Data Access

Version 5.0.5.RELEASE

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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 1. Transaction Management

1.1. 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, and Java Persistence API (JPA).
- 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 transactions describes 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.
- Transaction bound event describes how you could use application events within a transaction.

1.2. 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.

1.2.1. 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.

1.2.2. 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.

1.2.3. 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.

1.3. 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:

- *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 Transaction propagation.
- *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?
- *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.

The above definition of the `dataSource` bean uses the `<jndi-lookup/>` tag from the `jee` namespace. For more information see 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.

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.hibernate5.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.hibernate5.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
"/>
```

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.

1.4. 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 JPA, 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`.

1.4.1. 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.

1.4.2. Low-level synchronization approach

Classes such as `DataSourceUtils` (for JDBC), `EntityManagerFactoryUtils` (for JPA), `SessionFactoryUtils` (for Hibernate), 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.

1.4.3. 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.

1.5. Declarative transaction management

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 or Hibernate 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.

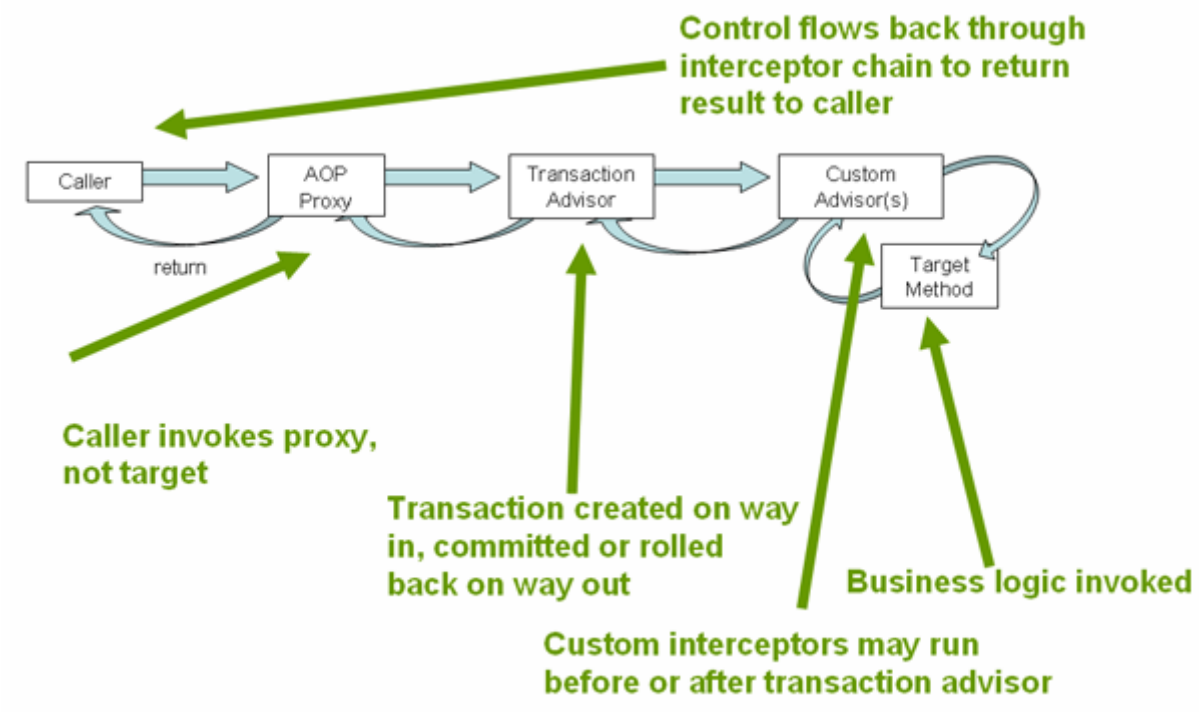
1.5.1. Understanding the Spring Framework's declarative transaction implementation

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*.

Spring AOP is covered in the AOP section.

Conceptually, calling a method on a transactional proxy looks like this…



1.5.2. 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.

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 the AOP section 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>
```

In this example it is assumed that all your service interfaces are defined in the `x.y.service` package; see the AOP section 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)
```

1.5.3. 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`. (`Error`s 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 it 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.

1.5.4. 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>
```

1.5.5. <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 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. Only applicable to propagation REQUIRED or REQUIRES_NEW.
`timeout`	No	-1	Transaction timeout (seconds). Only applicable to propagation REQUIRED or REQUIRES_NEW.
`read-only`	No	false	Read/write vs. read-only transaction. Only applicable to REQUIRED or REQUIRES_NEW.

Attribute	Required?	Default	Description
`rollback-for`	No		`Exception(s)` that trigger rollback; comma-delimited. For example, `com.foo.MyBusinessException,ServletException`.
`no-rollback-for`	No		`Exception(s)` that do *not* trigger rollback; comma-delimited. For example, `com.foo.MyBusinessException,ServletException`.

1.5.6. 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 standard `javax.transaction.Transactional` annotation is also supported as a drop-in replacement to Spring's own annotation. Please refer to JTA 1.2 documentation for more details.

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
<strong>@Transactional</strong>
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 -->
    <em><tx:annotation-driven transaction-manager="txManager"/></em><!-- 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>
```

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.

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.

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*.

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`. Also, the proxy must be fully initialized to provide the expected behaviour so you should not rely on this feature in your initialization code, i.e. `@PostConstruct`.

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 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.
`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 Spring configuration for details on how to set up load-time weaving.)

XML Attribute	Annotation Attribute	Default	Description
`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 interface-based proxies are created. (See 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 Advice ordering.) No specified ordering means that the AOP subsystem determines the order of the advice.

The default advice mode for processing `@Transactional` annotations is "proxy" which allows for interception of calls through the proxy only; local calls within the same class cannot get intercepted that way. For a more advanced mode of interception, consider switching to "aspectj" mode in combination with compile/load-time weaving.

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 [aop-proxying] for a discussion of the different proxy types.)

`@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 MVC 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 3. @Transactional Settings

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. Only applicable to propagation REQUIRED or REQUIRES_NEW.
`timeout`	int (in seconds granularity)	Optional transaction timeout. Only applicable to propagation REQUIRED or REQUIRES_NEW.
`readOnly`	boolean	Read/write vs. read-only transaction. Only applicable to REQUIRED or REQUIRES_NEW.
`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.
`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() { ... }
}
```

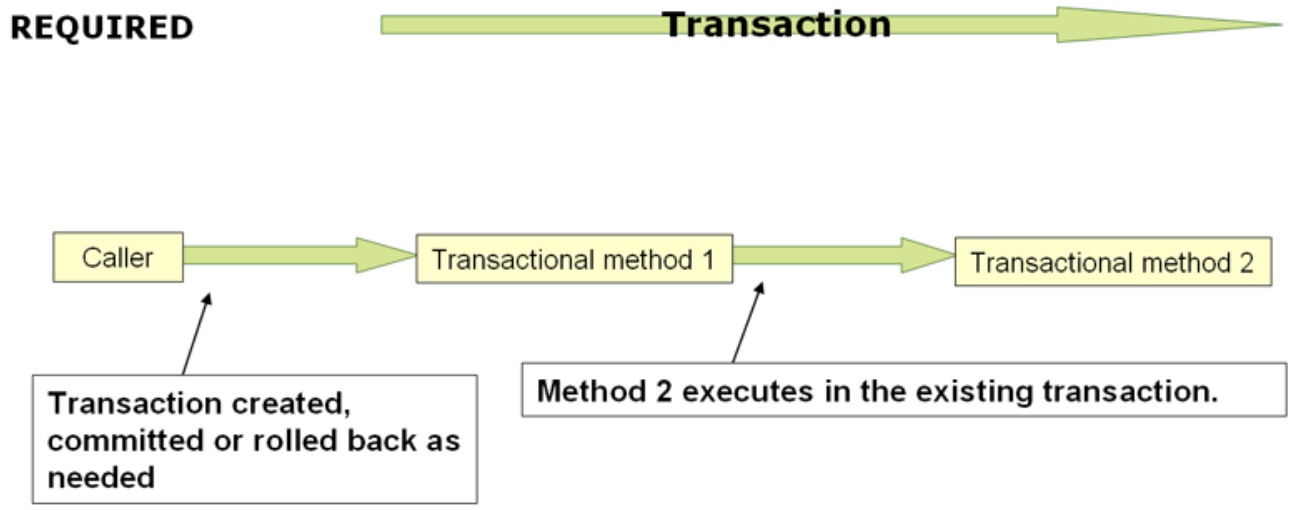
Here we have used the syntax to define the transaction manager qualifier, but could also have included propagation behavior, rollback rules, timeouts etc.

1.5.7. 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



PROPAGATION_REQUIRED

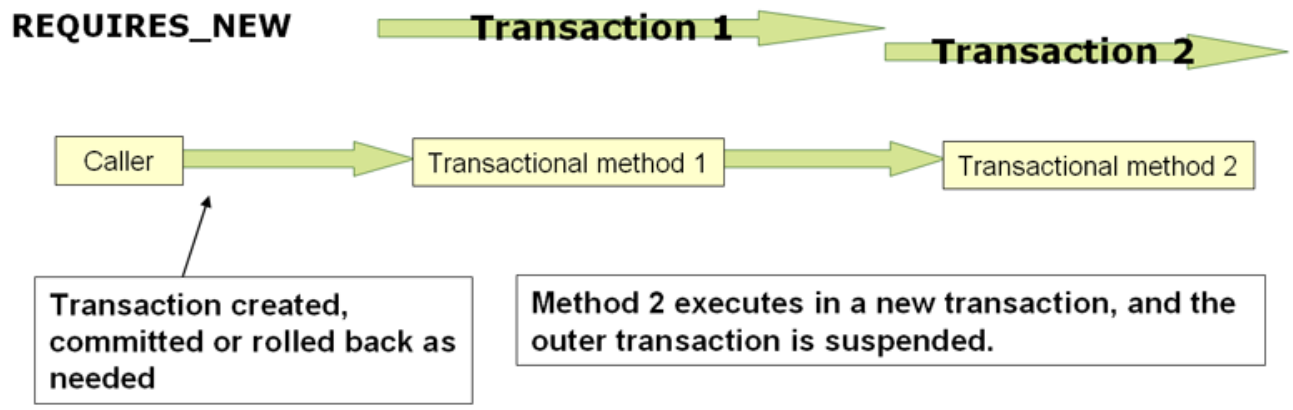
`PROPAGATION_REQUIRED` enforces a physical transaction: either locally for the current scope if no transaction exists yet, or participating in an existing 'outer' transaction defined for a larger scope. This is a fine default in common call stack arrangements within the same thread, e.g. a service facade delegating to several repository methods where all the underlying resources have to participate in the service-level transaction.

By default, a participating transaction will join the characteristics of the outer scope, silently ignoring the local isolation level, timeout value or read-only flag (if any). Consider switching the "validateExistingTransactions" flag to "true" on your transaction manager if you'd like isolation level declarations to get rejected when participating in an existing transaction with a different isolation level. This non-lenient mode will also reject read-only mismatches, i.e. an inner read-write transaction trying to participate in a read-only outer scope.

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



PROPAGATION_REQUIRES_NEW

`PROPAGATION_REQUIRES_NEW`, in contrast to `PROPAGATION_REQUIRED`, always uses an *independent* physical transaction for each affected transaction scope, never participating in an existing transaction for an outer scope. In such an arrangement, the underlying resource transactions are different and hence can commit or roll back independently, with an outer transaction not affected by an inner transaction's rollback status, and with an inner transaction's locks released immediately after its completion. Such an independent inner transaction may also declare its own isolation level, timeout and read-only settings, never inheriting an outer transaction's characteristics.

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`.

1.5.8. 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.

This chapter is not concerned with explaining AOP in any great detail (except as it applies to transactions). See AOP 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 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 <strong>is</strong> 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
<?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.

1.5.9. 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 Using @Transactional. Because we're focusing here on applications running outside of a Spring container, we'll show you how to do it programmatically.

Prior to continuing, you may want to read Using @Transactional and AOP 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);
```

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 public 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 Load-time weaving with AspectJ in the Spring Framework for a discussion of load-time weaving with AspectJ.

1.6. 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.

1.6.1. 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.

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) {
        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 <strong>TransactionCallbackWithoutResult</strong>() {
    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) {
            <strong>status.setRollbackOnly();</strong>
        }
    }
});
```

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) {
        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.

1.6.2. 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);
```

1.7. 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.

1.8. Transaction bound event

As of Spring 4.2, the listener of an event can be bound to a phase of the transaction. The typical example is to handle the event when the transaction has completed successfully: this allows events to be used with more flexibility when the outcome of the current transaction actually matters to the listener.

Registering a regular event listener is done via the `@EventListener` annotation. If you need to bind it to the transaction use `@TransactionalEventListener`. When you do so, the listener will be bound to the commit phase of the transaction by default.

Let's take an example to illustrate this concept. Assume that a component publishes an order created event and we want to define a listener that should only handle that event once the transaction in which it has been published has committed successfully:

```
@Component
public class MyComponent {

    @TransactionalEventListener
    public void handleOrderCreatedEvent(CreationEvent<Order> creationEvent) {
        ...
    }
}
```

The `TransactionalEventListener` annotation exposes a `phase` attribute that allows us to customize which phase of the transaction the listener should be bound to. The valid phases are `BEFORE_COMMIT`, `AFTER_COMMIT` (default), `AFTER_ROLLBACK` and `AFTER_COMPLETION` that aggregates the transaction completion (be it a commit or a rollback).

If no transaction is running, the listener is not invoked at all since we can't honor the required semantics. It is however possible to override that behaviour by setting the `fallbackExecution` attribute of the annotation to `true`.

1.9. 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.

1.9.1. 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 6.1.0.9 and later. With this adapter, Spring-driven transaction suspension (suspend/resume as initiated by `PROPAGATION_REQUIRES_NEW`) is officially

supported by IBM.

1.9.2. 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.

1.10. Solutions to common problems

1.10.1. 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.

1.11. 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.

Chapter 2. DAO support

2.1. Introduction

The Data Access Object (DAO) support in Spring is aimed at making it easy to work with data access technologies like JDBC, Hibernate or JPA 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.

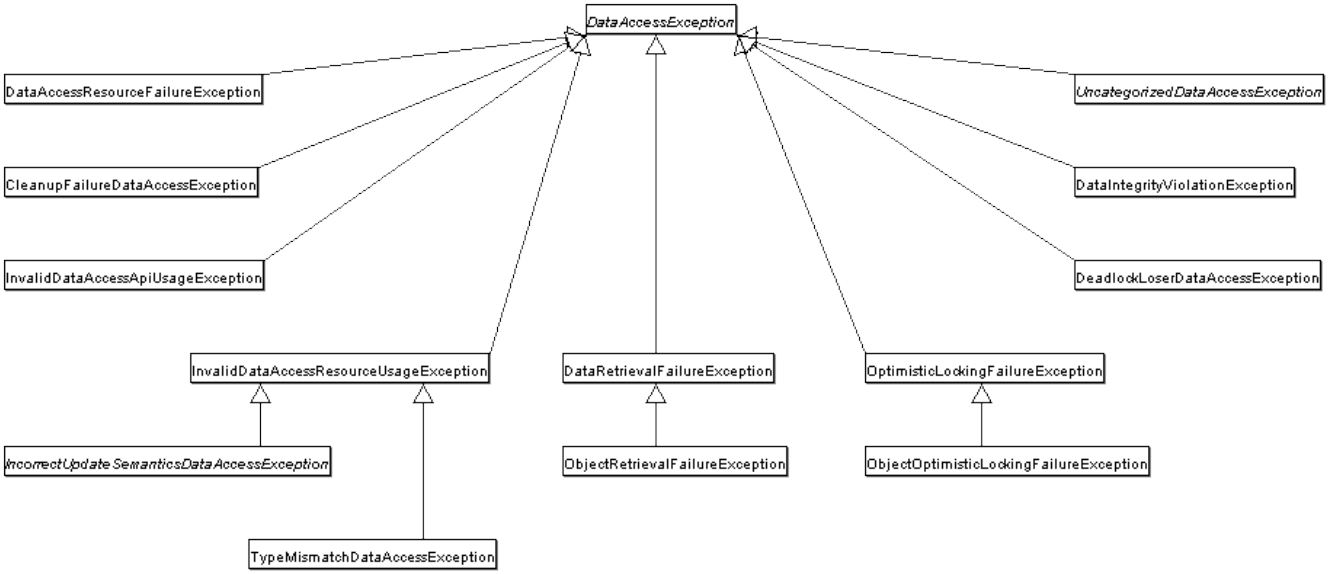
2.2. Consistent exception hierarchy

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 to a set of focused runtime exceptions (the same is true for 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 `PersistenceExceptions` itself, preferably via delegating to `SessionFactoryUtils' `convertHibernateAccessException(..)` or `convertJpaAccessException()` methods respectively. These methods convert the exceptions to ones that are compatible with the exceptions in the `org.springframework.dao` exception hierarchy. As `PersistenceExceptions` 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.)



2.3. 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.

```
<strong>@Repository</strong>
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);
    }

    // ...

}
```

Please see the specific coverage of each persistence technology for details on how to configure the application context to take advantage of these annotations.

Chapter 3. Data access with JDBC

3.1. 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 4. 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.

3.1.1. 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.

3.1.2. 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 Using the JDBC core classes to control basic JDBC processing and error handling, JDBC batch operations, and 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 embedded databases using Java database engines such as HSQL, H2, and Derby. See Controlling database connections and 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 Modeling JDBC operations as Java objects. This approach is modeled by JDO, although objects returned by queries are naturally *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 SQLExceptionTranslator.

3.2. Using the JDBC core classes to control basic JDBC processing and error handling

3.2.1. 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 `ResultSet`s 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.

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` nested 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) {
        <strong>this.jdbcTemplate = new JdbcTemplate(dataSource);</strong>
    }

    // 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`.

```
<strong>@Repository</strong>
public class JdbcCorporateEventDao implements CorporateEventDao {

    private JdbcTemplate jdbcTemplate;

    <strong>@Autowired</strong>
    public void setDataSource(DataSource dataSource) {
        <strong>this.jdbcTemplate = new JdbcTemplate(dataSource);</strong>
    }

    // 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`.

3.2.2. 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 JdbcTemplate best practices for guidelines on using the `NamedParameterJdbcTemplate` class in the context of an application.

3.2.3. 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:

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`.

3.2.4. 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))");
    }
}
```

3.2.5. 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);
    }
}
```

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}]
```

3.2.6. 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
);
    }
}
```

3.2.7. 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
```

3.3. Controlling database connections

3.3.1. 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.

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"/>
```

3.3.2. 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`.

3.3.3. 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.

3.3.4. 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.

3.3.5. 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.

3.3.6. 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`.

3.3.7. 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.

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.)

3.3.8. 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!

3.4. 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.

3.4.1. 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) {
        return this.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();
                    }
                });
    }

    // ... 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.

3.4.2. 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 `SqlParameterSourceUtils.createBatch` convenience methods to create this array, passing in an array of bean-style objects (with getter methods corresponding to parameters) and/or String-keyed Maps (containing the corresponding parameters as 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(List<Actor> actors) {
        return this.namedParameterJdbcTemplate.batchUpdate(
                "update t_actor set first_name = :firstName, last_name = :lastName
where id = :id",
                SqlParameterSourceUtils.createBatch(actors));
    }

    // ... 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);
        }
        return this.jdbcTemplate.batchUpdate(
                "update t_actor set first_name = ?, last_name = ? where id = ?",
                batch);
    }

    // ... 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.

In such a scenario with automatic setting of values on an underlying `PreparedStatement`, the corresponding JDBC type for each value needs to be derived from the given Java type. While this usually works well, there is a potential for issues, e.g. with Map-contained `null` values: Spring will by default call `ParameterMetaData.getParameterType` in such a case which may be expensive with your JDBC driver. Please make sure to use a recent driver version, and consider setting the "spring.jdbc.getParameterType.ignore" property to "true" (as a JVM system property or in a `spring.properties` file in the root of your classpath) if you encounter a performance issue, e.g. as reported on Oracle 12c (SPR-16139).

Alternatively, simply consider specifying the corresponding JDBC types explicitly: either via a 'BatchPreparedStatementSetter' as shown above, or via an explicit type array given to a 'List<Object[]>' based call, or via 'registerSqlType' calls on a custom 'MapSqlParameterSource' instance, or via a 'BeanPropertySqlParameterSource' which derives the SQL type from the Java-declared property type even for a null value.

3.4.3. 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 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.

3.5. 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.

3.5.1. 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.

3.5.2. 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 `executeAndReturnKey` 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 `executeAndReturnKeyHolder` method.

3.5.3. 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.

3.5.4. 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.

3.5.5. 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 `LinkedCaseInsensitiveMap`. 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`. 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.

3.5.6. 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`.

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.

3.5.7. How to define SqlParameters

To define a parameter for the SimpleJdbc classes and also for the RDBMS operations classes, covered in 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.

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.

3.5.8. 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.

3.5.9. 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 `BeanPropertyRowMapper` 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",
                BeanPropertyRowMapper.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.

3.6. 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.

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.

3.6.1. 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.

3.6.2. 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;
}
```

3.6.3. 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);
    }
}
```

3.6.4. 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 `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 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);
    }
}
```

3.7. 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.

3.7.1. 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.

3.7.2. Handling BLOB and CLOB objects

You can store images, other binary data, and large chunks of text in the database. These large objects are called BLOBs (Binary Large OBject) for binary data and CLOBs (Character Large OBject) 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 (Large OBject) 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 `AbstractLobCreatingPreparedStatementCallback`. 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, `lobHandler`, 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) { ①
        protected void setValues(PreparedStatement ps, LobCreator lobCreator) throws
SQLException {
            ps.setLong(1, 1L);
            lobCreator.setClobAsCharacterStream(ps, 2, clobReader, (int)clobIn.length
()); ②
            lobCreator.setBlobAsBinaryStream(ps, 3, blobIs, (int)blobIn.length()); ③
        }
    }
);
blobIs.close();
clobReader.close();
```

① Pass in the `lobHandler` that in this example is a plain `DefaultLobHandler`.

② Using the method `setClobAsCharacterStream`, pass in the contents of the CLOB.

③ Using the method `setBlobAsBinaryStream`, pass in the contents of the BLOB.

If you invoke the `setBlobAsBinaryStream`, `setClobAsAsciiStream`, or `setClobAsCharacterStream` method on the `LobCreator` returned from `DefaultLobHandler.getLobCreator()`, you can optionally specify a negative value for the `contentLength` argument. If the specified content length is negative, the `DefaultLobHandler` will use the JDBC 4.0 variants of the set-stream methods without a length parameter; otherwise, it will pass the specified length on to the driver.

Consult the documentation for the JDBC driver in use to verify support for streaming a LOB without providing the content length.

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"); ①
results.put("CLOB", clobText); byte[] blobBytes = lobHandler.getBlobAsBytes(rs,
"a_blob"); ②
results.put("BLOB", blobBytes); return results; } });
```

① Using the method `getClobAsString`, retrieve the contents of the CLOB.

② Using the method `getBlobAsBytes`, retrieve the contents of the BLOB.

3.7.3. 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.

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.

3.7.4. 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 `StructDescriptor`s, as shown in the following example, or `ArrayDescriptor`s.

```
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;
    }
};
```

3.8. 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.

3.8.1. 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.

3.8.2. Creating an embedded database 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" generate-name="true">
    <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 `test-data.sql` resources in the root of the classpath. In addition, as a best practice, the embedded database will be assigned a uniquely generated name. The embedded database is made available to the Spring container as a bean of type `javax.sql.DataSource` which can then be injected into data access objects as needed.

3.8.3. Creating an embedded database programmatically

The `EmbeddedDatabaseBuilder` class provides a fluent API for constructing an embedded database programmatically. Use this when you need to create an embedded database in a standalone environment or in a standalone integration test like in the following example.

```
EmbeddedDatabase db = new EmbeddedDatabaseBuilder()
        .generateUniqueName(true)
        .setType(H2)
        .setScriptEncoding("UTF-8")
        .ignoreFailedDrops(true)
        .addScript("schema.sql")
        .addScripts("user_data.sql", "country_data.sql")
        .build();

// perform actions against the db (EmbeddedDatabase extends javax.sql.DataSource)

db.shutdown()
```

Consult the Javadoc for `EmbeddedDatabaseBuilder` for further details on all supported options.

The `EmbeddedDatabaseBuilder` can also be used to create an embedded database using Java Config like in the following example.

```
@Configuration
public class DataSourceConfig {

    @Bean
    public DataSource dataSource() {
        return new EmbeddedDatabaseBuilder()
                .generateUniqueName(true)
                .setType(H2)
                .setScriptEncoding("UTF-8")
                .ignoreFailedDrops(true)
                .addScript("schema.sql")
                .addScripts("user_data.sql", "country_data.sql")
                .build();
    }
}
```

3.8.4. Selecting the embedded database type

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 you are using the builder API, call the `setType(EmbeddedDatabaseType)` method with `EmbeddedDatabaseType.DERBY`.

3.8.5. 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 integration test template that uses an embedded database. Using a template like this can be useful for *one-offs* when the embedded database does not need to be reused across test classes. However, if you wish to create an embedded database that is shared within a test suite, consider using the Spring TestContext Framework and configuring the embedded database as a bean in the Spring `ApplicationContext` as described in Creating an embedded database using Spring XML and Creating an embedded database programmatically.

```
public class DataAccessIntegrationTestTemplate {

    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()
                .generateUniqueName(true)
                .addDefaultScripts()
                .build();
    }

    @Test
    public void testDataAccess() {
        JdbcTemplate template = new JdbcTemplate(db);
        template.query( /* ... */ );
    }

    @After
    public void tearDown() {
        db.shutdown();
    }

}
```

3.8.6. Generating unique names for embedded databases

Development teams often encounter errors with embedded databases if their test suite inadvertently attempts to recreate additional instances of the same database. This can happen quite easily if an XML configuration file or `@Configuration` class is responsible for creating an embedded database and the corresponding configuration is then reused across multiple testing scenarios

within the same test suite (i.e., within the same JVM process) — for example, integration tests against embedded databases whose `ApplicationContext` configuration only differs with regard to which bean definition profiles are active.

The root cause of such errors is the fact that Spring's `EmbeddedDatabaseFactory` (used internally by both the `<jdbc:embedded-database>` XML namespace element and the `EmbeddedDatabaseBuilder` for Java Config) will set the name of the embedded database to `"testdb"` if not otherwise specified. For the case of `<jdbc:embedded-database>`, the embedded database is typically assigned a name equal to the bean's `id` (i.e., often something like `"dataSource"`). Thus, subsequent attempts to create an embedded database will not result in a new database. Instead, the same JDBC connection URL will be reused, and attempts to create a new embedded database will actually point to an existing embedded database created from the same configuration.

To address this common issue Spring Framework 4.2 provides support for generating *unique* names for embedded databases. To enable the use of generated names, use one of the following options.

- `EmbeddedDatabaseFactory.setGenerateUniqueDatabaseName()`
- `EmbeddedDatabaseBuilder.generateUniqueName()`
- `<jdbc:embedded-database generate-name="true" … >`

3.8.7. 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.
- 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.

3.9. 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.

3.9.1. Initializing a database 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 executes the two scripts specified against the database: the first script creates a

schema, and the second populates tables with a test data set. 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 you are executing the scripts against a database that already has test data in it. The likelihood of accidentally deleting data is reduced by following the common pattern (as shown above) of creating the tables first and then inserting the data — the first step will fail if the tables already exist.

However, to gain more control over the creation and deletion of existing data, the XML namespace provides a few additional options. The first is a 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), for example:

```
<jdbc:initialize-database data-source="dataSource"
    <strong>enabled="#{systemProperties.INITIALIZE_DATABASE}"</strong>>
    <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, for example:

```
<jdbc:initialize-database data-source="dataSource" <strong>ignore-
failures="DROPS"</strong>>
    <jdbc:script location="..."/>
</jdbc:initialize-database>
```

In this example we are saying we expect that sometimes the scripts will be executed 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 `DROP` statements, 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).

Each statement should be separated by `;` or a new line if the `;` character is not present at all in the script. You can control that globally or script by script, for example:

```
<jdbc:initialize-database data-source="dataSource" <strong>separator="@@"</strong>>
    <jdbc:script location="classpath:com/foo/sql/db-schema.sql" <strong>
separator=";"</strong>/>
    <jdbc:script location="classpath:com/foo/sql/db-test-data-1.sql"/>
    <jdbc:script location="classpath:com/foo/sql/db-test-data-2.sql"/>
</jdbc:initialize-database>
```

In this example, the two `test-data` scripts use `@@` as statement separator and only the `db-schema.sql` uses `;`. This configuration specifies that the default separator is `@@` and override that default for the `db-schema` script.

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 `DataSource` instance and executes the scripts provided in its initialization callback (analogous to an `init-method` in an XML bean definition, a `@PostConstruct` method in a component, or the `afterPropertiesSet()` method in a component that implements `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 data from the database on application startup.

To get around this issue you have 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 include:

- 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 include:

- Rely on the default behavior of the Spring `BeanFactory`, 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 in XML configuration 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. the parent context contains the `DataSource`, and child context contains the business components). This structure is common in Spring web applications but can be more generally applied.

Chapter 4. Object Relational Mapping (ORM) Data Access

4.1. Introduction to ORM with Spring

The Spring Framework supports integration with the Java Persistence API (JPA) as well as native Hibernate 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 or JPA APIs.

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.

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.

4.2. General ORM integration considerations

This section highlights considerations that apply to all ORM technologies. The 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.

4.2.1. 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 and JPA support through the Hibernate and JPA transaction managers as well as JTA support. For details on transaction support, see the Transaction Management chapter.

4.2.2. Exception translation

When you use Hibernate or JPA in a DAO, you must decide how to handle the persistence technology's native exception classes. The DAO throws a subclass of a `HibernateException` or `PersistenceException` depending on the technology. These exceptions are all runtime 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.

4.3. Hibernate

We will start with a coverage of Hibernate 5 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.

As of Spring Framework 5.0, Spring requires Hibernate ORM 4.3 or later for JPA support and even Hibernate ORM 5.0+ for programming against the native Hibernate Session API. Note that the Hibernate team does not maintain any versions prior to 5.0 anymore and is likely to focus on 5.2+ exclusively soon.

4.3.1. 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.hibernate5.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.

4.3.2. Implementing DAOs based on plain Hibernate API

Hibernate 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 API, while still being able to participate in Spring-managed transactions.

4.3.3. 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.

Prior to continuing, you are *strongly* encouraged to read Declarative transaction management if you have not done so.

You may 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();
    }

}
```

All you need to set up in the container is the `PlatformTransactionManager` implementation as a bean as well as a "<tx:annotation-driven/>" entry, opting into `@Transactional` processing at runtime.

```
<?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.hibernate5.HibernateTransactionManager">
        <property name="sessionFactory" ref="sessionFactory"/>
    </bean>

    <tx:annotation-driven/>

    <bean id="myProductService" class="product.SimpleProductService">
        <property name="productDao" ref="myProductDao"/>
    </bean>

</beans>
```

4.3.4. 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.hibernate5.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.

4.3.5. 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.

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.

4.3.6. 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.

4.3.7. 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.

4.4. 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, while being aware of the underlying implementation in order to provide additional features.

4.4.1. 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

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

Use this option when deploying to a Java EE 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 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 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

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>
```

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 server. In a full Java EE 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 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 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`.

4.4.2. Implementing DAOs based on JPA: EntityManagerFactory and EntityManager

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 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.

4.4.3. Spring-driven JPA transactions

You are *strongly* encouraged to read Declarative transaction management if you have not done so, to get a more detailed coverage of Spring's declarative transaction support.

The recommended strategy for JPA is local transactions via JPA's native transaction support. Spring's `JpaTransactionManager` provides many capabilities known from local JDBC transactions, such as transaction-specific isolation levels and resource-level read-only optimizations, against any regular JDBC connection pool (no XA requirement).

Spring JPA also allows a configured `JpaTransactionManager` to expose a JPA transaction to JDBC access code that accesses the same `DataSource`, provided that the registered `JpaDialect` supports retrieval of the underlying JDBC `Connection`. Out of the box, Spring provides dialects for the EclipseLink and Hibernate JPA implementations. See the next section for details on the `JpaDialect` mechanism.

4.4.4. JpaDialect and JpaVendorAdapter

As an advanced feature `JpaTransactionManager` and subclasses of `AbstractEntityManagerFactoryBean`

support a custom JpaDialect, to be passed into the jpaDialect bean property. 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.

As an even broader provider adaptation facility primarily for Spring's full-featured LocalContainerEntityManagerFactoryBean setup, JpaVendorAdapter combines the capabilities of JpaDialect with other provider-specific defaults. Specifying a HibernateJpaVendorAdapter or EclipseLinkJpaVendorAdapter is the most convenient way of auto-configuring an EntityManagerFactory setup for Hibernate or EclipseLink, respectively. Note that those provider adapters are primarily designed for use with Spring-driven transaction management, i.e. for use with JpaTransactionManager.

See the JpaDialect and JpaVendorAdapter javadocs for more details of its operations and how they are used within Spring's JPA support.

4.4.5. Setting up JPA with JTA transaction management

As an alternative to JpaTransactionManager, Spring also allows for multi-resource transaction coordination via JTA, either in a Java EE environment or with a standalone transaction coordinator such as Atomikos. Aside from choosing Spring's JtaTransactionManager instead of JpaTransactionManager, there are a few further steps to take:

- The underlying JDBC connection pools need to be XA-capable and integrated with your transaction coordinator. This is usually straightforward in a Java EE environment, simply exposing a different kind of DataSource via JNDI. Check your application server documentation for details. Analogously, a standalone transaction coordinator usually comes with special XA-integrated DataSource implementations; again, check its docs.
- The JPA EntityManagerFactory setup needs to be configured for JTA. This is provider-specific, typically via special properties to be specified as "jpaProperties" on LocalContainerEntityManagerFactoryBean. In the case of Hibernate, these properties are even version-specific; please check your Hibernate documentation for details.
- Spring's HibernateJpaVendorAdapter enforces certain Spring-oriented defaults such as the connection release mode "on-close" which matches Hibernate's own default in Hibernate 5.0 but not anymore in 5.1/5.2. For a JTA setup, either do not declare HibernateJpaVendorAdapter to begin with, or turn off its prepareConnection flag. Alternatively, set Hibernate 5.2's "hibernate.connection.handling_mode" property to "DELAYED_ACQUISITION_AND_RELEASE_AFTER_STATEMENT" to restore Hibernate's own default. See Spurious application server warnings with Hibernate for a related note about

WebLogic.

- Alternatively, consider obtaining the `EntityManagerFactory` from your application server itself, i.e. via a JNDI lookup instead of a locally declared `LocalContainerEntityManagerFactoryBean`. A server-provided `EntityManagerFactory` might require special definitions in your server configuration, making the deployment less portable, but will be set up for the server's JTA environment out of the box.

Chapter 5. Marshalling XML using O/X Mappers

5.1. 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:

5.1.1. 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 namespace-based configuration is available for a number of marshallers, making the configuration even simpler.

5.1.2. 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 Castor) in a non-intrusive fashion, leveraging the strength of each technology.

5.1.3. 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.

5.2. 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.

5.2.1. Marshaller

Spring abstracts all marshalling operations behind the `org.springframework.oxm.Marshaller` interface, the main method of which is shown below.

```
public interface Marshaller {

    /**
     * Marshal 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`

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.

5.2.2. Unmarshaller

Similar to the `Marshaller`, there is the `org.springframework.oxm.Unmarshaller` interface.

```
public interface Unmarshaller {

    /**
     * Unmarshal 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`

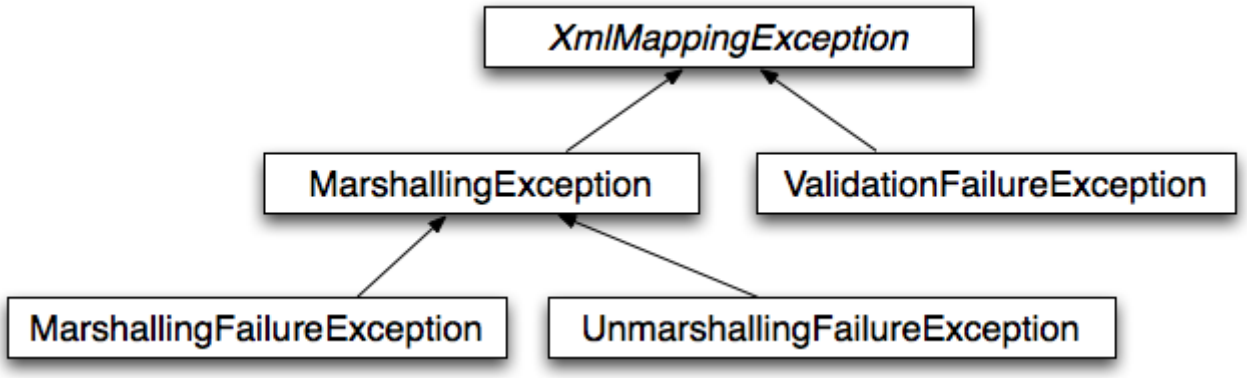
Even though there are two separate marshalling interfaces (`Marshaller` and `Unmarshaller`), all implementations found in Spring-WS implement both in one class. This means that you can wire up one marshaller class and refer to it both as a marshaller and an unmarshaller in your `applicationContext.xml`.

5.2.3. 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:



O/X Mapping exception hierarchy

5.3. 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"/>
```

5.4. XML configuration namespace

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"
    <strong>xmlns:oxm="http://www.springframework.org/schema/oxm"</strong>
xsi:schemaLocation="http://www.springframework.org/schema/beans
http://www.springframework.org/schema/beans/spring-beans.xsd
<strong>http://www.springframework.org/schema/oxm
http://www.springframework.org/schema/oxm/spring-oxm.xsd"</strong>>
```

Currently, the following tags are available:

- `jaxb2-marshaller`
- `jibx-marshaller`
- `castor-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"/>
```

5.5. 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 Marshaller and Unmarshaller. The corresponding integration classes reside in the `org.springframework.oxm.jaxb` package.

5.5.1. 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 configuration namespace

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

5.6. 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.

5.6.1. 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>
```

5.6.2. 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 configuration namespace

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
`mapping-location`	location of a Castor XML mapping file	no

5.7. JiBX

The JiBX framework offers a solution similar to that which Hibernate 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.

5.7.1. 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 `JibxMarshaller`s with different `targetClass` property values.

XML configuration namespace

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

5.8. 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.

5.8.1. 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>
```

By default, XStream allows for arbitrary classes to be unmarshalled, which can lead to unsafe Java serialization effects. 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 choose to use the `XStreamMarshaller` to unmarshal XML from an external source, set the `supportedClasses` property on the `XStreamMarshaller`, like as follows:

```
<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 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.

Chapter 6. Appendix

6.1. XML Schemas

This part of the appendix lists XML schemas for data access.

6.1.1. The `tx` 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 Transaction Management.

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"
        <em>xmlns:tx="http://www.springframework.org/schema/tx"</em>
xsi:schemaLocation="
        http://www.springframework.org/schema/beans
http://www.springframework.org/schema/beans/spring-beans.xsd
        <em>http://www.springframework.org/schema/tx
http://www.springframework.org/schema/tx/spring-tx.xsd</em>
        http://www.springframework.org/schema/aop
http://www.springframework.org/schema/aop/spring-aop.xsd"> <!-- bean definitions here
-->

</beans>
```

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.

6.1.2. 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 Embedded database support and 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"
    <em>xmlns:jdbc="http://www.springframework.org/schema/jdbc"</em>
xsi:schemaLocation="
        http://www.springframework.org/schema/beans
http://www.springframework.org/schema/beans/spring-beans.xsd
        <em>http://www.springframework.org/schema/jdbc
http://www.springframework.org/schema/jdbc/spring-jdbc.xsd"</em>> <!-- bean
definitions here -->

</beans>
```