, Spring provides a convenient `JdoDaoSupport` base class that provides a `setPersistenceManagerFactory(..)` method for receiving a `PersistenceManagerFactory`, and `getPersistenceManagerFactory()` and `getJdoTemplate()` for use by subclasses. In combination, this allows for very simple DAO implementations for typical requirements:

```
public class ProductDaoImpl extends JdoDaoSupport implements ProductDao {

    public Collection loadProductsByCategory(String category) throws DataAccessException {
        return getJdoTemplate().find(Product.class,
                "category = pCategory", "String category", new Object[] {category});
    }

}
```

As alternative to working with Spring's `JdoTemplate`, you can also code Spring-based DAOs at the JDO API level, explicitly opening and closing a `PersistenceManager`. As elaborated in the corresponding Hibernate section, the main advantage of this approach is that your data access code is able to throw checked exceptions. `JdoDaoSupport` offers a variety of support methods for this scenario, for fetching and releasing a transactional `PersistenceManager` as well as for converting exceptions.

JPA

For the currently recommended usage patterns for JPA see Section 15.5, "JPA"

JpaTemplate and `JpaDaoSupport`

Each JPA-based DAO will then receive a `EntityManagerFactory` via dependency injection. Such a DAO can be coded against plain JPA and work with the given `EntityManagerFactory` or through Spring's `JpaTemplate`:

```
<beans>

    <bean id="myProductDao" class="product.ProductDaoImpl">
        <property name="entityManagerFactory" ref="myEmf"/>
    </bean>

</beans>
```

```
public class JpaProductDao implements ProductDao {

    private JpaTemplate jpaTemplate;

    public void setEntityManagerFactory(EntityManagerFactory emf) {
        this.jpaTemplate = new JpaTemplate(emf);
    }

    public Collection loadProductsByCategory(final String category) throws DataAccessException {
        return (Collection) this.jpaTemplate.execute(new JpaCallback() {
            public Object doInJpa(EntityManager em) throws PersistenceException {
                Query query = em.createQuery("from Product as p where p.category = :category");
                query.setParameter("category", category);
                List result = query.getResultList();
                // do some further processing with the result list
                return result;
            }
        });
    }

}
```

The `JpaCallback` implementation allows any type of JPA data access. The `JpaTemplate` will ensure that `EntityManager` s are properly opened and closed and automatically participate in transactions. Moreover, the `JpaTemplate` properly handles exceptions, making sure resources are cleaned up and the appropriate transactions rolled back. The template instances are thread-safe and reusable and they can be kept as instance variable of the enclosing class. Note that `JpaTemplate` offers single-step actions such as find, load, merge, etc along with alternative convenience methods that can replace one line callback implementations.

Furthermore, Spring provides a convenient `JpaDaoSupport` base class that provides the `get/setEntityManagerFactory` and `getJpaTemplate()` to be used by subclasses:

```
public class ProductDaoImpl extends JpaDaoSupport implements ProductDao {

    public Collection loadProductsByCategory(String category) throws DataAccessException {
        Map<String, String> params = new HashMap<String, String>();
        params.put("category", category);
        return getJpaTemplate().findByNamedParams("from Product as p where p.category = :category",
 params);
    }

}
```

Besides working with Spring's `JpaTemplate`, one can also code Spring-based DAOs against the JPA, doing one's own explicit `EntityManager` handling. As also elaborated in the corresponding Hibernate section, the main advantage of this approach is that your data access code is able to throw checked exceptions. `JpaDaoSupport` offers a variety of support methods for this scenario, for retrieving and releasing a transaction `EntityManager`, as well as for converting exceptions.

JpaTemplate mainly exists as a sibling of JdoTemplate and HibernateTemplate, offering the same style for people used to it.

32.2 Classic Spring MVC

…

32.3 JMS Usage

One of the benefits of Spring's JMS support is to shield the user from differences between the JMS 1.0.2 and 1.1 APIs. (For a description of the differences between the two APIs see sidebar on Domain Unification). Since it is now common to encounter only the JMS 1.1 API the use of classes that are based on the JMS 1.0.2 API has been deprecated in Spring 3.0. This section describes Spring JMS support for the JMS 1.0.2 deprecated classes.

Domain Unification

There are two major releases of the JMS specification, 1.0.2 and 1.1.

JMS 1.0.2 defined two types of messaging domains, point-to-point (Queues) and publish/subscribe (Topics). The 1.0.2 API reflected these two messaging domains by providing a parallel class hierarchy for each domain. As a result, a client application became domain specific in its use of the JMS API. JMS 1.1 introduced the concept of domain unification that minimized both the functional differences and client API differences between the two domains. As an example of a functional difference that was removed, if you use a JMS 1.1 provider you can transactionally consume a message from one domain and produce a message on the other using the same `Session`.

> **Note**
>
> The JMS 1.1 specification was released in April 2002 and incorporated as part of J2EE 1.4 in November 2003. As a result, common J2EE 1.3 application servers which are still in widespread use (such as BEA WebLogic 8.1 and IBM WebSphere 5.1) are based on JMS 1.0.2.

JmsTemplate

Located in the package `org.springframework.jms.core` the class `JmsTemplate102` provides all of the features of the `JmsTemplate` described the JMS chapter, but is based on the JMS 1.0.2 API instead of the JMS 1.1 API. As a consequence, if you are using JmsTemplate102 you need to set the boolean property `pubSubDomain` to configure the `JmsTemplate` with knowledge of what JMS domain is being used. By default the value of this property is false, indicating that the point-to-point domain, Queues, will be used.

Asynchronous Message Reception

MessageListenerAdapter's are used in conjunction with Spring's message listener containers to support asynchronous message reception by exposing almost any class as a Message-driven POJO. If you are using the JMS 1.0.2 API, you will want to use the 1.0.2 specific classes such as `MessageListenerAdapter102`, `SimpleMessageListenerContainer102`, and `DefaultMessageListenerContainer102`. These classes provide the same functionality as the JMS 1.1 based counterparts but rely only on the JMS 1.0.2 API.

Connections

The `ConnectionFactory` interface is part of the JMS specification and serves as the entry point for working with JMS. Spring provides an implementation of the `ConnectionFactory` interface, `SingleConnectionFactory102`, based on the JMS 1.0.2 API that will return the same `Connection` on all `createConnection()` calls and ignore calls to `close()`. You will need to set the boolean property `pubSubDomain` to indicate which messaging domain is used as `SingleConnectionFactory102` will always explicitly differentiate between a `javax.jms.QueueConnection` and a `javax.jmsTopicConnection`.

Transaction Management

In a JMS 1.0.2 environment the class `JmsTransactionManager102` provides support for managing JMS transactions for a single Connection Factory. Please refer to the reference documentation on JMS Transaction Management for more information on this functionality.

33. Classic Spring AOP Usage

In this appendix we discuss the lower-level Spring AOP APIs and the AOP support used in Spring 1.2 applications. For new applications, we recommend the use of the Spring 2.0 AOP support described in the AOP chapter, but when working with existing applications, or when reading books and articles, you may come across Spring 1.2 style examples. Spring 2.0 is fully backwards compatible with Spring 1.2 and everything described in this appendix is fully supported in Spring 2.0.

33.1 Pointcut API in Spring

Let's look at how Spring handles the crucial pointcut concept.

Concepts

Spring's pointcut model enables pointcut reuse independent of advice types. It's possible to target different advice using the same pointcut.

The `org.springframework.aop.Pointcut` interface is the central interface, used to target advices to particular classes and methods. The complete interface is shown below:

```
public interface Pointcut {

    ClassFilter getClassFilter();

    MethodMatcher getMethodMatcher();

}
```

Splitting the `Pointcut` interface into two parts allows reuse of class and method matching parts, and fine-grained composition operations (such as performing a "union" with another method matcher).

The `ClassFilter` interface is used to restrict the pointcut to a given set of target classes. If the `matches()` method always returns true, all target classes will be matched:

```
public interface ClassFilter {

    boolean matches(Class clazz);

}
```

The `MethodMatcher` interface is normally more important. The complete interface is shown below:

```
public interface MethodMatcher {

    boolean matches(Method m, Class targetClass);

    boolean isRuntime();

    boolean matches(Method m, Class targetClass, Object[] args);

}
```

The `matches(Method, Class)` method is used to test whether this pointcut will ever match a given method on a target class. This evaluation can be performed when an AOP proxy is created, to avoid the need for a test on every method invocation. If the 2-argument matches method returns true for a given method, and the `isRuntime()` method for the MethodMatcher returns true, the 3-argument matches method will be invoked on every method invocation. This enables a pointcut to look at the arguments passed to the method invocation immediately before the target advice is to execute.

Most MethodMatchers are static, meaning that their `isRuntime()` method returns false. In this case, the 3-argument matches method will never be invoked.

> **Tip**
>
> If possible, try to make pointcuts static, allowing the AOP framework to cache the results of pointcut evaluation when an AOP proxy is created.

Operations on pointcuts

Spring supports operations on pointcuts: notably, *union* and *intersection*.

- Union means the methods that either pointcut matches.
- Intersection means the methods that both pointcuts match.
- Union is usually more useful.
- Pointcuts can be composed using the static methods in the *org.springframework.aop.support.Pointcuts* class, or using the *ComposablePointcut* class in the same package. However, using AspectJ pointcut expressions is usually a simpler approach.

AspectJ expression pointcuts

Since 2.0, the most important type of pointcut used by Spring is `org.springframework.aop.aspectj.AspectJExpressionPointcut`. This is a pointcut that uses an AspectJ supplied library to parse an AspectJ pointcut expression string.

See the previous chapter for a discussion of supported AspectJ pointcut primitives.

Convenience pointcut implementations

Spring provides several convenient pointcut implementations. Some can be used out of the box; others are intended to be subclassed in application-specific pointcuts.

Static pointcuts

Static pointcuts are based on method and target class, and cannot take into account the method's arguments. Static pointcuts are sufficient - *and best* - for most usages. It's possible for Spring to evaluate a static pointcut only once, when a method is first invoked: after that, there is no need to evaluate the pointcut again with each method invocation.

Let's consider some static pointcut implementations included with Spring.

Regular expression pointcuts

One obvious way to specify static pointcuts is regular expressions. Several AOP frameworks besides Spring make this possible. `org.springframework.aop.support.Perl5RegexpMethodPointcut` is a generic regular expression pointcut, using Perl 5 regular expression syntax. The `Perl5RegexpMethodPointcut` class depends on Jakarta ORO for regular expression matching. Spring also provides the `JdkRegexpMethodPointcut` class that uses the regular expression support in JDK 1.4+.

Using the `Perl5RegexpMethodPointcut` class, you can provide a list of pattern Strings. If any of these is a match, the pointcut will evaluate to true. (So the result is effectively the union of these pointcuts.)

The usage is shown below:

```
<bean id="settersAndAbsquatulatePointcut"
        class="org.springframework.aop.support.Perl5RegexpMethodPointcut">
    <property name="patterns">
        <list>
            <value>.set.</value>
            <value>.*absquatulate</value>
        </list>
    </property>
</bean>
```

Spring provides a convenience class, `RegexpMethodPointcutAdvisor`, that allows us to also reference an Advice (remember that an Advice can be an interceptor, before advice, throws advice etc.). Behind the scenes, Spring will use a `JdkRegexpMethodPointcut`. Using `RegexpMethodPointcutAdvisor` simplifies wiring, as the one bean encapsulates both pointcut and advice, as shown below:

```
<bean id="settersAndAbsquatulateAdvisor"
        class="org.springframework.aop.support.RegexpMethodPointcutAdvisor">
    <property name="advice">
        <ref bean="beanNameOfAopAllianceInterceptor"/>
    </property>
    <property name="patterns">
        <list>
            <value>.set.</value>
            <value>.*absquatulate</value>
        </list>
    </property>
</bean>
```

RegexpMethodPointcutAdvisor can be used with any Advice type.

Attribute-driven pointcuts

An important type of static pointcut is a *metadata-driven* pointcut. This uses the values of metadata attributes: typically, source-level metadata.

Dynamic pointcuts

Dynamic pointcuts are costlier to evaluate than static pointcuts. They take into account method*arguments*, as well as static information. This means that they must be evaluated with every method invocation; the result cannot be cached, as arguments will vary.

The main example is the `control flow` pointcut.

Control flow pointcuts

Spring control flow pointcuts are conceptually similar to AspectJ *cflow* pointcuts, although less powerful. (There is currently no way to specify that a pointcut executes below a join point matched by another pointcut.) A control flow pointcut matches the current call stack. For example, it might fire if the join point was invoked by a method in the `com.mycompany.web` package, or by the `SomeCaller` class. Control flow pointcuts are specified using the `org.springframework.aop.support.ControlFlowPointcut` class.

> **Note**
>
> Control flow pointcuts are significantly more expensive to evaluate at runtime than even other dynamic pointcuts. In Java 1.4, the cost is about 5 times that of other dynamic pointcuts.

Pointcut superclasses

Spring provides useful pointcut superclasses to help you to implement your own pointcuts.

Because static pointcuts are most useful, you'll probably subclass StaticMethodMatcherPointcut, as shown below. This requires implementing just one abstract method (although it's possible to override other methods to customize behavior):

```
class TestStaticPointcut extends StaticMethodMatcherPointcut {

    public boolean matches(Method m, Class targetClass) {
        // return true if custom criteria match
    }

}
```

There are also superclasses for dynamic pointcuts.

You can use custom pointcuts with any advice type in Spring 1.0 RC2 and above.

Custom pointcuts

Because pointcuts in Spring AOP are Java classes, rather than language features (as in AspectJ) it's possible to declare custom pointcuts, whether static or dynamic. Custom pointcuts in Spring can be arbitrarily complex. However, using the AspectJ pointcut expression language is recommended if possible.

> **Note**
>
> Later versions of Spring may offer support for "semantic pointcuts" as offered by JAC: for example, "all methods that change instance variables in the target object."

33.2 Advice API in Spring

Let's now look at how Spring AOP handles advice.

Advice lifecycles

Each advice is a Spring bean. An advice instance can be shared across all advised objects, or unique to each advised object. This corresponds to *per-class* or *per-instance* advice.

Per-class advice is used most often. It is appropriate for generic advice such as transaction advisors. These do not depend on the state of the proxied object or add new state; they merely act on the method and arguments.

Per-instance advice is appropriate for introductions, to support mixins. In this case, the advice adds state to the proxied object.

It's possible to use a mix of shared and per-instance advice in the same AOP proxy.

Advice types in Spring

Spring provides several advice types out of the box, and is extensible to support arbitrary advice types. Let us look at the basic concepts and standard advice types.

Interception around advice

The most fundamental advice type in Spring is *interception around advice*.

Spring is compliant with the AOP Alliance interface for around advice using method interception. MethodInterceptors implementing around advice should implement the following interface:

```
public interface MethodInterceptor extends Interceptor {

    Object invoke(MethodInvocation invocation) throws Throwable;

}
```

The `MethodInvocation` argument to the `invoke()` method exposes the method being invoked; the target join point; the AOP proxy; and the arguments to the method. The `invoke()` method should return the invocation's result: the return value of the join point.

A simple `MethodInterceptor` implementation looks as follows:

```
public class DebugInterceptor implements MethodInterceptor {

    public Object invoke(MethodInvocation invocation) throws Throwable {
        System.out.println("Before: invocation=[" + invocation + "]");
        Object rval = invocation.proceed();
        System.out.println("Invocation returned");
        return rval;
    }

}
```

Note the call to the MethodInvocation's `proceed()` method. This proceeds down the interceptor chain towards the join point. Most interceptors will invoke this method, and return its return value. However, a MethodInterceptor, like any around advice, can return a different value or throw an exception rather than invoke the proceed method. However, you don't want to do this without good reason!

> **Note**
>
> MethodInterceptors offer interoperability with other AOP Alliance-compliant AOP implementations. The other advice types discussed in the remainder of this section implement common AOP concepts, but in a Spring-specific way. While there is an advantage in using the most specific advice type, stick with MethodInterceptor around advice if you are likely to want to run the aspect in another AOP framework. Note that pointcuts are not currently interoperable between frameworks, and the AOP Alliance does not currently define pointcut interfaces.

Before advice

A simpler advice type is a *before advice*. This does not need a `MethodInvocation` object, since it will only be called before entering the method.

The main advantage of a before advice is that there is no need to invoke the `proceed()` method, and therefore no possibility of inadvertently failing to proceed down the interceptor chain.

The `MethodBeforeAdvice` interface is shown below. (Spring's API design would allow for field before advice, although the usual objects apply to field interception and it's unlikely that Spring will ever implement it).

```
public interface MethodBeforeAdvice extends BeforeAdvice {

    void before(Method m, Object[] args, Object target) throws Throwable;

}
```

Note the return type is `void`. Before advice can insert custom behavior before the join point executes, but cannot change the return value. If a before advice throws an exception, this will abort further execution of the interceptor chain. The exception will propagate back up the interceptor chain. If it is unchecked, or on the signature of the invoked method, it will be passed directly to the client; otherwise it will be wrapped in an unchecked exception by the AOP proxy.

An example of a before advice in Spring, which counts all method invocations:

```
public class CountingBeforeAdvice implements MethodBeforeAdvice {

    private int count;

    public void before(Method m, Object[] args, Object target) throws Throwable {
        ++count;
    }

    public int getCount() {
        return count;
    }
}
```

> **Tip**
>
> Before advice can be used with any pointcut.

Throws advice

Throws advice is invoked after the return of the join point if the join point threw an exception. Spring offers typed throws advice. Note that this means that the `org.springframework.aop.ThrowsAdvice` interface does not contain any methods: It is a tag interface identifying that the given object implements one or more typed throws advice methods. These should be in the form of:

```
afterThrowing([Method, args, target], subclassOfThrowable)
```

Only the last argument is required. The method signatures may have either one or four arguments, depending on whether the advice method is interested in the method and arguments. The following classes are examples of throws advice.

The advice below is invoked if a `RemoteException` is thrown (including subclasses):

```
public class RemoteThrowsAdvice implements ThrowsAdvice {

    public void afterThrowing(RemoteException ex) throws Throwable {
        // Do something with remote exception
    }

}
```

The following advice is invoked if a `ServletException` is thrown. Unlike the above advice, it declares 4 arguments, so that it has access to the invoked method, method arguments and target object:

```
public class ServletThrowsAdviceWithArguments implements ThrowsAdvice {

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }

}
```

The final example illustrates how these two methods could be used in a single class, which handles both `RemoteException` and `ServletException`. Any number of throws advice methods can be combined in a single class.

```
public static class CombinedThrowsAdvice implements ThrowsAdvice {

    public void afterThrowing(RemoteException ex) throws Throwable {
        // Do something with remote exception
    }

    public void afterThrowing(Method m, Object[] args, Object target, ServletException ex) {
        // Do something with all arguments
    }
}
```

Note: If a throws-advice method throws an exception itself, it will override the original exception (i.e. change the exception thrown to the user). The overriding exception will typically be a RuntimeException; this is compatible with any method signature. However, if a throws-advice method throws a checked exception, it will have to match the declared exceptions of the target method and is hence to some degree coupled to specific target method signatures. *Do not throw an undeclared checked exception that is incompatible with the target method's signature!*

> **Tip**
>
> Throws advice can be used with any pointcut.

After Returning advice

An after returning advice in Spring must implement the *org.springframework.aop.AfterReturningAdvice* interface, shown below:

```
public interface AfterReturningAdvice extends Advice {

    void afterReturning(Object returnValue, Method m, Object[] args,
            Object target) throws Throwable;

}
```

An after returning advice has access to the return value (which it cannot modify), invoked method, methods arguments and target.

The following after returning advice counts all successful method invocations that have not thrown exceptions:

```
public class CountingAfterReturningAdvice implements AfterReturningAdvice {

    private int count;

    public void afterReturning(Object returnValue, Method m, Object[] args,
            Object target) throws Throwable {
        ++count;
    }

    public int getCount() {
        return count;
    }

}
```

This advice doesn't change the execution path. If it throws an exception, this will be thrown up the interceptor chain instead of the return value.

> **Tip**
>
> After returning advice can be used with any pointcut.

Introduction advice

Spring treats introduction advice as a special kind of interception advice.

Introduction requires an `IntroductionAdvisor`, and an `IntroductionInterceptor`, implementing the following interface:

```
public interface IntroductionInterceptor extends MethodInterceptor {

    boolean implementsInterface(Class intf);

}
```

The `invoke()` method inherited from the AOP Alliance `MethodInterceptor` interface must implement the introduction: that is, if the invoked method is on an introduced interface, the introduction interceptor is responsible for handling the method call - it cannot invoke `proceed()`.

Introduction advice cannot be used with any pointcut, as it applies only at class, rather than method, level. You can only use introduction advice with the `IntroductionAdvisor`, which has the following methods:

```
public interface IntroductionAdvisor extends Advisor, IntroductionInfo {

    ClassFilter getClassFilter();

    void validateInterfaces() throws IllegalArgumentException;

}

public interface IntroductionInfo {

    Class[] getInterfaces();

}
```

There is no `MethodMatcher`, and hence no `Pointcut`, associated with introduction advice. Only class filtering is logical.

The `getInterfaces()` method returns the interfaces introduced by this advisor.

The `validateInterfaces()` method is used internally to see whether or not the introduced interfaces can be implemented by the configured `IntroductionInterceptor`.

Let's look at a simple example from the Spring test suite. Let's suppose we want to introduce the following interface to one or more objects:

```
public interface Lockable {

    void lock();

    void unlock();

    boolean locked();

}
```

This illustrates a *mixin*. We want to be able to cast advised objects to Lockable, whatever their type, and call lock and unlock methods. If we call the lock() method, we want all setter methods to throw a `LockedException`. Thus we can add an aspect that provides the ability to make objects immutable, without them having any knowledge of it: a good example of AOP.

Firstly, we'll need an `IntroductionInterceptor` that does the heavy lifting. In this case, we extend the `org.springframework.aop.support.DelegatingIntroductionInterceptor` convenience class. We could implement IntroductionInterceptor directly, but using `DelegatingIntroductionInterceptor` is best for most cases.

The `DelegatingIntroductionInterceptor` is designed to delegate an introduction to an actual implementation of the introduced interface(s), concealing the use of interception to do so. The delegate can be set to any object using a constructor argument; the default delegate (when the no-arg constructor is used) is this. Thus in the example below, the delegate is the `LockMixin` subclass of `DelegatingIntroductionInterceptor`. Given a delegate (by default itself), a `DelegatingIntroductionInterceptor` instance looks for all interfaces implemented by the delegate (other than IntroductionInterceptor), and will support introductions against any of them. It's possible for subclasses such as `LockMixin` to call the `suppressInterface(Class intf)` method to suppress interfaces that should not be exposed. However, no matter how many interfaces an `IntroductionInterceptor` is prepared to support, the `IntroductionAdvisor` used will control which interfaces are actually exposed. An introduced interface will conceal any implementation of the same interface by the target.

Thus LockMixin subclasses `DelegatingIntroductionInterceptor` and implements Lockable itself. The superclass automatically picks up that Lockable can be supported for introduction, so we don't need to specify that. We could introduce any number of interfaces in this way.

Note the use of the `locked` instance variable. This effectively adds additional state to that held in the target object.

```
public class LockMixin extends DelegatingIntroductionInterceptor implements Lockable {

    private boolean locked;

    public void lock() {
        this.locked = true;
    }

    public void unlock() {
        this.locked = false;
    }

    public boolean locked() {
        return this.locked;
    }

    public Object invoke(MethodInvocation invocation) throws Throwable {
        if (locked() && invocation.getMethod().getName().indexOf("set") == 0) {
            throw new LockedException();
        }
        return super.invoke(invocation);
    }

}
```

Often it isn't necessary to override the `invoke()` method: the `DelegatingIntroductionInterceptor` implementation - which calls the delegate method if the method is introduced, otherwise proceeds towards the join point - is usually sufficient. In the present case, we need to add a check: no setter method can be invoked if in locked mode.

The introduction advisor required is simple. All it needs to do is hold a distinct `LockMixin` instance, and specify the introduced interfaces - in this case, just `Lockable`. A more complex example might take a reference to the introduction interceptor (which would be defined as a prototype): in this case, there's no configuration relevant for a `LockMixin`, so we simply create it using `new`.

```
public class LockMixinAdvisor extends DefaultIntroductionAdvisor {

    public LockMixinAdvisor() {
        super(new LockMixin(), Lockable.class);
    }

}
```

We can apply this advisor very simply: it requires no configuration. (However, it *is* necessary: It's impossible to use an `IntroductionInterceptor` without an *IntroductionAdvisor*.) As usual with introductions, the advisor must be per-instance, as it is stateful. We need a different instance of `LockMixinAdvisor`, and hence `LockMixin`, for each advised object. The advisor comprises part of the advised object's state.

We can apply this advisor programmatically, using the `Advised.addAdvisor()` method, or (the recommended way) in XML configuration, like any other advisor. All proxy creation choices discussed below, including "auto proxy creators," correctly handle introductions and stateful mixins.

33.3 Advisor API in Spring

In Spring, an Advisor is an aspect that contains just a single advice object associated with a pointcut expression.

Apart from the special case of introductions, any advisor can be used with any advice. `org.springframework.aop.support.DefaultPointcutAdvisor` is the most commonly used

advisor class. For example, it can be used with a `MethodInterceptor`, `BeforeAdvice` or `ThrowsAdvice`.

It is possible to mix advisor and advice types in Spring in the same AOP proxy. For example, you could use a interception around advice, throws advice and before advice in one proxy configuration: Spring will automatically create the necessary interceptor chain.

33.4 Using the ProxyFactoryBean to create AOP proxies

If you're using the Spring IoC container (an ApplicationContext or BeanFactory) for your business objects - and you should be! - you will want to use one of Spring's AOP FactoryBeans. (Remember that a factory bean introduces a layer of indirection, enabling it to create objects of a different type.)

> **Note**
>
> The Spring 2.0 AOP support also uses factory beans under the covers.

The basic way to create an AOP proxy in Spring is to use the *org.springframework.aop.framework.ProxyFactoryBean*. This gives complete control over the pointcuts and advice that will apply, and their ordering. However, there are simpler options that are preferable if you don't need such control.

Basics

The `ProxyFactoryBean`, like other Spring `FactoryBean` implementations, introduces a level of indirection. If you define a `ProxyFactoryBean` with name `foo`, what objects referencing `foo` see is not the `ProxyFactoryBean` instance itself, but an object created by the `ProxyFactoryBean`'s implementation of the `getObject()` method. This method will create an AOP proxy wrapping a target object.

One of the most important benefits of using a `ProxyFactoryBean` or another IoC-aware class to create AOP proxies, is that it means that advices and pointcuts can also be managed by IoC. This is a powerful feature, enabling certain approaches that are hard to achieve with other AOP frameworks. For example, an advice may itself reference application objects (besides the target, which should be available in any AOP framework), benefiting from all the pluggability provided by Dependency Injection.

JavaBean properties

In common with most `FactoryBean` implementations provided with Spring, the `ProxyFactoryBean` class is itself a JavaBean. Its properties are used to:

- Specify the target you want to proxy.
- Specify whether to use CGLIB (see below and also the section called "JDK- and CGLIB-based proxies").

Some key properties are inherited from `org.springframework.aop.framework.ProxyConfig` (the superclass for all AOP proxy factories in Spring). These key properties include:

- `proxyTargetClass`: `true` if the target class is to be proxied, rather than the target class' interfaces. If this property value is set to `true`, then CGLIB proxies will be created (but see also below the section called "JDK- and CGLIB-based proxies").

- `optimize`: controls whether or not aggressive optimizations are applied to proxies *created via CGLIB*. One should not blithely use this setting unless one fully understands how the relevant AOP proxy handles optimization. This is currently used only for CGLIB proxies; it has no effect with JDK dynamic proxies.

- `frozen`: if a proxy configuration is `frozen`, then changes to the configuration are no longer allowed. This is useful both as a slight optimization and for those cases when you don't want callers to be able to manipulate the proxy (via the `Advised` interface) after the proxy has been created. The default value of this property is `false`, so changes such as adding additional advice are allowed.

- `exposeProxy`: determines whether or not the current proxy should be exposed in a `ThreadLocal` so that it can be accessed by the target. If a target needs to obtain the proxy and the `exposeProxy` property is set to `true`, the target can use the `AopContext.currentProxy()` method.

- `aopProxyFactory`: the implementation of `AopProxyFactory` to use. Offers a way of customizing whether to use dynamic proxies, CGLIB or any other proxy strategy. The default implementation will choose dynamic proxies or CGLIB appropriately. There should be no need to use this property; it is intended to allow the addition of new proxy types in Spring 1.1.

Other properties specific to `ProxyFactoryBean` include:

- `proxyInterfaces`: array of String interface names. If this isn't supplied, a CGLIB proxy for the target class will be used (but see also below the section called "JDK- and CGLIB-based proxies").

- `interceptorNames`: String array of `Advisor`, interceptor or other advice names to apply. Ordering is significant, on a first come-first served basis. That is to say that the first interceptor in the list will be the first to be able to intercept the invocation.

The names are bean names in the current factory, including bean names from ancestor factories. You can't mention bean references here since doing so would result in the `ProxyFactoryBean` ignoring the singleton setting of the advice.

You can append an interceptor name with an asterisk (`*`). This will result in the application of all advisor beans with names starting with the part before the asterisk to be applied. An example of using this feature can be found in the section called "Using *global* advisors".

- singleton: whether or not the factory should return a single object, no matter how often the `getObject()` method is called. Several `FactoryBean` implementations offer such a method. The default value is `true`. If you want to use stateful advice - for example, for stateful mixins - use prototype advices along with a singleton value of `false`.

JDK- and CGLIB-based proxies

This section serves as the definitive documentation on how the `ProxyFactoryBean` chooses to create one of either a JDK- and CGLIB-based proxy for a particular target object (that is to be proxied).

> **Note**
>
> The behavior of the `ProxyFactoryBean` with regard to creating JDK- or CGLIB-based proxies changed between versions 1.2.x and 2.0 of Spring. The `ProxyFactoryBean` now exhibits similar semantics with regard to auto-detecting interfaces as those of the `TransactionProxyFactoryBean` class.

If the class of a target object that is to be proxied (hereafter simply referred to as the target class) doesn't implement any interfaces, then a CGLIB-based proxy will be created. This is the easiest scenario, because JDK proxies are interface based, and no interfaces means JDK proxying isn't even possible. One simply plugs in the target bean, and specifies the list of interceptors via the `interceptorNames` property. Note that a CGLIB-based proxy will be created even if the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `false`. (Obviously this makes no sense, and is best removed from the bean definition because it is at best redundant, and at worst confusing.)

If the target class implements one (or more) interfaces, then the type of proxy that is created depends on the configuration of the `ProxyFactoryBean`.

If the `proxyTargetClass` property of the `ProxyFactoryBean` has been set to `true`, then a CGLIB-based proxy will be created. This makes sense, and is in keeping with the principle of least surprise. Even if the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, the fact that the `proxyTargetClass` property is set to `true` *will* cause CGLIB-based proxying to be in effect.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has been set to one or more fully qualified interface names, then a JDK-based proxy will be created. The created proxy will implement all of the interfaces that were specified in the `proxyInterfaces` property; if the target class happens to implement a whole lot more interfaces than those specified in the `proxyInterfaces` property, that is all well and good but those additional interfaces will not be implemented by the returned proxy.

If the `proxyInterfaces` property of the `ProxyFactoryBean` has *not* been set, but the target class *does implement one (or more)* interfaces, then the `ProxyFactoryBean` will auto-detect the fact that the target class does actually implement at least one interface, and a JDK-based proxy will be created. The interfaces that are actually proxied will be *all* of the interfaces that the target class implements; in effect, this is the same as simply supplying a list of each and every interface that the target class implements to the `proxyInterfaces` property. However, it is significantly less work, and less prone to typos.

Proxying interfaces

Let's look at a simple example of `ProxyFactoryBean` in action. This example involves:

- A *target bean* that will be proxied. This is the "personTarget" bean definition in the example below.
- An Advisor and an Interceptor used to provide advice.
- An AOP proxy bean definition specifying the target object (the personTarget bean) and the interfaces to proxy, along with the advices to apply.

```
<bean id="personTarget" class="com.mycompany.PersonImpl">
    <property name="name"><value>Tony</value></property>
    <property name="age"><value>51</value></property>
</bean>

<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty"><value>Custom string property value</value></property>
</bean>

<bean id="debugInterceptor" class="org.springframework.aop.interceptor.DebugInterceptor">
</bean>

<bean id="person" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces"><value>com.mycompany.Person</value></property>
    <property name="target"><ref bean="personTarget"/></property>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>
```

Note that the `interceptorNames` property takes a list of String: the bean names of the interceptor or advisors in the current factory. Advisors, interceptors, before, after returning and throws advice objects can be used. The ordering of advisors is significant.

> **Note**
>
> You might be wondering why the list doesn't hold bean references. The reason for this is that if the ProxyFactoryBean's singleton property is set to false, it must be able to return independent proxy instances. If any of the advisors is itself a prototype, an independent instance would need to be returned, so it's necessary to be able to obtain an instance of the prototype from the factory; holding a reference isn't sufficient.

The "person" bean definition above can be used in place of a Person implementation, as follows:

```
Person person = (Person) factory.getBean("person");
```

Other beans in the same IoC context can express a strongly typed dependency on it, as with an ordinary Java object:

```
<bean id="personUser" class="com.mycompany.PersonUser">
    <property name="person"><ref bean="person" /></property>
</bean>
```

The `PersonUser` class in this example would expose a property of type Person. As far as it's concerned, the AOP proxy can be used transparently in place of a "real" person implementation. However, its class would be a dynamic proxy class. It would be possible to cast it to the `Advised` interface (discussed below).

It's possible to conceal the distinction between target and proxy using an anonymous *inner bean*, as follows. Only the `ProxyFactoryBean` definition is different; the advice is included only for completeness:

```
<bean id="myAdvisor" class="com.mycompany.MyAdvisor">
    <property name="someProperty"><value>Custom string property value</value></property>
</bean>

<bean id="debugInterceptor" class="org.springframework.aop.interceptor.DebugInterceptor"/>

<bean id="person" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="proxyInterfaces"><value>com.mycompany.Person</value></property>
    <!-- Use inner bean, not local reference to target -->
    <property name="target">
        <bean class="com.mycompany.PersonImpl">
            <property name="name"><value>Tony</value></property>
            <property name="age"><value>51</value></property>
        </bean>
    </property>
    <property name="interceptorNames">
        <list>
            <value>myAdvisor</value>
            <value>debugInterceptor</value>
        </list>
    </property>
</bean>
```

This has the advantage that there's only one object of type `Person`: useful if we want to prevent users of the application context from obtaining a reference to the un-advised object, or need to avoid any ambiguity with Spring IoC *autowiring*. There's also arguably an advantage in that the ProxyFactoryBean definition is self-contained. However, there are times when being able to obtain the un-advised target from the factory might actually be an *advantage*: for example, in certain test scenarios.

Proxying classes

What if you need to proxy a class, rather than one or more interfaces?

Imagine that in our example above, there was no `Person` interface: we needed to advise a class called `Person` that didn't implement any business interface. In this case, you can configure Spring to use CGLIB proxying, rather than dynamic proxies. Simply set the `proxyTargetClass` property on the ProxyFactoryBean above to true. While it's best to program to interfaces, rather than classes, the ability to advise classes that don't implement interfaces can be useful when working with legacy code. (In general, Spring isn't prescriptive. While it makes it easy to apply good practices, it avoids forcing a particular approach.)

If you want to, you can force the use of CGLIB in any case, even if you do have interfaces.

CGLIB proxying works by generating a subclass of the target class at runtime. Spring configures this generated subclass to delegate method calls to the original target: the subclass is used to implement the *Decorator* pattern, weaving in the advice.

CGLIB proxying should generally be transparent to users. However, there are some issues to consider:

- `Final` methods can't be advised, as they can't be overridden.
- As of Spring 3.2 it is no longer required to add CGLIB to your project classpath. CGLIB classes have been repackaged under org.springframework and included directly in the spring-core JAR. This is both for user convenience as well as to avoid potential conflicts with other projects that have dependence on a differing version of CGLIB.

There's little performance difference between CGLIB proxying and dynamic proxies. As of Spring 1.0, dynamic proxies are slightly faster. However, this may change in the future. Performance should not be a decisive consideration in this case.

Using *global* advisors

By appending an asterisk to an interceptor name, all advisors with bean names matching the part before the asterisk, will be added to the advisor chain. This can come in handy if you need to add a standard set of *global* advisors:

```
<bean id="proxy" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="target" ref="service"/>
    <property name="interceptorNames">
        <list>
            <value>global*</value>
        </list>
    </property>
</bean>

<bean id="global_debug" class="org.springframework.aop.interceptor.DebugInterceptor"/>
<bean id="global_performance" class="org.springframework.aop.interceptor.PerformanceMonitorInterceptor"/
>
```

33.5 Concise proxy definitions

Especially when defining transactional proxies, you may end up with many similar proxy definitions. The use of parent and child bean definitions, along with inner bean definitions, can result in much cleaner and more concise proxy definitions.

First a parent, *template*, bean definition is created for the proxy:

```
<bean id="txProxyTemplate" abstract="true"
        class="org.springframework.transaction.interceptor.TransactionProxyFactoryBean">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributes">
        <props>
            <prop key="*">PROPAGATION_REQUIRED</prop>
        </props>
    </property>
</bean>
```

This will never be instantiated itself, so may actually be incomplete. Then each proxy which needs to be created is just a child bean definition, which wraps the target of the proxy as an inner bean definition, since the target will never be used on its own anyway.

```
<bean id="myService" parent="txProxyTemplate">
    <property name="target">
        <bean class="org.springframework.samples.MyServiceImpl">
        </bean>
    </property>
</bean>
```

It is of course possible to override properties from the parent template, such as in this case, the transaction propagation settings:

```
<bean id="mySpecialService" parent="txProxyTemplate">
    <property name="target">
        <bean class="org.springframework.samples.MySpecialServiceImpl">
        </bean>
    </property>
    <property name="transactionAttributes">
        <props>
            <prop key="get*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="find*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="load*">PROPAGATION_REQUIRED,readOnly</prop>
            <prop key="store*">PROPAGATION_REQUIRED</prop>
        </props>
    </property>
</bean>
```

Note that in the example above, we have explicitly marked the parent bean definition as *abstract* by using the *abstract* attribute, as described previously, so that it may not actually ever be instantiated. Application contexts (but not simple bean factories) will by default pre-instantiate all singletons. It is therefore important (at least for singleton beans) that if you have a (parent) bean definition which you intend to use only as a template, and this definition specifies a class, you must make sure to set the*abstract* attribute to *true*, otherwise the application context will actually try to pre-instantiate it.

33.6 Creating AOP proxies programmatically with the ProxyFactory

It's easy to create AOP proxies programmatically using Spring. This enables you to use Spring AOP without dependency on Spring IoC.

The following listing shows creation of a proxy for a target object, with one interceptor and one advisor. The interfaces implemented by the target object will automatically be proxied:

```
ProxyFactory factory = new ProxyFactory(myBusinessInterfaceImpl);
factory.addInterceptor(myMethodInterceptor);
factory.addAdvisor(myAdvisor);
MyBusinessInterface tb = (MyBusinessInterface) factory.getProxy();
```

The first step is to construct an object of type `org.springframework.aop.framework.ProxyFactory`. You can create this with a target object, as in the above example, or specify the interfaces to be proxied in an alternate constructor.

You can add interceptors or advisors, and manipulate them for the life of the ProxyFactory. If you add an IntroductionInterceptionAroundAdvisor you can cause the proxy to implement additional interfaces.

There are also convenience methods on ProxyFactory (inherited from `AdvisedSupport`) which allow you to add other advice types such as before and throws advice. AdvisedSupport is the superclass of both ProxyFactory and ProxyFactoryBean.

> **Tip**
>
> Integrating AOP proxy creation with the IoC framework is best practice in most applications. We recommend that you externalize configuration from Java code with AOP, as in general.

33.7 Manipulating advised objects

However you create AOP proxies, you can manipulate them using the `org.springframework.aop.framework.Advised` interface. Any AOP proxy can be cast to this interface, whichever other interfaces it implements. This interface includes the following methods:

```
Advisor[] getAdvisors();

void addAdvice(Advice advice) throws AopConfigException;

void addAdvice(int pos, Advice advice) throws AopConfigException;

void addAdvisor(Advisor advisor) throws AopConfigException;

void addAdvisor(int pos, Advisor advisor) throws AopConfigException;

int indexOf(Advisor advisor);

boolean removeAdvisor(Advisor advisor) throws AopConfigException;

void removeAdvisor(int index) throws AopConfigException;

boolean replaceAdvisor(Advisor a, Advisor b) throws AopConfigException;

boolean isFrozen();
```

The `getAdvisors()` method will return an Advisor for every advisor, interceptor or other advice type that has been added to the factory. If you added an Advisor, the returned advisor at this index will be the object that you added. If you added an interceptor or other advice type, Spring will have wrapped this in an advisor with a pointcut that always returns true. Thus if you added a `MethodInterceptor`, the advisor returned for this index will be an `DefaultPointcutAdvisor` returning your `MethodInterceptor` and a pointcut that matches all classes and methods.

The `addAdvisor()` methods can be used to add any Advisor. Usually the advisor holding pointcut and advice will be the generic `DefaultPointcutAdvisor`, which can be used with any advice or pointcut (but not for introductions).

By default, it's possible to add or remove advisors or interceptors even once a proxy has been created. The only restriction is that it's impossible to add or remove an introduction advisor, as existing proxies from the factory will not show the interface change. (You can obtain a new proxy from the factory to avoid this problem.)

A simple example of casting an AOP proxy to the `Advised` interface and examining and manipulating its advice:

```
Advised advised = (Advised) myObject;
Advisor[] advisors = advised.getAdvisors();
int oldAdvisorCount = advisors.length;
System.out.println(oldAdvisorCount + " advisors");

// Add an advice like an interceptor without a pointcut
// Will match all proxied methods
// Can use for interceptors, before, after returning or throws advice
advised.addAdvice(new DebugInterceptor());

// Add selective advice using a pointcut
advised.addAdvisor(new DefaultPointcutAdvisor(mySpecialPointcut, myAdvice));

assertEquals("Added two advisors", oldAdvisorCount + 2, advised.getAdvisors().length);
```

> **Note**
>
> It's questionable whether it's advisable (no pun intended) to modify advice on a business object in production, although there are no doubt legitimate usage cases. However, it can be very useful in development: for example, in tests. I have sometimes found it very useful to be able to add test code in the form of an interceptor or other advice, getting inside a method invocation I want to test.

> (For example, the advice can get inside a transaction created for that method: for example, to run SQL to check that a database was correctly updated, before marking the transaction for roll back.)

Depending on how you created the proxy, you can usually set a `frozen` flag, in which case the `Advised` `isFrozen()` method will return true, and any attempts to modify advice through addition or removal will result in an `AopConfigException`. The ability to freeze the state of an advised object is useful in some cases, for example, to prevent calling code removing a security interceptor. It may also be used in Spring 1.1 to allow aggressive optimization if runtime advice modification is known not to be required.

33.8 Using the "autoproxy" facility

So far we've considered explicit creation of AOP proxies using a `ProxyFactoryBean` or similar factory bean.

Spring also allows us to use "autoproxy" bean definitions, which can automatically proxy selected bean definitions. This is built on Spring "bean post processor" infrastructure, which enables modification of any bean definition as the container loads.

In this model, you set up some special bean definitions in your XML bean definition file to configure the auto proxy infrastructure. This allows you just to declare the targets eligible for autoproxying: you don't need to use `ProxyFactoryBean`.

There are two ways to do this:

- Using an autoproxy creator that refers to specific beans in the current context.
- A special case of autoproxy creation that deserves to be considered separately; autoproxy creation driven by source-level metadata attributes.

Autoproxy bean definitions

The `org.springframework.aop.framework.autoproxy` package provides the following standard autoproxy creators.

BeanNameAutoProxyCreator

The `BeanNameAutoProxyCreator` class is a `BeanPostProcessor` that automatically creates AOP proxies for beans with names matching literal values or wildcards.

```
<bean class="org.springframework.aop.framework.autoproxy.BeanNameAutoProxyCreator">
    <property name="beanNames"><value>jdk*,onlyJdk</value></property>
    <property name="interceptorNames">
        <list>
            <value>myInterceptor</value>
        </list>
    </property>
</bean>
```

As with `ProxyFactoryBean`, there is an `interceptorNames` property rather than a list of interceptors, to allow correct behavior for prototype advisors. Named "interceptors" can be advisors or any advice type.

As with auto proxying in general, the main point of using `BeanNameAutoProxyCreator` is to apply the same configuration consistently to multiple objects, with minimal volume of configuration. It is a popular choice for applying declarative transactions to multiple objects.

Bean definitions whose names match, such as "jdkMyBean" and "onlyJdk" in the above example, are plain old bean definitions with the target class. An AOP proxy will be created automatically by the `BeanNameAutoProxyCreator`. The same advice will be applied to all matching beans. Note that if advisors are used (rather than the interceptor in the above example), the pointcuts may apply differently to different beans.

DefaultAdvisorAutoProxyCreator

A more general and extremely powerful auto proxy creator is `DefaultAdvisorAutoProxyCreator`. This will automagically apply eligible advisors in the current context, without the need to include specific bean names in the autoproxy advisor's bean definition. It offers the same merit of consistent configuration and avoidance of duplication as `BeanNameAutoProxyCreator`.

Using this mechanism involves:

- Specifying a `DefaultAdvisorAutoProxyCreator` bean definition.
- Specifying any number of Advisors in the same or related contexts. Note that these *must* be Advisors, not just interceptors or other advices. This is necessary because there must be a pointcut to evaluate, to check the eligibility of each advice to candidate bean definitions.

The `DefaultAdvisorAutoProxyCreator` will automatically evaluate the pointcut contained in each advisor, to see what (if any) advice it should apply to each business object (such as "businessObject1" and "businessObject2" in the example).

This means that any number of advisors can be applied automatically to each business object. If no pointcut in any of the advisors matches any method in a business object, the object will not be proxied. As bean definitions are added for new business objects, they will automatically be proxied if necessary.

Autoproxying in general has the advantage of making it impossible for callers or dependencies to obtain an un-advised object. Calling getBean("businessObject1") on this ApplicationContext will return an AOP proxy, not the target business object. (The "inner bean" idiom shown earlier also offers this benefit.)

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="customAdvisor" class="com.mycompany.MyAdvisor"/>

<bean id="businessObject1" class="com.mycompany.BusinessObject1">
    <!-- Properties omitted -->
</bean>

<bean id="businessObject2" class="com.mycompany.BusinessObject2"/>
```

The `DefaultAdvisorAutoProxyCreator` is very useful if you want to apply the same advice consistently to many business objects. Once the infrastructure definitions are in place, you can simply add new business objects without including specific proxy configuration. You can also drop in additional aspects very easily - for example, tracing or performance monitoring aspects - with minimal change to configuration.

The DefaultAdvisorAutoProxyCreator offers support for filtering (using a naming convention so that only certain advisors are evaluated, allowing use of multiple, differently configured, AdvisorAutoProxyCreators in the same factory) and ordering. Advisors can implement the

`org.springframework.core.Ordered` interface to ensure correct ordering if this is an issue. The TransactionAttributeSourceAdvisor used in the above example has a configurable order value; the default setting is unordered.

AbstractAdvisorAutoProxyCreator

This is the superclass of DefaultAdvisorAutoProxyCreator. You can create your own autoproxy creators by subclassing this class, in the unlikely event that advisor definitions offer insufficient customization to the behavior of the framework `DefaultAdvisorAutoProxyCreator`.

Using metadata-driven auto-proxying

A particularly important type of autoproxying is driven by metadata. This produces a similar programming model to .NET `ServicedComponents`. Instead of using XML deployment descriptors as in EJB, configuration for transaction management and other enterprise services is held in source-level attributes.

In this case, you use the `DefaultAdvisorAutoProxyCreator`, in combination with Advisors that understand metadata attributes. The metadata specifics are held in the pointcut part of the candidate advisors, rather than in the autoproxy creation class itself.

This is really a special case of the `DefaultAdvisorAutoProxyCreator`, but deserves consideration on its own. (The metadata-aware code is in the pointcuts contained in the advisors, not the AOP framework itself.)

The `/attributes` directory of the JPetStore sample application shows the use of attribute-driven autoproxying. In this case, there's no need to use the `TransactionProxyFactoryBean`. Simply defining transactional attributes on business objects is sufficient, because of the use of metadata-aware pointcuts. The bean definitions include the following code, in `/WEB-INF/declarativeServices.xml`. Note that this is generic, and can be used outside the JPetStore:

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="transactionInterceptor"
        class="org.springframework.transaction.interceptor.TransactionInterceptor">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributeSource">
        <bean class="org.springframework.transaction.interceptor.AttributesTransactionAttributeSource">
            <property name="attributes" ref="attributes"/>
        </bean>
    </property>
</bean>

<bean id="attributes" class="org.springframework.metadata.commons.CommonsAttributes"/>
```

The `DefaultAdvisorAutoProxyCreator` bean definition (the name is not significant, hence it can even be omitted) will pick up all eligible pointcuts in the current application context. In this case, the "transactionAdvisor" bean definition, of type `TransactionAttributeSourceAdvisor`, will apply to classes or methods carrying a transaction attribute. The TransactionAttributeSourceAdvisor depends on a TransactionInterceptor, via constructor dependency. The example resolves this via autowiring. The `AttributesTransactionAttributeSource` depends on an implementation of the `org.springframework.metadata.Attributes` interface. In this fragment, the "attributes" bean satisfies this, using the Jakarta Commons Attributes API to obtain attribute information. (The application code must have been compiled using the Commons Attributes compilation task.)

The `/annotation` directory of the JPetStore sample application contains an analogous example for auto-proxying driven by JDK 1.5+ annotations. The following configuration enables automatic detection of Spring's `Transactional` annotation, leading to implicit proxies for beans containing that annotation:

```
<bean class="org.springframework.aop.framework.autoproxy.DefaultAdvisorAutoProxyCreator"/>

<bean class="org.springframework.transaction.interceptor.TransactionAttributeSourceAdvisor">
    <property name="transactionInterceptor" ref="transactionInterceptor"/>
</bean>

<bean id="transactionInterceptor"
        class="org.springframework.transaction.interceptor.TransactionInterceptor">
    <property name="transactionManager" ref="transactionManager"/>
    <property name="transactionAttributeSource">
        <bean class="org.springframework.transaction.annotation.AnnotationTransactionAttributeSource"/>
    </property>
</bean>
```

The `TransactionInterceptor` defined here depends on a `PlatformTransactionManager` definition, which is not included in this generic file (although it could be) because it will be specific to the application's transaction requirements (typically JTA, as in this example, or Hibernate, JDO or JDBC):

```
<bean id="transactionManager"
        class="org.springframework.transaction.jta.JtaTransactionManager"/>
```

> **Tip**
>
> If you require only declarative transaction management, using these generic XML definitions will result in Spring automatically proxying all classes or methods with transaction attributes. You won't need to work directly with AOP, and the programming model is similar to that of .NET ServicedComponents.

This mechanism is extensible. It's possible to do autoproxying based on custom attributes. You need to:

- Define your custom attribute.
- Specify an Advisor with the necessary advice, including a pointcut that is triggered by the presence of the custom attribute on a class or method. You may be able to use an existing advice, merely implementing a static pointcut that picks up the custom attribute.

It's possible for such advisors to be unique to each advised class (for example, mixins): they simply need to be defined as prototype, rather than singleton, bean definitions. For example, the `LockMixin` introduction interceptor from the Spring test suite, shown above, could be used in conjunction with an attribute-driven pointcut to target a mixin, as shown here. We use the generic `DefaultPointcutAdvisor`, configured using JavaBean properties:

```
<bean id="lockMixin" class="org.springframework.aop.LockMixin"
        scope="prototype"/>

<bean id="lockableAdvisor" class="org.springframework.aop.support.DefaultPointcutAdvisor"
        scope="prototype">
    <property name="pointcut" ref="myAttributeAwarePointcut"/>
    <property name="advice" ref="lockMixin"/>
</bean>

<bean id="anyBean" class="anyclass" ...
```

If the attribute aware pointcut matches any methods in the `anyBean` or other bean definitions, the mixin will be applied. Note that both `lockMixin` and `lockableAdvisor` definitions are prototypes.

The `myAttributeAwarePointcut` pointcut can be a singleton definition, as it doesn't hold state for individual advised objects.

33.9 Using TargetSources

Spring offers the concept of a *TargetSource*, expressed in the `org.springframework.aop.TargetSource` interface. This interface is responsible for returning the "target object" implementing the join point. The `TargetSource` implementation is asked for a target instance each time the AOP proxy handles a method invocation.

Developers using Spring AOP don't normally need to work directly with TargetSources, but this provides a powerful means of supporting pooling, hot swappable and other sophisticated targets. For example, a pooling TargetSource can return a different target instance for each invocation, using a pool to manage instances.

If you do not specify a TargetSource, a default implementation is used that wraps a local object. The same target is returned for each invocation (as you would expect).

Let's look at the standard target sources provided with Spring, and how you can use them.

> **Tip**
>
> When using a custom target source, your target will usually need to be a prototype rather than a singleton bean definition. This allows Spring to create a new target instance when required.

Hot swappable target sources

The `org.springframework.aop.target.HotSwappableTargetSource` exists to allow the target of an AOP proxy to be switched while allowing callers to keep their references to it.

Changing the target source's target takes effect immediately. The `HotSwappableTargetSource` is threadsafe.

You can change the target via the `swap()` method on HotSwappableTargetSource as follows:

```
HotSwappableTargetSource swapper = (HotSwappableTargetSource) beanFactory.getBean("swapper");
Object oldTarget = swapper.swap(newTarget);
```

The XML definitions required look as follows:

```
<bean id="initialTarget" class="mycompany.OldTarget"/>

<bean id="swapper" class="org.springframework.aop.target.HotSwappableTargetSource">
    <constructor-arg ref="initialTarget"/>
</bean>

<bean id="swappable" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="swapper"/>
</bean>
```

The above `swap()` call changes the target of the swappable bean. Clients who hold a reference to that bean will be unaware of the change, but will immediately start hitting the new target.

Although this example doesn't add any advice - and it's not necessary to add advice to use a `TargetSource` - of course any `TargetSource` can be used in conjunction with arbitrary advice.

Pooling target sources

Using a pooling target source provides a similar programming model to stateless session EJBs, in which a pool of identical instances is maintained, with method invocations going to free objects in the pool.

A crucial difference between Spring pooling and SLSB pooling is that Spring pooling can be applied to any POJO. As with Spring in general, this service can be applied in a non-invasive way.

Spring provides out-of-the-box support for Jakarta Commons Pool 1.3, which provides a fairly efficient pooling implementation. You'll need the commons-pool Jar on your application's classpath to use this feature. It's also possible to subclass `org.springframework.aop.target.AbstractPoolingTargetSource` to support any other pooling API.

Sample configuration is shown below:

```
<bean id="businessObjectTarget" class="com.mycompany.MyBusinessObject" scope="prototype">
    ... properties omitted
</bean>

<bean id="poolTargetSource" class="org.springframework.aop.target.CommonsPoolTargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
    <property name="maxSize" value="25"/>
</bean>

<bean id="businessObject" class="org.springframework.aop.framework.ProxyFactoryBean">
    <property name="targetSource" ref="poolTargetSource"/>
    <property name="interceptorNames" value="myInterceptor"/>
</bean>
```

Note that the target object - "businessObjectTarget" in the example - *must* be a prototype. This allows the `PoolingTargetSource` implementation to create new instances of the target to grow the pool as necessary. See the Javadoc for `AbstractPoolingTargetSource` and the concrete subclass you wish to use for information about its properties: "maxSize" is the most basic, and always guaranteed to be present.

In this case, "myInterceptor" is the name of an interceptor that would need to be defined in the same IoC context. However, it isn't necessary to specify interceptors to use pooling. If you want only pooling, and no other advice, don't set the interceptorNames property at all.

It's possible to configure Spring so as to be able to cast any pooled object to the `org.springframework.aop.target.PoolingConfig` interface, which exposes information about the configuration and current size of the pool through an introduction. You'll need to define an advisor like this:

```
<bean id="poolConfigAdvisor" class="org.springframework.beans.factory.config.MethodInvokingFactoryBean">
    <property name="targetObject" ref="poolTargetSource"/>
    <property name="targetMethod" value="getPoolingConfigMixin"/>
</bean>
```

This advisor is obtained by calling a convenience method on the `AbstractPoolingTargetSource` class, hence the use of MethodInvokingFactoryBean. This advisor's name ("poolConfigAdvisor" here) must be in the list of interceptors names in the ProxyFactoryBean exposing the pooled object.

The cast will look as follows:

```
PoolingConfig conf = (PoolingConfig) beanFactory.getBean("businessObject");
System.out.println("Max pool size is " + conf.getMaxSize());
```

> **Note**
>
> Pooling stateless service objects is not usually necessary. We don't believe it should be the default choice, as most stateless objects are naturally thread safe, and instance pooling is problematic if resources are cached.

Simpler pooling is available using autoproxying. It's possible to set the TargetSources used by any autoproxy creator.

Prototype target sources

Setting up a "prototype" target source is similar to a pooling TargetSource. In this case, a new instance of the target will be created on every method invocation. Although the cost of creating a new object isn't high in a modern JVM, the cost of wiring up the new object (satisfying its IoC dependencies) may be more expensive. Thus you shouldn't use this approach without very good reason.

To do this, you could modify the `poolTargetSource` definition shown above as follows. (I've also changed the name, for clarity.)

```
<bean id="prototypeTargetSource" class="org.springframework.aop.target.PrototypeTargetSource">
    <property name="targetBeanName" ref="businessObjectTarget"/>
</bean>
```

There's only one property: the name of the target bean. Inheritance is used in the TargetSource implementations to ensure consistent naming. As with the pooling target source, the target bean must be a prototype bean definition.

ThreadLocal target sources

`ThreadLocal` target sources are useful if you need an object to be created for each incoming request (per thread that is). The concept of a `ThreadLocal` provide a JDK-wide facility to transparently store resource alongside a thread. Setting up a `ThreadLocalTargetSource` is pretty much the same as was explained for the other types of target source:

```
<bean id="threadlocalTargetSource" class="org.springframework.aop.target.ThreadLocalTargetSource">
    <property name="targetBeanName" value="businessObjectTarget"/>
</bean>
```

> **Note**
>
> ThreadLocals come with serious issues (potentially resulting in memory leaks) when incorrectly using them in a multi-threaded and multi-classloader environments. One should always consider wrapping a threadlocal in some other class and never directly use the `ThreadLocal` itself (except of course in the wrapper class). Also, one should always remember to correctly set and unset (where the latter simply involved a call to `ThreadLocal.set(null)`) the resource local to the thread. Unsetting should be done in any case since not unsetting it might result in problematic behavior. Spring's ThreadLocal support does this for you and should always be considered in favor of using ThreadLocals without other proper handling code.

33.10 Defining new Advice types

Spring AOP is designed to be extensible. While the interception implementation strategy is presently used internally, it is possible to support arbitrary advice types in addition to the out-of-the-box interception around advice, before, throws advice and after returning advice.

The `org.springframework.aop.framework.adapter` package is an SPI package allowing support for new custom advice types to be added without changing the core framework. The only constraint on a custom `Advice` type is that it must implement the `org.aopalliance.aop.Advice` tag interface.

Please refer to the `org.springframework.aop.framework.adapter` package's Javadocs for further information.

33.11 Further resources

Please refer to the Spring sample applications for further examples of Spring AOP:

- The JPetStore's default configuration illustrates the use of the `TransactionProxyFactoryBean` for declarative transaction management.
- The `/attributes` directory of the JPetStore illustrates the use of attribute-driven declarative transaction management.

34. XML Schema-based configuration

34.1 Introduction

This appendix details the XML Schema-based configuration introduced in Spring 2.0 and enhanced and extended in Spring 2.5 and 3.0.

> **DTD support?**
>
> Authoring Spring configuration files using the older DTD style is still fully supported.
>
> Nothing will break if you forego the use of the new XML Schema-based approach to authoring Spring XML configuration files. All that you lose out on is the opportunity to have more succinct and clearer configuration. Regardless of whether the XML configuration is DTD- or Schema-based, in the end it all boils down to the same object model in the container (namely one or more `BeanDefinition` instances).

The central motivation for moving to XML Schema based configuration files was to make Spring XML configuration easier. The *'classic'* `<bean/>`-based approach is good, but its generic-nature comes with a price in terms of configuration overhead.

From the Spring IoC containers point-of-view, *everything* is a bean. That's great news for the Spring IoC container, because if everything is a bean then everything can be treated in the exact same fashion. The same, however, is not true from a developer's point-of-view. The objects defined in a Spring XML configuration file are not all generic, vanilla beans. Usually, each bean requires some degree of specific configuration.

Spring 2.0's new XML Schema-based configuration addresses this issue. The `<bean/>` element is still present, and if you wanted to, you could continue to write the *exact same* style of Spring XML configuration using only `<bean/>` elements. The new XML Schema-based configuration does, however, make Spring XML configuration files substantially clearer to read. In addition, it allows you to express the intent of a bean definition.

The key thing to remember is that the new custom tags work best for infrastructure or integration beans: for example, AOP, collections, transactions, integration with 3rd-party frameworks such as Mule, etc., while the existing bean tags are best suited to application-specific beans, such as DAOs, service layer objects, validators, etc.

The examples included below will hopefully convince you that the inclusion of XML Schema support in Spring 2.0 was a good idea. The reception in the community has been encouraging; also, please note the fact that this new configuration mechanism is totally customisable and extensible. This means you can write your own domain-specific configuration tags that would better represent your application's domain; the process involved in doing so is covered in the appendix entitled Chapter 35, *Extensible XML authoring*.

34.2 XML Schema-based configuration

Referencing the schemas

To switch over from the DTD-style to the new XML Schema-style, you need to make the following change.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE beans PUBLIC "-//SPRING//DTD BEAN 2.0//EN"
        "http://www.springframework.org/dtd/spring-beans-2.0.dtd">

<beans>

<!-- bean definitions here -->

</beans>
```

The equivalent file in the XML Schema-style would be…

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd">

    <!-- bean definitions here -->

</beans>
```

> **Note**
>
> The `'xsi:schemaLocation'` fragment is not actually required, but can be included to reference a local copy of a schema (which can be useful during development).

The above Spring XML configuration fragment is boilerplate that you can copy and paste (!) and then plug `<bean/>` definitions into like you have always done. However, the entire point of switching over is to take advantage of the new Spring 2.0 XML tags since they make configuration easier. The section entitled the section called “the util schema” demonstrates how you can start immediately by using some of the more common utility tags.

The rest of this chapter is devoted to showing examples of the new Spring XML Schema based configuration, with at least one example for every new tag. The format follows a before and after style, with a *before* snippet of XML showing the old (but still 100% legal and supported) style, followed immediately by an *after* example showing the equivalent in the new XML Schema-based style.

the util schema

First up is coverage of the `util` tags. As the name implies, the `util` tags deal with common, *utility* configuration issues, such as configuring collections, referencing constants, and suchlike.

To use the tags in the `util` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the snippet below references the correct schema so that the tags in the `util` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:util="http://www.springframework.org/schema/util" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/util http://www.springframework.org/schema/util/spring-
util.xsd"> <!-- bean definitions here -->

</beans>
```

<util:constant/>

Before…

```
<bean id="..." class="...">
    <property name="isolation">
        <bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
                class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean" />
    </property>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `FieldRetrievingFactoryBean`, to set the value of the `isolation` property on a bean to the value of the `java.sql.Connection.TRANSACTION_SERIALIZABLE` constant. This is all well and good, but it is a tad verbose and (unnecessarily) exposes Spring's internal plumbing to the end user.

The following XML Schema-based version is more concise and clearly expresses the developer's intent (*'inject this constant value'*), and it just reads better.

```
<bean id="..." class="...">
    <property name="isolation">
        <util:constant static-field="java.sql.Connection.TRANSACTION_SERIALIZABLE"/>
    </property>
</bean>
```

Setting a bean property or constructor arg from a field value

`FieldRetrievingFactoryBean` is a `FactoryBean` which retrieves a `static` or non-static field value. It is typically used for retrieving `public static final` constants, which may then be used to set a property value or constructor arg for another bean.

Find below an example which shows how a `static` field is exposed, by using the `staticField` property:

```
<bean id="myField"
        class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean">
    <property name="staticField" value="java.sql.Connection.TRANSACTION_SERIALIZABLE"/>
</bean>
```

There is also a convenience usage form where the `static` field is specified as the bean name:

```
<bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
        class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean"/>
```

This does mean that there is no longer any choice in what the bean id is (so any other bean that refers to it will also have to use this longer name), but this form is very concise to define, and very convenient to use as an inner bean since the id doesn't have to be specified for the bean reference:

```
<bean id="..." class="...">
    <property name="isolation">
        <bean id="java.sql.Connection.TRANSACTION_SERIALIZABLE"
                class="org.springframework.beans.factory.config.FieldRetrievingFactoryBean" />
    </property>
</bean>
```

It is also possible to access a non-static (instance) field of another bean, as described in the API documentation for the `FieldRetrievingFactoryBean` class.

Injecting enum values into beans as either property or constructor arguments is very easy to do in Spring, in that you don't actually have to *do* anything or know anything about the Spring internals (or

even about classes such as the `FieldRetrievingFactoryBean`). Let's look at an example to see how easy injecting an enum value is; consider this JDK 5 enum:

```
package javax.persistence;

public enum PersistenceContextType {

    TRANSACTION,
    EXTENDED

}
```

Now consider a setter of type `PersistenceContextType`:

```
package example;

public class Client {

    private PersistenceContextType persistenceContextType;

    public void setPersistenceContextType(PersistenceContextType type) {
        this.persistenceContextType = type;
    }

}
```

a. and the corresponding bean definition:

```
<bean class="example.Client">
    <property name="persistenceContextType" value="TRANSACTION" />
</bean>
```

This works for classic type-safe emulated enums (on JDK 1.4 and JDK 1.3) as well; Spring will automatically attempt to match the string property value to a constant on the enum class.

<util:property-path/>

Before…

```
<!-- target bean to be referenced by name -->
<bean id="testBean" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

<!-- will result in 10, which is the value of property age of bean testBean -->
<bean id="testBean.age" class="org.springframework.beans.factory.config.PropertyPathFactoryBean"/>
```

The above configuration uses a Spring `FactoryBean` implementation, the `PropertyPathFactoryBean`, to create a bean (of type `int`) called `testBean.age` that has a value equal to the `age` property of the `testBean` bean.

After…

```
<!-- target bean to be referenced by name -->
<bean id="testBean" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

<!-- will result in 10, which is the value of property age of bean testBean -->
<util:property-path id="name" path="testBean.age"/>
```

The value of the `path` attribute of the `<property-path/>` tag follows the form `beanName.beanProperty`.

Using <util:property-path/> to set a bean property or constructor-argument

`PropertyPathFactoryBean` is a `FactoryBean` that evaluates a property path on a given target object. The target object can be specified directly or via a bean name. This value may then be used in another bean definition as a property value or constructor argument.

Here's an example where a path is used against another bean, by name:

```
// target bean to be referenced by name
<bean id="person" class="org.springframework.beans.TestBean" scope="prototype">
    <property name="age" value="10"/>
    <property name="spouse">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="11"/>
        </bean>
    </property>
</bean>

// will result in 11, which is the value of property spouse.age of bean person
<bean id="theAge"
        class="org.springframework.beans.factory.config.PropertyPathFactoryBean">
    <property name="targetBeanName" value="person"/>
    <property name="propertyPath" value="spouse.age"/>
</bean>
```

In this example, a path is evaluated against an inner bean:

```
<!-- will result in 12, which is the value of property age of the inner bean -->
<bean id="theAge"
        class="org.springframework.beans.factory.config.PropertyPathFactoryBean">
    <property name="targetObject">
        <bean class="org.springframework.beans.TestBean">
            <property name="age" value="12"/>
        </bean>
    </property>
    <property name="propertyPath" value="age"/>
</bean>
```

There is also a shortcut form, where the bean name is the property path.

```
<!-- will result in 10, which is the value of property age of bean person -->
<bean id="person.age"
        class="org.springframework.beans.factory.config.PropertyPathFactoryBean"/>
```

This form does mean that there is no choice in the name of the bean. Any reference to it will also have to use the same id, which is the path. Of course, if used as an inner bean, there is no need to refer to it at all:

```
<bean id="..." class="...">
    <property name="age">
        <bean id="person.age"
                class="org.springframework.beans.factory.config.PropertyPathFactoryBean"/>
    </property>
</bean>
```

The result type may be specifically set in the actual definition. This is not necessary for most use cases, but can be of use for some. Please see the Javadocs for more info on this feature.

<util:properties/>

Before…

```
<!-- creates a java.util.Properties instance with values loaded from the supplied location -->
<bean id="jdbcConfiguration" class="org.springframework.beans.factory.config.PropertiesFactoryBean">
    <property name="location" value="classpath:com/foo/jdbc-production.properties"/>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `PropertiesFactoryBean`, to instantiate a `java.util.Properties` instance with values loaded from the supplied `Resource` location).

After…

```
<!-- creates a java.util.Properties instance with values loaded from the supplied location -->
<util:properties id="jdbcConfiguration" location="classpath:com/foo/jdbc-production.properties"/>
```

<util:list/>

Before…

```
<!-- creates a java.util.List instance with values loaded from the supplied sourceList -->
<bean id="emails" class="org.springframework.beans.factory.config.ListFactoryBean">
    <property name="sourceList">
        <list>
            <value>pechorin@hero.org</value>
            <value>raskolnikov@slums.org</value>
            <value>stavrogin@gov.org</value>
            <value>porfiry@gov.org</value>
        </list>
    </property>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `ListFactoryBean`, to create a `java.util.List` instance initialized with values taken from the supplied `sourceList`.

After…

```
<!-- creates a java.util.List instance with the supplied values -->
<util:list id="emails">
    <value>pechorin@hero.org</value>
    <value>raskolnikov@slums.org</value>
    <value>stavrogin@gov.org</value>
    <value>porfiry@gov.org</value>
</util:list>
```

You can also explicitly control the exact type of `List` that will be instantiated and populated via the use of the `list-class` attribute on the `<util:list/>` element. For example, if we really need a `java.util.LinkedList` to be instantiated, we could use the following configuration:

```
<util:list id="emails" list-class="java.util.LinkedList">
    <value>jackshaftoe@vagabond.org</value>
    <value>eliza@thinkingmanscrumpet.org</value>
    <value>vanhoek@pirate.org</value>
    <value>d'Arcachon@nemesis.org</value>
</util:list>
```

If no `list-class` attribute is supplied, a `List` implementation will be chosen by the container.

<util:map/>

Before…

```
<!-- creates a java.util.Map instance with values loaded from the supplied sourceMap -->
<bean id="emails" class="org.springframework.beans.factory.config.MapFactoryBean">
    <property name="sourceMap">
        <map>
            <entry key="pechorin" value="pechorin@hero.org"/>
            <entry key="raskolnikov" value="raskolnikov@slums.org"/>
            <entry key="stavrogin" value="stavrogin@gov.org"/>
            <entry key="porfiry" value="porfiry@gov.org"/>
        </map>
    </property>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `MapFactoryBean`, to create a `java.util.Map` instance initialized with key-value pairs taken from the supplied `'sourceMap'`.

After…

```
<!-- creates a java.util.Map instance with the supplied key-value pairs -->
<util:map id="emails">
    <entry key="pechorin" value="pechorin@hero.org"/>
    <entry key="raskolnikov" value="raskolnikov@slums.org"/>
    <entry key="stavrogin" value="stavrogin@gov.org"/>
    <entry key="porfiry" value="porfiry@gov.org"/>
</util:map>
```

You can also explicitly control the exact type of `Map` that will be instantiated and populated via the use of the `'map-class'` attribute on the `<util:map/>` element. For example, if we really need a `java.util.TreeMap` to be instantiated, we could use the following configuration:

```
<util:map id="emails" map-class="java.util.TreeMap">
    <entry key="pechorin" value="pechorin@hero.org"/>
    <entry key="raskolnikov" value="raskolnikov@slums.org"/>
    <entry key="stavrogin" value="stavrogin@gov.org"/>
    <entry key="porfiry" value="porfiry@gov.org"/>
</util:map>
```

If no `'map-class'` attribute is supplied, a `Map` implementation will be chosen by the container.

<util:set/>

Before…

```
<!-- creates a java.util.Set instance with values loaded from the supplied sourceSet -->
<bean id="emails" class="org.springframework.beans.factory.config.SetFactoryBean">
    <property name="sourceSet">
        <set>
            <value>pechorin@hero.org</value>
            <value>raskolnikov@slums.org</value>
            <value>stavrogin@gov.org</value>
            <value>porfiry@gov.org</value>
        </set>
    </property>
</bean>
```

The above configuration uses a Spring `FactoryBean` implementation, the `SetFactoryBean`, to create a `java.util.Set` instance initialized with values taken from the supplied `'sourceSet'`.

After…

```
<!-- creates a java.util.Set instance with the supplied values -->
<util:set id="emails">
    <value>pechorin@hero.org</value>
    <value>raskolnikov@slums.org</value>
    <value>stavrogin@gov.org</value>
    <value>porfiry@gov.org</value>
</util:set>
```

You can also explicitly control the exact type of `Set` that will be instantiated and populated via the use of the `'set-class'` attribute on the `<util:set/>` element. For example, if we really need a `java.util.TreeSet` to be instantiated, we could use the following configuration:

```
<util:set id="emails" set-class="java.util.TreeSet">
    <value>pechorin@hero.org</value>
    <value>raskolnikov@slums.org</value>
    <value>stavrogin@gov.org</value>
    <value>porfiry@gov.org</value>
</util:set>
```

If no `'set-class'` attribute is supplied, a `Set` implementation will be chosen by the container.

the jee schema

The `jee` tags deal with Java EE (Java Enterprise Edition)-related configuration issues, such as looking up a JNDI object and defining EJB references.

To use the tags in the `jee` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `jee` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jee="http://www.springframework.org/schema/jee" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/jee http://www.springframework.org/schema/jee/spring-
jee.xsd"> <!-- bean definitions here -->

</beans>
```

<jee:jndi-lookup/> (simple)

Before…

```
<bean id="dataSource" class="org.springframework.jndi.JndiObjectFactoryBean">
    <property name="jndiName" value="jdbc/MyDataSource"/>
</bean>
<bean id="userDao" class="com.foo.JdbcUserDao">
    <!-- Spring will do the cast automatically (as usual) -->
    <property name="dataSource" ref="dataSource"/>
</bean>
```

After…

```
<jee:jndi-lookup id="dataSource" jndi-name="jdbc/MyDataSource"/>

<bean id="userDao" class="com.foo.JdbcUserDao">
    <!-- Spring will do the cast automatically (as usual) -->
    <property name="dataSource" ref="dataSource"/>
</bean>
```

<jee:jndi-lookup/> (with single JNDI environment setting)

Before…

```
<bean id="simple" class="org.springframework.jndi.JndiObjectFactoryBean">
    <property name="jndiName" value="jdbc/MyDataSource"/>
    <property name="jndiEnvironment">
        <props>
            <prop key="foo">bar</prop>
        </props>
    </property>
</bean>
```

After…

```
<jee:jndi-lookup id="simple" jndi-name="jdbc/MyDataSource">
    <jee:environment>foo=bar</jee:environment>
</jee:jndi-lookup>
```

<jee:jndi-lookup/> (with multiple JNDI environment settings)

Before…

```
<bean id="simple" class="org.springframework.jndi.JndiObjectFactoryBean">
    <property name="jndiName" value="jdbc/MyDataSource"/>
    <property name="jndiEnvironment">
        <props>
            <prop key="foo">bar</prop>
            <prop key="ping">pong</prop>
        </props>
    </property>
</bean>
```

After…

```
<jee:jndi-lookup id="simple" jndi-name="jdbc/MyDataSource">
    <!-- newline-separated, key-value pairs for the environment (standard Properties format) -->
    <jee:environment>
        foo=bar
        ping=pong
    </jee:environment>
</jee:jndi-lookup>
```

<jee:jndi-lookup/> (complex)

Before…

```
<bean id="simple" class="org.springframework.jndi.JndiObjectFactoryBean">
    <property name="jndiName" value="jdbc/MyDataSource"/>
    <property name="cache" value="true"/>
    <property name="resourceRef" value="true"/>
    <property name="lookupOnStartup" value="false"/>
    <property name="expectedType" value="com.myapp.DefaultFoo"/>
    <property name="proxyInterface" value="com.myapp.Foo"/>
</bean>
```

After…

```
<jee:jndi-lookup id="simple"
        jndi-name="jdbc/MyDataSource"
        cache="true"
        resource-ref="true"
        lookup-on-startup="false"
        expected-type="com.myapp.DefaultFoo"
        proxy-interface="com.myapp.Foo"/>
```

<jee:local-slsb/> (simple)

The `<jee:local-slsb/>` tag configures a reference to an EJB Stateless SessionBean.

Before…

```
<bean id="simple"
        class="org.springframework.ejb.access.LocalStatelessSessionProxyFactoryBean">
    <property name="jndiName" value="ejb/RentalServiceBean"/>
    <property name="businessInterface" value="com.foo.service.RentalService"/>
</bean>
```

After…

```
<jee:local-slsb id="simpleSlsb" jndi-name="ejb/RentalServiceBean"
        business-interface="com.foo.service.RentalService"/>
```

<jee:local-slsb/> (complex)

```
<bean id="complexLocalEjb"
        class="org.springframework.ejb.access.LocalStatelessSessionProxyFactoryBean">
    <property name="jndiName" value="ejb/RentalServiceBean"/>
    <property name="businessInterface" value="com.foo.service.RentalService"/>
    <property name="cacheHome" value="true"/>
    <property name="lookupHomeOnStartup" value="true"/>
    <property name="resourceRef" value="true"/>
</bean>
```

After…

```
<jee:local-slsb id="complexLocalEjb"
        jndi-name="ejb/RentalServiceBean"
        business-interface="com.foo.service.RentalService"
        cache-home="true"
        lookup-home-on-startup="true"
        resource-ref="true">
```

<jee:remote-slsb/>

The `<jee:remote-slsb/>` tag configures a reference to a `remote` EJB Stateless SessionBean.

Before…

```
<bean id="complexRemoteEjb"
        class="org.springframework.ejb.access.SimpleRemoteStatelessSessionProxyFactoryBean">
    <property name="jndiName" value="ejb/MyRemoteBean"/>
    <property name="businessInterface" value="com.foo.service.RentalService"/>
    <property name="cacheHome" value="true"/>
    <property name="lookupHomeOnStartup" value="true"/>
    <property name="resourceRef" value="true"/>
    <property name="homeInterface" value="com.foo.service.RentalService"/>
    <property name="refreshHomeOnConnectFailure" value="true"/>
</bean>
```

After…

```
<jee:remote-slsb id="complexRemoteEjb"
        jndi-name="ejb/MyRemoteBean"
        business-interface="com.foo.service.RentalService"
        cache-home="true"
        lookup-home-on-startup="true"
        resource-ref="true"
        home-interface="com.foo.service.RentalService"
        refresh-home-on-connect-failure="true">
```

the lang schema

The `lang` tags deal with exposing objects that have been written in a dynamic language such as JRuby or Groovy as beans in the Spring container.

These tags (and the dynamic language support) are comprehensively covered in the chapter entitled Chapter 29, *Dynamic language support*. Please do consult that chapter for full details on this support and the `lang` tags themselves.

In the interest of completeness, to use the tags in the `lang` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `lang` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:lang="http://www.springframework.org/schema/lang" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/lang http://www.springframework.org/schema/lang/spring-
lang.xsd"> <!-- bean definitions here -->

</beans>
```

the jms schema

The `jms` tags deal with configuring JMS-related beans such as Spring's MessageListenerContainers. These tags are detailed in the section of the JMS chapter entitled Section 24.7, "JMS Namespace Support". Please do consult that chapter for full details on this support and the `jms` tags themselves.

In the interest of completeness, to use the tags in the `jms` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `jms` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jms="http://www.springframework.org/schema/jms" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/jms http://www.springframework.org/schema/jms/spring-
jms.xsd"> <!-- bean definitions here -->

</beans>
```

the tx (transaction) schema

The `tx` tags deal with configuring all of those beans in Spring's comprehensive support for transactions. These tags are covered in the chapter entitled Chapter 12, *Transaction Management*.

> **Tip**
>
> You are strongly encouraged to look at the `'spring-tx.xsd'` file that ships with the Spring distribution. This file is (of course), the XML Schema for Spring's transaction configuration, and covers all of the various tags in the `tx` namespace, including attribute defaults and suchlike. This file is documented inline, and thus the information is not repeated here in the interests of adhering to the DRY (Don't Repeat Yourself) principle.

In the interest of completeness, to use the tags in the `tx` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `tx` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:aop="http://www.springframework.org/schema/aop"
        xmlns:tx="http://www.springframework.org/schema/tx" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/tx http://www.springframework.org/schema/tx/spring-tx.xsd
        http://www.springframework.org/schema/aop http://www.springframework.org/schema/aop/spring-
aop.xsd"> <!-- bean definitions here -->

</beans>
```

> **Note**
>
> Often when using the tags in the `tx` namespace you will also be using the tags from the `aop` namespace (since the declarative transaction support in Spring is implemented using AOP). The above XML snippet contains the relevant lines needed to reference the `aop` schema so that the tags in the `aop` namespace are available to you.

the aop schema

The `aop` tags deal with configuring all things AOP in Spring: this includes Spring's own proxy-based AOP framework and Spring's integration with the AspectJ AOP framework. These tags are comprehensively covered in the chapter entitled Chapter 9, *Aspect Oriented Programming with Spring*.

In the interest of completeness, to use the tags in the `aop` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `aop` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:aop="http://www.springframework.org/schema/aop" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/aop http://www.springframework.org/schema/aop/spring-
aop.xsd"> <!-- bean definitions here -->

</beans>
```

the context schema

The `context` tags deal with `ApplicationContext` configuration that relates to plumbing - that is, not usually beans that are important to an end-user but rather beans that do a lot of grunt work in Spring, such as `BeanfactoryPostProcessors`. The following snippet references the correct schema so that the tags in the `context` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:context="http://www.springframework.org/schema/context" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/context http://www.springframework.org/schema/context/
spring-context.xsd"> <!-- bean definitions here -->

</beans>
```

> **Note**
>
> The `context` schema was only introduced in Spring 2.5.

<property-placeholder/>

This element activates the replacement of `${...}` placeholders, resolved against the specified properties file (as a Spring resource location). This element is a convenience mechanism that sets up a`PropertyPlaceholderConfigurer` for you; if you need more control over the `PropertyPlaceholderConfigurer`, just define one yourself explicitly.

<annotation-config/>

Activates the Spring infrastructure for various annotations to be detected in bean classes: Spring's `@Required` and `@Autowired`, as well as JSR 250's `@PostConstruct`, `@PreDestroy` and `@Resource` (if available), and JPA's `@PersistenceContext` and `@PersistenceUnit` (if available). Alternatively, you can choose to activate the individual `BeanPostProcessors` for those annotations explicitly.

> **Note**
>
> This element does *not* activate processing of Spring's `@Transactional` annotation. Use the `<tx:annotation-driven/>` element for that purpose.

<component-scan/>

This element is detailed in Section 5.9, "Annotation-based container configuration".

<load-time-weaver/>

This element is detailed in the section called “Load-time weaving with AspectJ in the Spring Framework”.

<spring-configured/>

This element is detailed in the section called “Using AspectJ to dependency inject domain objects with Spring”.

<mbean-export/>

This element is detailed in the section called “Configuring annotation based MBean export”.

the tool schema

The `tool` tags are for use when you want to add tooling-specific metadata to your custom configuration elements. This metadata can then be consumed by tools that are aware of this metadata, and the tools can then do pretty much whatever they want with it (validation, etc.).

The `tool` tags are not documented in this release of Spring as they are currently undergoing review. If you are a third party tool vendor and you would like to contribute to this review process, then do mail the Spring mailing list. The currently supported `tool` tags can be found in the file `'spring-tool.xsd'` in the `'src/org/springframework/beans/factory/xml'` directory of the Spring source distribution.

the jdbc schema

The `jdbc` tags allow you to quickly configure an embedded database or initialize an existing data source. These tags are documented in Section 14.8, “Embedded database support” and Section 14.9, “Initializing a DataSource” respectively.

To use the tags in the `jdbc` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `jdbc` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/jdbc" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/jdbc http://www.springframework.org/schema/jdbc/spring-jdbc.xsd"> <!-- bean definitions here -->

</beans>
```

the cache schema

The `cache` tags can be used to enable support for Spring’s `@CacheEvict`, `@CachePut` and `@Caching` annotations. It it also supports declarative XML-based caching. See the section called “Enable caching annotations” and Section 30.5, “Declarative XML-based caching” for details.

To use the tags in the `cache` schema, you need to have the following preamble at the top of your Spring XML configuration file; the text in the following snippet references the correct schema so that the tags in the `cache` namespace are available to you.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:jdbc="http://www.springframework.org/schema/cache" xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.springframework.org/schema/cache http://www.springframework.org/schema/jdbc/spring-
cache.xsd"> <!-- bean definitions here -->

</beans>
```

the beans schema

Last but not least we have the tags in the `beans` schema. These are the same tags that have been in Spring since the very dawn of the framework. Examples of the various tags in the `beans` schema are not shown here because they are quite comprehensively covered in the section called “Dependencies and configuration in detail” (and indeed in that entire chapter).

One thing that is new to the beans tags themselves in Spring 2.0 is the idea of arbitrary bean metadata. In Spring 2.0 it is now possible to add zero or more key / value pairs to `<bean/>` XML definitions. What, if anything, is done with this extra metadata is totally up to your own custom logic (and so is typically only of use if you are writing your own custom tags as described in the appendix entitled Chapter 35, *Extensible XML authoring*).

Find below an example of the `<meta/>` tag in the context of a surrounding `<bean/>` (please note that without any logic to interpret it the metadata is effectively useless as-is).

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd">

    <bean id="foo" class="x.y.Foo">
        <meta key="cacheName" value="foo"/>
        <property name="name" value="Rick"/>
    </bean>

</beans>
```

In the case of the above example, you would assume that there is some logic that will consume the bean definition and set up some caching infrastructure using the supplied metadata.

35. Extensible XML authoring

35.1 Introduction

Since version 2.0, Spring has featured a mechanism for schema-based extensions to the basic Spring XML format for defining and configuring beans. This section is devoted to detailing how you would go about writing your own custom XML bean definition parsers and integrating such parsers into the Spring IoC container.

To facilitate the authoring of configuration files using a schema-aware XML editor, Spring's extensible XML configuration mechanism is based on XML Schema. If you are not familiar with Spring's current XML configuration extensions that come with the standard Spring distribution, please first read the appendix entitledChapter 34, *XML Schema-based configuration*.

Creating new XML configuration extensions can be done by following these (relatively) simple steps:

- Authoring an XML schema to describe your custom element(s).
- Coding a custom `NamespaceHandler` implementation (this is an easy step, don't worry).
- Coding one or more `BeanDefinitionParser` implementations (this is where the real work is done).
- Registering the above artifacts with Spring (this too is an easy step).

What follows is a description of each of these steps. For the example, we will create an XML extension (a custom XML element) that allows us to configure objects of the type `SimpleDateFormat` (from the `java.text` package) in an easy manner. When we are done, we will be able to define bean definitions of type `SimpleDateFormat` like this:

```
<myns:dateformat id="dateFormat"
    pattern="yyyy-MM-dd HH:mm"
    lenient="true"/>
```

(Don't worry about the fact that this example is very simple; much more detailed examples follow afterwards. The intent in this first simple example is to walk you through the basic steps involved.)

35.2 Authoring the schema

Creating an XML configuration extension for use with Spring's IoC container starts with authoring an XML Schema to describe the extension. What follows is the schema we'll use to configure `SimpleDateFormat` objects.

```
<!-- myns.xsd (inside package org/springframework/samples/xml) -->

<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns="http://www.mycompany.com/schema/myns"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        xmlns:beans="http://www.springframework.org/schema/beans"
        targetNamespace="http://www.mycompany.com/schema/myns"
        elementFormDefault="qualified"
        attributeFormDefault="unqualified">

    <xsd:import namespace="http://www.springframework.org/schema/beans"/>

    <xsd:element name="dateformat">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="beans:identifiedType">
                    <xsd:attribute name="lenient" type="xsd:boolean"/>
                    <xsd:attribute name="pattern" type="xsd:string" use="required"/>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
</xsd:schema>
```

(The emphasized line contains an extension base for all tags that will be identifiable (meaning they have an `id` attribute that will be used as the bean identifier in the container). We are able to use this attribute because we imported the Spring-provided `'beans'` namespace.)

The above schema will be used to configure `SimpleDateFormat` objects, directly in an XML application context file using the `<myns:dateformat/>` element.

```
<myns:dateformat id="dateFormat"
    pattern="yyyy-MM-dd HH:mm"
    lenient="true"/>
```

Note that after we've created the infrastructure classes, the above snippet of XML will essentially be exactly the same as the following XML snippet. In other words, we're just creating a bean in the container, identified by the name `'dateFormat'` of type `SimpleDateFormat`, with a couple of properties set.

```
<bean id="dateFormat" class="java.text.SimpleDateFormat">
    <constructor-arg value="yyyy-HH-dd HH:mm"/>
    <property name="lenient" value="true"/>
</bean>
```

> **Note**
>
> The schema-based approach to creating configuration format allows for tight integration with an IDE that has a schema-aware XML editor. Using a properly authored schema, you can use autocompletion to have a user choose between several configuration options defined in the enumeration.

35.3 Coding a NamespaceHandler

In addition to the schema, we need a `NamespaceHandler` that will parse all elements of this specific namespace Spring encounters while parsing configuration files. The `NamespaceHandler` should in our case take care of the parsing of the `myns:dateformat` element.

The `NamespaceHandler` interface is pretty simple in that it features just three methods:

- `init()` - allows for initialization of the `NamespaceHandler` and will be called by Spring before the handler is used

- `BeanDefinition parse(Element, ParserContext)` - called when Spring encounters a top-level element (not nested inside a bean definition or a different namespace). This method can register bean definitions itself and/or return a bean definition.

- `BeanDefinitionHolder decorate(Node, BeanDefinitionHolder, ParserContext)` - called when Spring encounters an attribute or nested element of a different namespace. The decoration of one or more bean definitions is used for example with theout-of-the-box scopes Spring 2.0 supports. We'll start by highlighting a simple example, without using decoration, after which we will show decoration in a somewhat more advanced example.

Although it is perfectly possible to code your own `NamespaceHandler` for the entire namespace (and hence provide code that parses each and every element in the namespace), it is often the case that each top-level XML element in a Spring XML configuration file results in a single bean definition (as in our case, where a single `<myns:dateformat/>` element results in a single `SimpleDateFormat` bean definition). Spring features a number of convenience classes that support this scenario. In this example, we'll make use the `NamespaceHandlerSupport` class:

```
package org.springframework.samples.xml;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class MyNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        registerBeanDefinitionParser("dateformat", new SimpleDateFormatBeanDefinitionParser());
    }

}
```

The observant reader will notice that there isn't actually a whole lot of parsing logic in this class. Indeed… the `NamespaceHandlerSupport` class has a built in notion of delegation. It supports the registration of any number of `BeanDefinitionParser` instances, to which it will delegate to when it needs to parse an element in its namespace. This clean separation of concerns allows a `NamespaceHandler` to handle the orchestration of the parsing of *all* of the custom elements in its namespace, while delegating to `BeanDefinitionParsers` to do the grunt work of the XML parsing; this means that each `BeanDefinitionParser` will contain just the logic for parsing a single custom element, as we can see in the next step

35.4 BeanDefinitionParser

A `BeanDefinitionParser` will be used if the `NamespaceHandler` encounters an XML element of the type that has been mapped to the specific bean definition parser (which is `'dateformat'` in this case). In other words, the `BeanDefinitionParser` is responsible for parsing *one* distinct top-level XML element defined in the schema. In the parser, we'll have access to the XML element (and thus its subelements too) so that we can parse our custom XML content, as can be seen in the following example:

```
package org.springframework.samples.xml;

import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.xml.AbstractSingleBeanDefinitionParser;
import org.springframework.util.StringUtils;
import org.w3c.dom.Element;

import java.text.SimpleDateFormat;

public class SimpleDateFormatBeanDefinitionParser extends AbstractSingleBeanDefinitionParser { ❶

    protected Class getBeanClass(Element element) {
        return SimpleDateFormat.class; ❷
    }

    protected void doParse(Element element, BeanDefinitionBuilder bean) {
        // this will never be null since the schema explicitly requires that a value be supplied
        String pattern = element.getAttribute("pattern");
        bean.addConstructorArg(pattern);

        // this however is an optional property
        String lenient = element.getAttribute("lenient");
        if (StringUtils.hasText(lenient)) {
            bean.addPropertyValue("lenient", Boolean.valueOf(lenient));
        }
    }

}
```

❶ We use the Spring-provided `AbstractSingleBeanDefinitionParser` to handle a lot of the basic grunt work of creating a *single* `BeanDefinition`.

❷ We supply the `AbstractSingleBeanDefinitionParser` superclass with the type that our single `BeanDefinition` will represent.

In this simple case, this is all that we need to do. The creation of our single `BeanDefinition` is handled by the `AbstractSingleBeanDefinitionParser` superclass, as is the extraction and setting of the bean definition's unique identifier.

35.5 Registering the handler and the schema

The coding is finished! All that remains to be done is to somehow make the Spring XML parsing infrastructure aware of our custom element; we do this by registering our custom `namespaceHandler` and custom XSD file in two special purpose properties files. These properties files are both placed in a `'META-INF'` directory in your application, and can, for example, be distributed alongside your binary classes in a JAR file. The Spring XML parsing infrastructure will automatically pick up your new extension by consuming these special properties files, the formats of which are detailed below.

META-INF/spring.handlers

The properties file called `'spring.handlers'` contains a mapping of XML Schema URIs to namespace handler classes. So for our example, we need to write the following:

```
http\://www.mycompany.com/schema/myns=org.springframework.samples.xml.MyNamespaceHandler
```

(The `':'` character is a valid delimiter in the Java properties format, and so the `':'` character in the URI needs to be escaped with a backslash.)

The first part (the key) of the key-value pair is the URI associated with your custom namespace extension, and needs to *match exactly* the value of the `'targetNamespace'` attribute as specified in your custom XSD schema.

META-INF/spring.schemas

The properties file called `'spring.schemas'` contains a mapping of XML Schema locations (referred to along with the schema declaration in XML files that use the schema as part of the `'xsi:schemaLocation'` attribute) to *classpath* resources. This file is needed to prevent Spring from absolutely having to use a default `EntityResolver` that requires Internet access to retrieve the schema file. If you specify the mapping in this properties file, Spring will search for the schema on the classpath (in this case `'myns.xsd'` in the `'org.springframework.samples.xml'` package):

```
http\://www.mycompany.com/schema/myns/myns.xsd=org/springframework/samples/xml/myns.xsd
```

The upshot of this is that you are encouraged to deploy your XSD file(s) right alongside the `NamespaceHandler` and `BeanDefinitionParser` classes on the classpath.

35.6 Using a custom extension in your Spring XML configuration

Using a custom extension that you yourself have implemented is no different from using one of the *custom* extensions that Spring provides straight out of the box. Find below an example of using the custom `<dateformat/>` element developed in the previous steps in a Spring XML configuration file.

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:myns="http://www.mycompany.com/schema/myns"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.mycompany.com/schema/myns http://www.mycompany.com/schema/myns/myns.xsd">

    <!-- as a top-level bean -->
    <myns:dateformat id="defaultDateFormat" pattern="yyyy-MM-dd HH:mm" lenient="true"/>

    <bean id="jobDetailTemplate" abstract="true">
        <property name="dateFormat">
            <!-- as an inner bean -->
            <myns:dateformat pattern="HH:mm MM-dd-yyyy"/>
        </property>
    </bean>

</beans>
```

35.7 Meatier examples

Find below some much meatier examples of custom XML extensions.

Nesting custom tags within custom tags

This example illustrates how you might go about writing the various artifacts required to satisfy a target of the following configuration:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:foo="http://www.foo.com/schema/component"
    xsi:schemaLocation="
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-
beans.xsd
        http://www.foo.com/schema/component http://www.foo.com/schema/component/component.xsd">

    <foo:component id="bionic-family" name="Bionic-1">
        <foo:component name="Mother-1">
            <foo:component name="Karate-1"/>
            <foo:component name="Sport-1"/>
        </foo:component>
        <foo:component name="Rock-1"/>
    </foo:component>

</beans>
```

The above configuration actually nests custom extensions within each other. The class that is actually configured by the above `<foo:component/>` element is the `Component` class (shown directly below). Notice how the `Component` class does *not* expose a setter method for the `'components'` property; this makes it hard (or rather impossible) to configure a bean definition for the `Component` class using setter injection.

```
package com.foo;

import java.util.ArrayList;
import java.util.List;

public class Component {

    private String name;
    private List<Component> components = new ArrayList<Component> ();

    // mmm, there is no setter method for the components
    public void addComponent(Component component) {
        this.components.add(component);
    }

    public List<Component> getComponents() {
        return components;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

}
```

The typical solution to this issue is to create a custom `FactoryBean` that exposes a setter property for the `'components'` property.

```
package com.foo;

import org.springframework.beans.factory.FactoryBean;

import java.util.List;

public class ComponentFactoryBean implements FactoryBean<Component> {

    private Component parent;
    private List<Component> children;

    public void setParent(Component parent) {
        this.parent = parent;
    }

    public void setChildren(List<Component> children) {
        this.children = children;
    }

    public Component getObject() throws Exception {
        if (this.children != null && this.children.size() > 0) {
            for (Component child : children) {
                this.parent.addComponent(child);
            }
        }
        return this.parent;
    }

    public Class<Component> getObjectType() {
        return Component.class;
    }

    public boolean isSingleton() {
        return true;
    }

}
```

This is all very well, and does work nicely, but exposes a lot of Spring plumbing to the end user. What we are going to do is write a custom extension that hides away all of this Spring plumbing. If we stick to the steps described previously, we'll start off by creating the XSD schema to define the structure of our custom tag.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.foo.com/schema/component"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        targetNamespace="http://www.foo.com/schema/component"
        elementFormDefault="qualified"
        attributeFormDefault="unqualified">

    <xsd:element name="component">
        <xsd:complexType>
            <xsd:choice minOccurs="0" maxOccurs="unbounded">
                <xsd:element ref="component"/>
            </xsd:choice>
            <xsd:attribute name="id" type="xsd:ID"/>
            <xsd:attribute name="name" use="required" type="xsd:string"/>
        </xsd:complexType>
    </xsd:element>

</xsd:schema>
```

We'll then create a custom `NamespaceHandler`.

```
package com.foo;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class ComponentNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        registerBeanDefinitionParser("component", new ComponentBeanDefinitionParser());
    }

}
```

Next up is the custom `BeanDefinitionParser`. Remember that what we are creating is a `BeanDefinition` describing a `ComponentFactoryBean`.

```
package com.foo;

import org.springframework.beans.factory.config.BeanDefinition;
import org.springframework.beans.factory.support.AbstractBeanDefinition;
import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.support.ManagedList;
import org.springframework.beans.factory.xml.AbstractBeanDefinitionParser;
import org.springframework.beans.factory.xml.ParserContext;
import org.springframework.util.xml.DomUtils;
import org.w3c.dom.Element;

import java.util.List;

public class ComponentBeanDefinitionParser extends AbstractBeanDefinitionParser {

    protected AbstractBeanDefinition parseInternal(Element element, ParserContext parserContext) {
        return parseComponentElement(element);
    }

    private static AbstractBeanDefinition parseComponentElement(Element element) {
        BeanDefinitionBuilder factory =
 BeanDefinitionBuilder.rootBeanDefinition(ComponentFactoryBean.class);
        factory.addPropertyValue("parent", parseComponent(element));

        List<Element> childElements = DomUtils.getChildElementsByTagName(element, "component");
        if (childElements != null && childElements.size() > 0) {
            parseChildComponents(childElements, factory);
        }

        return factory.getBeanDefinition();
    }

    private static BeanDefinition parseComponent(Element element) {
        BeanDefinitionBuilder component = BeanDefinitionBuilder.rootBeanDefinition(Component.class);
        component.addPropertyValue("name", element.getAttribute("name"));
        return component.getBeanDefinition();
    }

    private static void parseChildComponents(List<Element> childElements, BeanDefinitionBuilder factory)
 {
        ManagedList<BeanDefinition> children = new ManagedList<BeanDefinition>(childElements.size());
        for (Element element : childElements) {
            children.add(parseComponentElement(element));
        }
        factory.addPropertyValue("children", children);
    }

}
```

Lastly, the various artifacts need to be registered with the Spring XML infrastructure.

```
# in META-INF/spring.handlers
http\://www.foo.com/schema/component=com.foo.ComponentNamespaceHandler
```

```
# in META-INF/spring.schemas
http\://www.foo.com/schema/component/component.xsd=com/foo/component.xsd
```

Custom attributes on *normal* elements

Writing your own custom parser and the associated artifacts isn't hard, but sometimes it is not the right thing to do. Consider the scenario where you need to add metadata to already existing bean definitions. In this case you certainly don't want to have to go off and write your own entire custom extension; rather you just want to add an additional attribute to the existing bean definition element.

By way of another example, let's say that the service class that you are defining a bean definition for a service object that will (unknown to it) be accessing a clustered JCache, and you want to ensure that the named JCache instance is eagerly started within the surrounding cluster:

```
<bean id="checkingAccountService" class="com.foo.DefaultCheckingAccountService"
        jcache:cache-name="checking.account">
    <!-- other dependencies here... -->
</bean>
```

What we are going to do here is create another `BeanDefinition` when the `'jcache:cache-name'` attribute is parsed; this `BeanDefinition` will then initialize the named JCache for us. We will also modify the existing `BeanDefinition` for the `'checkingAccountService'` so that it will have a dependency on this new JCache-initializing `BeanDefinition`.

```
package com.foo;

public class JCacheInitializer {

    private String name;

    public JCacheInitializer(String name) {
        this.name = name;
    }

    public void initialize() {
        // lots of JCache API calls to initialize the named cache...
    }

}
```

Now onto the custom extension. Firstly, the authoring of the XSD schema describing the custom attribute (quite easy in this case).

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.foo.com/schema/jcache"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        targetNamespace="http://www.foo.com/schema/jcache"
        elementFormDefault="qualified">

    <xsd:attribute name="cache-name" type="xsd:string"/>

</xsd:schema>
```

Next, the associated `NamespaceHandler`.

```
package com.foo;

import org.springframework.beans.factory.xml.NamespaceHandlerSupport;

public class JCacheNamespaceHandler extends NamespaceHandlerSupport {

    public void init() {
        super.registerBeanDefinitionDecoratorForAttribute("cache-name",
            new JCacheInitializingBeanDefinitionDecorator());
    }

}
```

Next, the parser. Note that in this case, because we are going to be parsing an XML attribute, we write a `BeanDefinitionDecorator` rather than a `BeanDefinitionParser`.

```
package com.foo;

import org.springframework.beans.factory.config.BeanDefinitionHolder;
import org.springframework.beans.factory.support.AbstractBeanDefinition;
import org.springframework.beans.factory.support.BeanDefinitionBuilder;
import org.springframework.beans.factory.xml.BeanDefinitionDecorator;
import org.springframework.beans.factory.xml.ParserContext;
import org.w3c.dom.Attr;
import org.w3c.dom.Node;

import java.util.ArrayList;
import java.util.Arrays;
import java.util.List;

public class JCacheInitializingBeanDefinitionDecorator implements BeanDefinitionDecorator {

    private static final String[] EMPTY_STRING_ARRAY = new String[0];

    public BeanDefinitionHolder decorate(Node source, BeanDefinitionHolder holder,
            ParserContext ctx) {
        String initializerBeanName = registerJCacheInitializer(source, ctx);
        createDependencyOnJCacheInitializer(holder, initializerBeanName);
        return holder;
    }

    private void createDependencyOnJCacheInitializer(BeanDefinitionHolder holder,
            String initializerBeanName) {
        AbstractBeanDefinition definition = ((AbstractBeanDefinition) holder.getBeanDefinition());
        String[] dependsOn = definition.getDependsOn();
        if (dependsOn == null) {
            dependsOn = new String[]{initializerBeanName};
        } else {
            List dependencies = new ArrayList(Arrays.asList(dependsOn));
            dependencies.add(initializerBeanName);
            dependsOn = (String[]) dependencies.toArray(EMPTY_STRING_ARRAY);
        }
        definition.setDependsOn(dependsOn);
    }

    private String registerJCacheInitializer(Node source, ParserContext ctx) {
        String cacheName = ((Attr) source).getValue();
        String beanName = cacheName + "-initializer";
        if (!ctx.getRegistry().containsBeanDefinition(beanName)) {
            BeanDefinitionBuilder initializer =
 BeanDefinitionBuilder.rootBeanDefinition(JCacheInitializer.class);
            initializer.addConstructorArg(cacheName);
            ctx.getRegistry().registerBeanDefinition(beanName, initializer.getBeanDefinition());
        }
        return beanName;
    }

}
```

Lastly, the various artifacts need to be registered with the Spring XML infrastructure.

```
# in META-INF/spring.handlers
http\://www.foo.com/schema/jcache=com.foo.JCacheNamespaceHandler
```

```
# in META-INF/spring.schemas
http\://www.foo.com/schema/jcache/jcache.xsd=com/foo/jcache.xsd
```

35.8 Further Resources

Find below links to further resources concerning XML Schema and the extensible XML support described in this chapter.

- The XML Schema Part 1: Structures Second Edition
- The XML Schema Part 2: Datatypes Second Edition

36. spring.tld

36.1 Introduction

One of the view technologies you can use with the Spring Framework is Java Server Pages (JSPs). To help you implement views using Java Server Pages the Spring Framework provides you with some tags for evaluating errors, setting themes and outputting internationalized messages.

Please note that the various tags generated by this form tag library are compliant with the XHTML-1.0-Strict specification and attendant DTD.

This appendix describes the `spring.tld` tag library.

- Section 36.2, “the bind tag”
- Section 36.3, “the escapeBody tag”
- Section 36.4, “the hasBindErrors tag”
- Section 36.5, “the htmlEscape tag”
- Section 36.6, “the message tag”
- Section 36.7, “the nestedPath tag”
- Section 36.8, “the theme tag”
- Section 36.9, “the transform tag”
- Section 36.10, “the url tag”
- Section 36.11, “the eval tag”

36.2 the bind tag

Provides BindStatus object for the given bind path. The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a "defaultHtmlEscape" context-param in web.xml).

Table 36.1. Attributes

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
ignoreNestedPath	false	true	Set whether to ignore a nested path, if any. Default is to not ignore.
path	true	true	The path to the bean or bean property to bind status information for. For instance account.name, company.address.zipCode or just employee. The status object will exported to the page scope, specifically for this bean or bean property

36.3 the escapeBody tag

Escapes its enclosed body content, applying HTML escaping and/or JavaScript escaping. The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a "defaultHtmlEscape" context-param in web.xml).

Table 36.2. Attributes

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
javaScriptEscape	false	true	Set JavaScript escaping for this tag, as boolean value. Default is false.

36.4 the hasBindErrors tag

Provides Errors instance in case of bind errors. The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a "defaultHtmlEscape" context-param in web.xml).

Table 36.3. Attributes

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
name	true	true	The name of the bean in the request, that needs to be inspected for errors. If errors are available for this bean, they will be bound under the *errors* key.

36.5 the htmlEscape tag

Sets default HTML escape value for the current page. Overrides a "defaultHtmlEscape" context-param in web.xml, if any.

Table 36.4. Attributes

Attribute	Required?	Runtime Expression?	Description
defaultHtmlEscape	true	true	Set the default value for HTML escaping, to be put into the current PageContext.

36.6 the message tag

Retrieves the message with the given code, or text if code isn't resolvable. The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a "defaultHtmlEscape" context-param in web.xml).

Table 36.5. Attributes

Attribute	Required?	Runtime Expression?	Description
arguments	false	true	Set optional message arguments for this tag, as a (comma-)delimited String (each String argument can contain JSP EL), an Object array (used as argument array), or a single Object (used as single argument).
argumentSeparator	false	true	The separator character to be used for splitting the arguments string value; defaults to a *comma* (,).
code	false	true	The code (key) to use when looking up the message. If code is not provided, the text attribute will be used.
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
javaScriptEscape	false	true	Set JavaScript escaping for this tag, as boolean value. Default is false.
message	false	true	A MessageSourceResolvable argument (direct or through JSP EL). Fits nicely when used in conjunction with Spring's own validation error classes which all implement the MessageSourceResolvable interface. For example, this allows you to iterate over all of the errors in a form, passing each error (using a runtime expression) as the value of this *message* attribute, thus effecting the easy display of such error messages.
scope	false	true	The scope to use when exporting the result to a variable. This attribute is only used when var is also set. Possible values are page, request, session and application.
text	false	true	Default text to output when a message for the given code could not be found. If both text and code are not set, the tag will output null.
var	false	true	The string to use when binding the result to the page, request, session or application scope. If not specified, the result gets outputted to the writer (i.e. typically directly to the JSP).

36.7 the nestedPath tag

Sets a nested path to be used by the bind tag's path.

Table 36.6. Attributes

Attribute	Required?	Runtime Expression?	Description
path	true	true	Set the path that this tag should apply. E.g. *customer* to allow bind paths like *address.street* rather than *customer.address.street*.

36.8 the theme tag

Retrieves the theme message with the given code, or text if code isn't resolvable. The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a "defaultHtmlEscape" context-param in web.xml).

Table 36.7. Attributes

Attribute	Required?	Runtime Expression?	Description
arguments	false	true	Set optional message arguments for this tag, as a (comma-)delimited String (each String argument can contain JSP EL), an Object array (used as argument array), or a single Object (used as single argument).
argumentSeparator	false	true	The separator character to be used for splitting the arguments string value; defaults to a *comma* (,).
code	false	true	The code (key) to use when looking up the message. If code is not provided, the text attribute will be used.
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
javaScriptEscape	false	true	Set JavaScript escaping for this tag, as boolean value. Default is false.
message	false	true	A MessageSourceResolvable argument (direct or through JSP EL).
scope	false	true	The scope to use when exporting the result to a variable. This attribute is only used when var is also set. Possible values are page, request, session and application.
text	false	true	Default text to output when a message for the given code could not be found. If both text and code are not set, the tag will output null.
var	false	true	The string to use when binding the result to the page, request, session or application scope. If not

Attribute	Required?	Runtime Expression?	Description
			specified, the result gets outputted to the writer (i.e. typically directly to the JSP).

36.9 the transform tag

Provides transformation of variables to Strings, using an appropriate custom PropertyEditor from BindTag (can only be used inside BindTag). The HTML escaping flag participates in a page-wide or application-wide setting (i.e. by HtmlEscapeTag or a *defaultHtmlEscape* context-param in web.xml).

Table 36.8. Attributes

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Set HTML escaping for this tag, as boolean value. Overrides the default HTML escaping setting for the current page.
scope	false	true	The scope to use when exported the result to a variable. This attribute is only used when var is also set. Possible values are page, request, session and application.
value	true	true	The value to transform. This is the actual object you want to have transformed (for instance a Date). Using the PropertyEditor that is currently in use by the *spring:bind* tag.
var	false	true	The string to use when binding the result to the page, request, session or application scope. If not specified, the result gets outputted to the writer (i.e. typically directly to the JSP).

36.10 the url tag

Creates URLs with support for URI template variables, HTML/XML escaping, and Javascript escaping. Modeled after the JSTL c:url tag with backwards compatibility in mind.

Table 36.9. Attributes

Attribute	Required?	Runtime Expression?	Description
url	true	true	The URL to build. This value can include template {placeholders} that are replaced with the URL encoded value of the named parameter. Parameters must be defined using the param tag inside the body of this tag.
context	false	true	Specifies a remote application context path. The default is the current application context path.

Attribute	Required?	Runtime Expression?	Description
var	false	true	The name of the variable to export the URL value to. If not specified the URL is written as output.
scope	false	true	The scope for the var. *application*, *session*, *request* and *page* scopes are supported. Defaults to page scope. This attribute has no effect unless the var attribute is also defined.
htmlEscape	false	true	Set HTML escaping for this tag, as a boolean value. Overrides the default HTML escaping setting for the current page.
javaScriptEscape	false	true	Set JavaScript escaping for this tag, as a boolean value. Default is false.

36.11 the eval tag

Evaluates a Spring expression (SpEL) and either prints the result or assigns it to a variable.

Table 36.10. Attributes

Attribute	Required?	Runtime Expression?	Description
expression	true	true	The expression to evaluate.
var	false	true	The name of the variable to export the evaluation result to. If not specified the evaluation result is converted to a String and written as output.
scope	false	true	The scope for the var. *application*, *session*, *request* and *page* scopes are supported. Defaults to page scope. This attribute has no effect unless the var attribute is also defined.
htmlEscape	false	true	Set HTML escaping for this tag, as a boolean value. Overrides the default HTML escaping setting for the current page.
javaScriptEscape	false	true	Set JavaScript escaping for this tag, as a boolean value. Default is false.

37. spring-form.tld

37.1 Introduction

One of the view technologies you can use with the Spring Framework is Java Server Pages (JSPs). To help you implement views using Java Server Pages the Spring Framework provides you with some tags for evaluating errors, setting themes and outputting internationalized messages.

Please note that the various tags generated by this form tag library are compliant with the XHTML-1.0-Strict specification and attendant DTD.

This appendix describes the `spring-form.tld` tag library.

- Section 37.2, “the checkbox tag”
- Section 37.3, “the checkboxes tag”
- Section 37.4, “the errors tag”
- Section 37.5, “the form tag”
- Section 37.6, “the hidden tag”
- Section 37.7, “the input tag”
- Section 37.8, “the label tag”
- Section 37.9, “the option tag”
- Section 37.10, “the options tag”
- Section 37.11, “the password tag”
- Section 37.12, “the radiobutton tag”
- Section 37.13, “the radiobuttons tag”
- Section 37.14, “the select tag”
- Section 37.15, “the textarea tag”

37.2 the checkbox tag

Renders an HTML *input* tag with type *checkbox*.

Table 37.1. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute

Attribute	Required?	Runtime Expression?	Description
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
label	false	true	Value to be displayed as part of the tag
lang	false	true	HTML Standard Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute
value	false	true	HTML Optional Attribute

37.3 the checkboxes tag

Renders multiple HTML *input* tags with type *checkbox*.

Table 37.2. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
delimiter	false	true	Delimiter to use between each *input* tag with type *checkbox*. There is no delimiter by default.
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
element	false	true	Specifies the HTML element that is used to enclose each *input* tag with type *checkbox*. Defaults to *span*.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
itemLabel	false	true	Value to be displayed as part of the *input* tags with type *checkbox*
items	true	true	The Collection, Map or array of objects used to generate the *input* tags with type *checkbox*
itemValue	false	true	Name of the property mapped to *value* attribute of the *input* tags with type *checkbox*
lang	false	true	HTML Standard Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.4 the errors tag

Renders field errors in an HTML *span* tag.

Table 37.3. Attributes

Attribute	Required?	Runtime Expression?	Description
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
delimiter	false	true	Delimiter for displaying multiple error messages. Defaults to the br tag.
dir	false	true	HTML Standard Attribute
element	false	true	Specifies the HTML element that is used to render the enclosing errors.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	false	true	Path to errors object for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.5 the form tag

Renders an HTML *form* tag and exposes a binding path to inner tags for binding.

Table 37.4. Attributes

Attribute	Required?	Runtime Expression?	Description
acceptCharset	false	true	Specifies the list of character encodings for input data that is accepted by the server processing this form. The value is a space- and/or comma-delimited list of charset values. The client must interpret this list as an exclusive-or list, i.e., the server is able to accept any single character encoding per entity received.
action	false	true	HTML Required Attribute
commandName	false	true	Name of the model attribute under which the form object is exposed. Defaults to *command*.
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
enctype	false	true	HTML Optional Attribute
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
method	false	true	HTML Optional Attribute
modelAttribute	false	true	Name of the model attribute under which the form object is exposed. Defaults to *command*.

Attribute	Required?	Runtime Expression?	Description
name	false	true	HTML Standard Attribute - added for backwards compatibility cases
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
onreset	false	true	HTML Event Attribute
onsubmit	false	true	HTML Event Attribute
target	false	true	HTML Optional Attribute
title	false	true	HTML Standard Attribute

37.6 the hidden tag

Renders an HTML *input* tag with type *hidden* using the bound value.

Table 37.5. Attributes

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
path	true	true	Path to property for data binding

37.7 the input tag

Renders an HTML *input* tag with type *text* using the bound value.

Table 37.6. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
alt	false	true	HTML Optional Attribute
autocomplete	false	true	Common Optional Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
maxlength	false	true	HTML Optional Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
onselect	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
path	true	true	Path to property for data binding
readonly	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will make the HTML element readonly.
size	false	true	HTML Optional Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.8 the label tag

Renders a form field label in an HTML *label* tag.

Table 37.7. Attributes

Attribute	Required?	Runtime Expression?	Description
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute.
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used only when errors are present.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
for	false	true	HTML Standard Attribute
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to errors object for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.9 the option tag

Renders a single HTML *option*. Sets *selected* as appropriate based on bound value.

Table 37.8. Attributes

Attribute	Required?	Runtime Expression?	Description
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
label	false	true	HTML Optional Attribute
lang	false	true	HTML Standard Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmouseup	false	true	HTML Event Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute
value	true	true	HTML Optional Attribute

37.10 the options tag

Renders a list of HTML *option* tags. Sets *selected* as appropriate based on bound value.

Table 37.9. Attributes

Attribute	Required?	Runtime Expression?	Description
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
itemLabel	false	true	Name of the property mapped to the inner text of the *option* tag
items	true	true	The Collection, Map or array of objects used to generate the inner *option* tags
itemValue	false	true	Name of the property mapped to *value* attribute of the *option* tag
lang	false	true	HTML Standard Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.11 the password tag

Renders an HTML *input* tag with type *password* using the bound value.

Table 37.10. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
alt	false	true	HTML Optional Attribute
autocomplete	false	true	Common Optional Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
maxlength	false	true	HTML Optional Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
onselect	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
readonly	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will make the HTML element readonly.
showPassword	false	true	Is the password value to be shown? Defaults to false.
size	false	true	HTML Optional Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.12 the radiobutton tag

Renders an HTML *input* tag with type *radio*.

Table 37.11. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute

Attribute	Required?	Runtime Expression?	Description
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
label	false	true	Value to be displayed as part of the tag
lang	false	true	HTML Standard Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute
value	false	true	HTML Optional Attribute

37.13 the radiobuttons tag

Renders multiple HTML *input* tags with type *radio*.

Table 37.12. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute

Attribute	Required?	Runtime Expression?	Description
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
delimiter	false	true	Delimiter to use between each *input* tag with type *radio*. There is no delimiter by default.
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
element	false	true	Specifies the HTML element that is used to enclose each *input* tag with type *radio*. Defaults to *span*.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
itemLabel	false	true	Value to be displayed as part of the *input* tags with type *radio*
items	true	true	The Collection, Map or array of objects used to generate the *input* tags with type *radio*
itemValue	false	true	Name of the property mapped to *value* attribute of the *input* tags with type *radio*
lang	false	true	HTML Standard Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.14 the select tag

Renders an HTML *select* element. Supports databinding to the selected option.

Table 37.13. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
itemLabel	false	true	Name of the property mapped to the inner text of the *option* tag
items	false	true	The Collection, Map or array of objects used to generate the inner *option* tags
itemValue	false	true	Name of the property mapped to *value* attribute of the *option* tag
lang	false	true	HTML Standard Attribute
multiple	false	true	HTML Optional Attribute
onblur	false	true	HTML Event Attribute

Attribute	Required?	Runtime Expression?	Description
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
size	false	true	HTML Optional Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute

37.15 the textarea tag

Renders an HTML *textarea*.

Table 37.14. Attributes

Attribute	Required?	Runtime Expression?	Description
accesskey	false	true	HTML Standard Attribute
cols	false	true	HTML Required Attribute
cssClass	false	true	Equivalent to "class" - HTML Optional Attribute
cssErrorClass	false	true	Equivalent to "class" - HTML Optional Attribute. Used when the bound field has errors.
cssStyle	false	true	Equivalent to "style" - HTML Optional Attribute
dir	false	true	HTML Standard Attribute
disabled	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will disable the HTML element.

Attribute	Required?	Runtime Expression?	Description
htmlEscape	false	true	Enable/disable HTML escaping of rendered values.
id	false	true	HTML Standard Attribute
lang	false	true	HTML Standard Attribute
onblur	false	true	HTML Event Attribute
onchange	false	true	HTML Event Attribute
onclick	false	true	HTML Event Attribute
ondblclick	false	true	HTML Event Attribute
onfocus	false	true	HTML Event Attribute
onkeydown	false	true	HTML Event Attribute
onkeypress	false	true	HTML Event Attribute
onkeyup	false	true	HTML Event Attribute
onmousedown	false	true	HTML Event Attribute
onmousemove	false	true	HTML Event Attribute
onmouseout	false	true	HTML Event Attribute
onmouseover	false	true	HTML Event Attribute
onmouseup	false	true	HTML Event Attribute
onselect	false	true	HTML Event Attribute
path	true	true	Path to property for data binding
readonly	false	true	HTML Optional Attribute. Setting the value of this attribute to *true* (without the quotes) will make the HTML element readonly.
rows	false	true	HTML Required Attribute
tabindex	false	true	HTML Standard Attribute
title	false	true	HTML Standard Attribute