



spring

Core Spring

Four Day Workshop

Building Enterprise Applications using Spring

Version 4.3.b

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Welcome to Core Spring

A 4-day bootcamp that trains you how to use the Spring Framework to create well-designed, testable, business, applications

Logistics

- Student introductions
- Self introduction
- Course registration (if needed)
- Courseware
- Internet access
- Phones on silent
- Working hours
- Lunch and breaks
- Toilets/Restrooms
- Fire alarms
- Emergency exits
- Any other questions?

**LOGISTICS**

How You will Benefit

- Learn to use Spring for web and other applications
- Gain hands-on experience
 - Generous mixture of presentation and labs
- Access to experienced, certified instructors



Covered in this section

- **Agenda**
- Spring and Pivotal



Course Agenda: Day 1

- Introduction to Spring
- Using Spring to configure an application
- Java-based dependency injection
- Annotation-based dependency injection
- XML-based dependency injection
- Spring FactoryBeans

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Course Agenda: Day 2

- Understanding the bean life-cycle
- Testing a Spring-based application using multiple profiles
- Adding behavior to an application using aspects
- Introducing data access with Spring
- Simplifying JDBC-based data access

2



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Course Agenda: Day 3

- Driving database transactions in a Spring environment
- Introducing object-to-relational mapping (ORM)
- Working with JPA in a Spring environment
- Effective web application architecture
- Getting started with Spring MVC

3



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Course Agenda: Day 4

- Rapidly start new projects with Spring Boot
- Securing web applications with Spring Security
- Implementing REST with Spring MVC
- Microservices and Cloud Native Applications using Spring Cloud

4



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Covered in this section

- Agenda
- **Spring and Pivotal**



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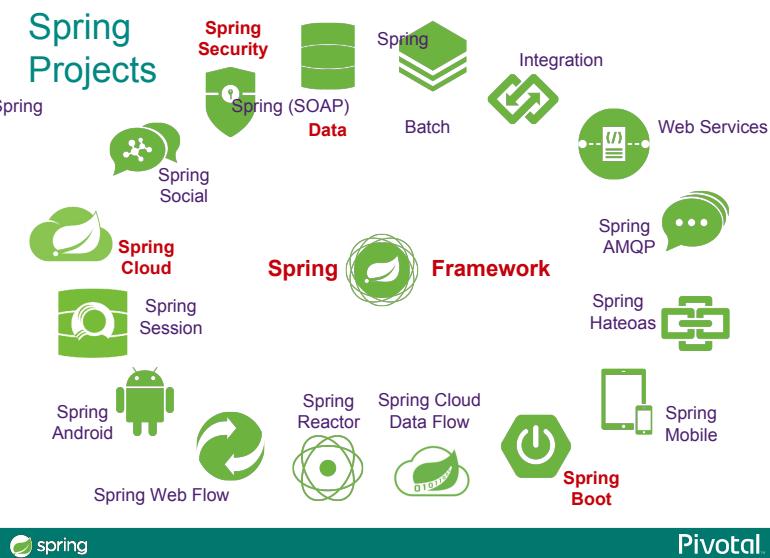
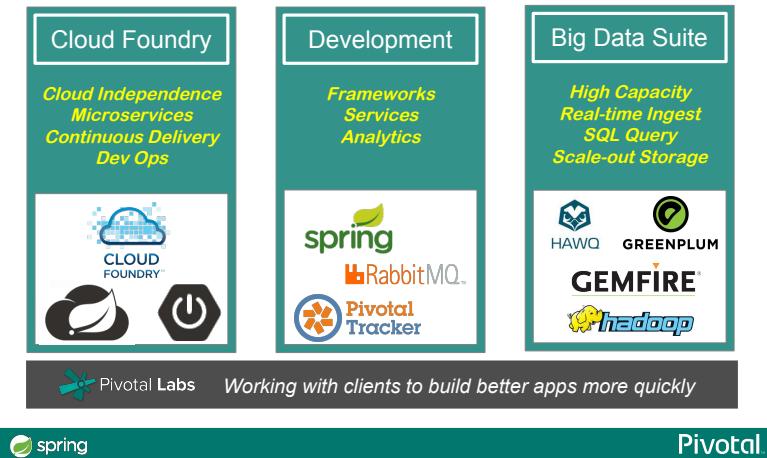
Spring and Pivotal

- SpringSource, the company behind Spring
 - acquired by VMware in 2009
 - transferred to Pivotal joint venture 2013
- Spring projects key to Pivotal's big-data and cloud strategies
 - Virtualize your Java Apps
 - Save license cost
 - Deploy to private, public, hybrid clouds
 - Real-time analytics
 - Spot trends as they happen
 - Spring Data, Spring Hadoop, Spring XD & Pivotal HD



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The Pivotal World



Covered in this section

- Agenda
- Spring and Pivotal

Let's get on with the course..!



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Overview of the Spring Framework

Introducing Spring in the Context of Enterprise Application Architecture

What is Spring and why would you use it?

Objectives

- After completing this lesson, you should be able to:
 - Define the Spring Framework
 - Understand what Spring is used for
 - Understand why Spring is successful
 - Explain where it fits in your world



Topics in this session

- **What is the Spring Framework?**
- Spring is a Container
- Spring Framework history
- What is Spring Used For?



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What is the Spring Framework?

- Spring is an Open Source, Lightweight, Container and Framework for building Java enterprise applications



- Open Source
- Lightweight
- Container
- Framework



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What is the Spring Framework?

Open Source



- Spring binary and source code is freely available
- Apache 2 license
- Code is available at:
 - <https://github.com/spring-projects/spring-framework>
- Binaries available at Maven Central
 - <http://mvnrepository.com/artifact/org.springframework>
- Documentation available at:
 - <http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle>



The use of a transitive dependency management system (Maven, Gradle, Ant/Ivy) is recommended for any Java application



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What is the Spring Framework?

Lightweight

- Spring applications do not require a Java EE application server
 - But they can be deployed on one
- Spring is not *invasive*
 - Does not require you to extend framework classes or implement framework interfaces for most usage
 - You write your code as POJOs
- Low overhead
 - Spring jars are relatively small
 - JARs used in this course are < 8 MB



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What is the Spring Framework? Container

- Spring serves as a container for your application objects.
 - Your objects do not have to worry about finding / connecting to each other.
- Spring instantiates and dependency injects your objects
 - Serves as a lifecycle manager



What is the Spring Framework? Framework

- Enterprise applications must deal with a wide variety of technologies / resources
 - JDBC, JMS, AMQP, Transactions, ORM / JPA, NoSQL, Security, Web, Tasks, Scheduling, Mail, Files, XML/JSON Marshalling, Remoting, REST services, SOAP services, Mobile, Social, ...
- Spring provides framework classes to simplify working with lower-level technologies



Topics in this session

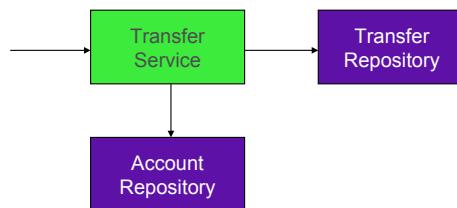
- What is the Spring Framework?
- **Spring is a Container**
- Spring Framework History
- What is Spring Used For?



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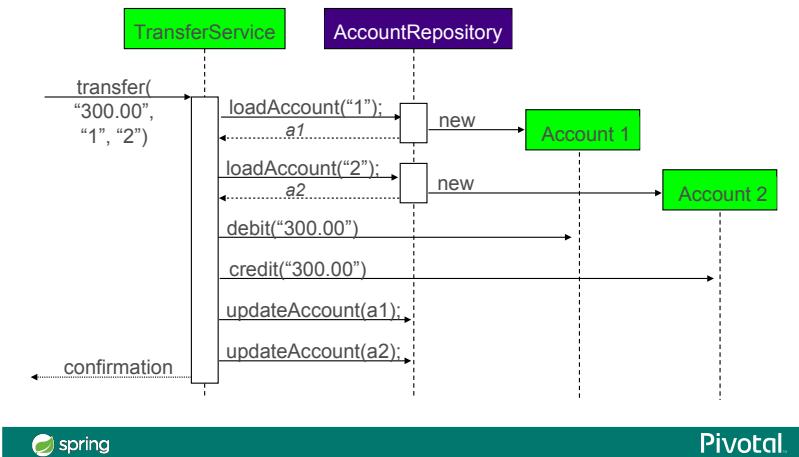
Application Configuration

- A typical application system consists of several parts working together to carry out a use case



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Example: Money Transfer System

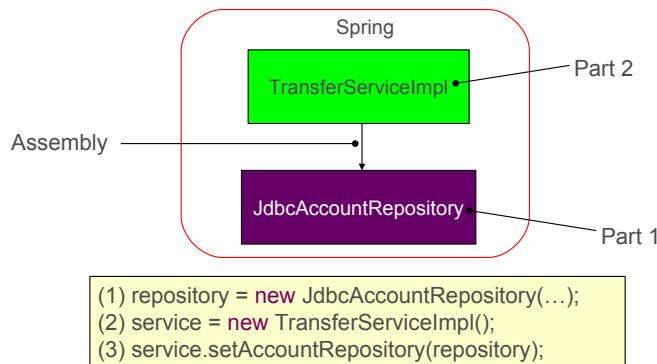


Spring's Configuration Support

- Spring provides support for assembling such an application system from its parts
 - Parts do not worry about finding each other
 - Any part can easily be swapped out



Money Transfer System Assembly



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Parts are Just *Plain Old Java Objects* (POJOs)

```
public class JdbcAccountRepository implements  
    AccountRepository {  
    ...  
}
```

Part 1
Implements a service (business) interface

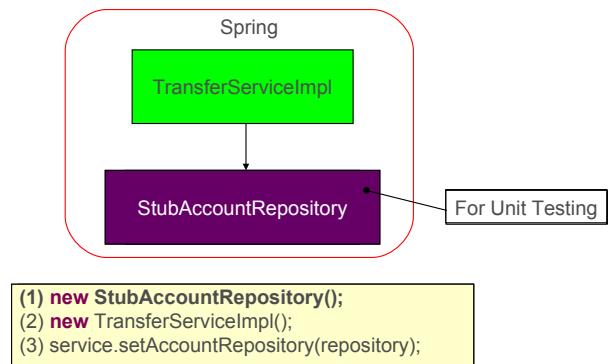
```
public class TransferServiceImpl implements TransferService {  
    private AccountRepository accountRepository;  
  
    public void setAccountRepository(AccountRepository ar) {  
        accountRepository = ar;  
    }  
    ...  
}
```

Part 2
Depends on an *interface*:
– conceals complexity of implementation;
– allows for swapping out implementation

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Swapping Out Part Implementations



Topics in this session

- What is the Spring Framework?
- Spring is a Container
- **Spring Framework History**
- What is Spring Used For?



Why is Spring Successful?

A brief history of Java

- The early years:
 - 1995 – Java introduced, Applets are popular
 - 1997 – Servlets introduced
 - Efficient, dynamic web pages become possible.
 - 1999 – JSP introduced
 - Efficient, dynamic web pages become easy.
- Questions arise regarding “Enterprise” applications
 - How should a Servlet / JSP application handle:
 - Persistence?
 - Transactions?
 - Security?
 - Business Logic?
 - Messaging?
 - Etc.?



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Introducing J2EE and EJB

- Java's answer: J2EE
 - 1999 – J2EE introduced
 - Featuring Enterprise Java Beans (EJB)
 - Answers the questions of persistence, transactions, business logic, security, etc
- However EJBs prove to be problematic:
 - Difficult to code.
 - Must extend / implement specific classes /interfaces
 - Complicated programming model required
 - Difficult to unit test
 - Expensive to run
 - Must have application server, resource intensive



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The Birth of Spring

- Rod Johnson publishes J2EE Development without EJB
- 2004 - Spring Framework 1.0 released
 - Champions dependency injection
 - Encourages POJOs
 - Uses XML files to describe application configuration
 - Becomes popular quickly as an EJB alternative



Spring Framework History

- Spring 2.0 (2006):
 - XML simplification, async JMS, JPA, AspectJ support
- Spring 2.5 (2007, last release 2.5.6)
 - Requires Java 1.4+ and supports JUnit 4
 - Annotation DI, @MVC controllers, XML namespaces
- Spring 3.x (3.2.17 released July 2016)
 - Environment & Profiles, @Cacheable, @EnableXXX ...
 - Requires Java 1.5+ and JUnit 4.7+
 - REST support, JavaConfig, SpEL, more annotations
- Spring 4.x (released Dec 2013)
 - Support for Java 8, @Conditional, Web-sockets
- Spring 5.x (2017)
 - Reactive programming focus



Topics in this session

- What is the Spring Framework?
- Spring is a Container
- Spring Framework History
- **What is Spring Used For?**



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What is Spring Used For?

- Spring provides comprehensive infrastructural support for developing enterprise Java™ applications
 - Spring deals with the plumbing
 - So you can focus on solving the domain problem
- Spring used to build enterprise applications dealing with:



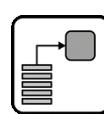
Web Interfaces



Messaging



Persistence



Batch



Integration



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The Current World

- Spring is not simply an alternative to J2EE / EJB
 - Modern application development challenges are different today than 2000
- Spring continues to innovate
 - **Web:** AJAX, WebSockets, REST, Mobile, Social
 - **Data:** NoSQL, Big Data, Stream processing
 - **Cloud:** Distributed systems, Cloud, Microservices
 - **Productivity:** Spring Boot, Spring Cloud Data Flow
 - and many more



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More on Spring's Ecosystem



- Visit <http://spring.io/projects>



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Lab

Developing an Application from Plain
Java Objects



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Dependency Injection Using Spring

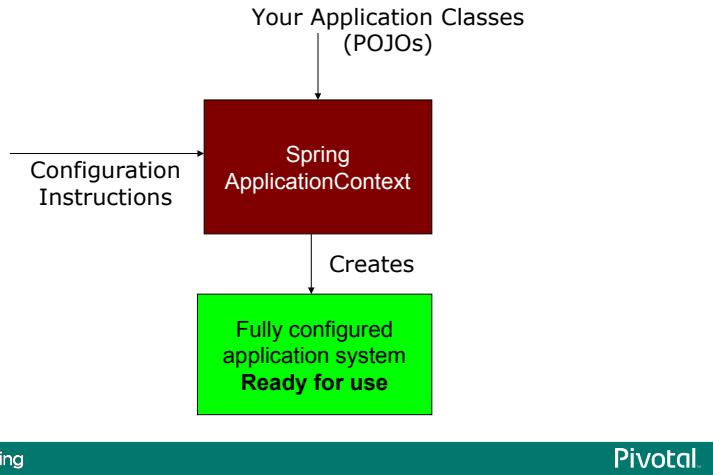
Introducing the Spring Application Context
and Spring's Java Configuration capability

@Configuration and ApplicationContext

Topics in this session

- **Spring quick start**
- Creating an application context
- Bean scope
- Lab

How Spring Works



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Your Application Classes

```
public class TransferServiceImpl implements TransferService {  
    public TransferServiceImpl(AccountRepository ar) {  
        this.accountRepository = ar;  
    }  
    ...  
}
```

Needed to perform money transfers between accounts

```
public class JdbcAccountRepository implements AccountRepository {  
    public JdbcAccountRepository(DataSource ds) {  
        this.dataSource = ds;  
    }  
    ...  
}
```

Needed to load accounts from the database

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Configuration Instructions

```
@Configuration  
public class ApplicationConfig {  
    @Bean public TransferService transferService() {  
        return new TransferServiceImpl( accountRepository() );  
    }  
    @Bean public AccountRepository accountRepository() {  
        return new JdbcAccountRepository( dataSource() );  
    }  
    @Bean public DataSource dataSource() {  
        BasicDataSource dataSource = new BasicDataSource();  
        dataSource.setDriverClassName("org.postgresql.Driver");  
        dataSource.setUrl("jdbc:postgresql://localhost/transfer");  
        dataSource.setUsername("transfer-app");  
        dataSource.setPassword("secret45");  
        return dataSource;  
    }  
}
```



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Creating and Using the Application

```
// Create the application from the configuration  
ApplicationContext context =  
    SpringApplication.run( ApplicationConfig.class );  
  
// Look up the application service interface  
TransferService service =  
    (TransferService) context.getBean("transferService");  
  
// Use the application  
service.transfer(new MonetaryAmount("300.00"), "1", "2");
```

Bean ID
Based on method name



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Accessing a Bean

- Multiple ways

```
ApplicationContext context = SpringApplication.run(...);

// Classic way: cast is needed
TransferService ts1 = (TransferService) context.getBean("transferService");

// Use typed method to avoid cast
TransferService ts2 = context.getBean("transferService", TransferService.class);

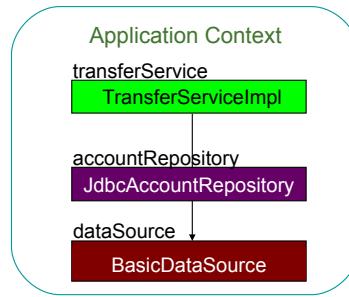
// No need for bean id if type is unique
TransferService ts3 = context.getBean(TransferService.class);
```



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Inside the Spring Application Context

```
// Create the application from the configuration
ApplicationContext context =
    SpringApplication.run(ApplicationConfig.class);
```



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Bean Descriptions

- Allows you to provide helpful information about any bean

```
@Bean  
{@Description("Handles all transfer related use-cases")  
public TransferService transferService() { ... }  
  
@Bean  
{@Description("Provides access to data from the Accounts table")  
public AccountRepository accountRepository() { ... }  
  
@Bean  
{@Description("Data-source for the underlying RDB we are using")  
public DataSource dataSource() { ... }}
```



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Quick Start Summary

- Spring separates application configuration from application objects
- Spring manages your application objects
 - Creating them in the correct order
 - Ensuring they are fully initialized before use
- Each bean is given a unique id / name
 - Should reflect service or role the bean provides to clients
 - Bean ids should not contain implementation details



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Topics in this session

- Spring quick start
- **Creating an application context**
- Multiple Configuration Files
- Bean scope
- Lab



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Creating a Spring Application Context

- Spring application contexts can be bootstrapped in any environment, including
 - JUnit system test
 - Web application
 - Standalone application



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ApplicationContext Example

Instantiating Within a System (Integration) Test

```
public class TransferServiceTests {  
    private TransferService service;  
  
    @Before public void setUp() {  
        // Create the application from the configuration  
        ApplicationContext context =  
            SpringApplication.run( ApplicationConfig.class )  
        // Look up the application service interface  
        service = context.getBean(TransferService.class);  
    }  
  
    @Test public void moneyTransfer() {  
        Confirmation receipt =  
            service.transfer(new MonetaryAmount("300.00"), "1", "2");  
        Assert.assertEquals("500.00", receipt.getNewBalance());  
    }  
}
```

Bootstraps the system to test

Tests the system



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Topics in this session

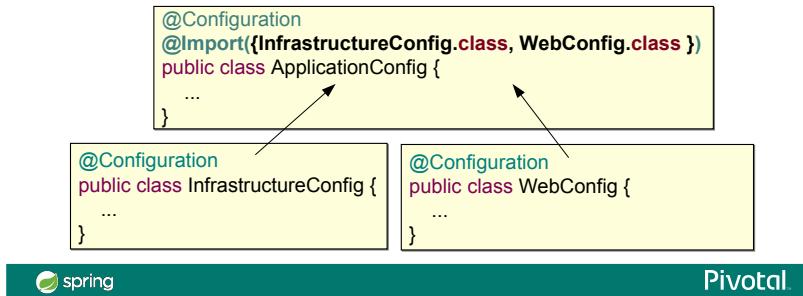
- Spring quick start
- Creating an application context
- **Multiple Configuration Files**
- Bean scope
- Lab



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Creating an Application Context from Multiple Files

- Your `@Configuration` class can get very long
 - Instead use *multiple* files combined with `@Import`
 - Defines a single Application Context
 - With beans sourced from multiple files

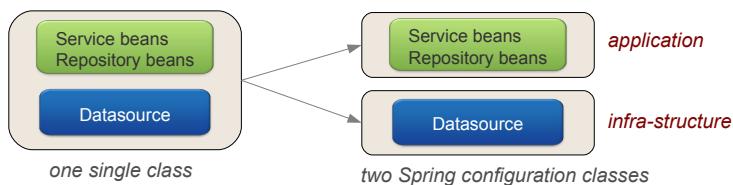


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Creating an Application Context from Multiple Files

- Organize your `@Configuration` classes however you like
- Best practice: separate out “application” beans from “infrastructure” beans
 - Infrastructure often changes between environments



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Mixed Configuration

```
@Configuration  
public class ApplicationConfig {  
  
    @Bean public TransferService transferService()  
    { return new TransferServiceImpl( accountRepository() ); }  
  
    @Bean public AccountRepository accountRepository()  
    { return new JdbcAccountRepository( dataSource() ); }  
  
    @Bean public DataSource dataSource()  
    {  
        BasicDataSource dataSource = new BasicDataSource();  
        dataSource.setDriverClassName("org.postgresql.Driver");  
        dataSource.setUrl("jdbc:postgresql://localhost/transfer");  
        dataSource.setUsername("transfer-app");  
        dataSource.setPassword("secret45");  
        return dataSource;  
    }  
}
```

application beans

Coupled to a local Postgres environment

infrastructure bean



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Partitioning Configuration

```
@Configuration  
public class ApplicationConfig {  
    @Autowired DataSource dataSource;  
  
    @Bean public TransferService transferService()  
    { return new TransferServiceImpl( accountRepository() ); }  
  
    @Bean public AccountRepository accountRepository()  
    { return new JdbcAccountRepository( dataSource ); }  
}  
  
@Configuration  
public class TestInfrastructureConfig {  
    @Bean public DataSource dataSource()  
    ...  
}
```

application beans

infrastructure bean



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Referencing Beans Defined in Another File

- Use `@Autowired` to reference a bean defined elsewhere

```
@Configuration  
@Import( InfrastructureConfig.class )  
public class AppConfig {  
    private final DataSource dataSource;  
  
    @Autowired  
    public AppConfig(DataSource ds) {  
        this.dataSource = ds;  
    }  
  
    @Bean  
    public AccountRepository accountRepository() {  
        return new JdbcAccountRepository( dataSource );  
    }  
}
```

Pre Spring 4.3: Auto-wire a property setter, can't use a constructor



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Referencing Dependencies Via Arguments

- Alternative:* Define `@Bean` method arguments
 - Spring finds bean that matches type & populates the argument

```
@Configuration  
@Import( InfrastructureConfig.class )  
public class ApplicationConfig {  
    @Bean  
    public AccountRepository accountRepository( DataSource dataSource ) {  
        return new JdbcAccountRepository( dataSource );  
    }  
}
```

```
@Configuration  
public class InfrastructureConfig {  
    @Bean public DataSource dataSource() {  
        DataSource ds = new BasicDataSource();  
        ...  
        return ds;  
    }  
}
```



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... But Avoid “Tramp Data”

```
@Configuration  
@Import( InfrastructureConfig.class )  
public class ApplicationConfig {  
    @Bean public AccountService accountService( DataSource dataSource ){  
        return new accountService( accountRepository(dataSource) );  
    }  
  
    @Bean public AccountService accountRepository( DataSource dataSource ) {  
        return new accountRepository( dataSource );  
    }  
}  
  
@Configuration  
@Import( InfrastructureConfig.class )  
public class ApplicationConfig {  
    @Bean public AccountService accountService( AccountRepository repo ) {  
        return new accountService( repo );  
    }  
    @Bean public AccountService accountRepository( DataSource ds ) {  
        return new accountRepository( ds );  
    }  
}
```

Bad: dataSource is a “tramp”!

tramp

Better: Pass *actual* dependency



Beware Duplicate Beans

Use `@Order` annotation
to control which order
`@Bean` methods run
(since Spring 4.2)

- It is *not* illegal to define the same bean more than once
 - You get the last bean Spring sees defined

```
@Configuration  
public class Config1 {  
    @Bean  
    public String example() {  
        return new String("example1");  
    }  
}  
  
@Configuration  
public class Config2 {  
    @Bean  
    public String example() {  
        return new String("example2");  
    }  
}  
  
@Import({ Config1.class, Config2.class })  
public class TestApp {  
    public static void main(String[] args) {  
        ApplicationContext context = SpringApplication.run(TestApp.class);  
        System.out.println("Id=" + context.getBean("example"));  
    }  
}
```

Console output is `Id=example2`



Topics in this session

- Spring quick start
- Creating an application context
- Multiple Configuration Files
- **Bean scope**
- Lab



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Bean Scope: default

service1 == service2

- Default scope is *singleton*

```
@Bean  
public AccountService accountService() {  
    return ...  
}
```

```
@Bean  
@Scope("singleton")  
public AccountService accountService() {  
    return ...  
}
```

One single instance

```
AccountService service1 = (AccountService) context.getBean("accountService");  
AccountService service2 = (AccountService) context.getBean("accountService");  
assert service1 == service2; // True – same object
```



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Bean Scope: prototype

service1 != service2

- Scope "prototype"
 - New instance created every time bean is referenced

```
@Bean  
@Scope("prototype")  
public AccountService accountService() {  
    return ...  
}
```

```
@Scope(scopeName="prototype")
```

```
AccountService service1 = (AccountService) context.getBean("accountService");  
AccountService service2 = (AccountService) context.getBean("accountService");  
assert service1 != service2; // True – different objects
```

TWO instances



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Common Spring Scopes

- The most commonly used scopes are:

singleton A single instance is used

prototype A new instance is created each time the bean is referenced

session A new instance is created once per user session - web environment only

request A new instance is created once per request – web environment only



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Other Scopes

- Spring has other more specialized scopes
 - Web Socket scope
 - Refresh Scope
 - Thread Scope (defined but not registered by default)
- Custom scopes (rarely)
 - You define a factory for creating bean instances
 - Register to define a custom scope name
- All are outside the scope of this course



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Dependency Injection Summary

- Your object is handed what it needs to work
 - Frees it from the burden of resolving its dependencies
 - Simplifies your code, improves code reusability
- Promotes programming to interfaces
 - Conceals implementation details of dependencies
- Improves testability
 - Dependencies easily stubbed out for unit testing
- Allows for centralized control over object lifecycle
 - Opens the door for new possibilities



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Lab

Using Spring to Configure an Application



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Dependency Injection Using Spring 2

Deeper Look into Spring's Java
Configuration Capability

External Properties, Profiles and Proxies

Topics in this session

- **External Properties**
- Profiles
- Spring Expression Language
- Proxying

Setting property values

- Consider this bean definition from the last chapter:

```
@Bean  
public DataSource dataSource() {  
    DataSource ds = new BasicDataSource();  
    ds.setDriverClassName("org.postgresql.Driver");  
    ds.setUrl("jdbc:postgresql://localhost/transfer");  
    ds.setUser("transfer-app");  
    ds.setPassword("secret45");  
    return ds;  
}
```

- Unwise to hard-code DB connection parameters
 - “Externalize” these to a properties file



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Spring's Environment Abstraction – 1

- Environment** object used to obtain properties from runtime environment
- Properties from many sources:
 - JVM System Properties
 - Java Properties Files
 - Servlet Context Parameters
 - System Environment Variables
 - JNDI



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Spring's Environment Abstraction – 2

```
@Configuration  
public class DbConfig {  
    private static final String DB_DRIVER = "db.driver";  
    private static final String DB_URL = "db.url";  
    private static final String DB_USER = "db.user";  
    private static final String DB_PWD = "db.password";  
  
    @Autowired public Environment env;  
  
    @Bean public DataSource dataSource() {  
        DataSource ds = new BasicDataSource();  
        ds.setDriverClassName( env.getProperty( DB_DRIVER ));  
        ds.setUrl( env.getProperty( DB_URL ));  
        ds.setUser( env.getProperty( DB_USER ));  
        ds.setPassword( env.getProperty( DB_PWD ));  
        return ds;  
    }  
}
```

Property names

Fetch property values from environment



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Property Sources

- Environment obtains values from “property sources”
 - *Environment Variables* and *Java System Properties* always populated automatically
 - **@PropertySource** contributes *additional* properties
 - Available resource prefixes: classpath: file: http:

```
@Configuration  
@PropertySource ( "classpath:/com/organization/config/app.properties" )  
@PropertySource ( "file:config/local.properties" )  
public class ApplicationConfig {  
    ...  
}
```

Adds properties from these files *in addition to* environment variables and system properties



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Accessing Properties using @Value

```
@Configuration  
public class DbConfig {  
  
    @Bean  
    public DataSource dataSource(  
        @Value("${db.driver}") String driver,  
        @Value("${db.url}") String url,  
        @Value("${db.user}") String user,  
        @Value("${db.password}") String pwd) {  
        DataSource ds = new BasicDataSource();  
        ds.setDriverClassName( driver);  
        ds.setUrl( url);  
        ds.setUser( user);  
        ds.setPassword( pwd));  
        return ds;  
    }  
}
```

Convenient alternative to explicitly using Environment

BUT: How are these \${...} variables resolved? Next slide ...



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Evaluating \${...} Variables

- \${...} variables are evaluated by a dedicated Spring bean
 - The `PropertySourcesPlaceholderConfigurer`
 - **Note:** make this a `static` bean
 - Ensures \${..} placeholder expressions are evaluated *before* any beans are created that might use them

```
@Bean  
public static PropertySourcesPlaceholderConfigurer pspc() {  
    return new PropertySourcesPlaceholderConfigurer();  
}
```

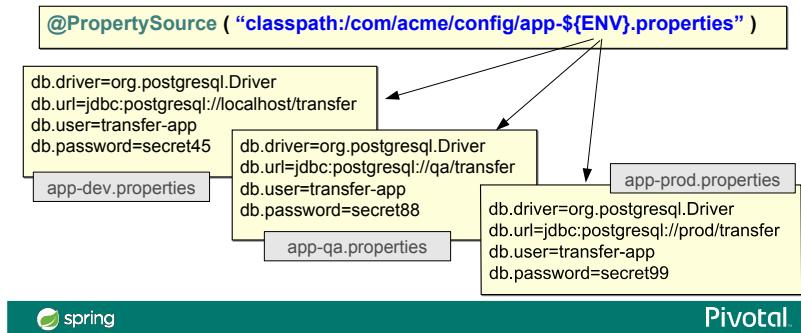
• \${..} placeholders are *not resolved unless this bean declared*



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`${...}` Placeholders

- `${...}` placeholders in a `@PropertySource` are resolved against existing properties
 - Such as System properties & Environment variables

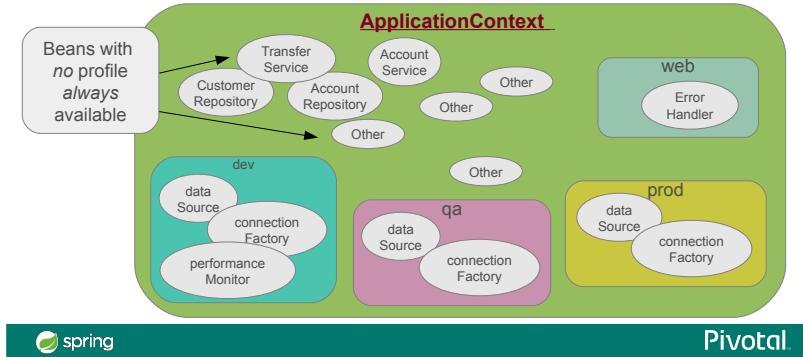


Topics in this session

- External Properties
- **Profiles**
- Spring Expression Language
- Proxying

Profiles

- Beans can be grouped into Profiles
 - Profiles can represent purpose: "web", "offline"
 - Or environment: "dev", "qa", "uat", "prod"
 - Beans included / excluded based on profile membership



Defining Profiles – 1

- Using **@Profile** annotation on configuration class
 - All beans in Configuration belong to the profile

```
@Configuration  
{@Profile("dev")}  
public class DevConfig {  
  
    @Bean  
    public DataSource dataSource() {  
        EmbeddedDatabaseBuilder builder = new EmbeddedDatabaseBuilder();  
        return builder.setName("testdb")  
            .setType(EmbeddedDatabaseType.HSQL)  
            .addScript("classpath:/testdb/schema.db")  
            .addScript("classpath:/testdb/test-data.db").build();  
    }  
    ...  
}
```



Defining Profiles - 2

- Using **@Profile** annotation on **@Bean** methods

```
@Configuration  
public class DataSourceConfig {  
    @Bean(name="dataSource")  
    @Profile("dev")  
    public DataSource dataSourceForDev() {  
        EmbeddedDatabaseBuilder builder = new EmbeddedDatabaseBuilder();  
        return builder.setName("testdb") ...  
    }  
  
    @Bean(name="dataSource")  
    @Profile("prod")  
    public DataSource dataSourceForProd() {  
        DataSource dataSource = new BasicDataSource();  
        ...  
        return dataSource;  
    }  
}
```

Explicit bean-name overrides method name

Both profiles define same bean id, so only one profile should be activated at a time.



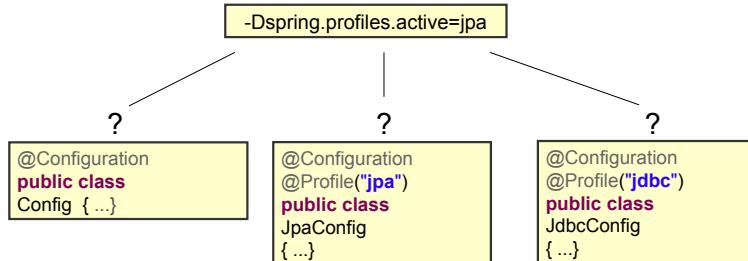
Ways to Activate Profiles

- Profiles must be activated at run-time
 - System property via command-line
 - System property programmatically
 - Integration Test: Use **@ActiveProfiles** (later section)
 - Note: **@ActiveProfiles** only works in a Spring-driven test
- ```
-Dspring.profiles.active=dev,jpa
```
- ```
System.setProperty("spring.profiles.active", "dev,jpa");  
SpringApplication.run(AppConfig.class);
```



Quiz:

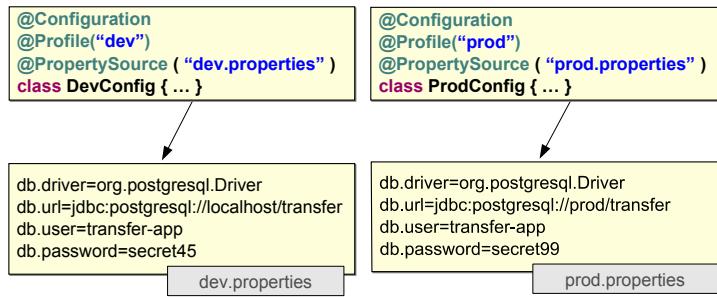
Which of the Following is/are Selected?



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Property Source selection

- @Profile can control which @PropertySources are included in the Environment



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Topics in this session

- External Properties
- Profiles
- **Spring Expression Language**
- Proxying



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Spring Expression Language

- SpEL for short
 - Inspired by the Expression Language used in Spring WebFlow
 - Based on Unified Expression Language used by JSP and JSF
- Pluggable/extendable by other Spring-based frameworks



This is just a brief introduction, for full details see
<http://docs.spring.io/spring/docs/current/spring-framework-reference/html/expressions.html>



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SpEL examples – Using @Value

```
@Configuration  
class TaxConfig  
{  
    @Value("#{ systemProperties['user.region'] }") String region;  
  
    @Bean public TaxCalculator taxCalculator1() {  
        return new TaxCalculator( region );  
    }  
  
    @Bean public TaxCalculator taxCalculator2  
        (@Value("#{ systemProperties['user.region'] }") String region, ...) {  
        return new TaxCalculator( region );  
    }  
    ...  
}
```

Option 1: Set an attribute then use it

Option 2: Pass as a bean method argument



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SpEL – Accessing Spring Beans

```
class StrategyBean {  
    private KeyGenerator gen = new KeyGenerator.getInstance("Blowfish");  
    public KeyGenerator getKeyGenerator() { return gen; }  
}  
  
@Configuration  
class StrategyConfig  
{  
    @Bean public StrategyBean strategyBean() {  
        return new StrategyBean();  
    }  
}  
  
@Configuration  
class AnotherConfig  
{  
    @Value("#{strategyBean.keyGenerator}") KeyGenerator kgen;  
    ...  
}
```



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Accessing Properties

- Can access properties via the *environment*
 - These are equivalent

```
@Value("${daily.limit}")
int maxTransfersPerDay;
```

```
@Value("#{environment['daily.limit']}")
int maxTransfersPerDay;
```

- Properties are Strings
 - May need to cast in expressions

```
@Value("#{new Integer(environment['daily.limit']) * 2}")
@Value("#{new java.net.URL(environment['home.page']).host}")
```



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SpEL

- EL Attributes can be:
 - Spring beans (like *strategyBean*)
 - Implicit references
 - Spring's *environment*, *systemProperties*, *systemEnvironment* available by default
 - Others depending on context
- SpEL allows to create custom functions and references
 - Widely used in Spring projects
 - Spring Security, Spring WebFlow
 - Spring Batch, Spring Integration
 - Each may add *their own* implicit references



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Topics in this session

- External Properties
- Profiles
- Spring Expression Language
- **Proxying**



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Quiz

```
@Bean implementation?  
public AccountRepository accountRepository() {  
    return new JdbcAccountRepository();  
}
```

```
@Bean  
public TransferService transferService1() {  
    TransferServiceImpl service = new TransferServiceImpl();  
    service.setAccountRepository(accountRepository());  
    return service;  
}
```

```
@Bean  
public TransferService transferService2() {  
    return new TransferServiceImpl( new JdbcAccountRepository() );  
}
```

1. Method call?

2. New instance?

Prefer call to dedicated method. Let's discuss why ...



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Working with Singletons

```
@Bean  
public AccountRepository accountRepository() {  
    return new JdbcAccountRepository();  
}  
  
@Bean  
public TransferService transferService() {  
    TransferServiceImpl service = new TransferServiceImpl();  
    service.setAccountRepository(accountRepository());  
    return service;  
}  
  
@Bean  
public AccountService accountService() {  
    return new AccountServiceImpl( accountRepository() );  
}
```

Singleton??

Method called twice more

HOW IS IT POSSIBLE?



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Singletons Require Proxies

- At startup time, a proxy subclass is created
 - Subclass performs *scope-control*
 - Only calls *super* on *first* invocation of singleton bean method
 - Singleton instance is cached by the *ApplicationContext*

```
@Configuration  
public class AppConfig {  
    @Bean public AccountRepository accountRepository() { ... }  
    @Bean public TransferService transferService() { ... }  
}
```

↑ *inherits from*

```
public class AppConfig$$EnhancerByCGLIB$$ extends AppConfig {  
    public AccountRepository accountRepository() { // ... }  
    public TransferService transferService() { // ... }  
}
```



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Inheritance-based Proxies

- Child class is the entry point

```
public class AppConfig$$EnhancerByCGLIB$ extends AppConfig {  
  
    public AccountRepository accountRepository() {  
        // if bean is in the applicationContext, then return bean  
        // else call super.accountRepository(), store bean in context, return bean  
    }  
  
    public TransferService transferService() {  
        // if bean is in the applicationContext, then return bean  
        // else call super.transferService(), store bean in context, return bean  
    }  
}
```



Java Configuration uses *cglib* for inheritance-based proxies



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Summary

- Property values are easily externalized using Spring's Environment abstraction
- Profiles are used to group sets of beans
- Spring Expression Language
- Spring proxies your @Configuration classes to allow for scope control.



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Annotations in Spring

Annotations for Dependency Injection and Interception

Component scanning and auto-injection

Topics in this Session

- Fundamentals
 - Annotation-based Configuration
 - Best practices: when to use what?
 - @PostConstruct and @PreDestroy
 - Stereotypes and meta annotations
- Lab
- Advanced features
 - @Resource
 - Standard annotations (JSR 330)

Before – Explicit Bean Definition

- Configuration is external to bean-class
 - Separation of concerns
 - Java-based dependency injection

```
@Configuration  
public class TransferModuleConfig {  
  
    @Bean public TransferService transferService() {  
        return new TransferServiceImpl( accountRepository() );  
    }  
  
    @Bean public AccountRepository accountRepository() {  
        ...  
    }  
}
```

Dependency
Injection



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After - Implicit Configuration

- Annotation-based configuration *within* bean-class

```
@Component  
public class TransferServiceImpl implements TransferService {  
    @Autowired  
    public TransferServiceImpl(AccountRepository repo) {  
        this.accountRepository = repo;  
    }  
}
```

Bean id derived from classname: *transferServiceImpl*

Annotations embedded
with POJOs

```
@Configuration  
@ComponentScan ( "com.bank" )  
public class AnnotationConfig {  
    // No bean definition needed any more  
}
```

Find @Component classes
within designated (sub)packages



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Usage of @Autowired

Unique dependency of
correct **type** must exist

- Constructor-injection

```
@Autowired  
public TransferServiceImpl(AccountRepository a) {  
    this.accountRepository = a;  
}
```

- Method-injection

```
@Autowired  
public void setAccountRepository(AccountRepository a) {  
    this.accountRepository = a;  
}
```

- Field-injection

```
@Autowired  
private AccountRepository accountRepository;
```

Even when field is private!!
– but hard to unit test, see URL



<http://olivergierke.de/2013/11/why-field-injection-is-evil/>

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@Autowired dependencies: required or not?

- Default behavior: required

```
@Autowired  
public void setAccountRepository(AccountRepository a) {  
    this.accountRepository = a;  
}
```

Exception if no
dependency found

- Use required attribute to override default behavior

```
@Autowired(required=false)  
public void setAccountRepository(AccountRepository a) {  
    this.accountRepository = a;  
}
```

Only inject if
dependency exists



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Java 8 Optional<T>

- Another way to inject optional dependencies
 - `Optional<T>` introduced to reduce null pointer errors

```
@Autowired(required=false)
AccountService accountService;

public void doSomething() {
    if (accountService != null) {
        // do something
    }
}
```

```
@Autowired
Optional<AccountService> accountService;

public void doSomething() {
    accountService.ifPresent( s -> {
        // s is the AccountService instance,
        // use s to do something
    });
}
```

Note the use of the lambda



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Constructor vs Setter Dependency Injection

- Spring doesn't care – can use either
 - But which is best?

Constructors	Setters
Mandatory dependencies	Optional / changeable dependencies
Immutable dependencies	Circular dependencies
Concise (pass several params at once)	Inherited automatically If constructor needs too many params

- Follow the same rules as standard Java
 - Be consistent across your project team
 - Many classes use both



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Autowiring and Disambiguation – 1

- What happens here?

```
@Component  
public class TransferServiceImpl implements TransferService {  
    @Autowired  
    public TransferServiceImpl(AccountRepository accountRepository) { ... }  
}
```

```
@Component  
public class JpaAccountRepository implements AccountRepository {..}  
  
@Component  
public class JdbcAccountRepository implements AccountRepository {..}
```

Which one should get injected?

At startup: *NoSuchBeanDefinitionException*, no unique bean of type [AccountRepository] is defined: expected single bean but found 2...



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Autowiring and Disambiguation – 2

- Use of the @Qualifier annotation

```
@Component("transferService")  
public class TransferServiceImpl implements TransferService {  
    @Autowired  
    public TransferServiceImpl( @Qualifier("jdbcAccountRepository")  
        AccountRepository accountRepository) { ... }  
  
    @Component("jdbcAccountRepository")  
    public class JdbcAccountRepository implements AccountRepository {..}  
  
    @Component("jpaAccountRepository")  
    public class JpaAccountRepository implements AccountRepository {..}
```

qualifier

bean ID



@Qualifier also available with method injection and field injection
Component names should *not* show implementation details *unless*
there are 2 implementations of the *same* interface (as here)



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Autowiring and Disambiguation – 3

- Autowired resolution rules
 - Look for unique bean of required *type*
 - Use `@Qualifier` if supplied
 - Try to find a matching bean by *name*
- Example
 - We have multiple *Queue* beans
 - Spring finds bean with id matching what is being set: “`ack`”

```
@Autowired  
public myBean(Queue ack) {  
    ...  
}
```

```
@Autowired  
public void setQueue(Queue ack) {  
    ...  
}
```

```
@Autowired  
private Queue ack;
```

Looks for Queue bean with id = “`ack`”



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Using `@Value` to set Attributes

- Constructor-injection

Can use \$ variables or
SpEL

```
@Autowired  
public TransferServiceImpl(@Value("${daily.limit}") int max) {  
    this.maxTransfersPerDay = max;  
}
```

- Method-injection

```
@Autowired  
public void setDailyLimit(@Value("${daily.limit}") int max) {  
    this.maxTransfersPerDay = max;  
}
```

- Field-injection

```
@Value("#${environment['daily.limit']}")  
int maxTransfersPerDay;
```

Not private so we can
initialize in a unit-test



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More on @Value

- Providing a fall-back value
 - If `daily.limit` undefined, use colon :

```
@Autowired  
public TransferServiceImpl(@Value("${daily.limit : 100000}") int max) {  
    this.maxTransfersPerDay = max;  
}
```

– For SpEL, use the “Elvis” operator `?:`

```
@Autowired  
public setLimit(@Value("#{environment[daily.limit] ?: 100000}") int max) {  
    this.maxTransfersPerDay = max;  
}
```

`x ?: y` is short for `x != null ? x : y`

Equivalent operators



Elvis lives!



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Component Names

- When not specified
 - Names are auto-generated
 - De-capitalized non-qualified classname by default
 - But will pick up implementation details from classname
 - *Recommendation:* never rely on generated names!
- When specified
 - Allow disambiguation when 2 bean classes implement the same interface



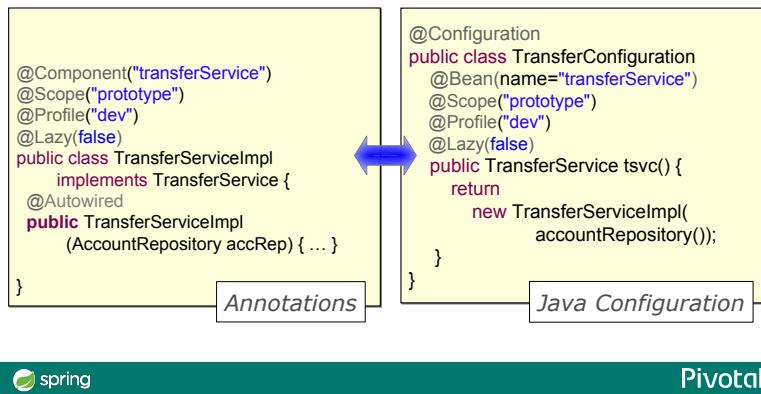
Common strategy: avoid using qualifiers when possible.
Usually rare to have 2 beans of same type in ApplicationContext



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Java Config vs Annotations syntax

- Similar options are available



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Topics in this Session

- Fundamentals
 - Annotation-based Configuration
 - Best practices: when to use what?**
 - `@PostConstruct` and `@PreDestroy`
 - Stereotypes and meta annotations
- Lab
- Advanced features
 - `@Resource`
 - Standard annotations (JSR 330)

spring

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About Component Scanning

- Components are scanned at startup
 - JAR dependencies also scanned!
 - Could result in slower startup time if too many files scanned
 - Especially for large applications
 - A few seconds slower in the worst case
- What are the best practices?



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Best practices

- Really bad:
`@ComponentScan ({ "org", "com" })`

All “org” and “com”
packages in the classpath
will be scanned!!

- Still bad:
`@ComponentScan ("com")`

- OK:
`@ComponentScan ("com.bank.app")`

- Optimized:
`@ComponentScan ({ "com.bank.app.repository",
"com.bank.app.service", "com.bank.app.controller" })`



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When to use what?

Java

Java Configuration

- Pros:
 - Is centralized in one (or a few) places
 - Write any Java code you need
 - Strong type checking enforced by compiler (and IDE)
 - Can be used for all classes (not just your own)
- Cons:
 - More verbose than annotations



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When to use what?

@

Annotations

- Nice for frequently changing beans
- Pros:
 - Single place to edit (just the class)
 - Allows for very rapid development
- Cons:
 - Configuration spread across your code base
 - Harder to debug/maintain
 - Only works for your own code
 - Merges configuration and code (bad sep. of concerns)



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Mixing Java Config and Annotations

- You can mix and match in many ways
- Common approach:
 - Use annotations whenever possible
 - Your classes
 - But still use Java Configuration for
 - Third-party beans that aren't annotated
 - Legacy code that can't be changed



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Topics in this Session

- Fundamentals
 - Annotation-based Configuration
 - Best practices: when to use what?
 - **@PostConstruct and @PreDestroy**
 - Stereotypes and meta annotations
- Lab
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 - **@Resource**
 - Standard annotations (JSR 330)



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@PostConstruct and @PreDestroy

- Add behavior at startup and shutdown

```
public class JdbcAccountRepository {  
    @PostConstruct  
    void populateCache() {}  
  
    @PreDestroy  
    void clearCache() {}  
}
```

Method called at startup after dependency all injection

Method called at shutdown prior to destroying the bean instance



Annotated methods can have any visibility but *must* take *no* parameters and *only* return *void*



About @PostConstruct & @PreDestroy

- Beans are created in the usual ways:
 - Returned from @Bean methods
 - Found and created by the component-scanner
- Spring then invokes these methods *automatically*
 - During bean-creation process
- These are not Spring annotations
 - Defined by JSR-250, part of Java since Java 6
 - In `javax.annotation` package
 - Supported by Spring, *and* by JEE



@PostConstruct

- Called after setter methods are called

```
public class JdbcAccountRepository {  
    private DataSource dataSource;  
    @Autowired  
    public void setDataSource(DataSource dataSource)  
    { this.dataSource = dataSource; } 1  
  
    @PostConstruct  
    public void populateCache()  
    { Connection conn = dataSource.getConnection(); //... } 2  
}
```



@PreDestroy

- Called when a *ConfigurableApplicationContext* is closed
 - If application (JVM) exits normally
 - Useful for releasing resources & 'cleaning up'
 - Not called for prototype beans

```
ConfigurableApplicationContext context = SpringApplication.run(...);  
// Triggers call of all @PreDestroy annotated methods  
context.close();
```

Causes Spring to invoke this method

```
public class JdbcAccountRepository {  
    @PreDestroy  
    public void clearCache() { ... }  
    ...  
}
```



Lifecycle Methods via @Bean

- Alternatively, `@Bean` has options to define these *life-cycle* methods

```
@Bean (initMethod="populateCache", destroyMethod="clearCache")
public AccountRepository accountRepository() {
    // ...
}
```

- Common Usage:
 - `@PostConstruct/@PreDestroy` for your own classes
 - `@Bean` properties for classes you didn't write and can't annotate



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Topics in this Session

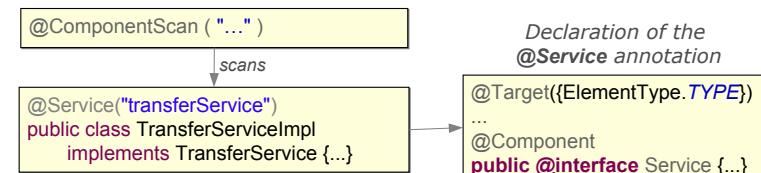
- Fundamentals
 - Annotation-based Configuration
 - Best practices: when to use what?
 - `@PostConstruct` and `@PreDestroy`
 - Stereotypes and meta annotations**
- Lab
- Advanced features
 - `@Resource`
 - Standard annotations (JSR 330)



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Stereotype Annotations

- Component scanning also checks for annotations that are themselves annotated with @Component
 - So-called *sereotype annotations*



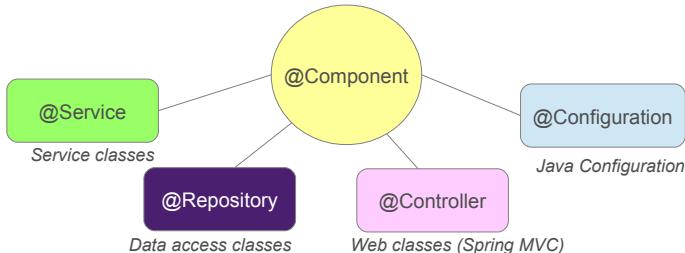
@Service annotation is part of the Spring framework



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Predefined Stereotype Annotations

- Spring framework stereotype annotations



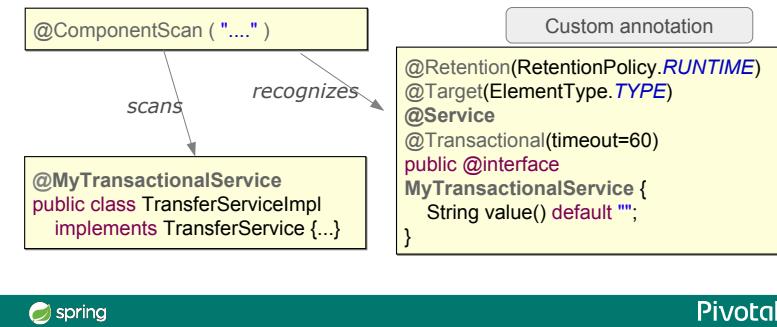
Other Spring projects provide their own stereotype annotations
(Spring Web-Services, Spring Integration...)



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Meta-annotations

- Annotation which can be used to annotate other annotations
 - e.g. all service beans should be configurable using component scanning and be transactional



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Summary

- Spring beans can be defined:
 - Explicitly using `@Bean` methods
 - Implicitly using `@Component` and component-scanning
- Most applications use both
 - Implicit for your classes
 - Explicit for the rest
- Can perform initialization and clean-up
 - Use `@PostConstruct` and `@PreDestroy`
- Use Spring's stereotypes and/or define your own meta annotations

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Lab

Using Spring Annotations
To Configure and Test an application

Coming Up: Other Annotations for Dependency Injection



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Topics in this Session

- Fundamentals
 - Annotation-based Configuration
 - Best practices: when to use what?
 - @PostConstruct and @PreDestroy
 - Stereotypes and meta annotations
- Lab
- Advanced features
 - **@Resource**
 - Standard annotations (JSR 330)



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Using @Resource

- From JSR-250, supported by EJB 3.0 and Spring
 - Identifies dependencies by *name*, not by *type*
 - Name is Spring bean-name
 - @Autowired matches by *type*
 - Supports setter and field injection *only*

```
@Resource(name="jdbcAccountRepository")
public void setAccountRepository(AccountRepository repo) {
    this.accountRepository = repo;
}
```

Setter
Injection

```
@Resource(name="jdbcAccountRepository")
private AccountRepository accountRepository;
```

Field
injection



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Qualifying @Resource

- @Autowired:** type *then* name
- When no name is supplied
 - Inferred from property/field name
 - Or falls back on injection by type
- Example
 - Looks for bean called *accountRepository*
 - because method is *setAccountRepository*
 - Then looks for bean of type *AccountRepository*

@Resource: name *then* type

```
@Resource
public void setAccountRepository(AccountRepository repo) {
    this.accountRepository = repo;
}
```



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Topics in this Session

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 - Standard annotations (JSR 330)



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JSR 330

- Java Specification Request 330
 - Also known as @Inject
 - Joint JCP effort by Google and SpringSource
 - Standardizes internal DI annotations
 - Published late 2009
 - Spring is a valid JSR-330 implementation
- Subset of functionality compared to Spring's @Autowired support
 - @Inject has 80% of what you need
 - Rely on @Autowired for the rest



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JSR 330 annotations

The diagram illustrates the mapping between Spring annotations and JSR 330 annotations. It shows two code snippets: one for a service implementation and one for a repository.

Annotations:

- @ComponentScan ("....")** (Spring) is equivalent to **Also scans JSR-330 annotations**.
- import javax.inject.Inject;** and **import javax.inject.Named;** (Spring) are equivalent to **Should be specified for component scanning (even without a name)**.
- @Named** (Spring) is equivalent to **@Named("accountRepository")** (JSR 330).
- @Inject** (Spring) is equivalent to **@Inject** (JSR 330).
- @Scope ("singleton")** (Spring) is equivalent to **@Singleton** (JSR 330).
- @Value** (Spring) has no equivalent in JSR 330.
- @Required** (Spring) is equivalent to **Redundant** (JSR 330).
- @Lazy** (Spring) has no equivalent in JSR 330.

Code Snippets:

```
@ComponentScan ("....")
```

```
import javax.inject.Inject;
import javax.inject.Named;
```

```
@Named
public class TransferServiceImpl implements TransferService {
    @Inject
    public TransferServiceImpl( @Named("accountRepository")
        AccountRepository accountRepository) { ... }
}
```

```
import javax.inject.Named;

@Named("accountRepository")
public class JdbcAccountRepository implements
    AccountRepository {..}
```



From `@Autowired` to `@Inject`

Spring	JSR 330	Comments
<code>@Autowired</code>	<code>@Inject</code>	<code>@Inject</code> always mandatory, has no required option
<code>@Component</code>	<code>@Named</code>	Spring also scans for <code>@Named</code>
<code>@Scope</code>	<code>@Scope</code>	JSR 330 Scope for meta-annotation and injection points only
<code>@Scope ("singleton")</code>	<code>@Singleton</code>	JSR 330 default scope is like Spring's 'prototype'
<code>@Qualifier</code>	<code>@Named</code>	
<code>@Value</code>	No equivalent	SpEL specific
<code>@Required</code>	Redundant	<code>@Inject</code> always required
<code>@Lazy</code>	No equivalent	Useful when needed, often abused



Dependency Injection Using XML

Spring's XML Configuration Language

Using <bean> definitions and namespaces

Topics in this session

- Writing bean definitions in XML
- Creating an application context
- Controlling Bean Behavior
- Factory Beans
- Namespaces
- Lab
- Advanced Topics

Note: XML is in the certification exam

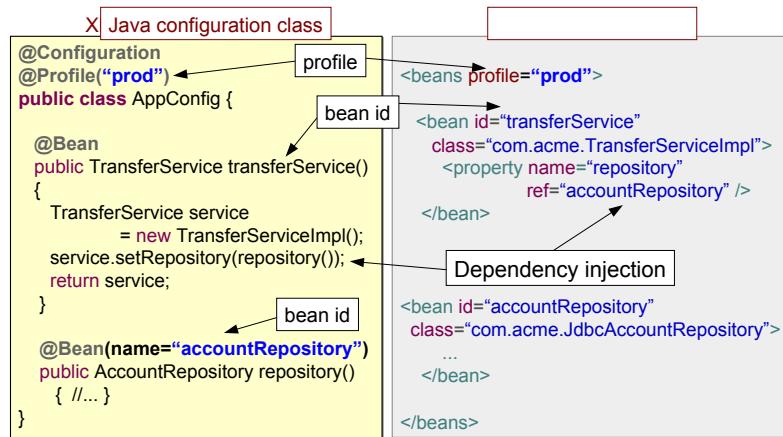


XML Configuration

- Original form of Configuration / Dependency Injection
 - Dating back to before 2004
 - Still fully supported
- Most commonly seen in existing applications
 - ... and in older blogs, books, etc.
- External *explicit* configuration as with Java Config
 - Uses custom XML instead of Java



@Configuration Comparison



Constructor Injection Configuration

- One parameter

```
<bean id="transferService" class="com.acme.TransferServiceImpl">
    <constructor-arg ref="accountRepository"/>
</bean>

<bean id="accountRepository" class="com.acme.AccountRepositoryImpl"/>
```

- Multiple parameters

```
<bean id="transferService" class="com.acme.TransferServiceImpl">
    <constructor-arg ref="accountRepository"/>
    <constructor-arg ref="customerRepository"/>
</bean>

<bean id="accountRepository" class="com.acme.AccountRepositoryImpl"/>
<bean id="customerRepository" class="com.acme.CustomerRepositoryImpl"/>
```

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Constructor Injection 'Under the Hood'

```
<bean id="service" class="com.acme.ServiceImpl">
    <constructor-arg ref="repository"/>
</bean>

<bean id="repository" class="com.acme.RepositoryImpl"/>
```

Equivalent to:

```
@Bean public Repository repository() {
    return new RepositoryImpl();
}

@Bean public Service service() {
    return new ServiceImpl( repository() );
}
```

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spring

Setter Injection

```
<bean id="service" class="com.acme.ServiceImpl">
    <property name="repository" ref="repository"/>
</bean>
<bean id="repository" class="com.acme.RepositoryImpl"/>
```

Convention: implicitly refers to method `setRepository(...)`

Equivalent to:

```
@Bean public Repository repository() {
    return new RepositoryImpl();
}

@Bean public Service service() {
    Service svc = new ServiceImpl();
    svc.setRepository( repository() );
    return svc;
}
```



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Combining Constructor and Setter Injection

```
<bean id="service" class="com.acme.ServiceImpl">
    <constructor-arg ref="required" />
    <property name="optional" ref="optional" />
</bean>

<bean id="required" class="com.acme.RequiredImpl" />
<bean id="optional" class="com.acme.OptionalImpl" />
```

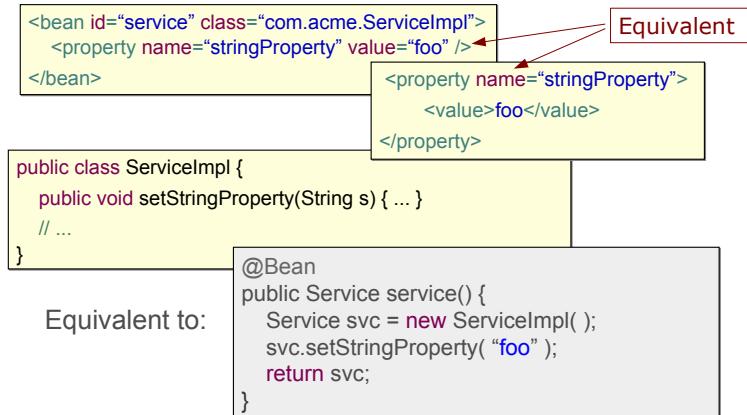
Equivalent to:

```
@Bean public RequiredImpl required() { ... }
@Bean public OptionalImpl optional() { ... }
@Bean public Service service() {
    Service svc = new ServiceImpl( required() );
    svc.setOptional( optional() );
    return svc;
}
```



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Injecting Scalar Values



spring

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Automatic Value Type Conversion



spring

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Topics in this session

- Writing bean definitions in XML
- **Creating an application context**
- Controlling Bean Behavior
- Factory Beans
- Namespaces
- Lab
- Advanced Topics



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Creating an ApplicationContext using XML

- Use a Java Configuration class
 - `@ImportResource` to define XML file(s):

```
SpringApplication.run(MainConfig.class);
```

```
@Configuration  
@ImportResource( {  
    "classpath:com/acme/application-config.xml",  
    "file:C:/Users/alex/application-config.xml" } )  
@Import(DatabaseConfig.class)  
public class MainConfig { ... }
```

- Multiple files possible.
- Valid prefixes are classpath: (default), file:, http:

Can combine with
`@Configuration` imports



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Remember @Import?

```
@Configuration  
@Import(DatabaseConfig.class)  
public class MainConfig {  
    ...  
}
```

- Use `<import />` to import other XML configuration files

```
<beans>  
    <import resource="db-config.xml" />  
</beans>
```

- Uses relative path by default
 - Same prefixes available (file, classpath, http)



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Creating the ApplicationContext – I

- So far, you have seen the ApplicationContext created like this:

```
ApplicationContext conteMainConfig.class).run()
```

- This is actually a Spring Boot class
 - But it works well for *any* Spring application
 - More general purpose than previous alternatives



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Creating the ApplicationContext

- Older “classic” techniques available as well
 - Context type defines *where* XML files are loaded from
 - Existing code (and many online examples) do it this way

```
// Load Java Configuration class  
new AnnotationConfigApplicationContext(MainConfig.class);  
  
// Load from $CLASSPATH/com/acme/application-config.xml  
new ClassPathXmlApplicationContext("com/acme/application-config.xml");  
  
// Load from absolute path: C:/Users/alex/application-config.xml  
new FileSystemXmlApplicationContext("C:/Users/alex/application-config.xml");  
  
// Load from path relative to the JVM working directory  
new FileSystemXmlApplicationContext("./application-config.xml");
```



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Topics in this session

- Writing bean definitions
- Creating an application context
- **Controlling Bean Behavior**
- Factory Beans
- Namespaces
- Lab
- Advanced Topics



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Remember @PostConstruct?

```
@PostConstruct  
public void setup() {  
    ...  
}
```

- Same option available in XML
 - But called “init-method”:

```
<bean id="accountService" class="com.acme.ServiceImpl" init-method="setup">  
    ...  
</bean>
```



Same rules: method can have any visibility, *must* take *no* parameters, must return *void*. Called after dependency injection.



Remember @PreDestroy?

```
@PreDestroy  
public void teardown() {  
    ...  
}
```

- Same option available in XML
 - But called “destroy-method”:

```
<bean id="Service" class="com.acme.ServiceImpl" destroy-method="teardown">  
    ...  
</bean>
```



Same rules: method can have any visibility, *must* take *no* parameters, must return *void*.



Remember Bean Scope?

```
@Bean  
@Scope("prototype")  
public AccountService accountService() {  
    return ...  
}  
  
@Component  
@Scope("prototype")  
public class AccountServiceImpl {  
    ...  
}
```

- Same options available in XML
 - singleton, prototype, request, session, (custom)

```
<bean id="accountService" class="com.acme.ServiceImpl" scope="prototype">  
    ...  
</bean>
```



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Remember @Lazy?

```
@Bean  
@Lazy("true")  
public AccountService accountService() {  
    return ...  
}  
  
@Component  
@Lazy()  
public class AccountServiceImpl {  
    ...  
}
```

- Same option available in XML
 - Still not recommended, often misused

```
<bean id="accountService" class="com.acme.ServiceImpl" lazy-init="true">  
    ...  
</bean>
```



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Profile Configuration in XML

- All bean definitions

```
<beans xmlns="http://www.springframework.org/schema/beans ...  
    profile="dev"> ... </beans>
```

Profile applies to *all*
Beans in the file

- Subset of bean definitions

```
<beans xmlns="http://www.springframework.org/schema/beans ...>  
    <bean id="rewardNetwork" ... /> <!-- Available to all profiles -->  
    ...  
    <beans profile="dev"> ... </beans>  
    <beans profile="prod"> ... </beans>  
</beans>
```

Different subset
of beans for each
profile, plus some
shared beans



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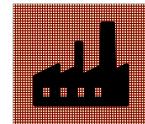
Topics in this session

- Writing bean definitions in XML
- Creating an application context
- Controlling Bean Behavior
- Factory Beans**
- Namespaces
- Lab



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Advanced XML Bean Instantiation



- Conditional configuration
 - @Bean methods can use *any* Java you need
 - Do property lookups
 - Use if-then-else and iterative logic
- No equivalent in XML
 - We did *not* implement <if>, <for-each>
- Instead Spring XML relies on the *Factory Pattern*
 - Use a factory to create the bean(s) we want
 - Use *any* complex Java code we need in the factory's internal logic



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The Spring FactoryBean interface



- Fall-back for complex configuration in XML

— Used long before @Bean methods introduced

```
public class AccountServiceFactoryBean
    implements FactoryBean<AccountService>
{
    public AccountService getObject() throws Exception {
        // Conditional logic – for example: selecting the right
        // implementation or sub-class of AccountService to create
        return accountService;
    }

    public boolean isSingleton() { return true; }
    public Class<?> getObjectType() { return AccountService.class; }
}
```

Note: even Java Configuration may use factory beans



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The FactoryBean interface

- Beans implementing *FactoryBean* are *auto-detected*
- Dependency injection using the factory bean id causes *getObject()* to be invoked transparently

```
<bean id="accountService"
      class="com.acme.AccountServiceFactoryBean"/>

<bean id="customerService" class="com.acme.CustomerServiceImpl">
    <property name="service" ref="accountService" />
</bean>
```

*getObject() called by
Spring internally*



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Using FactoryBeans with Java Configuration

- Works exactly the same way

```
@Configuration
public class ServiceConfig {

    @Bean
    public AccountServiceFactoryBean accountService() {
        return new AccountServiceFactoryBean();
    }

    @Bean
    public CustomerService customerService(AccountService accountService) {
        return new CustomerService(accountService);
    }
}
```

*getObject() called by
Spring internally*



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FactoryBeans in Spring

- FactoryBeans are widely used within Spring
 - EmbeddedDatabaseFactoryBean**
 - JndiObjectFactoryBean
 - One option for looking up JNDI objects
 - Creating Remoting proxies
 - Creating Caching proxies**
 - For configuring data access technologies**
 - JPA, Hibernate or MyBatis
- In XML, often hidden behind *namespaces*

** These will appear later in the course



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Topics in this session

- Writing bean definitions in XML
- Creating an application context
- Controlling Bean Behavior
- Factory Beans
- **Namespaces**
- Lab



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Default Namespace

- The default namespace in a Spring configuration file is typically the “beans” namespace

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



dozens of other namespaces are available!



Other Namespaces

- Defined for subsets of framework functionality*
 - aop (Aspect Oriented Programming)
 - tx (transactions)
 - util
 - jms
 - context
 - ...
- They allow hiding of actual bean definitions
 - Define “programming instructions” for bean files
 - Greatly reduce size of bean files (see next slides)



See <http://www.springframework.org/schema/> for complete list



Namespace Example 1

In-Memory DataStore using Bean XML

- Creating an in-memory test database

```
<bean id="dataSource" class="org.springframework.jdbc.datasource.  
    embedded.EmbeddedDatabaseFactoryBean">  
    <property name="databasePopulator" ref="populator"/>  
</bean>  
  
<bean id="populator" class="org.springframework.jdbc.datasource.  
    init.ResourceDatabasePopulator">  
    <property name="scripts">  
        <list>  
            <value>classpath:rewards/testdb/schema.sql</value>  
            <value>classpath:rewards/testdb/data.sql</value>  
        </list>  
    </property>  
</bean>
```

FactoryBean

Populate with
test-data

Bean XML requires two beans and
knowledge of the classes being used



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Namespace Example 1

In-Memory DataStore using jdbc Namespace

- Simplify using jdbc namespace

```
<jdbc:embedded-database type="HSQL" id="dataSource">  
    <jdbc:script location="classpath:rewards/testdb/schema.db"/>  
    <jdbc:script location=""classpath:rewards/testdb/test-data.db""/>  
</jdbc:embedded-database>
```

Equivalent to ...

```
@Bean public DataSource dataSource() {  
    EmbeddedDatabaseBuilder builder = new EmbeddedDatabaseBuilder();  
    return builder.setName("testdb")  
        .setType(EmbeddedDatabaseType.HSQL)  
        .addScript("classpath:rewards/testdb/schema.db")  
        .addScript("classpath:rewards/testdb/test-data.db").build();  
}
```



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Namespace Example 2

Property Placeholders

- Property Placeholders define property sources
 - XML Equivalent of @PropertySource
- Namespace just an elegant way to hide the underlying bean declaration
 - Same functionality, less typing

```
<context:property-placeholder location="db-config.properties" />
```



```
<bean class="org.springframework...PropertySourcesPlaceholderConfigurer">
    <property name="location" value="db-config.properties"/>
</bean>
```



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Accessing Properties in XML

```
<beans ...>
    <context:property-placeholder location="db-config.properties" />

    <bean id="dataSource" class="com.oracle.jdbc.pool.OracleDataSource">
        <property name="URL" value="${dbUrl}" />
        <property name="user" value="${dbUserName}" />
    </bean>
</beans>
```



dbUrl=jdbc:oracle:...
dbUserName=moneytransfer-app

db-config.properties



```
<bean id="dataSource"
      class="com.oracle.jdbc.pool.OracleDataSource">
    <property name="URL" value="jdbc:oracle:..." />
    <property name="user" value="moneytransfer-app" />
</bean>
```



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XML Profiles and Properties

```
<import resource="classpath:config/${current.env}-config.xml"/>
<context:property-placeholder properties-ref="configProps"/>
{<beans profile="dev">
    <util:properties id="configProps" location="config/app-dev.properties">
</beans>
<beans profile="prod">
    <util:properties id="configProps" location="config/app-prod.properties">
</beans>
```

current.env=dev
database.url=jdbc:derby:/test
database.user=tester

current.env=prod
database.url=jdbc:oracle:thin:...
database.user=admin

Equivalent to ...

```
@PropertySource ( "classpath:/com/acme/config/app-${ENV}.properties" )
```



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Typical Profiles & Namespaces Example

```
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:jdbc="http://www.springframework.org/schema/jdbc"
       xmlns:jee="http://www.springframework.org/schema/jee"
       xsi:schemaLocation="...">
    <beans profile="dev">
        <jdbc:embedded-database id="dataSource">
            <jdbc:script location="classpath:com/bank/sql/schema.sql"/>
            <jdbc:script location="classpath:com/bank/sql/test-data.sql"/>
        </jdbc:embedded-database>
    </beans>
    <beans profile="production">
        <jee:jndi-lookup id="dataSource" jndi-name="java:comp/env/jdbc/datasource" />
    </beans>
</beans>
```



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Power of Namespaces

- Greatly simplifies Spring configuration
 - Many advanced features of Spring need to declare a large number of beans

```
<?xml version="1.0" encoding="UTF-8"?>
<beans ...>
    <context:property-placeholder location="db-config.properties" />
        ↗ hides 1 bean definition
    <aop:aspectj-autoproxy /> ← AOP configuration: hides 5+ bean definitions
    <tx:annotation-driven /> ← Transactions configuration: hides more than 15 bean definitions!
</beans>
```



Transactions and AOP will be discussed later



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Remember @ComponentScan?

```
@Configuration
@ComponentScan ( { "com.acme.app.repository",
    "com.acme.app.service", "com.acme.app.controller" }
public class MainConfig {
    ...
}
```

- Available in the context namespace

```
<context:component-scan base-package="com.acme.app.repository,
    com.acme.app.service, com.acme.app.controller" />
```

Single String



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Namespaces Declarations are Tedium!

- What you need for beans, context and jdbc:

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

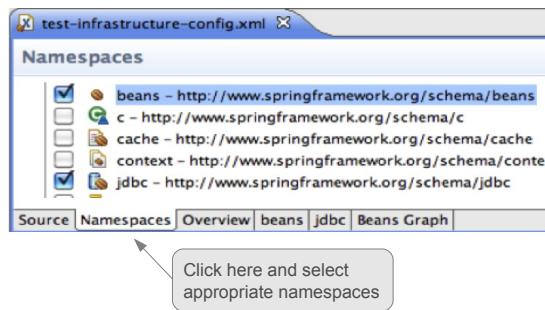
- A typo waiting to happen!
 - Fortunately there is an easier way ... (next slide)



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Adding namespace declaration

- XML syntax is error-prone
 - Use the dedicated STS XML editor Namespaces tab!



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Schema Version Numbers

[spring-beans-4.2.xsd](#) OR [spring-beans.xsd](#) ?

- Common practice: *do not* use a version number
 - Triggers use of most recent schema version
 - Easier migration
 - Will make it easier to upgrade to the next version of Spring

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="
           http://www.springframework.org/schema/beans
           http://www.springframework.org/schema/beans/spring-beans-4.2.xsd">
    <!-- ... -->
</beans>
```

Not needed!



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Summary

- Spring's XML definition language provides *explicit* bean definitions using `<bean>` syntax
 - Pre-dates Java Configuration
 - Provides many of the same options via attributes
- Factory Beans
 - Important configuration device
 - Understand how `getObject()` works
- Namespaces reduce verbosity, hide internal details



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Spring XML Best Practices

- XML has been around for a long time
 - Many shortcuts and useful techniques exist
 - Singleton and Factory Beans
 - Bean Definition Inheritance
 - Inner Beans
 - p and c namespaces
 - Using collections as Spring beans
- Optional Section at back of handout
 - **XML Dependency Injection Best Practices**
 - Optional lab also



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Lab (optional)

Using XML to Configure an Application



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Understanding the Bean Lifecycle

An In-Depth Look “Under the Hood”

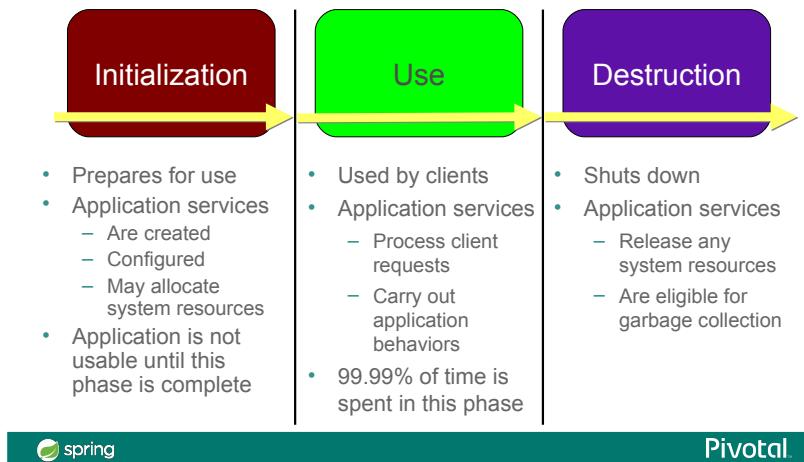
Using Bean Pre- and Post-Processors

Topics in this session

- **Introduction**
- The initialization phase
- The use phase
- The destruction phase

The content of this chapter is a *much simplified* view of Spring's inner workings

Phases of the Application Lifecycle



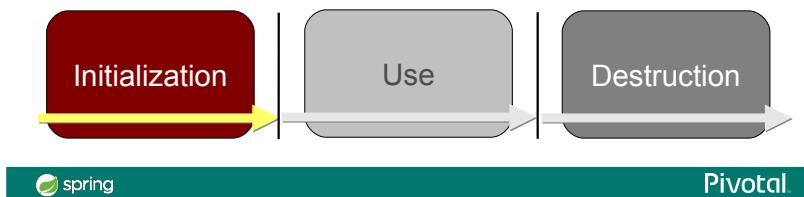
Spring's Role as a Lifecycle Manager

- Spring fits in to manage your application lifecycle
 - May play an important role in *all* phases
- Lifecycle applies to
 - Any class of application
 - Standalone Java or Spring Boot application
 - Integration/System Test
 - Java EE™ (web or full profile)
 - All 3 dependency injection styles
 - XML, annotations and Java Configuration



Topics in this session

- Introduction
- **The initialization phase**
- The use phase
- The destruction phase



Lifecycle of a Spring Application Context (1) *The Initialization Phase*

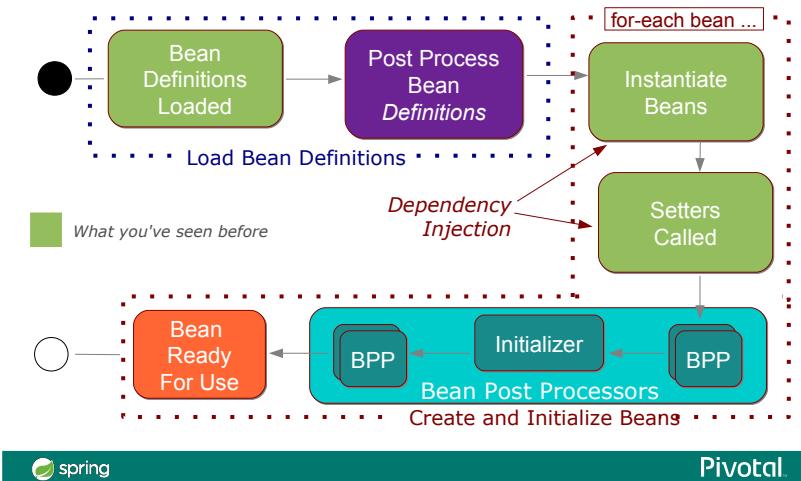
- When a context is created the initialization phase completes

```
// Create the application from the configuration
ApplicationContext context =
    SpringApplication.run(AppConfig.class);
```

- But what exactly happens in this phase?

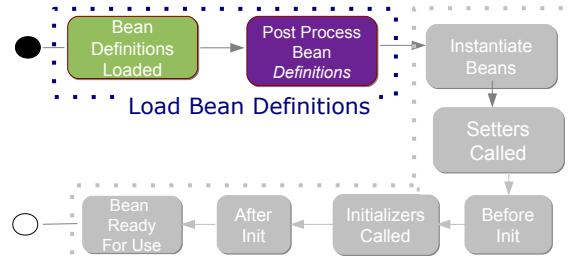


Bean Initialization Steps



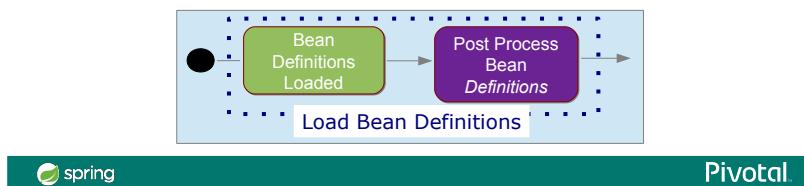
Inside The Application Context – Initialization Lifecycle (1)

- Load bean definitions
- Initialize bean instances



Load Bean Definitions

- The `@Configuration` classes are processed
 - And/or `@Components` are scanned for
 - And/or XML files are parsed
- Bean definitions added to a *BeanFactory*
 - Each indexed under its id
- Special `BeanFactoryPostProcessor` beans invoked
 - Can modify the *definition* of *any* bean



Load Bean Definitions

AppConfig.java

```
@Bean  
public TransferService transferService() { ... }  
@Bean  
public AccountRepository  
accountRepository() { ... }
```

TestInfrastructureConfig.java

```
@Bean  
public DataSource dataSource () { ... }
```

ApplicationContext

BeanFactory
transferService
accountRepository
dataSource

postProcess(BeanFactory)

Can modify the definition of
any bean in the factory
before any objects are created

BeanFactoryPostProcessors



BeanFactoryPostProcessor Extension Point

- Applies transformations to bean *definitions*
 - Before objects are actually created
- Several useful implementations provided in Spring
 - Reading properties, registering a custom scope ...
- You can write your own (not common)
 - Implement **BeanFactoryPostProcessor** interface

```
public interface BeanFactoryPostProcessor {  
    public void postProcessBeanFactory  
        (ConfigurableListableBeanFactory beanFactory);  
}
```



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Most Common Example of Using a **BeanFactoryPostProcessor**

- Recall @Value and \${...} variables
 - Need a **PropertySourcesPlaceholderConfigurer** to evaluate them
 - *This is a BeanFactoryPostProcessor*

```
@Configuration  
@PropertySource ( "classpath:/config/app.properties" )  
public class ApplicationConfig {  
  
    @Value("${max.retries}")  
    int maxRetries;  
  
    ...  
}
```



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Java Configuration uses *Static* beans

- To ensure these beans are created *without side-effects*, they must be defined as *static* methods
- Example:

— `PropertySourcesPlaceholderConfigurer`

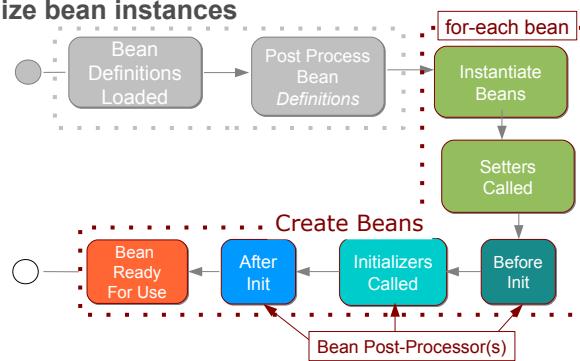
```
@Bean  
public static PropertySourcesPlaceholderConfigurer  
    propertySourcesPlaceholderConfigurer() {  
    return new PropertySourcesPlaceholderConfigurer();  
}
```

Or if using XML, `<context:property-placeholder/>` creates a `PropertySourcesPlaceholderConfigurer` for you



Inside the Application Context – Initialization Lifecycle (2)

- Load bean definitions
- Initialize bean instances



Bean Creation Summary

- Each bean is eagerly instantiated by default
 - Created in right order with its dependencies injected
 - Unless marked as lazy
- Next each bean goes through a *post-processing* phase
 - *BeanPostProcessors*
- Now the bean is fully initialized and ready for use
 - Tracked by its id until the context is destroyed
 - Except prototype beans



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The Initializer Extension Point

- Special case of a bean post-processor
 - Causes init (@PostConstruct) methods to be called
- Internally Spring uses several BPPs
 - *CommonAnnotationBeanPostProcessor* enables initialization



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The Initializer Extension Point - XML

- BPPs must be enabled when using *just* XML
 - Specify either `<context:annotation-config/>`
 - Or `<context:component-scan/>`
- Either enables same BPPs

```
<bean id="accountRepository" class="com.acme.JdbcAccountRepo"
      init-method="populateCache">
    ...
</bean>

<context:annotation-config/>
```

init-method ignored unless explicitly enabled



The BeanPostProcessor Extension Point



- An important extension point in Spring
 - Can modify bean *instances* in any way
 - *Powerful* enabling feature
- Must implement the `BeanPostProcessor` interface
 - Spring provides several implementations
 - You can write your own (not common)

Course will show several BPPs

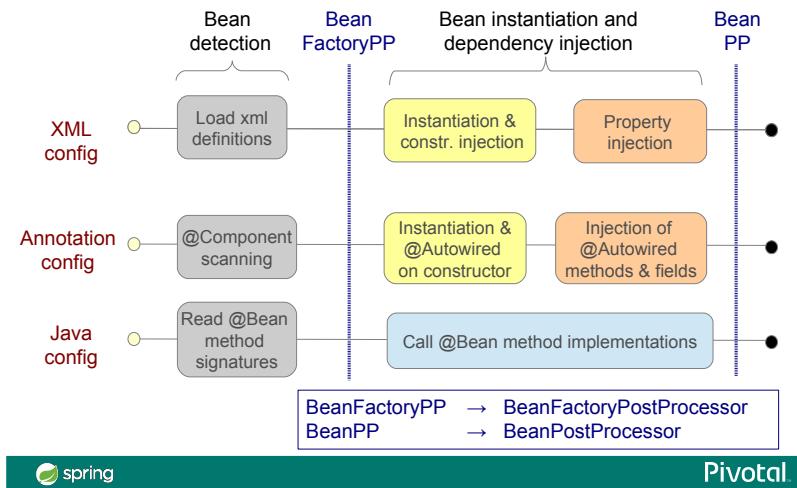
```
public interface BeanPostProcessor {
    public Object postProcessAfterInitialization(Object bean, String beanName);
    public Object postProcessBeforeInitialization(Object bean, String beanName);
}
```

Post-processed bean

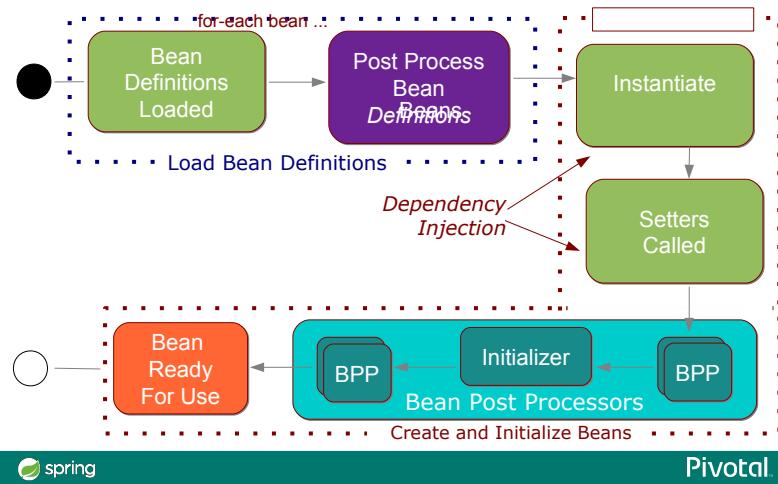
Original bean



Configuration Lifecycle



The Full Initialization Lifecycle



Topics in this session

- Introduction
- The initialization phase
- **The use phase**
- The destruction phase



Lifecycle of a Spring Application Context (2) The Use Phase

- When you invoke a bean obtained from the context the application is used

```
ApplicationContext context = // get it from somewhere
// Lookup the entry point into the application
TransferService service =
    (TransferService) context.getBean("transferService");
// Use it!
service.transfer(new MonetaryAmount("50.00"), "1", "2");
```

- But exactly what happens in this phase?

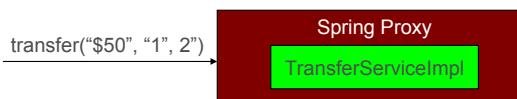


Inside The Bean Request (Use) Lifecycle

- The bean is just your raw object
 - it is simply invoked directly (nothing special)



- Your bean has been wrapped in a *proxy*
 - things become more interesting



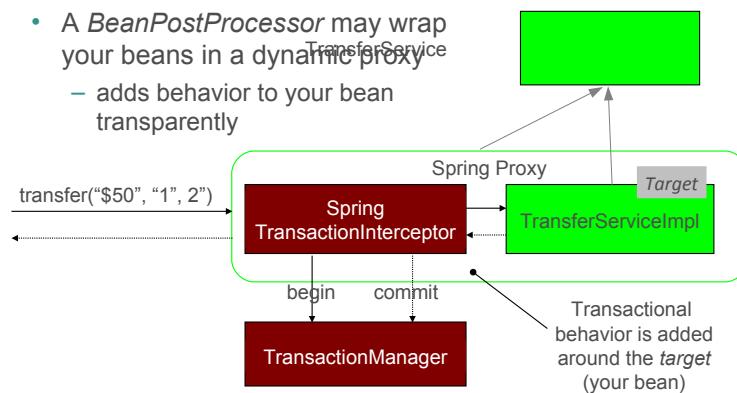
Proxy classes are created in the init phase by dedicated
BeanPostProcessors

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Proxy Power

- A *BeanPostProcessor* may wrap your beans in a *dynamic proxy*
 - adds behavior to your bean transparently



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Kinds of Proxies

- Spring will create either JDK or CGLib proxies

JDK Proxy

- Also called *dynamic* proxies
- API is built into the JDK
- Requirements: Java interface(s)
- All interfaces proxied

CGLib Proxy

- NOT built into JDK
- Included in Spring jars
- Used when interface not available
- Cannot be applied to final classes or methods



Recommendation: Code to interfaces / Use JDK proxies (default)

[See Spring Reference - 10.5.3 JDK- and CGLIB-based proxies](#)

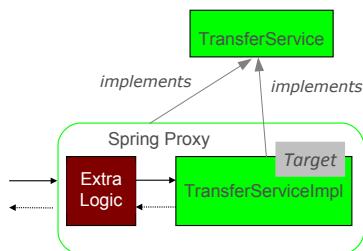


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JDK vs CGLib Proxies

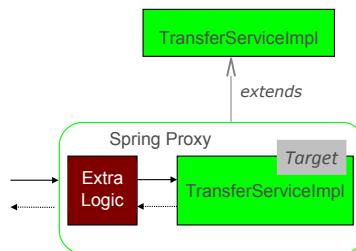
- JDK Proxy

- Interface based



- CGLib Proxy

- subclass based



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Topics in this session

- Introduction
- The initialization phase
- The use phase
- **The destruction phase**



Lifecycle of a Spring Application Context (3) The Destruction Phase

- When you close a context the destruction phase completes

```
// Need a configurable ApplicationContext
ConfigurableApplicationContext context =
    SpringApplication.run( AppConfig.class );

// Destroy the application
context.close();
```

- *But exactly what happens in this phase?*



ApplicationContext Destruction Lifecycle (1)

- Destroy bean instances if instructed
 - Call their destroy (clean-up) methods
 - Beans must have a *destroy method* defined
 - A no-arg method returning void
- Context then destroys (cleans-up) itself
 - The context is not usable again

Remember:
only GC actually
destroys objects

```
@Bean (destroyMethod="clearCache")  
public AccountRepository accountRepository() {  
    // ...  
}
```

A method on the
AccountRepository



- Called only when ApplicationContext / JVM exit *normally*
- Not called for *prototype* beans



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ApplicationContext Destruction Lifecycle (2)

- Can do the same using XML or annotations
 - Annotations require ~~the annotation config~~ scanner to be activated

Using XML

```
<bean id="accountRepository"  
      class="app.impl.AccountRepository"  
      destroy-method="clearCache">  
    ...  
</bean>
```

By Annotation

```
public class AccountRepository {  
  
    @PreDestroy  
    void clearCache() {  
        // close files, connections ...  
        // remove external resources ...  
    }  
}
```

```
<context:annotation-config/>
```

```
<context:component-scan ... />
```



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Topics Covered

- Spring Lifecycle
 - The initialization phase
 - Bean Post Processors for *initialization* and *proxies*
 - The use phase
 - Proxies at Work – most of Spring's “magic” uses a proxy
 - The destruction phase
 - Allow application to terminate cleanly



Testing Spring Applications

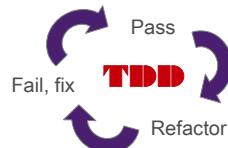
Unit Testing without Spring
Integration Testing with Spring

Testing in General, Spring and JUnit,
Profiles, Database Testing

Topics in this Session

- **Test Driven Development**
- Integration Testing with Spring
- Testing with Profiles
- Testing with Databases
- Lab
- Appendix on Unit Testing (Stubs & Mocks)

What is TDD?



- TDD = Test Driven Development
 - Is it writing tests before the code?
 - Is it writing tests at the same time as the code?
 - Ultimately that is not what is most important
- TDD is about:
 - Writing automated tests that verify code actually works
 - Driving development with well defined requirements in the form of tests



“But We Don’t Have Time to Write Tests!”

- Every development process includes testing
 - Either automated or manual
- Automated tests result in a faster development cycle overall
 - Your IDE is better at this than you are
- Properly done TDD is faster than development without tests



TDD and Agility

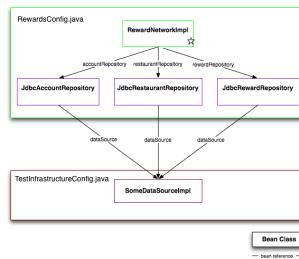


- Comprehensive test coverage provides confidence
- Confidence enables refactoring
- Refactoring is essential to agile development



TDD and Design

- Testing makes you think about your design
- If your code is hard to test then the design should be reconsidered



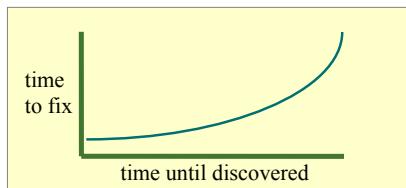
TDD and Focus

- A test case helps you focus on what matters
- It helps you not to write code that you don't need
- Find problems early



Benefits of Continuous Integration

- The cost to fix a bug grows exponentially in proportion to the time before it is discovered



- Continuous Integration (CI) focuses on reducing the time before the bug is discovered
 - Effective CI requires automated tests

Topics in this Session

- Test Driven Development
- **Integration Testing with Spring**
- Testing with Profiles
- Testing with Databases
- Lab
- Appendix on Unit Testing (Stubs & Mocks)



Unit Testing

Unit Testing *Without Spring*

- Unit Testing
 - Tests one unit of functionality
 - Keeps dependencies minimal
 - Isolated from the environment (including Spring)
 - Uses simplified alternatives for dependencies
 - Stubs and/or Mocks
 - See *Appendix for more details*



Integration Testing

Integration Testing With Spring

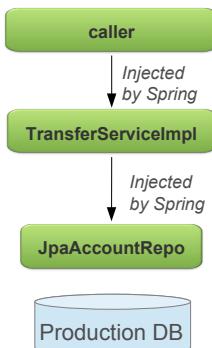
- Integration (System) Testing
 - Tests the interaction of multiple units working together
 - All should work individually (unit tests showed this)
- Tests application classes in context of their surrounding infrastructure
 - Out-of-container testing, no need to run up full JEE system
 - Infrastructure may be “scaled down”
 - Use Apache DBCP connection pool instead of container-provider pool obtained through JNDI
 - Use ActiveMQ to save expensive commercial JMS licenses



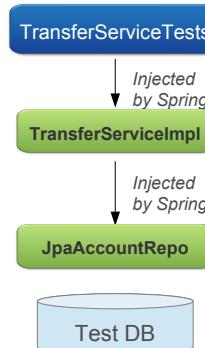
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Integration test example

- Production mode



- Integration test



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Spring's Integration Test Support

- Packaged as a separate module
 - spring-test.jar
- Consists of several JUnit test support classes
- Central support class is *SpringJUnit4ClassRunner*
 - Caches a *shared* ApplicationContext across test methods



See: Spring Framework Reference – Integration Testing

<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#integration-testing>



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Using Spring's Test Support

```
Run with Spring support
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)
public final class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void shouldTransferMoneySuccessfully() {
        TransferConfirmation conf = transferService.transfer(...);
        ...
    }
}
```

Point to system test configuration file

Inject bean to test

Test the system as normal

No need for @Before method



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Including Configuration as an inner class

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
public class JdbcAccountRepoTest {

    private JdbcAccountRepo repo = ...;

    @Test
    public void shouldUpdateDatabaseSuccessfully() {...}

    | @Configuration
    | @Import(SystemTestConfig.class)
    | static class TestConfiguration {
    |     @Bean public DataSource dataSource() { ... }
    | }
}
```

Don't specify config classes

Looks for configuration embedded in the class

Override a bean with a test alternative



@ContextConfiguration – XML

- Tests when using XML based configuration

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration("classpath:com/acme/system-test-config.xml")
public final class TransferServiceTests { ... }
```

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration({"classpath:config-1.xml", "file:db-config.xml"})
public final class TransferServiceTests { ... }
```

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
public class TransferServiceTests { ... }
```

Defaults to \${classname}-context.xml in same package

Loads TransferServiceTests-context.xml



Multiple test methods

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)
public final class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void successfulTransfer() {
        ...
    }

    @Test
    public void failedTransfer() {
        ...
    }
}
```

The ApplicationContext is instantiated only *once* for all tests that use the same set of config files (even across test classes)



Annotate test method with `@DirtiesContext` to force recreation of the cached ApplicationContext if method changes the contained beans



Test Property Sources

- Custom properties *just* for testing
 - Specify one or more properties
 - Will override any existing properties of same name
 - Specify location of one or more properties files to load
 - Defaults to looking for `[classname].properties`

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)
@TestPropertySource(properties = { "username=foo", "password=bar" }
    locations = "classpath:/transfer-test.properties")
public final class TransferServiceTests {
    ...
}
```



Spring 4.3 Simplification

Spring 4.3

- Can use `SpringRunner` as an alternative to the `SpringJUnit4ClassRunner`
 - Simply a sub-class with a nicer name

```
@RunWith(SpringRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)
public final class TransferServiceTests {
    ...
}
```



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Benefits of Testing with Spring

- No need to deploy to an external container to test application functionality
 - Run everything quickly inside your IDE
 - Supports *Continuous Integration* testing
- Allows reuse of your configuration between test and production environments
 - Application configuration logic is typically reused
 - Infrastructure configuration is environment-specific
 - DataSources
 - JMS Queues



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Topics in this Session

- Test Driven Development
- Integration Testing with Spring
- **Testing with Profiles**
- Testing with Databases
- Lab
- Appendix on Unit Testing (Stubs & Mocks)



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Activating Profiles For a Test

- **@ActiveProfiles** inside the test class
 - Define one or more profiles
 - Beans associated with that profile are instantiated
 - Also beans not associated with *any* profile
- Example: Two profiles activated – **jdbc** and **dev**

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=DevConfig.class)
@ActiveProfiles({ "jdbc", "dev" })

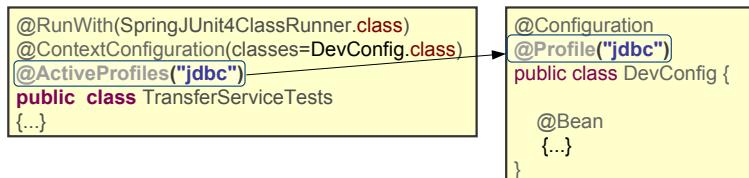
public class TransferServiceTests { ... }
```



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Profiles Activation with JavaConfig

- **@ActiveProfiles** inside the test class
- **@Profile** inside the **@Configuration** class

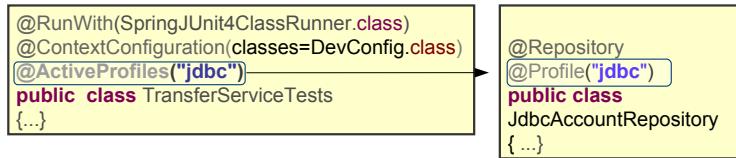


Remember: only `@Configurations` matching an active profile or with no profile are loaded



Profiles Activation with Annotations

- **@ActiveProfiles** inside the test class
- **@Profile** inside the Component class

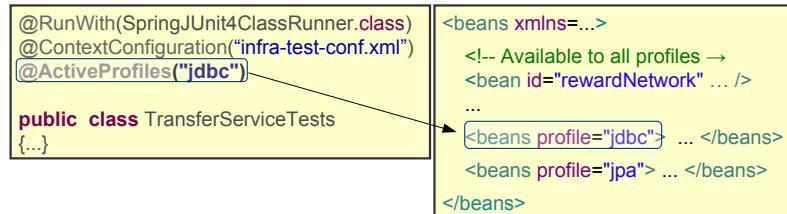


Only beans with current profile / no profile are component-scanned



Profiles Activation with XML

- **@ActiveProfiles** inside the test class
- **profile** attribute inside **<bean>** tag



Only beans with current profile / no profile are loaded



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Topics in this Session

- Test Driven Development
- Integration Testing with Spring
- Testing with Profiles
- **Testing with Databases**
- Lab
- Appendix on Unit Testing (Stubs & Mocks)



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Testing with Databases

- Integration testing against SQL database is common.
- In-memory databases useful for this kind of testing
 - No prior install needed
- Common requirement: populate DB before test runs
 - Use the `@Sql` annotation:

```
@Test
@Sql ( "/testfiles/test-data.sql" ) ← Run this SQL command
public void successfulTransfer() { ← Before this test method executes.
    ...
}
```



See: [Spring Framework Reference, Executing SQL Scripts](http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#testcontext-executing-sql)

<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#testcontext-executing-sql>



@Sql Examples

```
Run these scripts before
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(...)
@Sql( { "/testfiles/schema.sql", "/testfiles/general-data.sql" } ) ← each @Test method

public final class MainTests {

    @Test
    @Sql( { "/testfiles/error.sql" } ) ← Run script named (by default)
    public void success() { ... } ← MainTests.success.sql
                                         in same package

    @Test
    @Sql( { "/testfiles/cleanup.sql", "scripts= "/testfiles/cleanup.sql", executionPhase=Sql.ExecutionPhase.AFTER_TEST_METHOD } ) ← Run before @Test method...
    public void transferError() { ... } ← ...run after @Test method
}
```



@Sql Options

- When does the SQL run?
 - `executionPhase`: before (default) or after the test method
 - `config`: SqlConfig has many options to control SQL scripts
 - What to do if script fails? `FAIL_ON_ERROR`,
`CONTINUE_ON_ERROR`, `IGNORE_FAILED_DROPS`, `DEFAULT*`
 - SQL syntax control: comments, statement separator

```
@Sql( scripts = "/test-user-data.sql",
       executionPhase = ExecutionPhase.AFTER_TEST_METHOD,
       config = @SqlConfig(errorMode = ErrorMode.FAIL_ON_ERROR,
                            commentPrefix = "//", separator = "@@") )
```

*`DEFAULT` = whatever `@Sql` defines at class level, otherwise `FAIL_ON_ERROR`



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Summary

- Testing is an *essential* part of any development
- Unit testing tests a class in isolation
 - External dependencies should be minimized
 - Consider creating stubs or mocks to unit test
 - *You don't need Spring to unit test*
- Integration testing tests the interaction of multiple units working together
 - Spring provides good integration testing support
 - Profiles for different test & deployment configurations
 - Built-in support for testing with Databases



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Lab

Testing Spring Applications

Coming Up: Appendix on Unit Testing using Stubs or Mocks



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Topics in this Session

- Test Driven Development
- Integration Testing with Spring
- Testing with Profiles
- Testing with Databases
- **Appendix**
 - **Unit Testing (Stubs & Mocks)**



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Unit Testing vs. Integration Testing

- Unit Testing
 - Tests one unit of functionality
 - Keeps dependencies minimal
 - Isolated from the environment (including Spring)
- Integration Testing
 - Tests the interaction of multiple units working together
 - Integrates infrastructure
- Discussed Integration Testing earlier
 - Let's discuss Unit Testing here
 - Remember: *Unit Testing does not use Spring*



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Unit Testing

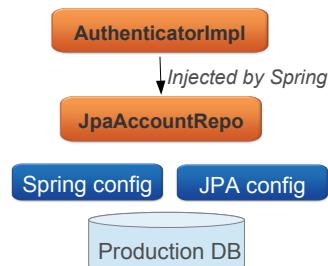
- Remove links with dependencies
 - The test shouldn't fail because of external dependencies
 - Spring is also considered as a dependency
 -
- 2 ways to create a “testing-purpose” implementation of your dependencies:
 - Stubs Create a simple test implementation
 - Mocks Dependency class generated at startup-time using a “Mocking framework”



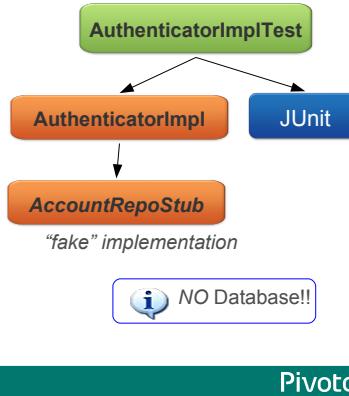
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Unit Testing example

- Production mode



- Unit test with Stubs



spring

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Example Unit to be Tested

```
public class AuthenticatorImpl implements Authenticator {  
    private AccountRepository accountRepository;  
  
    public AuthenticatorImpl(AccountRepository accountRepository) {  
        this.accountRepository = accountRepository; External dependency  
    }  
  
    public boolean authenticate(String username, String password) {  
        Account account = accountRepository.getAccount(username);  
  
        return account.getPassword().equals(password);  
    }  
}  
  
Note: Validation failure paths ignored for simplicity
```

Unit business logic
– 2 paths: success or fail

spring

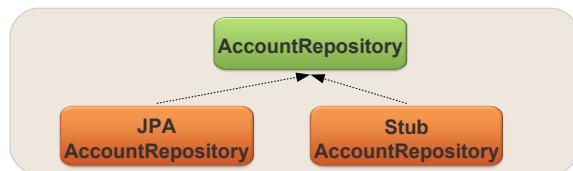
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Implementing a Stub

- Class created manually
 - Implements Business interface

```
class StubAccountRepository implements AccountRepository {  
    public Account getAccount(String user) {  
        return "lisa".equals(user) ? new Account("lisa", "secret") : null;  
    }  
}
```

Simple state



spring

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Unit Test using a Stub

```
import org.junit.Before; import org.junit.Test; ...  
  
public class AuthenticatorImplTests {  
  
    private AuthenticatorImpl authenticator in charge of  
    @Before public void setUp() {  
        authenticator = new AuthenticatorImpl( new StubAccountRepository() );  
    }  
    @Test public void successfulAuthentication() {  
        assertTrue(authenticator.authenticate("lisa", "secret"));  
    }  
    @Test public void invalidPassword() {  
        assertFalse(authenticator.authenticate("lisa", "invalid"));  
    }  
}
```

injecting dependencies

OK scenario

KO scenario

spring

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Unit Testing with Stubs

- Advantages
 - Easy to implement and understand
 - Reusable
- Disadvantages
 - Change to an interface requires change to stub
 - Your stub must implement all methods
 - even those not used by a specific scenario
 - If a stub is reused refactoring can break other tests



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Steps to Testing with a Mock

1. Use a mocking library to generate a mock object
 - Implements the dependent interface on-the-fly
2. Record the mock with expectations of how it will be used for a scenario
 - What methods will be called
 - What values to return
3. Exercise the scenario
4. Verify mock expectations were met



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Example: Using a Mock - I

- Setup

- A Mock class is created at startup time

```
import static org.easymock.classextensions.EasyMock.*;
```

public class AuthenticatorImplTests {
 private AccountRepository accountRepository
 = createMock(AccountRepository.class);

private AuthenticatorImpl authenticator
 = new AuthenticatorImpl(accountRepository);

// continued on next slide ...

Example: Using a Mock - II

```
// ... continued from previous slide
```

```
@Test public void validUserWithCorrectPassword() {  

    expect(accountRepository.getAccount("lisa")).  

        andReturn(new Account("lisa", "secret"));
```

```
replay(accountRepository);
```

```
assertTrue(authenticator.  

    authenticate("lisa", "secret"));
```

```
verify(accountRepository);  

}
```

Recording

What behavior to expect?

Recording Playback

“playback” mode

Mock now fully available

Verification

No planned method call has been omitted

Same Example using Mockito

```
import static org.mockito.Mockito.*;  
  
public class AuthenticatorImplTests {  
    private AccountRepository accountRepository  
        = mock(AccountRepository.class); // Create a mock object  
    private AuthenticatorImpl authenticator  
        = new AuthenticatorImpl(accountRepository); // Inject the mock object  
  
    @Test public void validUserWithCorrectPassword() {  
        when(accountRepository.getAccount("lisa")).thenReturn(new Account("lisa", "secret")); // Train the mock  
  
        assertTrue(authenticator.authenticate("lisa", "secret")); // Run test  
        verify(accountRepository).getAccount(); // Verify getAccount() was  
        // invoked on the mock  
    }  
}
```

No replay() step with Mockito



Mock Considerations

- Several mocking libraries available
 - Mockito, JMock, EasyMock
- Advantages
 - No additional class to maintain
 - You only need to setup what is necessary for the scenario you are testing
 - Test behavior as well as state
 - Were all mocked methods used? If not, why not?
- Disadvantages
 - A little harder to understand at first



Mocks or Stubs?

- You will probably use both
- General recommendations
 - Favor mocks for non-trivial interfaces
 - Use stubs when you have simple interfaces with repeated functionality
 - Always consider the specific situation
- Read “Mocks Aren’t Stubs” by Martin Fowler
 - <http://www.martinfowler.com/articles/mocksArentStubs.html>



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Developing Aspects with Spring AOP

Aspect Oriented Programming For
Declarative Enterprise Services

Using and Implementing Spring Proxies

Topics in this session

- **What Problem Does AOP Solve?**
- Core AOP Concepts
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Lab
- Advanced Topics



What Problem Does AOP Solve?

- Aspect-Oriented Programming (AOP) enables modularization of cross-cutting concerns



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What are Cross-Cutting Concerns?

- Generic functionality that is needed in many places in your application
- Examples
 - Logging and Tracing
 - Transaction Management
 - Security
 - Caching
 - Error Handling
 - Performance Monitoring
 - Custom Business Rules



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An Example Requirement

- Perform a role-based security check before every application method



A sign this requirement is a cross-cutting concern



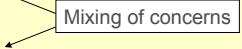
Implementing Cross Cutting Concerns Without Modularization

- Failing to modularize cross-cutting concerns leads to two things
 - Code tangling
 - A coupling of concerns
 - Code scattering
 - The same concern spread across modules



Symptom #1: Tangling

```
public class RewardNetworkImpl implements RewardNetwork {  
    public RewardConfirmation rewardAccountFor(Dining dining) {  
        if (!hasPermission(SecurityContext.getPrincipal())) {  
            throw new AccessDeniedException();  
        }  
  
        Account a = accountRepository.findByCreditCard(...);  
        Restaurant r = restaurantRepository.findByMerchantNumber(...);  
        MonetaryAmount amt = r.calculateBenefitFor(account, dining);  
        ...  
    }  
}
```

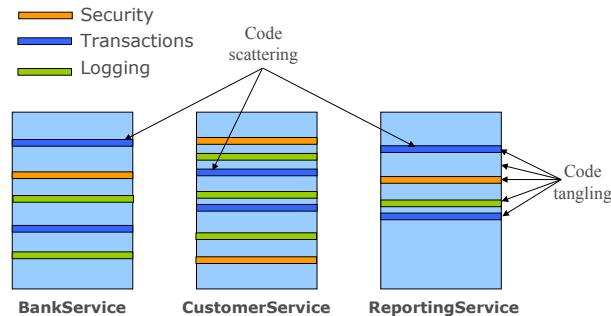


Symptom #2: Scattering

```
public class JpaAccountManager implements AccountManager {  
    public Account getAccountForEditing(Long id) {  
        if (!hasPermission(SecurityContext.getPrincipal())) {  
            throw new AccessDeniedException();  
        }  
        ...  
    }  
}  
  
public class JpaMerchantReportingService  
    implements MerchantReportingService {  
    public List<DiningSummary> findDinings(String merchantNumber,  
                                              DateInterval interval) {  
        if (!hasPermission(SecurityContext.getPrincipal())) {  
            throw new AccessDeniedException();  
        }  
        ...  
    }  
}
```



System Evolution Without Modularization



Aspect Oriented Programming (AOP)

- Aspect-Oriented Programming (AOP) enables modularization of cross-cutting concerns
 - To avoid tangling
 - To eliminate scattering

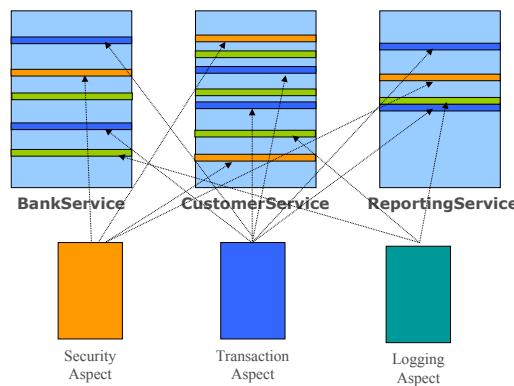


How AOP Works

- Implement your mainline application logic
 - Focusing on the core problem
- Write aspects to implement your cross-cutting concerns
 - Spring provides many aspects out-of-the-box
- Weave the aspects into your application
 - Adding the cross-cutting behaviours to the right places



System Evolution: AOP based



Leading AOP Technologies

- AspectJ
 - Original AOP technology (first version in 1995)
 - A full-blown Aspect Oriented Programming language
 - Uses byte code modification for aspect weaving
- Spring AOP
 - Java-based AOP framework with AspectJ integration
 - Uses dynamic proxies for aspect weaving
 - Focuses on using AOP to solve enterprise problems
 - The focus of this session



See: **Spring Framework Reference – Aspect Oriented Programming**
<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#aop>



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Topics in this session

- What Problem Does AOP Solve?
- **Core AOP Concepts**
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Lab
- Advanced Topics



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Core AOP Concepts

- Join Point
 - A point in the execution of a program such as a method call or exception thrown
- Pointcut
 - An expression that selects one or more Join Points
- Advice
 - Code to be executed at each selected Join Point
- Aspect
 - A module that encapsulates pointcuts and advice
- Weaving
 - Technique by which aspects are combined with main code



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Topics in this session

- What Problem Does AOP Solve?
- Core AOP Concepts
- **Quick Start**
- Defining Pointcuts
- Implementing Advice
- Lab
- Advanced Topics



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AOP Quick Start

- Consider this basic requirement

Log a message every time a property is about to change

- How can you use AOP to meet it?



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An Application Object Whose Properties Could Change

```
public class SimpleCache implements Cache
{
    private int cacheSize;
    private DataSource dataSource;
    private String name;

    public SimpleCache(String beanName) { name = beanName; }

    public void setCacheSize(int size) { cacheSize = size; }

    public void setDataSource(DataSource ds) { dataSource = ds; }

    ...

    public String toString() { return name; } // For convenience later
}
```

```
public interface Cache {
    public void setCacheSize(int size);
}
```



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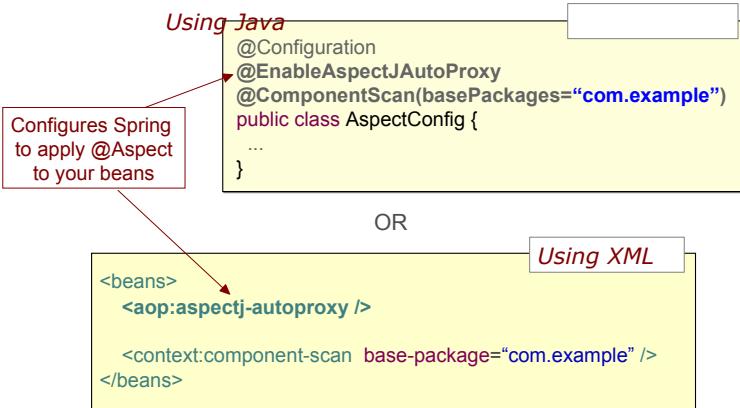
Implement the Aspect

```
@Aspect  
@Component  
public class PropertyChangeTracker {  
    private Logger logger = Logger.getLogger(getClass());  
  
    @Before("execution(void set*(*))")  
    public void trackChange() {  
        logger.info("Property about to change...");  
    }  
}
```



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Configure Aspect as a Bean



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Include the Aspect Configuration

```
@Configuration  
@Import(AspectConfig.class)  
public class MainConfig {  
  
    @Bean  
    public Cache cacheA() { return new SimpleCache("cacheA"); }  
  
    @Bean  
    public Cache cacheB() { return new SimpleCache("cacheB"); }  
  
    @Bean  
    public Cache cacheC() { return new SimpleCache("cacheC"); }  
}
```

Include aspect configuration



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Test the Application

```
ApplicationContext context = SpringApplication.run(MainConfig.class);
```

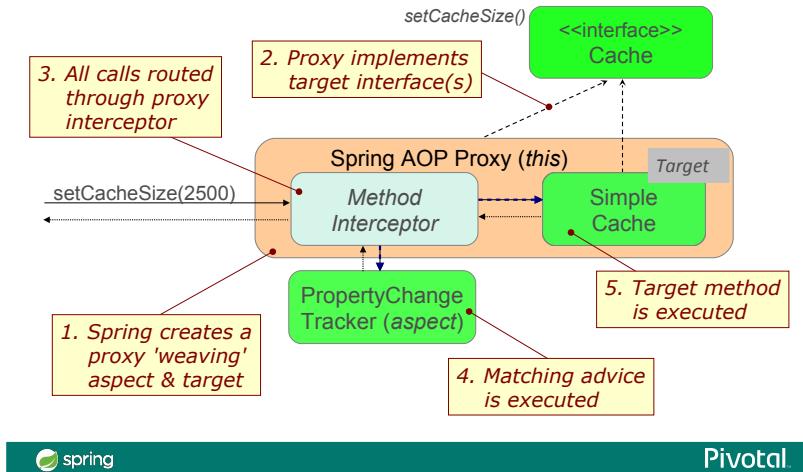
```
@Autowired @Qualifier("cacheA");  
private Cache cache;  
...  
cache.setCacheSize(2500);
```

INFO: Property about to change...



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How Aspects are Applied



Tracking Property Changes – With Context

- Context provided by the *JoinPoint* parameter

```
@Aspect  
public class PropertyChangeTracker {  
    private Logger logger = Logger.getLogger(getClass());  
  
    @Before("execution(void set*(*))")  
    public void trackChange(JoinPoint point) {  
        String name = point.getSignature().getName();  
        Object newValue = point.getArgs()[0];  
        logger.info(name + " about to change to " +  
                   newValue + " on " +  
                   point.getTarget());  
    }  
}
```

Annotations and context:

- @Aspect**: Context provided by the intercepted point.
- @Before("execution(void set*(*))")**: Context provided by the intercepted point.
- ToString() returns bean-name**: Context provided by the intercepted point.
- INFO: setCacheSize about to change to 2500 on cacheA**: Result of the logging statement.

Topics in this session

- What Problem Does AOP Solve?
- Core AOP Concepts
- Quick Start
- **Defining Pointcuts**
- Implementing Advice
- Lab
- Advanced Topics



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Defining Pointcuts

- Spring AOP uses AspectJ's pointcut expression language
 - For selecting where to apply advice
- Complete expression language reference available at
 - <http://www.eclipse.org/aspectj/docs.php>
- Spring AOP supports a practical subset



See: **Spring Framework Reference – Declaring a Pointcut**

<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#aop-pointcuts>



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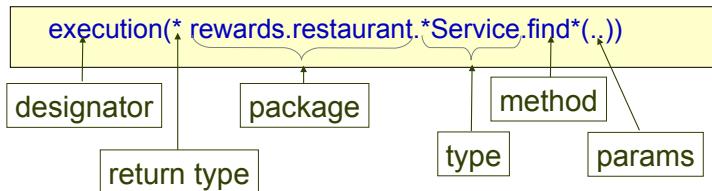
Common Pointcut Designator

- execution(<method pattern>)
 - The method must match the pattern
- Can chain together to create composite pointcuts
 - && (and), || (or), ! (not)
- Method Pattern
 - [Modifiers] ReturnType [ClassType]
 MethodName ([Arguments]) [throws ExceptionType]



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Writing Expressions



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Execution Expression Examples

Any Class or Package

`execution(void send*(String))`

- Any method starting with send that takes a single String parameter and has a void return type

`execution(* send(*)`

- Any method named send that takes a single parameter

`execution(* send(int, ..))`

- Any method named send whose first parameter is an int (the “..” signifies 0 or more parameters may follow)



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Execution Expression Examples

Implementations vs Interfaces

- Restrict by *class*

`execution(void example.MessageServiceImpl.*(..))`

- Any void method in the *MessageServiceImpl* class
 - Including any sub-class
- But will be ignored if a different implementation is used

- Restrict by *interface*

`execution(void example.MessageService.send(*))`

- Any void *send* method taking one argument, in any object implementing *MessageService*
- More flexible choice – works if implementation changes



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Execution Expression Examples

Using Annotations

`execution(@javax.annotation.security.RolesAllowed void send*(..))`

- Any void method whose name starts with “send” that is annotated with the `@RolesAllowed` annotation

```
public interface Mailer {  
    @RolesAllowed("USER")  
    public void sendMessage(String text);  
}
```

- Ideal for your own classes
 - Matches if annotation is present
 - Not if it isn't



Execution Expression Examples

Working with Packages

`execution(* rewards.*.restaurant.*.*(..))`

- There is one directory between rewards and restaurant

`execution(* rewards..restaurant.*.*(..))`

- There may be several directories between rewards and restaurant

`execution(* *..restaurant.*.*(..))`

- Any sub-package called restaurant



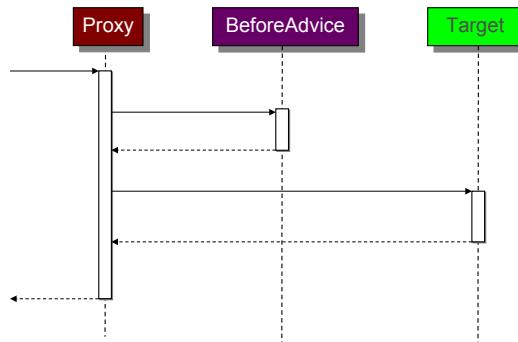
Topics in this session

- What Problem Does AOP Solve?
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Advice Types: Before



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Before Advice Example

- Use `@Before` annotation

```
@Aspect  
public class PropertyChangeTracker {  
    private Logger logger = Logger.getLogger(getClass());  
  
    @Before("execution(void set*(*))")  
    public void trackChange() {  
        logger.info("Property about to change...");  
    }  
}
```

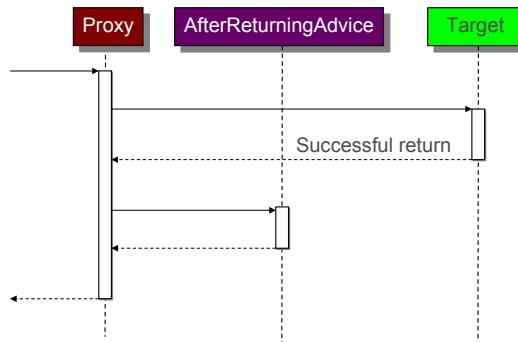
Track calls to all setter methods

- **Note:** if the advice throws an exception, target will not be called – this is a valid use of a *Before Advice*



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Advice Types: After Returning



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After Returning Advice - Example

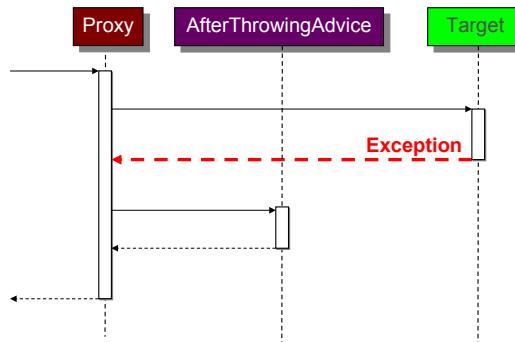
- Use `@AfterReturning` annotation with the *returning* attribute

Audit all operations in the *service* package that return a *Reward* object

```
@AfterReturning(value="execution(* service..*.*(..))",
               returning="reward")
public void audit(JoinPoint jp, Reward reward) {
    auditService.logEvent(jp.getSignature() +
        " returns the following reward object :" + reward.toString());
}
```



Advice Types: After Throwing



After Throwing Advice - Example

- Use `@AfterThrowing` annotation with the *throwing* attribute
 - Only invokes advice if the right exception type is thrown

Send an email every time a Repository class throws an exception of type `DataAccessException`

```
@AfterThrowing(value="execution(* *..Repository.*(..))", throwing="e")
public void report(JoinPoint jp, DataAccessException e) {
    mailService.emailFailure("Exception in repository", jp, e);
}
```



After Throwing Advice - Propagation

- The `@AfterThrowing` advice will not stop the exception from propagating
 - However it can throw a different type of exception

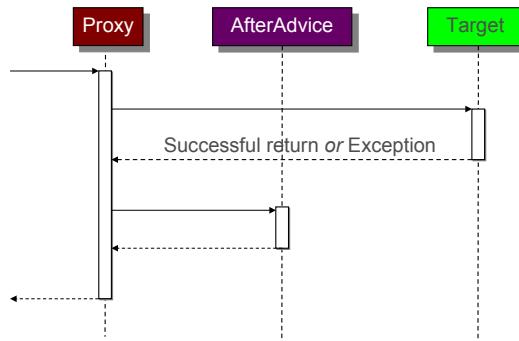
```
@AfterThrowing(value="execution(* *..Repository.*(..))", throwing="e")
public void report(JoinPoint jp, DataAccessException e) {
    mailService.emailFailure("Exception in repository", jp, e);
    throw new RewardsException(e);
}
```



If you wish to stop the exception from propagating any further, you can use an `@Around` advice (see later)



Advice Types: After



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After Advice Example

- Use `@After` annotation
 - Called regardless of whether an exception has been thrown by the target or not

```
@Aspect  
public class PropertyChangeTracker {  
    private Logger logger = Logger.getLogger(getClass());  
  
    @After("execution(void update(..))")  
    public void trackUpdate() {  
        logger.info("An update has been attempted ...");  
    }  
}
```

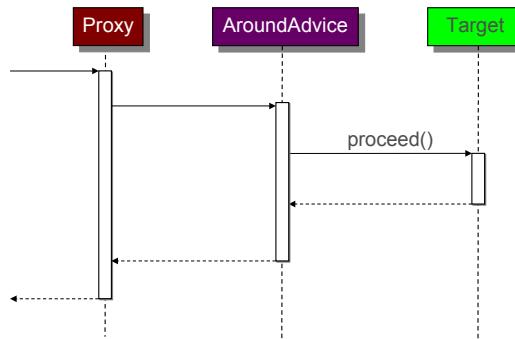
Track calls to all update methods

We don't know how the method terminated

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Advice Types: Around



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Around Advice Example

- Use `@Around` annotation and a `ProceedingJoinPoint`
 - Inherits from `JoinPoint` interface

```
@Around("execution(@example.Cacheable * rewards.service..*(..))")
public Object cache(ProceedingJoinPoint point) throws Throwable {
    Object value = cacheStore.get(CacheUtils.toKey(point));

    if (value == null) {                                ← Proceed only if not already cached
        value = point.proceed();
        cacheStore.put(CacheUtils.toKey(point), value);
    }

    return value;
}                                                       Cache values returned by cacheable services
```

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Limitations of Spring AOP

- Can only advise *non-private* methods
- Can only apply aspects to *Spring Beans*
- Limitations of weaving with proxies
 - When using proxies, suppose method a() calls method b()
on the *same* class/interface
 - advice will *never* be executed for method b()



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Summary



- Aspect Oriented Programming (AOP) *modularizes cross-cutting concerns*
- An aspect is a module (Java class) containing the cross-cutting behavior
 - Annotated with `@Aspect`
 - Behavior is implemented as an “advice” method
 - Pointcuts select *joinpoints* (methods) where *advice* applies
 - Five advice types
 - Before, AfterThrowing, AfterReturning, After and Around



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Lab

Developing Aspects using Spring AOP

Note: The lab is working when

- 1) your unit test is **green** *and*
- 2) you get console logging output

Coming Up: Named pointcuts, context selection, annotations in pointcuts



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Topics in this session

- What Problem Does AOP Solve?
- Core AOP Concepts
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Advanced topics
 - XML Configuration
 - Named Pointcuts
 - Context-Selecting Pointcuts
 - Working with Annotations



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Alternative Spring AOP Syntax - XML

- XML Based Alternative to @Annotations
 - More centralized configuration
- Approach
 - Aspect logic defined Java
 - Aspect configuration in XML
 - Uses the aop namespace



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Tracking Property Changes - Java Code

```
public class PropertyChangeTracker {  
    public void trackChange(JoinPoint point) {  
        ...  
    }  
}
```

Aspect is a Plain Java Class with no annotations



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Tracking Property Changes - XML Configuration

- XML configuration uses the `aop` namespace

```
<aop:config>
    <aop:aspect ref="propertyChangeTracker">
        <aop:before pointcut="execution(void set*(*))" method="trackChange"/>
    </aop:aspect>
</aop:config>

<bean id="propertyChangeTracker" class="example.PropertyChangeTracker" />
```



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Topics in this session

- What Problem Does AOP Solve?
- Core AOP Concepts
- Quick Start
- Defining Pointcuts
- Implementing Advice
- Advanced topics
 - XML Configuration
 - **Named Pointcuts**
 - Context-Selecting Pointcuts
 - Working with Annotations



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Named Pointcuts in XML

- A pointcut expression can have a name
 - Reuse it in multiple places

```
<aop:config>
  <aop:pointcut id="setterMethods" expression="execution(void set*(*))"/>

  <aop:aspect ref="propertyChangeTracker">
    <aop:after-returning pointcut-ref="setterMethods" method="trackChange"/>
    <aop:after-throwing pointcut-ref="setterMethods" method="logFailure"/>
  </aop:aspect>
</aop:config>

<bean id="propertyChangeTracker" class="example.PropertyChangeTracker" />
```



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Named Pointcut Annotation

```
@Aspect
public class PropertyChangeTracker {
  private Logger logger = Logger.getLogger(getClass());

  @Before("serviceMethod() || repositoryMethod()")
  public void monitor() {
    logger.info("A business method has been accessed...");
  }

  @Pointcut("execution(* rewards.service..*Service.*(..))")
  public void serviceMethod() {}

  @Pointcut("execution(* rewards.repository..*Repository.*(..))")
  public void repositoryMethod() {}
}
```

The method *name* becomes the pointcut ID.
The method is *not* executed.



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Named Pointcuts

- Expressions can be externalized

```
public class Pointcuts {  
    @Pointcut("execution(* rewards.service..*Service.*(..))")  
    public void serviceMethods() {}  
}
```

```
@Aspect  
public class ServiceMethodInvocationMonitor {  
    private Logger logger = Logger.getLogger(getClass());  
  
    @Before( "com.acme.Pointcuts.serviceMethods()" )  
    public void monitor() {  
        logger.info("A service method has been accessed...");  
    }  
}
```

Fully-qualified pointcut name



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Named Pointcuts - Summary

- Can break one complicated expression into several sub-expressions
- Allow pointcut expression reusability
- Best practice: consider externalizing expressions into one dedicated class
 - When working with many pointcuts
 - When writing complicated expressions



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Topics in this session

- What Problem Does AOP Solve?
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 - Named Pointcuts
 - **Context Selecting Pointcuts**
 - Working with Annotations



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Context Selecting Pointcuts

- Pointcuts may also select useful join point context
 - The target object
 - Method arguments
 - Annotations associated with the method, target, or arguments
 - The currently executing object (proxy)
- Allows for simple POJO advice methods
 - Alternative to working with a JoinPoint object directly



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Context Selecting Example

- Consider this basic requirement

Log a message every time Server is about to start

```
public interface Server {  
    public void start(Map input);  
    public void stop();  
}
```

In the advice, how do we access Server? Map?



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Without Context Selection

- All needed info must be obtained from *JoinPoint* object
 - No type-safety guarantees
 - Write advice *defensively*

```
@Before("execution(void example.Server.start(java.util.Map))")  
public void logServerStartup(JoinPoint jp) {  
    // A 'safe' implementation would also check target type  
    Server server = (Server) jp.getTarget();  
    // Don't assume args[0] exists  
    Object[] args= jp.getArgs();  
    Map map = args.length > 0 ? (Map) args[0] : new HashMap();  
    logger.info( server + " starting – params: " + map);  
}
```



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With Context Selection

- Best practice: use context selection
 - Method attributes are bound automatically
 - Types must match or advice skipped

```
@Before("execution(void example.Server.start(java.util.Map))  
    && target(server) && args(input)")  
public void logServerStartup(Server server, Map input) {  
    ...  
}
```

- target(server) selects the target of the execution (your object)
- this(server) would have selected the proxy



Context Selection - Named Pointcut

```
@Before("serverStartMethod(server, input)")  
public void logServerStartup(Server server, Map input) {  
    ...  
} 'target' binds the server starting up 'args' binds the argument value  
  
@Pointcut("execution(void example.Server.start(java.util.Map))  
    && target(server) && args(input)")  
public void serverStartMethod (Server server, Map input) {}
```



Topics in this session

- What Problem Does AOP Solve?
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Pointcut Expression Examples using Annotations

- Can match annotations everywhere
 - annotated methods, methods with annotated arguments, returning annotated objects, on annotated classes
- `execution(@org..transaction.annotation.Transactional * *(..))`
 - Any method marked with the `@Transactional` annotation
- `execution((@example.Sensitive *) *(..))`
 - Any method that returns a type marked as `@Sensitive`

```
@Sensitive  
public class MedicalRecord { ... }  
  
public class MedicalService {  
    public MedicalRecord lookup(...) { ... }  
}
```



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AOP and Annotations - Example

- Use of the *annotation()* designator

```
@Around("execution(* *(..)) && @annotation(txn)")  
public Object execute(ProceedingJoinPoint jp, Transactional txn) {  
    TransactionStatus tx;  
  
    try {  
        TransactionDefinition definition = new DefaultTransactionDefinition();  
        definition.setTimeout(txn.timeout());  
        definition.setReadOnly(txn.readOnly());  
        ...  
        tx = txnMgr.getTransaction(definition);  
        return jp.proceed();  
    }  
    ... // commit or rollback  
}
```

No need for `@Transactional` in `execution` expression – the `@annotation` matches it instead



AOP and Annotations – Named pointcuts

- Same example using a named-pointcut

```
@Around("transactionalMethod(txn)")  
public Object execute(ProceedingJoinPoint jp, Transactional txn) {  
    ...  
  
    @Pointcut("execution(* *(..)) && @annotation(txn)")  
    public void transactionalMethod(Transactional txn) {}
```



Advanced Topics Summary

- Topics covered were:
 - XML Configuration
 - Named Pointcuts
 - Context-Selecting Pointcuts
 - Working with Annotations



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Introduction to Data Management with Spring

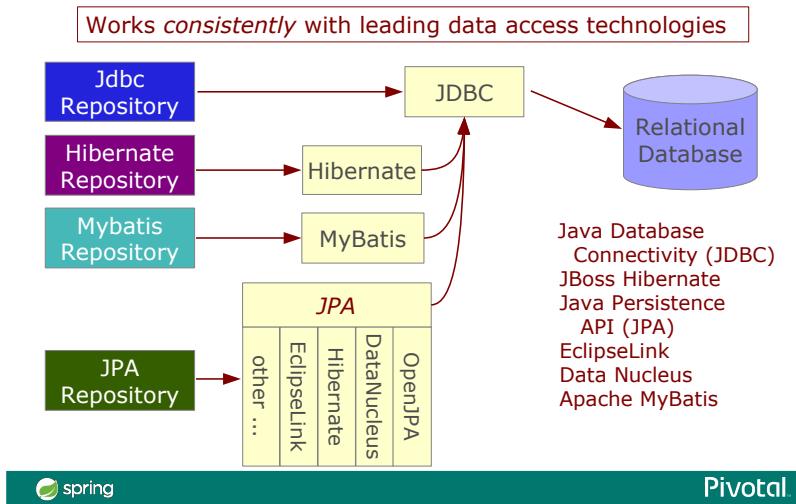
Implementing Data Access and Caching

Spring's Role in Supporting Data Access in an Enterprise Application

Topics in this Session

- **The Role of Spring in Enterprise Data Access**
- Spring's `DataAccessExceptionHierarchy`
- Using Test Databases
- Implementing Caching
- NoSQL databases

Spring Resource Management Works Everywhere



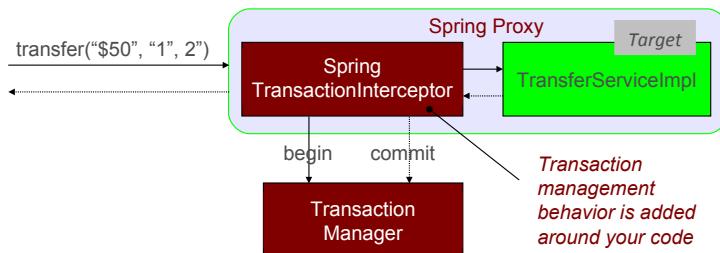
The Resource Management Problem

- Steps Required
 - Access a data source and establish a connection
 - Begin a transaction
 - Do the work – execute business logic
 - Commit or rollback the transaction
 - Close the connection
- Spring Advantages
 - No code to implement (classic cross-cutting concern)
 - No connection or session leakage
 - Throws own exceptions, independent of underlying API



Declarative Transaction Management

```
public class TransferServiceImpl implements TransferService {  
    @Transactional // marks method as needing a txn  
    public void transfer(...) { // your application logic  
    }
```



Template Design Pattern

- Widely used and useful pattern
 - http://en.wikipedia.org/wiki/Template_method_pattern
- Define the outline or skeleton of an algorithm
 - Leave the details to specific implementations later
 - Hides away large amounts of *boilerplate* code
- Spring provides many template classes
 - JdbcTemplate
 - JmsTemplate, RestTemplate, WebServiceTemplate ...
 - Most hide low-level resource management



Where are my Transactions?

- Every thread needs its own transaction
 - Typically: a web-driven request
- Spring transaction management
 - Transaction manager handles transaction
 - Puts it into thread-local storage
 - Data-access code, like JdbcTemplate, finds it automatically
 - Or you can get it yourself:
`DataSourceUtils.getConnection(dataSource)`



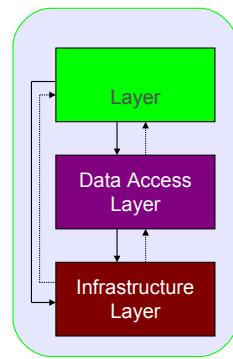
- Hibernate sessions, JTA (Java EE) work similarly

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Data Access in a Layered Architecture

- Many enterprise applications consist of three logical layers
 - *Service Layer* (or application layer)
 - Exposes high-level application functions
 - Use-cases, business logic defined here
 - *Data access Layer*
 - Defines interface to the application's data repository (such as a Relational or NoSQL database)
 - *Infrastructure Layer*
 - Exposes low-level services to the other layers



A classic Separation of Concerns

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Topics in this Session

- The Role of Spring in Enterprise Data Access
- **Spring's DataAccessExceptionHierarchy**
- Using Test Databases
- Implementing Caching
- NoSQL databases



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Exception Handling

- Checked Exceptions
 - Force developers to handle errors
 - But if you can't handle it, must declare it
 - **Bad:** intermediate methods must declare exception(s) from *all* methods below
 - A form of tight-coupling
- Unchecked Exceptions
 - Can be thrown up the call hierarchy to the best place to handle it
 - **Good:** Methods in between don't know about it
 - Better in an Enterprise Application
 - Spring throws Runtime (unchecked) Exceptions



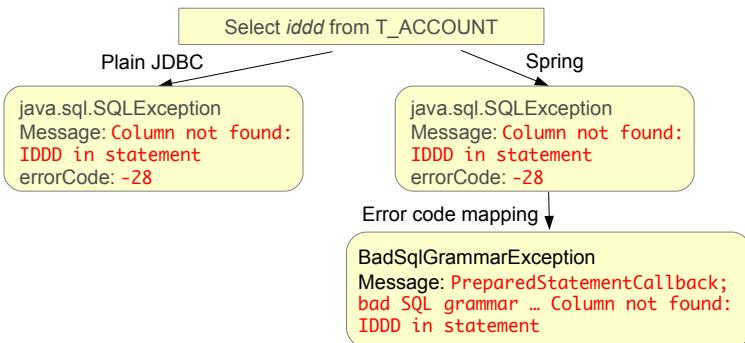
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Data Access Exceptions

- SQLException
 - Too general – one exception for every database error
 - Calling class 'knows' you are using JDBC
 - Tight coupling
- Spring provides **DataAccessException** hierarchy
 - Hides whether you are using JPA, Hibernate, JDBC ...
 - Actually a hierarchy of sub-exceptions
 - Not just one exception for everything
 - Consistent across all supported Data Access technologies
 - Unchecked



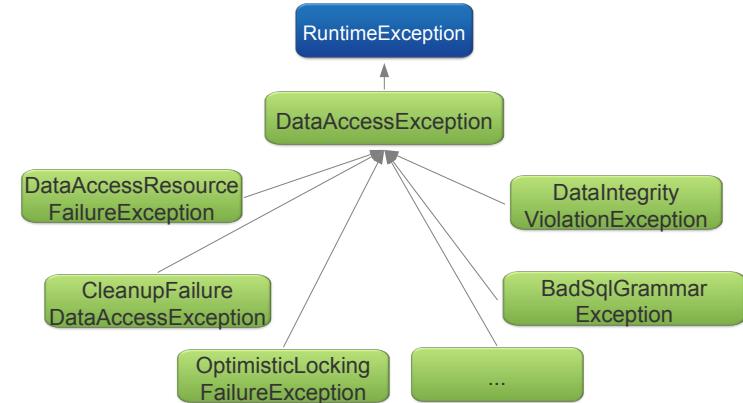
Example: *BadSqlGrammarException*



For more details on error codes: see
spring-jdbc.jar/org/springframework/jdbc/support/sql-error-codes.xml



Spring Data Access Exceptions



 spring

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Topics in this Session

- The Role of Spring in Enterprise Data Access
- Spring's `DataAccessExceptionHierarchy`
- **Using Test Databases**
- Implementing Caching
- NoSQL databases

 spring

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Embedded Database Builder

- Conveniently define a new (empty) in-memory database
 - And run script(s) to initialize it
 - HSQL, H2 and Derby are supported

```
@Bean  
public DataSource dataSource() {  
    EmbeddedDatabaseBuilder builder = new EmbeddedDatabaseBuilder();  
    return builder.setName("testdb")  
        .setType(EmbeddedDatabaseType.HSQL)  
        .addScript("classpath:/testdb/schema.db")  
        .addScript("classpath:/testdb/test-data.db").build();  
}
```



JDBC Namespace Equivalent

- Especially useful for testing
 - Supports H2, HSQL and Derby

```
<bean class="example.order.JdbcOrderRepository" >  
    <property name="dataSource" ref="dataSource" />  
</bean>  
  
<jdbc:embedded-database id="dataSource" type="H2">  
    <jdbc:script location="classpath: schema.sql" />  
    <jdbc:script location="classpath: test-data.sql" />  
</jdbc:embedded-database>
```

In memory database
(created at startup)



Initializing an Existing Test Database

XML provides jdbc:initialize-database

- Namespace supports populating other DataSources, too

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

<jdbc:initialize-database data-source="dataSource">
    <jdbc:script location="classpath:schema.sql" />
    <jdbc:script location="classpath:test-data.sql" />
</jdbc:initialize-database>
```

Initializes an **external** database



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Initializing and Existing Test Database

Java Configuration is not so Easy

```
@Configuration
public class DatabaseInitializer {
    @Value("classpath:schema.sql") private Resource schemaScript;
    @Value("classpath:test-data.sql") private Resource dataScript;

    private DatabasePopulator databasePopulator() {
        final ResourceDatabasePopulator populator =
            new ResourceDatabasePopulator();
        populator.addScript(schemaScript);
        populator.addScript(dataScript);
        return populator;
    }
}
```

Explicitly define a database Populator to run the init scripts

// continued on next slide



<http://stackoverflow.com/questions/16038360>

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Initializing and Existing Test Database

Java Configuration is not so Easy ... (continued)

- Bean can have any name, we won't use it (but Spring will)

```
// continued from previous slide
@Bean
public DataSourceInitializer anyName(final DataSource dataSource) {
    final DataSourceInitializer initializer = new DataSourceInitializer();
    initializer.setDataSource(dataSource);
    initializer.setDatabasePopulator(databasePopulator());
    return initializer;
}
```

Explicitly create a database
initializer which will do the work
in its post-construct method



<http://stackoverflow.com/questions/16038360>

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Topics in this Session

- The Role of Spring in Enterprise Data Access
- Spring's `DataAccessExceptionHierarchy`
- Using Test Databases
- **Implementing Caching**
- NoSQL databases



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About Caching

- What is a cache?
 - In this context: a key-value store = Map
- Where do we use this caching?
 - Any method that always returns the same result for the same argument(s)
 - This method could do anything
 - Calculate data on the fly
 - Execute a database query
 - Request data via RMI, JMS, a web-service ...
 - A unique key must be generated from the arguments
 - That's the cache key



Caching Support

- Transparently applies caching to Spring beans (AOP)
 - Mark methods cacheable
 - Indicate caching key(s)
 - Name of cache to use (multiple caches supported)
 - Define one or more caches in Spring configuration



See: [Spring Framework Reference – Cache Abstraction](http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#cache)
<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#cache>



Caching with @Cacheable

- `@Cacheable` marks a method for caching
 - its result is stored in a cache
 - subsequent invocations (with the *same arguments*)
 - fetch data from cache using key, method not executed
- `@Cacheable` attributes
 - value: name of cache to use
 - key: the key for each cached data-item
 - Uses SpEL and argument(s) of method

```
@Cacheable(value="topBooks", key="#refId.toUpperCase()")
public Book findBook(String refId) { ... }
```



Caching via Annotations

```
public class BookService {
    @Cacheable(value="topBooks", key="#title", condition="#title.length < 32")
    public Book findBook(String title, boolean checkWarehouse) { ... }

    @Cacheable(value="topBooks", key="#author.name")
    public Book findBook2(Author author, boolean checkWarehouse) { ... }

    @Cacheable(value="topBooks", key="T(example.KeyGen).hash(#author)")
    public Book findBook3(Author author, boolean checkWarehouse) { ... }

    @CacheEvict(value="topBooks")
    public void loadBooks() { ... }
}
```

Annotations and their effects:

- `value="topBooks"`: Use 'topBooks' cache
- `key="#title"`: Only cache if condition true
- `key="#author.name"`: use object property
- `key="T(example.KeyGen).hash(#author)"`: custom key generator
- `value="topBooks"`: clear cache before method invoked



Enabling Caching Proxy

- Caching must be enabled ...

```
@Configuration  
@EnableCaching  
public class MyConfig {  
    @Bean  
    public BookService bookService() { ... }  
}
```

OR

```
<cache:annotation-driven />  
  
<bean id="bookService" class="example.BookService" />
```



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Pure XML Cache Setup

- Or use XML instead (for example with third-party class)

```
<bean id="bookService" class="example.BookService">  
<aop:config>  
    <aop:advisor advice-ref="bookCache"  
        pointcut="execution(* *.BookService.*(..))"/>  
    </aop:config>  
    <cache:advice id="bookCache" cache-manager="cacheManager">  
        <cache:caching cache="topBooks">  
            <cache:cacheable method="findBook" key="#refId"/>  
            <cache:cache-evict method="loadBooks" all-entries="true" />  
        </cache:caching>  
    </cache:advice>
```

XML Cache Setup – no @Cachable



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Setup Cache Manager

- Must specify a cache-manager
 - Some provided, or write your own
 - See `org.springframework.cache` package
- SimpleCacheManager
 - For each cache name, it creates a `ConcurrentHashMap`

```
@Bean  
public CacheManager cacheManager() {  
    SimpleCacheManager cacheManager =  
        new SimpleCacheManager("topAuthors", "topBooks");  
    return cacheManager;  
}  
} Concurrent Map Cache
```

Keep `cacheManager` bean name

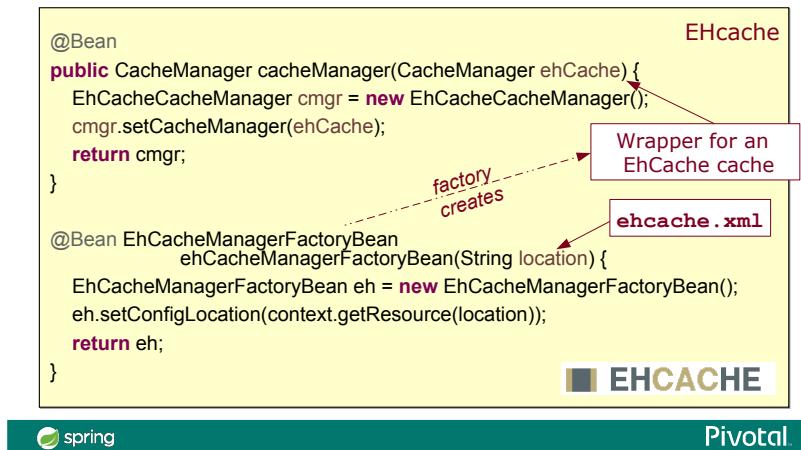


Third-Party Cache Implementations

- Simple Cache is OK for testing
 - But has no cache control options (overflow, eviction)
- Third-party alternatives
 - Terracotta's EhCache
 - Google's Guava and Caffeine
 - Pivotal's Gemfire



Third-Party Cache Manager – EHCache



Third-Party Cache Managers – Gemfire

- Gemfire: A distributed, shared nothing data-grid
 - Can be used to setup a distributed cache
 - Caches (regions) replicated across multiple nodes
 - Consistent updates occur on all copies in parallel
 - No loss of data if a storage node fails
 - Automatic recovery and rebalancing



The code snippets show XML configuration for Gemfire:

```
<gfe:cache-manager p:cache-ref="gemfire-cache"/>  
<gfe:cache id="gemfire-cache"/>  
  
<gfe:replicated-region id="topAuthors" p:cache-ref="gemfire-cache"/>  
<gfe:partitioned-region id="topBooks" p:cache-ref="gemfire-cache"/>
```



Spring Gemfire Project



- GemFire configuration in Spring config files
 - Also enables configuration injection for environments
- Features
 - Exception translation
 - GemfireTemplate
 - Transaction management (*GemfireTransactionManager*)
 - Injection of transient dependencies during deserialization
 - *Gemfire Cache Manager class*

GEMFIRE[®]



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Topics in this Session

- The Role of Spring in Enterprise Data Access
- Spring's `DataAccessExceptionHierarchy`
- Using Test Databases
- Implementing Caching
- **NoSQL databases**



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Not Only Relational



SPRING DATA

- NoSQL
 - Relational databases only store some data
 - LDAP, data-warehouses, files
 - Most documents and spreadsheets aren't in *any* database
- Other database products exist
 - Have strengths where RDB are weak
 - Non-tabular data
 - Hierarchical data: parts inventory, org chart
 - Network structures: telephone cables, roads, molecules
 - Documents: XML, spreadsheets, contracts, ...
 - Geographical data: maps, GPS navigation
 - Many more ...



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So Many Choices ...

- Many options – each has a particular strength

- Document databases

- MongoDB, *CouchDB coming*



MongoDB



CouchDB

- Distributed key-value Stores (smart caches)

- Redis, Riak



Redis



Riak

- Network (graph) database

- Neo4j



- Big Data

- Apache Hadoop (VMware Serengeti)



Hadoop

- Data Grid

- Gemfire



GEMFIRE

- Column Stores coming: HBase, Cassandra



Cassandra



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Summary

- Data Access with Spring
 - Enables layered architecture principles
 - Higher layers should not know about data management below
 - Isolate via Data Access Exceptions
 - Hierarchy makes them easier to handle
 - Provides consistent transaction management
 - Supports most leading data-access technologies
 - Relational and non-relational (NoSQL)
 - A key component of the core Spring libraries
 - Automatic caching facility



Introduction to Spring JDBC

Using JdbcTemplate

Simplifying JDBC-based data-access with Spring

Topics in this Session

- **Problems with traditional JDBC**
 - Results in redundant, error prone code
 - Leads to poor exception handling
- **Spring's JdbcTemplate**
 - Configuration
 - Query execution
 - Working with result sets
 - Exception handling



See: **Spring Framework Reference – Data access with JDBC**
<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#jdbc>

Redundant, Error Prone Code

```
public List findByLastName(String lastName) {  
    List personList = new ArrayList();  
    Connection conn = null;  
    String sql = "select first_name, age from PERSON where last_name=?";  
    try {  
        DataSource dataSource = DataSourceUtils.getDataSource();  
        conn = dataSource.getConnection();  
        PreparedStatement ps = conn.prepareStatement(sql);  
        ps.setString(1, lastName);  
        ResultSet rs = ps.executeQuery();  
        while (rs.next()) {  
            personList.add(new Person(rs.getString("first_name"), ...));  
        }  
    } catch (SQLException e) { /* ??? */ }  
    finally {  
        try {  
            conn.close();  
        } catch (SQLException e) { /* ??? */ }  
    }  
    return personList;  
}
```



Redundant, Error Prone Code

```
public List findByLastName(String lastName) {  
    List personList = new ArrayList();  
    Connection conn = null;  
    String sql = "select first_name, age from PERSON where last_name=?";  
    try {  
        DataSource dataSource = DataSourceUtils.getDataSource();  
        conn = dataSource.getConnection();  
        PreparedStatement ps = conn.prepareStatement(sql);  
        ps.setString(1, lastName);  
        ResultSet rs = ps.executeQuery();  
        while (rs.next()) {  
            personList.add(new Person(rs.getString("first_name"), ...));  
        }  
    } catch (SQLException e) { /* ??? */ }  
    finally {  
        try {  
            conn.close();  
        } catch (SQLException e) { /* ??? */ }  
    }  
    return personList;  
}
```

The bold matters - the
rest is boilerplate



Poor Exception Handling

```
public List findByName(String lastName) {  
    List personList = new ArrayList();  
    Connection conn = null;  
    String sql = "select first_name, age from PERSON where last_name=?";  
    try {  
        DataSource dataSource = DataSourceUtils.getDataSource();  
        conn = dataSource.getConnection();  
        PreparedStatement ps = conn.prepareStatement(sql);  
        ps.setString(1, lastName);  
        ResultSet rs = ps.executeQuery();  
        while (rs.next()) {  
            personList.add(new Person(rs.getString("first_name"), ...));  
        }  
    } catch (SQLException e) { /* ??? */ }  
    finally {  
        try {  
            conn.close();  
        } catch (SQLException e) { /* ??? */ }  
    }  
    return personList;  
}
```

What can
you do?



Topics in this session

- Problems with traditional JDBC
 - Results in redundant, error prone code
 - Leads to poor exception handling
- **Spring's JdbcTemplate**
 - Configuration
 - Query execution
 - Working with result sets
 - Exception handling



Spring's JdbcTemplate

- Greatly simplifies use of the JDBC API
 - Eliminates repetitive boilerplate code
 - Alleviates common causes of bugs
 - Handles SQLExceptions properly
- Without sacrificing power
 - Provides full access to the standard JDBC constructs



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JdbcTemplate in a Nutshell

```
int count = jdbcTemplate.queryForObject(  
    "SELECT COUNT(*) FROM CUSTOMER", Integer.class);
```

- Acquisition of the connection
- Participation in the transaction
- Execution of the statement
- Processing of the result set
- Handling any exceptions
- Release of the connection

All handled
by Spring



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JdbcTemplate Approach Overview

```
List<Customer> results = jdbcTemplate.query(someSql,  
    new RowMapper<Customer>() {  
        public Customer mapRow(ResultSet rs, int row) throws SQLException {  
            // map the current row to a Customer object  
        }  
    });  
  
class JdbcTemplate {  
    public List<Customer> query(String sql, RowMapper rowMapper) {  
        try {  
            // acquire connection  
            // prepare statement  
            // execute statement  
            // for each row in the result set  
            results.add(rowMapper.mapRow(rs, rowNum));  
        } catch (SQLException e) {  
            // convert to root cause exception  
        } finally {  
            // release connection  
        }  
    }  
}
```



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Creating a JdbcTemplate

- Requires a DataSource

```
JdbcTemplate template = new JdbcTemplate(dataSource);
```

- Create a template once and re-use it
 - Do not create one for each thread
 - Thread safe after construction



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When to use JdbcTemplate

- Useful standalone
 - Anytime JDBC is needed
 - In utility or test code
 - To clean up messy legacy code
- Useful for implementing a repository in a layered application
 - Also known as a data access object (DAO)



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Implementing a JDBC-based Repository

```
public class JdbcCustomerRepository implements CustomerRepository {  
    private JdbcTemplate jdbcTemplate;  
  
    public JdbcCustomerRepository(DataSource dataSource) {  
        this.jdbcTemplate = new JdbcTemplate(dataSource);  
    }  
  
    public int getCustomerCount() {  
        String sql = "select count(*) from customer";  
        return jdbcTemplate.queryForObject(sql, Integer.class);  
    }  
}
```

No try / catch needed
(unchecked exception)



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Querying with JdbcTemplate

- JdbcTemplate can query for
 - Simple types (int, long, String, Date, ...)
 - Generic Maps
 - Domain Objects



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Query for Simple Java Types

- Query with no bind variables: *queryForObject*

```
public Date getOldest() {  
    String sql = "select min(dob) from PERSON";  
    return jdbcTemplate.queryForObject(sql, Date.class);  
}  
  
public long getPersonCount() {  
    String sql = "select count(*) from PERSON";  
    return jdbcTemplate.queryForObject(sql, Long.class);  
}
```



queryForInt, queryForLong deprecated since Spring 3.2, just as easy to queryForObject instead (API improved in Spring 3)



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Query With Bind Variables

- Can query using bind variables: ?
 - Note the use of a variable argument list

```
private JdbcTemplate jdbcTemplate;

public int getCountOfNationalsOver(Nationality nationality, int age) {
    String sql = "select count(*) from PERSON " +
        "where age > ? and nationality = ?";
    return jdbcTemplate.queryForObject
        (sql, Integer.class, age, nationality.toString());
}
```

Bind to first ? Bind to second ?



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Generic Queries

- *JdbcTemplate* returns each row of a *ResultSet* as a **Map**
- When expecting a single row
 - Use `queryForMap(..)`
- When expecting multiple rows
 - Use `queryForList(..)`
- Useful for *ad hoc* reporting, testing use cases
 - The data fetched does not need mapping to a Java object



ad hoc – created or done for a particular purpose as necessary
– sometimes called “window-on-data” queries



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Querying for Generic Maps (1)

- Query for a single row

```
public Map<String, Object> getPersonInfo(int id) {  
    String sql = "select * from PERSON where id=?";  
    return jdbcTemplate.queryForMap(sql, id);  
}
```

- returns:

```
Map { ID=1, FIRST_NAME="John", LAST_NAME="Doe" }
```

A Map of [Column Name | Field Value] pairs



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Querying for Generic Maps (2)

- Query for multiple rows

```
public List<Map<String, Object>> getAllPersonInfo() {  
    String sql = "select * from PERSON";  
    return jdbcTemplate.queryForList(sql);  
}
```

- returns:

```
List {  
    0 - Map { ID=1, FIRST_NAME="John", LAST_NAME="Doe" }  
    1 - Map { ID=2, FIRST_NAME="Jane", LAST_NAME="Doe" }  
    2 - Map { ID=3, FIRST_NAME="Junior", LAST_NAME="Doe" }  
}
```

A List of Maps of [Column Name | Field Value] pairs



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Domain Object Queries

- Often it is useful to map relational data into domain objects
 - e.g. a ResultSet to an Account
- Spring's JdbcTemplate supports this using a callback approach
- You may prefer to use ORM for this
 - Need to decide between JdbcTemplate queries and JPA (or similar) mappings
 - Some tables may be too hard to map with JPA



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RowMapper

- Spring provides a RowMapper interface for mapping a single row of a ResultSet to an object
 - Can be used for both single and multiple row queries
 - Parameterized as of Spring 3.0

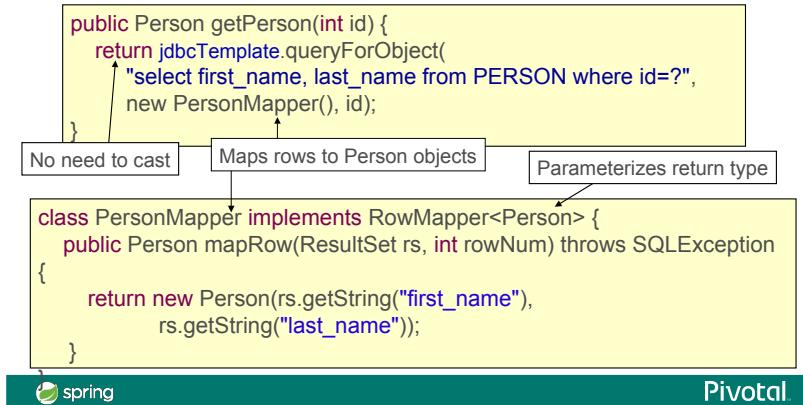
```
public interface RowMapper<T> {  
    T mapRow(ResultSet rs, int rowNum)  
        throws SQLException;  
}
```



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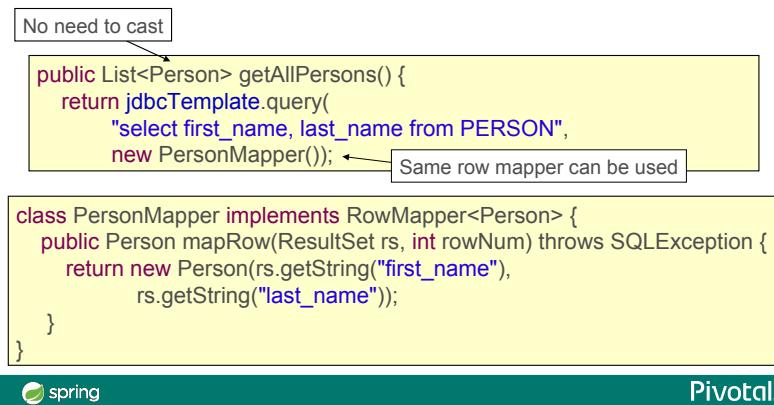
Querying for Domain Objects (1)

- Query for single row with JdbcTemplate



Querying for Domain Objects (2)

- Query for multiple rows



Querying for Domain Objects (3)

- Simplify using Java 8 Lambda Expressions
 - No need for Mapper class
 - Use inline code instead

```
public List<Person> getAllPersons() {  
    return jdbcTemplate.query(  
        "select first_name, last_name from PERSON",  
        (rs, rowNum) -> {  
            return new Person(rs.getString("first_name"),  
                rs.getString("last_name"));  
        });  
}  
  
public interface RowMapper<T> {  
    public T mapRow(ResultSet rs, int rowNum) throws SQLException;  
}
```

Replace RowMapper by a lambda



RowCallbackHandler

- Spring provides a simpler RowCallbackHandler interface when there is no return object
 - Streaming rows to a file
 - Converting rows to XML
 - Filtering rows before adding to a Collection
 - *but filtering in SQL is much more efficient*
 - Faster than JPA equivalent for big queries
 - avoids result-set to object mapping

```
public interface RowCallbackHandler {  
    void processRow(ResultSet rs) throws SQLException;  
}
```



Using a RowCallbackHandler (1)

```
public class JdbcOrderRepository {  
    public void generateReport(Writer out) {  
        // select all orders of year 2009 for a full report  
        jdbcTemplate.query("select * from order where year=?",  
                          new OrderReportWriter(out), 2009);  
    }  
}
```

returns "void"

```
class OrderReportWriter implements RowCallbackHandler {  
    public void processRow(ResultSet rs) throws SQLException {  
        // parse current row from ResultSet and stream to output  
    }  
    // May also be a stateful object: you could accumulate data and add  
    // convenience methods like getTotalOrderValue(), getCount() ...  
}
```



Using a RowCallbackHandler (2)

- Might use a Lambda – if *no* state needed
 - Need to cast, tells Java which callback lambda replaces

```
public class JdbcOrderRepository {  
    public void generateReport(final PrintWriter out) {  
        // select all orders of year 2009 for a full report  
        jdbcTemplate.query("select * from order where year=?",  
                          (RowCallbackHandler)(rs) ->  
                          { out.write(rs.getString("customer") ... );  
                            2016});  
    }  
}
```

Cast needed

Or using a *lambda*

```
public interface RowCallbackHandler {  
    void processRow(ResultSet rs) throws SQLException;  
}
```



ResultSetExtractor

- Spring provides a ResultSetExtractor interface for processing an entire ResultSet at once
 - You are responsible for iterating the ResultSet
 - e.g. for mapping entire ResultSet to a single object

```
public interface ResultSetExtractor<T> {  
    T extractData(ResultSet rs) throws SQLException,  
        DataAccessException;  
}
```



You may need this for the lab!



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Using a ResultSetExtractor (1)

```
public class JdbcOrderRepository {  
    public Order findByConfirmationNumber(String number) {  
        // execute an outer join between order and item tables  
        return jdbcTemplate.query(  
            "select...from order o, item i...conf_id = ?",  
            new OrderExtractor(), number);  
    }  
}  
  
class OrderExtractor implements ResultSetExtractor<Order> {  
    public Order extractData(ResultSet rs) throws SQLException {  
        Order order = null;  
        while (rs.next()) {  
            if (order == null) {  
                order = new Order(rs.getLong("ID"), rs.getString("NAME"), ...);  
            }  
            order.addItem(mapItem(rs));  
        }  
        return order;  
    }  
}
```



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Using a ResultSetExtractor (2)

```
public class JdbcOrderRepository {  
    public Order findByConfirmationNumber(String number) {  
        // execute an outer join between order and item tables  
        return jdbcTemplate.query(  
            "select...from order o, item i...conf_id = ?",  
            (ResultSetExtractor<Order>)(rs) -> {  
                Order order = null;  
                while (rs.next()) {  
                    if (order == null)  
                        order = new Order(rs.getLong("ID"), rs.getString("NAME"), ...);  
  
                    order.addItem(mapItem(rs));  
                }  
                return order;  
            },  
            number);  
    }  
}
```

Or using a *lambda*

```
public interface ResultSetExtractor<T> {  
    T extractData(ResultSet rs)  
    throws SQLException, DataAccessException;  
}
```



Summary of Callback Interfaces

- RowMapper
 - Best choice when *each* row of a ResultSet maps to a domain object
- RowCallbackHandler
 - Best choice when *no value* should be returned from the callback method for *each* row, especially large queries
- ResultSetExtractor
 - Best choice when *multiple* rows of a ResultSet map to a *single* object



Inserts and Updates (1)

- Inserting a new row
 - Returns number of rows modified

```
public int insertPerson(Person person) {  
    return jdbcTemplate.update(  
        "insert into PERSON (first_name, last_name, age)" +  
        "values (?, ?, ?)",  
        person.getFirstName(),  
        person.getLastName(),  
        person.getAge());  
}
```



Inserts and Updates (2)

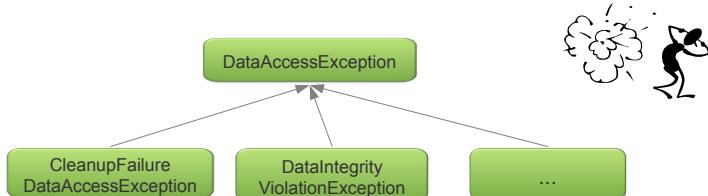
- Updating an existing row

```
public int updateAge(Person person) {  
    return jdbcTemplate.update(  
        "update PERSON set age=? where id=?",  
        person.getAge(),  
        person.getId());  
}
```



Exception Handling

- The JdbcTemplate transforms SQLExceptions into DataAccessExceptions



DataAccessException hierarchy was discussed in module “Introduction to Data Access”. You can refer to it for more information on this topic.



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Summary

- JDBC is useful
 - But using JDBC API directly is tedious and error-prone
- JdbcTemplate* simplifies data access and enforces consistency
 - DRY principle hides most of the JDBC
 - Many options for reading data
- SQLExceptions* typically cannot be handled where thrown
 - Should not be *checked Exceptions*
 - Spring provides *DataAccessException* instead



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Lab

Reimplementing repositories using
Spring's JdbcTemplate



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Transaction Management with Spring

Spring's Consistent Approach

Transactional Proxies and @Transactional

Topics in this session

- **Why use Transactions?**
- Java Transaction Management
- Spring Transaction Management
- Isolation Levels
- Transaction Propagation
- Rollback rules
- Testing
- Advanced topics

What is a Transaction?

- A set of tasks which take place as a single, indivisible action
 - An *Atomic, Consistent, Isolated, Durable* operation
 - Acronym: **ACID**



 spring

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Why use Transactions? To Enforce the ACID Principles

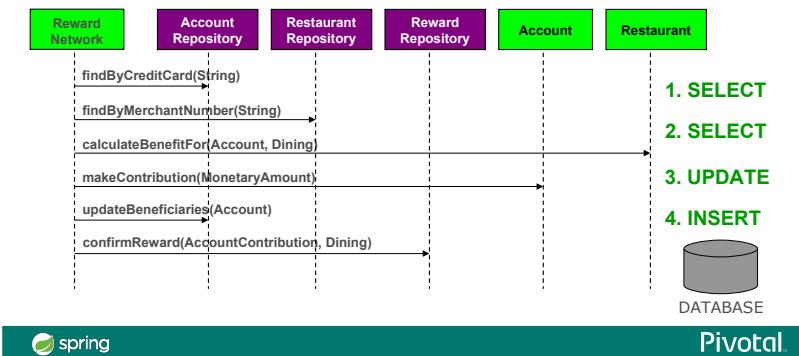
- **A**tomic
 - Each unit of work is an all-or-nothing operation
- **C**onsistent
 - Database integrity constraints are never violated
- **I**solated
 - Isolating transactions from each other
- **D**urable
 - Committed changes are permanent

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Transactions in the RewardNetwork

- The *rewardAccountFor(Dining)* method represents a unit-of-work that should be atomic



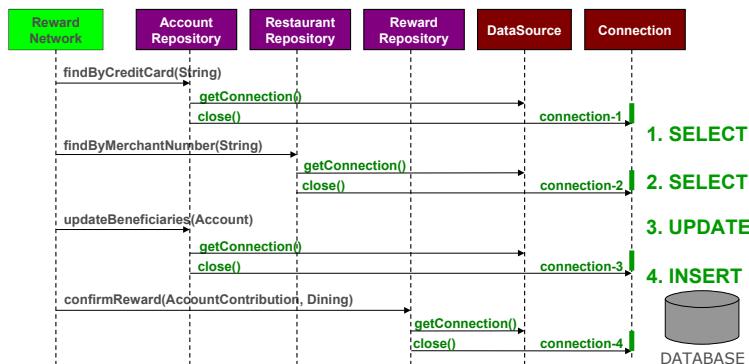
Naïve Approach

Connection per Data Access Operation

- This unit-of-work contains 4 data access operations
 - Each acquires, uses, and releases a distinct Connection
- The unit-of-work is ***non-transactional***



Running non-Transactionally

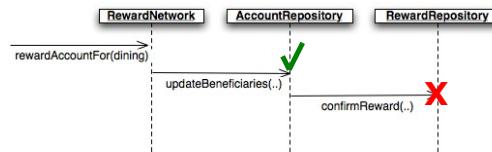


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Partial Failures

- Suppose an Account is being rewarded



- If the beneficiaries are updated...
- But the reward confirmation fails...
- There will be no record of the reward!

The unit-of-work
is **not atomic**

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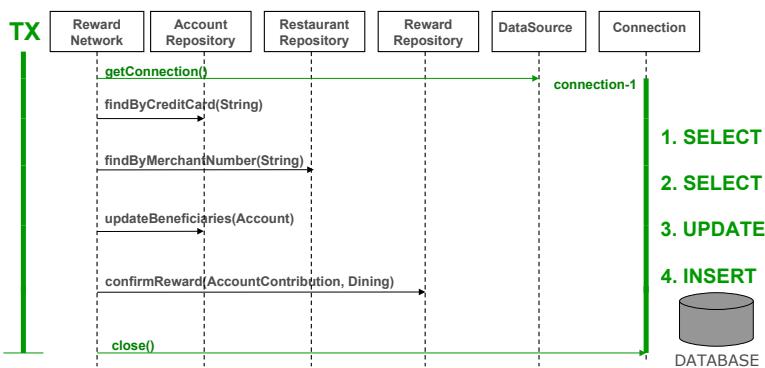
Correct Approach

Connection per Unit-of-Work

- More efficient
 - Same Connection reused for each operation
- Operations complete as an atomic unit
 - Either all succeed or all fail
- The unit-of-work can run in a *transaction*



Running in a Transaction



Topics in this session

- Why use Transactions?
- **Java Transaction Management**
- Spring Transaction Management
- Isolation Levels
- Transaction Propagation
- Rollback rules
- Testing
- Advanced topics



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Java Transaction Management

- Java has several APIs which handle transactions differently
 - JDBC, JMS, JTA, Hibernate, JPA, etc.
- Each uses program code to mark the start and end of the transaction
 - Transaction Demarcation
- Different APIs for Global vs Local transactions



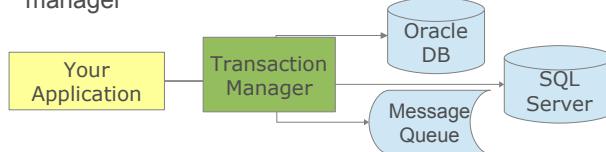
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Local and Global Transaction Management

- Local Transactions – Single Resource
 - Transactions managed by underlying resource



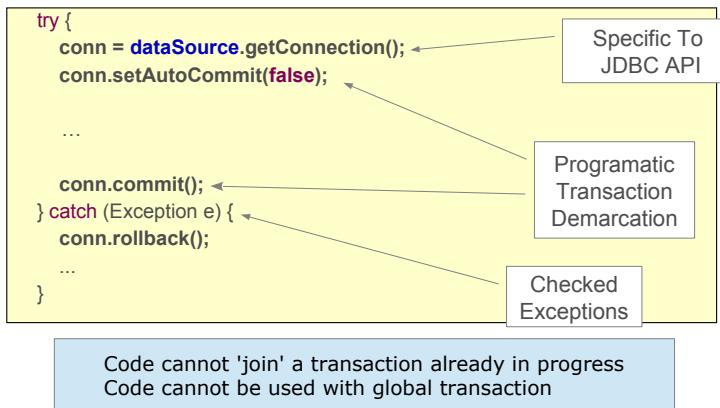
- Global (distributed) Transactions – Multiple
 - Transaction managed by separate, dedicated transaction manager



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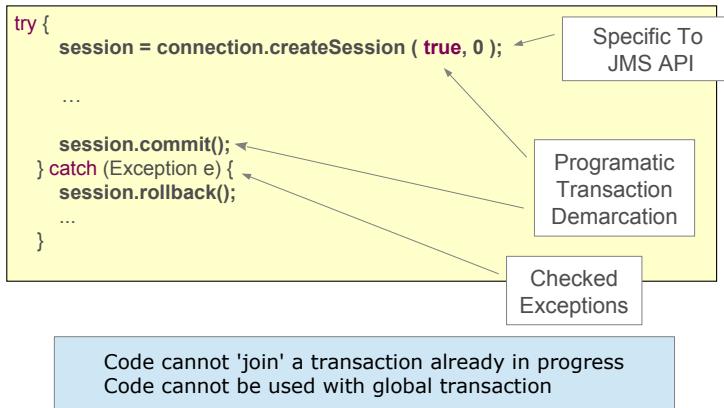
JDBC Transaction Management Example



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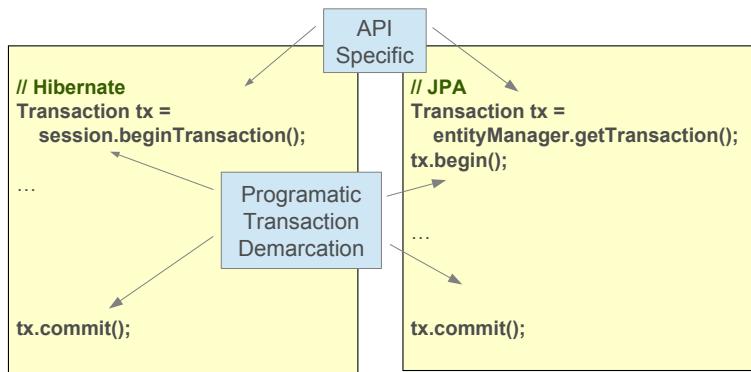
JMS Transaction Management Example



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JPA / Hibernate Transaction Management Example



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Java Transaction API (JTA) Example

```
try {  
    UserTransaction ut =  
        (UserTransaction) new InitialContext()  
            .lookup("java:comp/UserTransaction");  
    ut.begin(); ←  
    ...  
  
    ut.commit(); ←  
} catch (Exception e) {  
    ut.rollback(); ←  
    ...  
}
```

Programmatic
Transaction
Demarcation

Checked
Exceptions

Requires a JTA implementation:

- "Full" application server (WebSphere, WebLogic, JBoss, etc.)
- Standalone implementation (Atomikos, JTOM, etc.)



Problems with Java Transaction Management



- Multiple APIs for different local resources
- Programmatic transaction demarcation
 - Typically performed in the repository layer (wrong place)
 - Usually repeated (cross-cutting concern)
- Service layer more appropriate
 - Multiple data access methods often called within a single transaction
 - But: don't want data-access code in service-layer
- Orthogonal concerns
 - Transaction demarcation should be independent of transaction implementation



Topics in this session

- Why use Transactions?
- Java Transaction Management
- **Spring Transaction Management**
- Isolation Levels
- Transaction Propagation
- Rollback rules
- Testing
- Advanced topics



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Spring Transaction Management – 1

- Spring separates transaction *demarcation* from transaction *implementation*
 - Demarcation expressed declaratively via AOP
 - Programmatic approach also available
 - **PlatformTransactionManager** abstraction hides implementation details.
 - Several implementations available
- Spring uses the same API for global vs. local.
 - Change from local to global is minor
 - Just change the transaction manager



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Spring Transaction Management – 2

- There are only 2 steps
 - Declare a **PlatformTransactionManager** bean
 - Declare the transactional methods
 - Using Annotations, XML, Programmatic
 - Can mix and match



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PlatformTransactionManager

- Spring's **PlatformTransactionManager** is the base interface for the abstraction
- Several implementations are available
 - DataSourceTransactionManager
 - HibernateTransactionManager
 - JpaTransactionManager
 - JtaTransactionManager
 - WebLogicJtaTransactionManager
 - WebSphereUowTransactionManager
 - *and more*



Spring allows you to configure whether you use JTA or not.
It does not have *any* impact on your Java classes



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Deploying the Transaction Manager

- Create the required implementation
 - Just like any other Spring bean
 - Configure as appropriate
 - Here is the manager for a DataSource

A DataSource
bean must be
defined elsewhere

```
@Bean  
public PlatformTransactionManager  
transactionManager(DataSource dataSource) {  
    return new DataSourceTransactionManager(dataSource);  
}
```



Bean id “*transactionManager*” is default name. Can change it, but must specify alternative name everywhere – easier not to!



@Transactional Configuration

In your code

```
nts PlatformRewardNetworkImpl  
@Transactional  
public RewardConfirmation rewardAccountFor(Dining d) {  
    // atomic unit-of-work  
}
```

In your Spring configuration

```
@Configuration  
@EnableTransactionManagement  
public class TxnConfig {  
    @Bean  
    public PlatformTransactionManager transactionManager(DataSource ds) {  
        return new DataSourceTransactionManager(ds);  
    }  
}
```

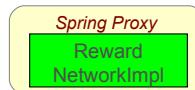
Defines a Bean Post-Processor
– proxies @Transactional beans

Or use <tx:annotation-driven/> - see Advanced Section

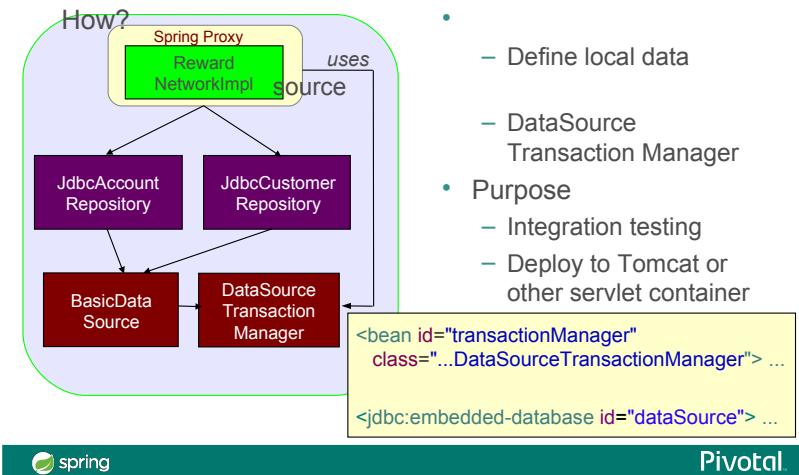


@Transactional: What Happens Exactly?

- Target object wrapped in a proxy
 - Uses an Around advice
- Proxy implements the following behavior
 - Transaction started before entering the method
 - Commit at the end of the method
 - Rollback if method throws a RuntimeException
 - Default behavior
 - Can be overridden (see later)
- Transaction context bound to current thread.
- All controlled by *configuration*

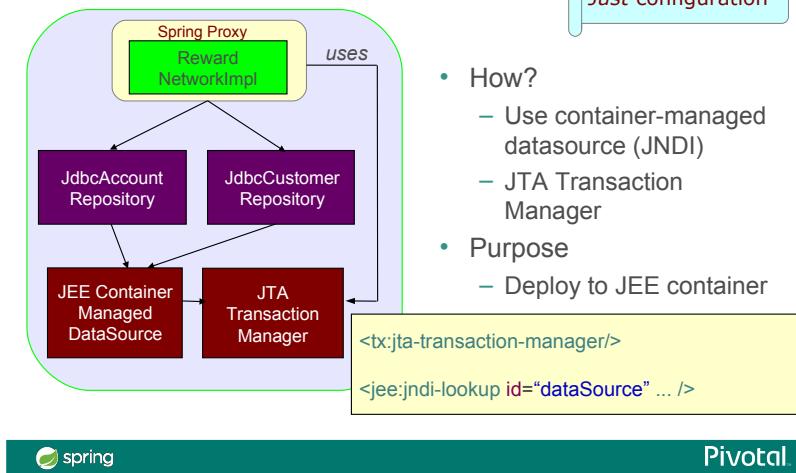


Local JDBC Configuration



JDBC Java EE Configuration

No code changes
Just configuration



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@Transactional – Class Level

- Applies to all methods declared by the interface(s)

```
@Transactional
public class RewardNetworkImpl implements RewardNetwork {

    public RewardConfirmation rewardAccountFor(Dining d) {
        // atomic unit-of-work
    }

    public RewardConfirmation updateConfirmation(RewardConfirmation rc) {
        // atomic unit-of-work
    }
}
```



Alternatively `@Transactional` can be declared on the interface instead
– if not using Spring Boot nor CGLIB proxies

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@Transactional

– Class *and* method levels

- Combining class and method levels

```
@Transactional(timeout=60) ← default settings
public class RewardNetworkImpl implements RewardNetwork {

    public RewardConfirmation rewardAccountFor(Dining d) {
        // atomic unit-of-work
    }
    @Transactional(timeout=45) ← override attributes at method level
    public RewardConfirmation updateConfirmation(RewardConfirmation rc) {
        // atomic unit-of-work
    }
}
```



Topics in this session

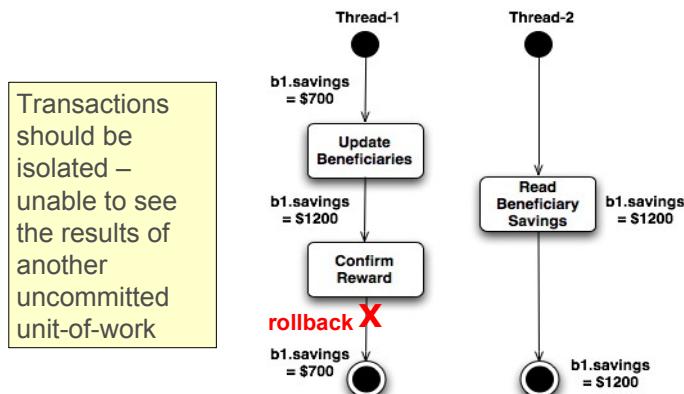
- Why use Transactions?
- Java Transaction Management
- Spring Transaction Management
- Isolation Levels**
- Transaction Propagation
- Rollback rules
- Testing
- Advanced topics



Isolation levels

- 4 isolation levels can be used:
 - READ_UNCOMMITTED
 - READ_COMMITTED
 - REPEATABLE_READ
 - SERIALIZABLE
- Some DBMSs do not support all isolation levels
- Isolation is a complicated subject
 - DBMS all have differences in the way their isolation policies have been implemented
 - We just provide general guidelines

Dirty Reads



READ_UNCOMMITTED

- Lowest isolation level – allows *dirty reads*
- Current transaction can see the results of another uncommitted unit-of-work
- Typically used for large, intrusive read-only transactions
- And/or where the data is constantly changing

```
public class RewardNetworkImpl implements RewardNetwork {  
    @Transactional (isolation=Isolation.READ_UNCOMMITTED)  
    public BigDecimal totalRewards(String merchantNumber, int year)  
        // Calculate total rewards for a restaurant for a whole year  
    }  
}
```



READ_COMMITTED

- Does not allow dirty reads
 - Only committed information can be accessed
- Default strategy for most databases

```
public class RewardNetworkImpl implements RewardNetwork {  
    @Transactional (isolation=Isolation.READ_COMMITTED)  
    public RewardConfirmation rewardAccountFor(Dining dining)  
        // atomic unit-of-work  
    }  
}
```



Highest isolation levels

- REPEATABLE_READ
 - Does not allow dirty reads
 - Non-repeatable reads are prevented
 - If a row is read twice in the same transaction, result will always be the same
 - Might result in locking depending on the DBMS
- SERIALIZABLE
 - Prevents non-repeatable reads and dirty-reads
 - Also prevents phantom reads



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Topics in this session

- Why use Transactions?
- Java Transaction Management
- Spring Transaction Management
- Isolation Levels
- **Transaction Propagation**
- Rollback rules
- Testing
- Advanced topics



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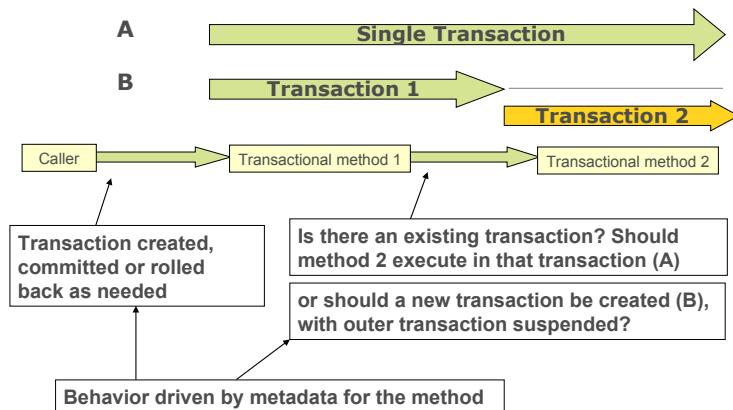
Understanding Transaction Propagation

- Consider the sample below. What should happen if ClientServiceImpl calls AccountServiceImpl?
 - Should everything run into a single transaction?
 - Should each service have its own transaction?

```
public class ClientServiceImpl  
    implements ClientService {  
    @Autowired  
    private AccountService accountService;  
  
    @Transactional  
    public void updateClient(Client c)  
    { // ...  
        this.accountService.update(c.getAccounts());  
    }  
}  
  
public class AccountServiceImpl  
    implements AccountService {  
    @Transactional  
    public void update(List <Account> l)  
    { // ...  
    }  
}
```

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Understanding Transaction Propagation



Transaction Propagation with Spring

- 7 levels of propagation
- The following examples show *REQUIRED* and *REQUIRES_NEW*
 - Check the documentation for other levels
- Can be used as follows:

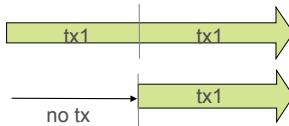
```
@Transactional(propagation=Propagation.REQUIRES_NEW)
```



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REQUIRED

- REQUIRED
 - Default value
 - Execute within a current transaction, create a new one if none exists



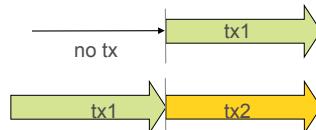
```
@Transactional(propagation=Propagation.REQUIRED)
```



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REQUIRES_NEW

- REQUIRES_NEW
 - Create a new transaction, suspending the current transaction if one exists



```
@Transactional(propagation=Propagation.REQUIRES_NEW)
```



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Topics in this session

- Why use Transactions?
- Java Transaction Management
- Spring Transaction Management
- Isolation Levels
- Transaction Propagation
- **Rollback rules**
- Testing
- Advanced topics



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Default Behavior

- By default, a transaction is rolled back if a RuntimeException has been thrown
 - Could be any kind of RuntimeException:
DataAccessException, HibernateException etc.

```
public class RewardNetworkImpl implements RewardNetwork {  
    @Transactional  
    public RewardConfirmation rewardAccountFor(Dining d) {  
        // ...  
        throw new RuntimeException();  
    }  
}
```

Triggers a rollback



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rollbackFor and noRollbackFor

- Default settings can be overridden with *rollbackFor* and/or *noRollbackFor* attributes

```
public class RewardNetworkImpl implements RewardNetwork {  
    @Transactional(rollbackFor=MyCheckedException.class,  
                 noRollbackFor={JmxException.class, MailException.class})  
    public RewardConfirmation rewardAccountFor(Dining d) throws Exception {  
        // ...  
    }  
}
```



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Topics in this session

- Why use Transactions?
- Java Transaction Management
- Spring Transaction Management
- Isolation Levels
- Transaction Propagation
- Rollback rules
- **Testing**
- Advanced topics



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@Transactional within Integration Test

- Annotate test method (or class) with **@Transactional**
 - Runs test methods in a transaction
 - Transaction will be *rolled back* afterwards
 - No need to clean up your database after testing!

```
@ContextConfiguration(classes=RewardsConfig.class)
@RunWith(SpringJUnit4ClassRunner.class)
public class RewardNetworkTest {
    @Test @Transactional
    public void testRewardAccountFor() {
        ...
    }
}
```

This test is now
transactional



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Controlling Transactional Tests

```
@ContextConfiguration(classes=RewardsConfig.class)
@RunWith(SpringJUnit4ClassRunner.class)
@Transactional
public class RewardNetworkTest {

    @Test
    @Commit
    public void testRewardAccountFor() {
        ... // Whatever happens here will be committed
    }
}
```

Make *all* tests transactional

Commit transaction at end of test



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Lab

Managing Transactions Declaratively
using Spring Annotations

Coming Up: Programmatic transactions, read-only and multiple
transactions, Global transactions, Propagation options



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Topics in this session

- Advanced topics
 - (1) XML Configuration
 - (2) Programmatic transactions
 - (3) Read-only transactions
 - (4) More on Transactional Tests
 - (5) Multiple and Global Transactions
 - (6) Propagation Options



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1. Deploying the Transaction Manager

- Declare as a Spring Bean

```
<bean id="transactionManager"
      class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
    <property name="dataSource" ref="dataSource"/>
</bean>
```

A dataSource
must be defined
elsewhere



Bean id “*transactionManager*” is default name. Can change it but must specify alternative name everywhere – easier not to!



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Automatic JTA Implementation Resolution

- For JTA, also possible to use custom XML tag:

```
<tx:jta-transaction-manager/>
```

- Resolves to appropriate implementation for the environment
 - WebLogicJtaTransactionManager
 - WebSphereUowTransactionManager
 - JtaTransactionManager
 - OC4JJtaTransactionManager
 - Obsolete, removed after Spring 3.2



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@Transactional Configuration Using XML

- Annotate classes and methods with `@Transactional` in usual way
- Enable using tx namespace in the configuration:

```
<tx:annotation-driven/>           Defines a Bean Post-Processor  
                                         - proxies @Transactional beans  
  
<bean id="transactionManager"  
      class="org.springframework.jdbc.datasource.DataSourceTransactionManager">  
    <property name="dataSource" ref="dataSource"/>  
</bean>  
  
<jdbc:embedded-database id="dataSource"> ... </jdbc:embedded-database>
```



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100% XML-based Spring Transactions

- @Transactional not always an option
 - Someone else may have written the service (without annotations)
 - Legacy code written before @Transactional
- Spring provides support for 100% XML
 - Predates annotations
 - An AOP pointcut declares what to advise
 - Spring's `tx` namespace enables a concise definition of transactional advice
 - Can add transactional behavior to any class used as a Spring Bean



Declarative Transactions: XML

```
<aspect name="rewardNetworkMethods">
    <!-- aspect named pointcut expression -->
    <aop:config>
        <aop:pointcut id="rewardNetworkMethods"
            expression="execution(* rewards.RewardNetwork.*(..))"/>
        <aop:advisor pointcut-ref="rewardNetworkMethods" advice-ref="txAdvice"/>
    </aop:config>
    <tx:advice id="txAdvice">
        <tx:attributes>
            <tx:method name="get*" read-only="true" timeout="10"/>
            <tx:method name="find*" read-only="true" timeout="10"/>
            <tx:method name="*" timeout="30"/>
        </tx:attributes>
    </tx:advice>
    <bean id="transactionManager"
        class="org.springframework.jdbc.datasource.DataSourceTransactionManager">
        <property name="dataSource" ref="dataSource"/>
    </bean>
```

Method-level configuration for transactional advice

Includes rewardAccountFor(..) and updateConfirmation(..)



2. Programmatic Transactions with Spring

- Declarative transaction management is highly recommended
 - Clean code
 - Flexible configuration
- Spring does enable programmatic transaction
 - Works with local or JTA transaction manager
 - `TransactionTemplate` plus callback



Can be useful inside a technical framework that would not rely on external configuration



Programmatic Transactions: example

```
Method not  
public RewardConfirmation rewardAccountFor(Dining dining) {  
    ...  
    return new TransactionTemplate(txManager).execute( (status) -> {  
        try {  
            ...  
            accountRepository.updateBeneficiaries(account);  
            confirmation = rewardRepository.confirmReward(contribution, dining);  
        }  
        catch (RewardException e) {  
            status.setRollbackOnly();  
            confirmation = new RewardFailure();  
        }  
        return confirmation;  
    };  
}
```

`@Transactional`

`Lambda syntax`

`Method no longer throws exception, using status to perform manual rollback`

`public interface TransactionCallback<T> {
 public T doInTransaction(TransactionStatus status)
 throws Exception;
}`



3. Read-only Transactions – Faster

- Why use transactions if you're only planning to read data?
 - Performance: allows Spring to optimize the transactional resource for read-only data access

```
public void rewardAccount1() {  
    jdbcTemplate.queryForList(...);  
    jdbcTemplate.queryForInt(...);  
}  
  
@Transactional(readOnly=true)  
public void rewardAccount2() {  
    jdbcTemplate.queryForList(...);  
    jdbcTemplate.queryForInt(...);  
}
```

2 connections

1 single connection



Read-only Transactions – Isolation

- Why use transactions if you're only planning to read data?
 - With a high isolation level, a read-only transaction prevents data from being modified until the transaction commits

```
@Transactional(readOnly=true, isolation=Isolation.REPEATABLE_READ)  
public void importantAccounts() {  
    List accounts = jdbcTemplate.queryForList  
        ("SELECT * FROM Accounts WHERE balance > 1000000");  
    process(accounts);  
    int nAccounts = jdbcTemplate.queryForInt  
        ("SELECT count(*) FROM Accounts WHERE balance > 1000000");  
    assert accounts.size() == nAccounts;  
}
```



4. Transactional Tests

@Before vs @BeforeTransaction

```
@ContextConfiguration(locations={"/rewards-config.xml"})
@RunWith(SpringJUnit4ClassRunner.class)
public class RewardNetworkTest {
    @BeforeTransaction
    public void verifyInitialDatabaseState() {...}
    @Before
    public void setUpTestDataInTransaction() {...}
    @Test @Transactional
    public void testRewardAccountFor() { ... }
```

Run before transaction is started

Within the transaction



@After and @AfterTransaction work in the same way as @Before and @BeforeTransaction

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@Sql and Transaction Control

- Transaction control options
 - *ISOLATED*: Used with *txn*, a PTM *must* exist
 - *INFERRRED*: If PTM exists, txn started using default propagation (so it uses txn around test method) otherwise a DataSource *must* exist (used with *no txn*)
 - *DEFAULT*: Whatever @Sql defines at class level, INFERRRED otherwise

```
@Sql( scripts = "/test-user-data.sql",
       config = @SqlConfig(
           transactionMode = TransactionMode.ISOLATED,
           transactionManager = "myTxnMgr",
           dataSource= "myDataSource" )
```

Optionally specify bean ids

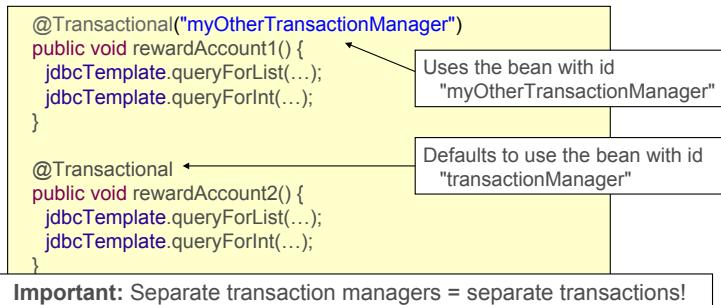
PTM = PlatformTransactionManager, txn = transaction

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5. Multiple Transaction Managers

- `@Transactional` can declare the id of the transaction manager that should be used

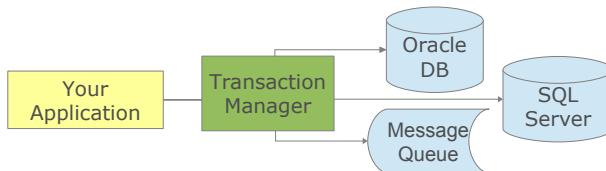


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Global Transactions

- Also called distributed transactions
- Involve multiple dissimilar resources:



- Global transactions typically require JTA and specific drivers (XA drivers)
 - Two-phase commit protocol

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Global Transactions → Spring Integration

- Many possible strategies
 - Spring allows you to switch easily from a non-JTA to a JTA transaction policy
 - Just change the type of the transaction manager
- Reference:
 - *Distributed transactions with Spring, with and without XA*
by Dr. Dave Syer

<http://www.javaworld.com/javaworld/jw-01-2009/jw-01-spring-transactions.html>

Learn More: Enterprise Spring

– 4 day course, including *global transactions*



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6. Propagation Levels and their Behaviors

Propagation Type	If NO current transaction	If there is a current transaction
MANDATORY	throw exception	use current transaction
NEVER	don't create a transaction, run method outside any transaction	throw exception
NOT_SUPPORTED	don't create a transaction, run method outside any transaction	suspend current transaction, run method outside any transaction
SUPPORTS	don't create a transaction, run method outside any transaction	use current transaction
REQUIRED(default)	create a new transaction	use current transaction
REQUIRES_NEW	create a new transaction	suspend current transaction, create a new independent transaction
NESTED	create a new transaction	create a new nested transaction



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JPA with Spring and Spring Data

Object Relational Mapping with
Spring & Java Persistence API

Using JPA with Spring, Spring Data Repositories

Topics in this session

- **Introduction to JPA**
 - General Concepts
 - Mapping
 - Querying
- Configuring JPA in Spring
- Implementing JPA DAOs
- Spring Data – JPA
- Lab
- Optional and Advanced Topics

Introduction to JPA

- The Java Persistence API is designed for operating on domain objects
 - Defined as POJO entities
 - No special interface required
- Replaces previous persistence mechanisms
 - EJB Entity Beans
 - Java Data Objects (JDO)
- A common API for object-relational mapping
 - Derived from the experience of existing products such as JBoss Hibernate and Oracle TopLink



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About JPA

- Java Persistence API
 - Current version: 2.1 May 2013
 - 2.2 Under discussion
- Configuration
 - Persistence Unit
- Key Features
 - Entity Manager
 - Entity Manager Factory
 - Persistence Context



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JPA Configuration

- **Persistence Unit**

- Describes a group of persistent classes (entities)
- Defines provider(s)
- Defines transactional types (local vs JTA)
- Multiple Units per application are allowed
- Defined by the file: `persistence.xml`



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JPA General Concepts

- **EntityManager**

- Manages a unit of work and persistent objects therein: the `PersistenceContext`
- Lifecycle often bound to a Transaction (usually container-managed)

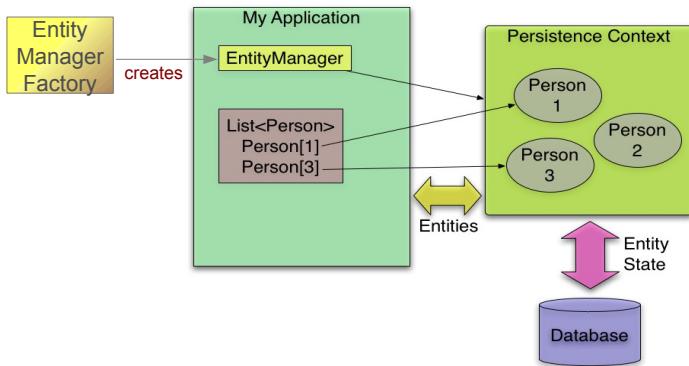
- **EntityManagerFactory**

- thread-safe, shareable object that represents a single data source / persistence unit
- Provides access to new application-managed EntityManagers

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Persistence Context and EntityManager



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The EntityManager API

the entity	<code>persist(Object o)</code>	Context: <i>SQL: insert into table ...</i>
	<code>remove(Object o)</code>	Removes the entity from the Persistence Context: <i>SQL: delete from table ...</i>
	<code>find(Class entity, Object primaryKey)</code>	Find by primary key: <i>SQL: select * from table where id = ?</i>
	<code>Query createQuery(String jpqlString)</code>	Create a JPQL query
	<code>flush()</code>	Force changed entity state to be written to database immediately

Plus other methods ...

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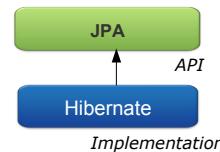
JPA Providers

- Several major implementations of JPA spec
 - Hibernate EntityManager
 - Used inside Jboss
 - EclipseLink (RI)
 - Used inside Glassfish
 - Apache OpenJPA
 - Used by Oracle WebLogic and IBM Websphere
 - Data Nucleus
 - Used by Google App Engine
- **Can all be used without application server as well**
 - Independent part of EJB 3 spec



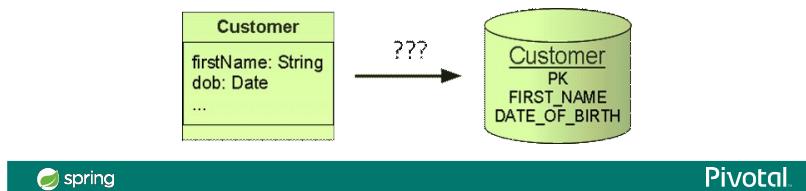
Hibernate JPA

- Hibernate adds JPA support through an additional library
 - The *Hibernate EntityManager*
 - Hibernate sessions used behind JPA *interfaces*
 - Custom annotations for Hibernate specific extensions not covered by JPA
 - less important since JPA version 2



JPA Mapping

- JPA requires metadata for mapping classes/fields to database tables/columns
 - Usually provided as annotations
 - XML mappings also supported ([orm.xml](#))
 - Intended for overrides only – not shown here
- JPA metadata relies on defaults
 - No need to provide metadata for the obvious



What can you Annotate?



- Classes
 - Applies to the entire class (such as table properties)
- Fields
 - Typically mapped to a column
 - By default, *all* treated as persistent
 - Mappings will be defaulted
 - Unless annotated with `@Transient` (non-persistent)
 - Accessed directly via Reflection
- Properties (getters)
 - Also mapped to a column
 - Annotate getters instead of fields



Mapping Using Fields (Data-Members)

```
@Entity  
@Table(name= "T_CUSTOMER")  
public class Customer {  
    @Id  
    @Column(name="cust_id")  
    private Long id;  
  
    @Column(name="first_name")  
    private String firstName;  
  
    @Transient  
    private User currentUser;  
}
```

... Only `@Entity` and `@Id` are mandatory

Mark as an *entity*
Optionally override *table name*

Mark *id-field* (primary key)

Optionally override *column names*

Not stored in database

Data members set *directly*
- using reflection
- "field" access
- no setters needed



Mapping Using Accessors (Properties)

```
public class Customer {  
    Must place @Id on the  
    getter method  
  
    Other annotations now also  
    placed on getter methods  
  
    @Entity @Table(name= "T_CUSTOMER")  
  
    private Long id;  
    private String firstName;  
  
    @Id  
    @Column (name="cust_id")  
    public Long getId()  
    { return this.id; }  
  
    @Column (name="first_name")  
    public String getFirstName()  
    { return this.firstName; }  
  
    public void setFirstName(String fn)  
    { this.firstName = fn; }  
}
```



Relationships

- Common relationship mappings supported
 - Single entities and entity collections both supported
 - Associations can be uni- or bi-directional

```
@Entity  
@Table(name= "T_CUSTOMER")  
public class Customer {  
    @Id  
    @Column (name="cust_id")  
    private Long id;  
  
    @OneToMany  
    @JoinColumn (name="cid")  
    private Set<Address> addresses;  
    ...  
}  
  
@Entity  
@Table(name= "T_ADDRESS")  
public class Address {  
    @Id private Long id;  
    private String street;  
    private String suburb;  
    private String city;  
    private String postcode;  
    private String country;  
}  
  
Foreign key in  
Address table
```



Embeddables

- Map a table row to multiple classes
 - Address fields also columns in T_CUSTOMER
 - @AttributeOverride overrides mapped column name

```
@Entity  
@Table(name= "T_CUSTOMER")  
public class Customer {  
    @Id  
    @Column (name="cust_id")  
    private Long id;  
  
    @Embedded  
    @AttributeOverride  
        (name="postcode", column=@Column(name="ZIP"))  
    private Address office;  
    ...  
}  
  
@Embeddable  
public class Address {  
    private String street;  
    private String suburb;  
    private String city;  
    private String postcode;  
    private String country;  
}  
  
Maps to ZIP  
column in  
T_CUSTOMER
```



JPA Querying

- JPA provides several options for accessing data
 - Retrieve an object by primary key
 - Query for objects using JPA Query Language (JPQL)
 - Similar to SQL and HQL
 - Query for objects using Criteria Queries (appendix)
 - API for creating ad hoc queries
 - Only in JPA 2
 - Execute SQL directly to underlying database (appendix)
 - “Native” queries, allow DBMS-specific SQL to be used
 - Consider JdbcTemplate instead when not using managed objects – more options/control, more efficient



JPA Querying: By Primary Key

- To retrieve an object by its database identifier simply call `find()` on the EntityManager

```
Long customerId = 123L;  
Customer customer = entityManager.find(Customer.class, customerId);
```

returns **null** if no object exists for the identifier

No cast required – JPA uses generics



JPA Querying: JPQL

- SELECT clause required
- can't use *

- Query for objects based on properties or associations ...

```
// Query with named parameters
TypedQuery<Customer> query = entityManager.createQuery(
    "select c from Customer c where c.address.city = :city", Customer.class);
query.setParameter("city", "Chicago");
List<Customer> customers = query.getResultList();

// ... or using a single statement
List<Customer> customers2 = entityManager.
    createQuery("select c from Customer c ...", Customer.class).
    setParameter("city", "Chicago").getResultList();

// ... or if expecting a single result
Customer customer = query.getSingleResult();
```

Specify Class to
Populate / return

Can also use bind ? Variables
– indexed from 1 like JDBC



Topics in this session

- Introduction to JPA
 - General Concepts
 - Mapping
 - Querying
- **Configuring JPA in Spring**
- Implementing JPA DAOs
- Spring Data – JPA
- Lab
- Optional and Advanced Topics



Quick Start – Spring JPA Configuration

Steps to using JPA with Spring

1. Define an EntityManagerFactory bean.
2. Define a DataSource bean
3. Define a Transaction Manager bean
4. Define Mapping Metadata (already covered)
5. Define DAOs



Note: There are many configuration options for EntityManagerFactory, persistence.xml, and DataSource. See the optional section for details.



Define the EntityManagerFactory

```
@Bean  
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {  
  
    HibernateJpaVendorAdapter adapter = new HibernateJpaVendorAdapter();  
    adapter.setShowSql(true);  
    adapter.setGenerateDdl(true);  
    adapter.setDatabase(Database.HSQL);  
  
    Properties props = new Properties();  
    props.setProperty("hibernate.format_sql", "true");  
  
    LocalContainerEntityManagerFactoryBean emfb =  
        new LocalContainerEntityManagerFactoryBean();  
    emfb.setDataSource(dataSource);  
    emfb.setPackagesToScan("rewards.internal");  
    emfb.setJpaProperties(props);  
    emfb.setJpaVendorAdapter(adapter);  
  
    return emfb;  
}
```

*NOTE: no persistence.xml
needed when using
packagesToScan property*



Configuration – XML Equivalent

```
<bean id="entityManagerFactory"
    class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean">
    <property name="dataSource" ref="dataSource"/>
    <property name="packagesToScan" value="rewards.internal"/>

    <property name="jpaVendorAdapter">
        <bean class="org.sfwk.orm.jpa.vendor.HibernateJpaVendorAdapter">
            <property name="showSql" value="true"/>
            <property name="generateDdl" value="true"/>
            <property name="database" value="HSQL"/>
        </bean>
    </property>

    <property name="jpaProperties">
        <props> <prop key="hibernate.format_sql">true</prop> </props>
    </property>
</bean>
```



Define DataSource & Transaction Manager

```
@Bean
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
    LocalContainerEntityManagerFactoryBean emfb =
        new LocalContainerEntityManagerFactoryBean();
    emfb.setDataSource(dataSource());
    ...
    return emfb; // Method returns a FactoryBean...
}

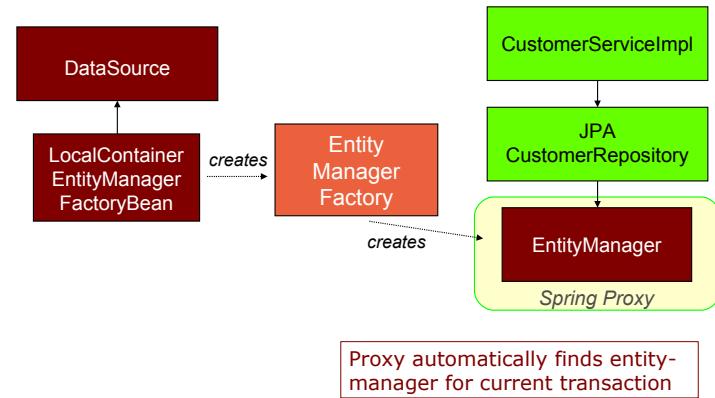
@Bean
public PlatformTransactionManager
    transactionManager(EntityManagerFactory emf) {
    return new JpaTransactionManager(emf);
}

@Bean
public DataSource dataSource() { // Lookup via JNDI or create locally. }
```

...Spring calls `getObject()` on the FactoryBean to obtain the EntityManagerFactory:



EntityManagerFactoryBean Configuration



spring

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Topics in this session

- Introduction to JPA
 - General Concepts
 - Mapping
 - Querying
- Configuring JPA in Spring
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spring

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Implementing JPA DAOs

- JPA provides configuration options so Spring can manage transactions via the EntityManager
- There are no Spring dependencies in your DAO implementations



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Spring-Managed Transactions & EntityManager (1)

- To transparently participate in Spring-driven transactions
 - Define a transaction manager
 - Either `JpaTransactionManager`
 - Or `JtaTransactionManager`
 - Use FactoryBean for building the `EntityManagerFactory`
 - Inject `EntityManager` “proxy” with `@PersistenceContext`
 - JPA’s equivalent to `@Autowired`
 - At runtime the proxy resolves to current `EntityManager` for current transaction in current thread



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Spring-Managed Transactions & EntityManager (2)

- The code – no Spring dependencies

```
public class JpaCustomerRepository implements CustomerRepository {  
    private EntityManager entityManager;  
  
    @PersistenceContext  
    public void setEntityManager (EntityManager entityManager) {  
        this.entityManager = entityManager;  
    }  
  
    public Customer findByld(long orderId) {  
        return entityManager.find(Customer.class, orderId);  
    }  
}
```

Automatic injection of EM Proxy

Proxy resolves to EM when used



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Spring-managed Transactions and EntityManager (3)

- The Configuration

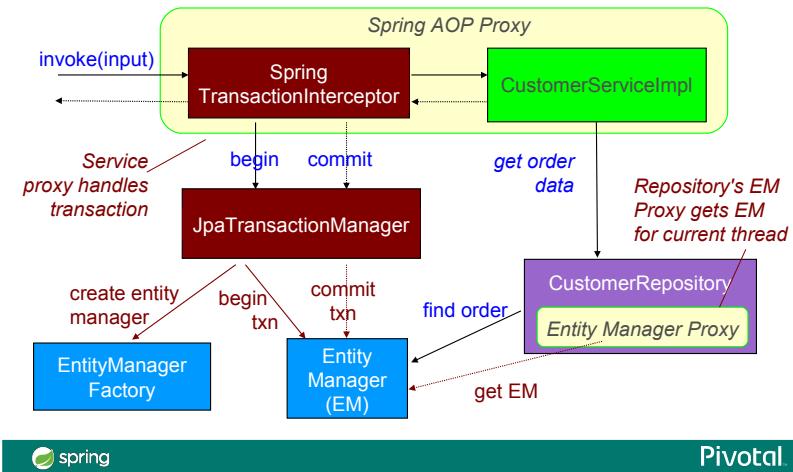
```
@Bean  
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {  
    ...  
}  
  
@Bean  
public CustomerRepository jpaCustomerRepository() {  
    return new JpaCustomerRepository();  
}  
  
@Bean  
public PlatformTransactionManager  
transactionManager(EntityManagerFactory emf) throws Exception {  
    return new JpaTransactionManager(emf);  
}
```

Automatic injection of entity-manager proxy

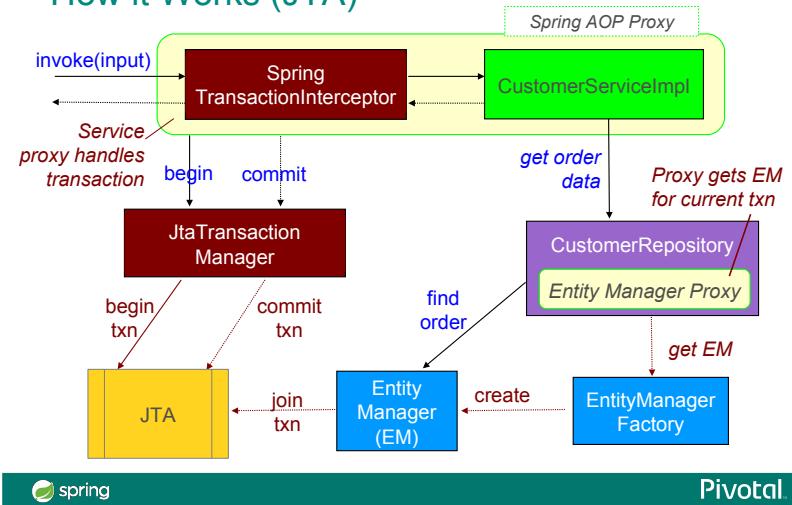


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How it Works (JPA)



How it Works (JTA)



Topics in this session

- Introduction to JPA
 - General Concepts
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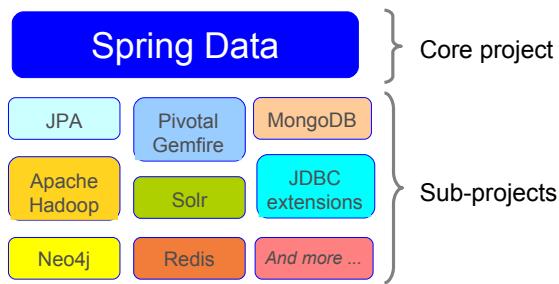
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What is Spring Data?



SPRING DATA

- Reduces boiler plate code for data access
 - Works in many environments



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Instant Repositories

- How?
 - **Step 1:** Annotate domain class
 - define keys & enable persistence
 - **Step 2:** Define your repository as an *interface*
- Spring will implement it at run-time
 - Scans for interfaces extending Spring's `Repository<T, K>`
 - CRUD methods auto-generated
 - Paging, custom queries and sorting supported
 - Variations exist for most Spring Data sub-projects



Step 1: Annotate Domain Class

Here we are using JPA

- Annotate JPA Domain object as normal
 - Nothing to see here!

```
@Entity  
@Table(...)  
public class Customer {  
  
    @Id  
    @GeneratedValue(strategy = GenerationType.AUTO)  
    private Long id;  
    private Date oderDate;  
    private String email;  
  
    // Other data-members and getters and setters omitted  
}
```

Domain Class

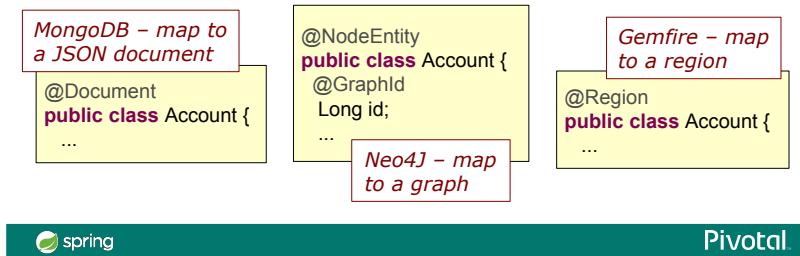
Note: Key is a Long





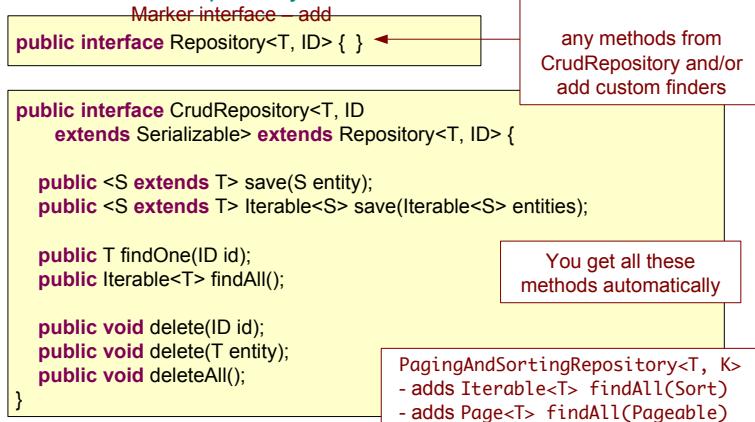
Domain Objects: Other Data Stores

- Spring Data provides similar annotations to JPA
 - `@Document, @Region, @NodeEntity ...`
- Templates (like `JdbcTemplate`) for basic CRUD access
 - `MongoTemplate, GemfireTemplate, RedisTemplate ...`



Step 2: Define a Repository Interface

Must extend `Repository<T, ID>`





Generating Repositories

- Spring scans for Repository interfaces
 - Implements them and creates as a Spring bean
- Java Configuration

```
@Configuration  
@EnableJpaRepositories(basePackages="com.acme.**.repository")  
@EnableMongoRepositories(...)  
public class MyConfig { ... }
```

- XML

```
<jpa:repositories base-package="com.acme.**.repository" />  
<mongo:repositories base-package="com.acme.**.repository" />  
<gfe:repositories base-package="com.acme.**.repository" />
```



Defining a JPA Repository

- Auto-generated finders obey naming convention
 - find(First)By<*DataMember*><*Op*>
 - <*Op*> can be GreaterThan, NotEquals, Between, Like ...

```
public interface CustomerRepository  
    extends CrudRepository<Customer, Long> {  
  
    public Customer findFirstByEmail(String someEmail); // No <Op> for Equals  
    public List<Customer> findByOrderDateLessThan(Date someDate);  
    public List<Customer> findByOrderDateBetween(Date d1, Date d2);  
  
    @Query("SELECT c FROM Customer c WHERE c.email NOT LIKE '%@%'")  
    public List<Customer> findInvalidEmails();  
}
```

Custom query uses query-language of underlying product (here JPQL)



Convention over Configuration

Extend **Repository**
and build your own
interface using
conventions.

- Note: Repository is an *interface* (*not a class!*)

```
import org.springframework.data.repository.Repository;  
import org.springframework.data.jpa.repository.Query;  
  
public interface CustomerRepository extends Repository<Customer, Long> {  
  
    <S extends Customer> save(S entity); // Definition as per CrudRepository  
    Customer findOne(long i); // Definition as per CrudRepository  
  
    Customer findFirstByEmailIgnoreCase(String email); // Case insensitive search  
  
    @Query("select u from Customer u where u.emailAddress = ?1")  
    Customer findByEmail(String email); // ?1 replaced by method param  
}
```



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Internal Behavior – Another Spring Proxy

- Before startup

Interface
CustomerRepository

- After startup

Interface
CustomerRepository

implements

\$Proxy1

```
@Configuration  
@EnableJpaRepositories(basePackages="com.acme.repository")  
public class CustomerConfig { ... }
```

```
<jpa:repositories base-package="com.acme.repository"/>
```



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Accessing the Repository

- Use Spring to inject *CustomerRepository* dependency

```
@Configuration  
@EnableJpaRepositories(basePackages="com.acme.repository")  
public class CustomerConfig {  
  
    @Autowired  
    public CustomerRepository customerRepository;  
  
    @Bean  
    public CustomerService customerService() {  
        return new CustomerService( customerRepository );  
    }  
}
```



Summary

- Use 100% JPA to define entities and access data
 - Repositories have no Spring dependency
 - Spring Data Repositories need no code!
- Use Spring to configure JPA entity-manager factory
 - Smart proxy works with Spring-driven transactions
 - Optional translation to DataAccessExceptions (see advanced section)



Lab

Reimplementing Repositories using Spring and JPA

Coming Up: Optional topics on JPA queries, connection factories, DataAccessExceptions, custom Spring Data repositories



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JPA Querying: Typed Queries

- Criteria Query API (JPA 2)
 - Build type safe queries: fewer run-time errors
 - Much more verbose

```
public List<Customer> findByLastName(String lastName) {  
    CriteriaBuilder builder = entityManager.getCriteriaBuilder();  
    CriteriaQuery<Customer> cq = builder.createQuery(Customer.class);  
    Predicate condition =  
        builder.equal( cq.from(Customer.class).get(Customer_.name), lastName);  
    cq.where(condition);  
  
    return entityManager.createQuery(cq).getResultList();  
}
```

Meta-data class created by JPA (note underscore)



JPA Querying: SQL

- Use a *native* query to execute raw SQL

```
// Query for multiple rows  
Query query = entityManager.createNativeQuery(  
    "SELECT cust_num FROM T_CUSTOMER c WHERE cust_name LIKE ?");  
query.setParameter(1, "%ACME%");  
List<String> customerNumbers = query.getResultList();  
  
// ... or if expecting a single result  
String customerNumber = (String) query.getSingleResult();  
  
// Query for multiple columns  
Query query = entityManager.createNativeQuery(  
    "SELECT ... FROM T_CUSTOMER c WHERE ...", Customer.class);  
List<Customer> customers = query.getResultList();
```

No named parameter support

Indexed from 1 - like JDBC

Specify Class to Populate / return



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Setting up an EntityManagerFactory

- Three ways to set up an EntityManagerFactory:
 - LocalEntityManagerFactoryBean
 - LocalContainerEntityManagerFactoryBean
 - Use a JNDI lookup
- **persistence.xml** required for configuration
 - From version 3.1, Spring allows no *persistence.xml* with LocalContainerEntityManagerFactoryBean



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persistence.xml

<?xml?>

- Always stored in META-INF
- Specifies “persistence unit”:
 - optional vendor-dependent information
 - DB Connection properties often specified here.

```
<persistence version="1.0"
    xmlns="http://java.sun.com/xml/ns/persistence"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://java.sun.com/xml/ns/persistence
        http://java.sun.com/xml/ns/persistence/persistence_1_0.xsd">
    <persistence-unit name="rewardNetwork"/>
    ...
</persistence>
```

- File is required in JPA, but optional when using Spring with JPA!



LocalEntityManagerFactoryBean

- Useful for standalone apps, integration tests
- Cannot specify a DataSource
 - Useful when only data access is via JPA
 - Uses standard JPA service location (SPI) mechanism

/META-INF/services/javax.persistence.spi.PersistenceProvider

```
@Bean
public LocalEntityManagerFactoryBean entityManager() {
    LocalEntityManagerFactoryBean em =
        new LocalEntityManagerFactoryBean();
    em.setPersistenceUnitName("rewardNetwork");
    return em;
}
```



LocalContainer EntityManagerFactoryBean

- Provides full JPA capabilities
- Integrates with existing DataSources
- Useful when fine-grained customization needed
 - Can specify vendor-specific configuration

We saw this earlier using
100% Spring configuration
In both XML and Java



Configuration – Spring Persistence Unit

```
@Bean
public LocalContainerEntityManagerFactoryBean entityManagerFactory() {
    LocalContainerEntityManagerFactoryBean emfb =
        new LocalContainerEntityManagerFactoryBean();
    emfb.setDataSource(dataSource);
    emfb.setPersistenceUnitName("rewardNetwork");
    return emfb;
}
```

Do JPA config in *persistence.xml*

```
<persistence-unit name="rewardNetwork">
    <provider>org.hibernate.ejb.HibernatePersistence</provider>
    <properties>
        <property name="hibernate.dialect"
                 value="org.hibernate.dialect.HSQLDialect"/>
        <property name="hibernate.hbm2ddl.auto" value="create"/>
        <property name="hibernate.show_sql" value="true" />
        <property name="hibernate.format_sql" value="true" />
    </properties>
</persistence-unit>
```

If using JTA – declare *<jta-data-source>* in the persistence-unit

Minimal Spring config



JNDI Lookups

- A jee:jndi-lookup can be used to retrieve *EntityManagerFactory* from application server
- Useful when deploying to JEE Application Servers (WebSphere, WebLogic, etc.)

```
@Bean  
public EntityManagerFactory entityManagerFactory() throws Exception {  
    Context ctx = new InitialContext();  
    return (DataSource) ctx.lookup("persistence/rewardNetwork");  
}
```

OR

```
<jee:jndi-lookup id="entityManagerFactory"  
    jndi-name="persistence/rewardNetwork"/>
```



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Transparent Exception Translation (1)

- Used as-is, the DAO implementations described earlier will throw unchecked JPA PersistenceExceptions
 - Not desirable to let these propagate up to the service layer or other users of the DAOs
 - Introduces dependency on the specific persistence solution that should not exist
- AOP allows translation to Spring's rich, vendor-neutral DataAccessException hierarchy
 - Hides access technology used



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Transparent Exception Translation (2)

- Spring provides this capability out of the box
 - Annotate with `@Repository`
 - Define a Spring-provided BeanPostProcessor

```
@Repository  
public class JpaCustomerRepository implements CustomerRepository {  
    ...  
}
```

```
<bean class="org.springframework.dao.annotation.  
PersistenceExceptionTranslationPostProcessor"/>
```



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Transparent Exception Translation (3)

- Or use XML configuration:

```
public class JpaCustomerRepository implements CustomerRepository {  
    ...  
}
```

No annotations

```
<bean id="persistenceExceptionInterceptor"  
      class="org.springframework.dao.support.  
          PersistenceExceptionTranslationInterceptor"/>  
  
<aop:config>  
    <aop:advisor pointcut="execution(* *..CustomerRepository+.*(..))"  
        advice-ref="persistenceExceptionInterceptor" />  
</aop:config>
```



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JPA Specific Interface

- Adds EntityManager specific options

```
public interface JpaRepository<T, ID extends Serializable>
    extends PagingAndSortingRepository<T, ID> {

    <S extends T> S saveAndFlush(S entity);
    void flush();

    // Implemented as a single DELETE
    void deleteInBatch(Iterable<T> entities);
    void deleteAllInBatch();

    // Returns a lazy-loading proxy, using JPA's EntityManager.getReference()
    // – equivalent to Hibernate's Session.load()
    T getOne(ID id);
}
```



Adding Custom Behavior (1)

- Not all use cases satisfied by automated methods
 - Enrich with custom repositories: *mix-ins*
- **Step 1:** Create normal interface and implementation

```
public class CustomerRepositoryImpl implements CustomerRepositoryCustom {
    Customer findDeadbeatCustomers() {
        // Your custom implementation to find unreliable
        // and bad-debt customers
    }
}

public interface CustomerRepositoryCustom {
    Customer findDeadbeatCustomers();
}
```



Adding Custom Behavior (2)

- **Step 2:** Combine with an automatic repository:

```
public interface CustomerRepository  
    extends CrudRepository<Account, Long>, CustomerRepositoryCustom {  
}
```

- Spring Data looks for implementation beans
 - ID = repository interface + “Impl” (configurable)
 - In this example: “CustomerRepositoryImpl”
- Result: *CustomerRepository* bean contains automatic and custom methods!



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Topics Covered

- Introduction to JPA
- Configuring JPA in Spring
- Implementing JPA DAOs
- Spring Data – JPA
- Advanced
 - JPA Typed Queries / Native Queries
 - EntityManagerFactoryBean alternatives and persistence.xml
 - Exception Translation
 - Customized Spring Data Repositories



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Overview of Spring Web

Developing Modern Web Applications

Servlet Configuration, Product Overview

Topics in this Session

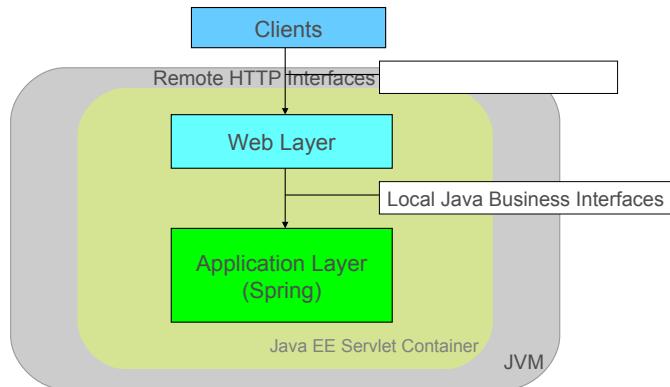
- **Introduction**
- Using Spring in Web Applications
- Overview of Spring Web
- Spring and other Web frameworks

Web Layer Integration

- Spring provides support in the Web layer
 - Spring MVC, Spring WebFlow...
- However, you are free to use Spring with any Java web framework
 - Integration might be provided by Spring or by the other framework itself
 - Spring also integrates with many of the common REST frameworks



Effective Web Application Architecture



Topics in this Session

- Introduction
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Spring Application Context Lifecycle in Web Applications

- Spring can be initialized within a webapp
 - start up business services, repositories, etc.
- Uses a standard servlet listener
 - initialization occurs before any servlets execute
 - application ready for user requests
 - `ApplicationContext.close()` is called when the application is stopped



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Configuration via WebApplicationInitializer

```
public class MyWebAppInitializer  
    extends AbstractContextLoaderInitializer {  
  
    @Override  
    protected WebApplicationContext createRootApplicationContext() {  
  
        // Create the 'root' Spring application context  
        AnnotationConfigWebApplicationContext rootContext =  
            new AnnotationConfigWebApplicationContext();  
  
        rootContext.getEnvironment().setActiveProfiles("jpa"); // optional  
        rootContext.register(RootConfig.class);  
        return rootContext;  
    }  
    ...  
}
```

Implements *WebApplicationInitializer*
Automatically detected by servlet container.

Multiple classes may be listed

Available in Servlet 3.0+ Environments, no more web.xml!



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Configuration via web.xml

- Only option prior to servlet 3.0
 - Just add a Spring-provided servlet listener

```
<context-param>  
    <param-name>contextConfigLocation</param-name>  
    <param-value>  
        /WEB-INF/merchant-reporting-webapp-config.xml  
    </param-value>  
</context-param>
```

web.xml

The application context's configuration file(s)

```
<listener>  
    <listener-class>  
        org.springframework.web.context.ContextLoaderListener  
    </listener-class>  
</listener>
```

Loads the ApplicationContext into the ServletContext before any Servlets are initialized



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web.xml Configuration Options

- Default resource location is document-root
 - Can use **classpath:** designator
 - Defaults to WEB-INF/applicationContext.xml

```
<context-param>
    <param-name>contextConfigLocation</param-name>
    <param-value>
        classpath:/rewards/internal/application-config.xml
        /WEB-INF/merchant-reporting-webapp-config.xml
    </param-value>
</context-param>
<context-param>
    <param-name>spring.profiles.active</param-name>
    <param-value>jpa</param-value>
</context-param>
```

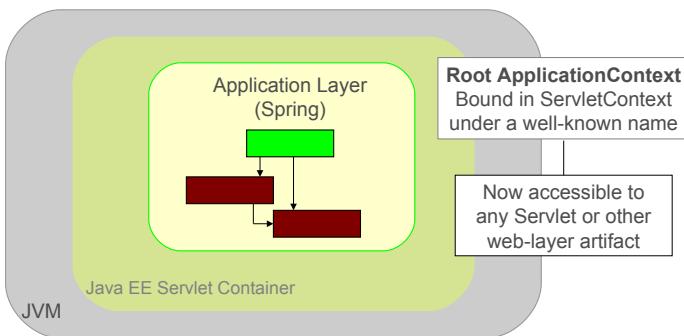
web.xml

Optionally specify profile(s) to use



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Servlet Container After Starting Up



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Instantiating Servlets

- Override `onStartup()` method to define servlets
 - Warning: Can't access Spring beans, not available yet

```
public class MyWebAppInitializer extends AbstractContextLoaderInitializer {  
  
    protected WebApplicationContext createRootApplicationContext() {  
        // ...Same configuration as previous slide...  
    }  
  
    public void onStartup(ServletContext container) {  
        super.onStartup(container);  
        // Register and map a servlet  
        ServletRegistration.Dynamic svlt =  
            container.addServlet("myServlet", new TopSpendersReportGenerator());  
        svlt.setLoadOnStartup(1);  
        svlt.addMapping("/");  
    }  
}
```

No beans are loaded yet at this point in the lifecycle...



Dependency Injection of Servlets

- Suitable for `web.xml` or `AbstractContextLoaderInitializer`
- Use `WebApplicationContextUtils`
 - gets Spring `ApplicationContext` from `ServletContext`

```
public class TopSpendersReportGenerator extends HttpServlet {  
    private ClientService clientService;  
  
    public void init() {  
        ApplicationContext context = WebApplicationContextUtils.  
            getRequiredWebApplicationContext(getServletContext());  
        clientService = (ClientService) context.getBean("clientService");  
    }  
    ...  
}
```



Spring MVC Supports Dependency Injection

- Example using Spring MVC

```
@Controller  
public class TopSpendersReportController {  
    private ClientService clientService;  
  
    @Autowired  
    public TopSpendersReportController(ClientService service) {  
        this.clientService = service;  
    }  
    ...  
}
```

↑
Dependency is automatically injected by type



No need for *WebApplicationContextUtils* anymore



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Topics in this Session

- Introduction
- Using Spring in Web Applications
- **Overview of Spring Web**
- Spring and other Web frameworks



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Spring Web

- Spring MVC
 - Web framework bundled with Spring
- Spring WebFlow
 - Plugs into Spring MVC
 - Implements navigation flows
- Spring Mobile
 - Routing between mobile / non-mobile versions of site
- Spring Social
 - Easy integration with Facebook, Twitter, etc.



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Spring Web MVC

- Spring's web framework
 - Uses Spring for its own configuration
 - Controllers are Spring beans
 - testable artifacts
- Annotation-based model since Spring 2.5
- Builds on the Java Servlet API
- The core platform for developing web applications with Spring
 - All higher-level modules such as WebFlow build on it



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Spring Web Flow

- Plugs into Spring Web MVC as a Controller technology for implementing stateful "flows"
 - Checks that users follow the right navigation path
 - Manages back button and multiple windows issues
 - Provides scopes beyond request and session
 - such as the *flow* and *flash* scope
 - Addresses the double-submit problem elegantly



Example Flow Definition Online Check-in

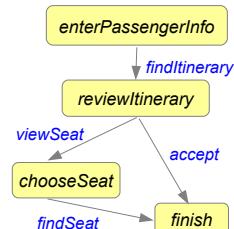
- Flows are declared in Xml

```
<flow ...>
  <view-state id="enterPassengerInfo">
    <transition on="findItinerary" to="reviewItinerary" />
  </view-state>

  <view-state id="reviewItinerary">
    <transition on="viewSeat" to="chooseSeat" />
    <transition on="accept" to="finish" />
  </view-state>

  <view-state id="chooseSeat">
    <transition on="findSeat" to="finish" />
  </view-state>

  <end-state id="finish">
  </flow>
```



More about WebFlow

- Online sample application is available here:
<http://richweb.springsource.org/swf-booking-faces/spring/intro>
- Sample applications can be downloaded here:
<http://projects.spring.io/spring-webflow/>



The screenshot shows a Firefox browser window displaying the "Spring Faces: Hotel Booking Sample Application". The title bar reads "Spring Faces: Hotel Booking Sample Application - Mozilla Firefox". The main content area shows a search result table titled "Hotel Results". The table has columns: Name, Address, City, State, Zip, and Action. The data includes:

Name	Address	City, State	Zip	Action
Westin Diplomat	3555 S. Ocean Drive	Hollywood, FL, USA	33019	View Hotel
Jameson Inn	890 Palm Bay Rd NE	Palm Bay, FL, USA	32905	View Hotel
Chilworth Manor	The Cottage, Southampton Business Park	Southampton, Hants, UK	SO16 7JF	View Hotel
Marriott Courtyard	Tower Place, Buckhead	Atlanta, GA, USA	30305	View Hotel
Doubletree	Tower Place, Buckhead	Atlanta, GA, USA	30305	View Hotel

At the bottom right of the table, there is a link "More Results".

On the left side of the browser window, there is a sidebar with a large image of a modern hotel building and the text "THE SPRING EXPERIENCE".

On the right side of the browser window, there is a vertical scroll bar.

At the bottom of the browser window, there is a toolbar with icons for File, Edit, View, History, Delicious, Bookmarks, Yahoo!, Tools, and Help.

At the bottom of the slide, there are two logos: "spring" on the left and "Pivotal" on the right.

Topics in this Session

- Introduction
- Using Spring in Web Applications
- Overview of Spring Web
- **Spring and other Web frameworks**



The screenshot shows a portion of the "Spring Faces: Hotel Booking Sample Application" interface. It displays a table titled "Hotel Results" with several rows of data. The table columns are: Name, Address, City, State, Zip, and Action. The data includes:

Name	Address	City, State	Zip	Action
Westin Diplomat	3555 S. Ocean Drive	Hollywood, FL, USA	33019	View Hotel
Jameson Inn	890 Palm Bay Rd NE	Palm Bay, FL, USA	32905	View Hotel
Chilworth Manor	The Cottage, Southampton Business Park	Southampton, Hants, UK	SO16 7JF	View Hotel
Marriott Courtyard	Tower Place, Buckhead	Atlanta, GA, USA	30305	View Hotel
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Spring – Struts 2 Integration

Java Configuration

```
@Action("/doLogin")
@ResultPath("/WEB-INF/views")
@Result(name = "success", location = "LoginSuccess.jsp"),
@Result(name = "error", location = "LoginError.jsp")
public class DoLoginAction extends ActionSupport {
    @Autowired
    private UserDAO userDAO;
    private User user;
    ...

    public String execute() {
        if (userDAO.checkLogin(user)) { return SUCCESS; }

        return ERROR;
    }
}
```

Inject Spring Beans in
The normal way



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Spring – Struts 2 Integration

XML Configuration

- Integration plug-in provided by Struts 2 framework

```
<struts>
    <!-- Define Spring as the object factory -->
    <constant name="struts.objectFactory" value="spring" />
    ...
</struts>
```

```
<struts>
    <include file="struts-default.xml"/>

    <package name="secure" namespace="/secure" extends="default">
        <action name="example" class="myBean">
            <result>example.ftl</result>
        </action>
    </package>
</struts>
```

class actually specifies
a Spring bean name



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Spring – JSF Integration

- Two options
 - Spring-centric integration
 - Provided by Spring Faces sub-project of Spring Web Flow
 - JSF-centric integration
 - Spring plugs in as the JSF managed bean provider

```
<managed-bean>
<managed-bean-name>userList</managed-bean-name>
<managed-bean-class>com.springsource.web.ClientController</managed-bean-class>
<managed-bean-scope>request</managed-bean-scope>
<managed-property>
<property-name>userManager</property-name>
<value>#{userManager}</value>
</managed-property>
```

JSF-centric integration



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Integration with Other Frameworks

- Wicket
 - Comes with an integration to Spring
<https://cwiki.apache.org/confluence/display/WICKET/Spring>
- Tapestry 5
 - Provides a dedicated integration module for Spring
<https://tapestry.apache.org/integrating-with-spring-framework.html>



tapestry



APACHE WICKET



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Summary

- Spring can be used with any web framework
 - Spring provides the ContextLoaderListener that can be declared in web.xml
- Spring MVC is a lightweight web framework where controllers are Spring beans
 - More about Spring MVC in the next module
- WebFlow plugs into Spring MVC as a Controller technology for implementing stateful "flows"



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Spring Web MVC Essentials

Getting Started With Spring MVC

Implementing a Simple Controller

What is Spring MVC?

- Web framework based on the Model/View/Controller pattern
 - Alternative to JSF, Struts 1, Struts 2 (WebWork), Tapestry, Wicket ...
- Based on Spring principles
 - POJO programming
 - Testable components
 - Uses Spring for configuration
- Supports a wide range of view technologies
 - JSP, XSLT, PDF, Excel, Velocity, Freemarker, Thymeleaf, etc.

Topics in this Session

- Request Processing Lifecycle
- Key Artifacts
 - DispatcherServlet
 - Controllers
 - Views
- Quick Start



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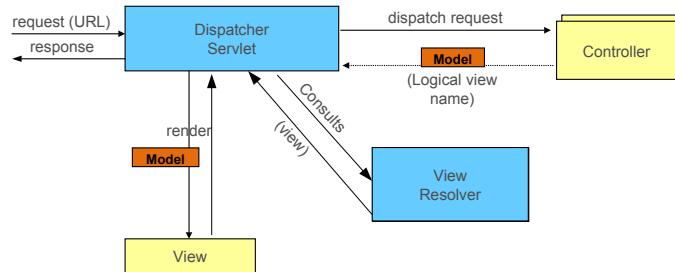
Web Request Handling Overview

- Web request handling is rather simple
 - Based on an incoming URL...
 - ...we need to call a method...
 - ...after which the return value (if any)...
 - ...needs to be rendered using a view



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Request Processing Lifecycle



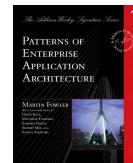
Topics in this Session

- Request Processing Lifecycle
- **Key Artifacts**
 - DispatcherServlet
 - Controllers
 - Views
- Quick Start



DispatcherServlet: The Heart of Spring Web MVC

- A “front controller”
 - coordinates all request handling activities
 - analogous to Struts ActionServlet / JSF FacesServlet
- Delegates to Web infrastructure beans
- Invokes user Web components
- Fully customizable
 - interfaces for all infrastructure beans
 - many extension points



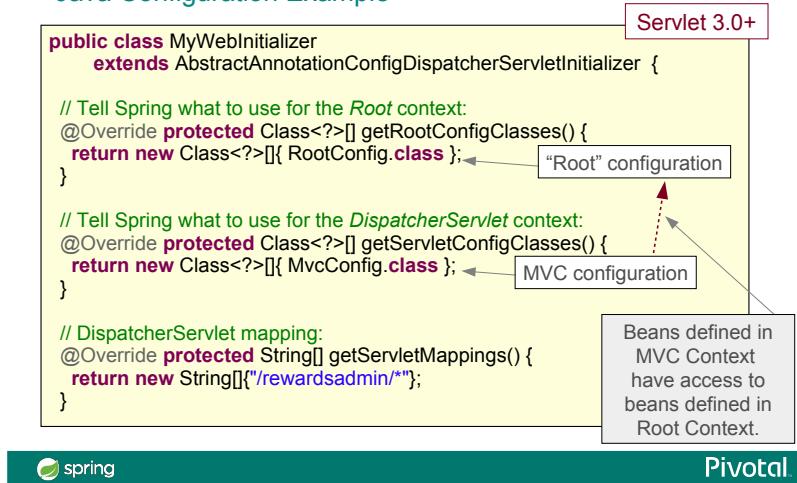
DispatcherServlet Configuration

- Defined by `WebApplicationInitializer` OR `web.xml`
- Uses Spring for its configuration
 - programming to interfaces + dependency injection
 - easy to swap parts in and out
- Creates separate “servlet” application context
 - configuration is private to DispatcherServlet
- Full access to the parent “root” context
 - instantiated via ContextLoaderListener
 - shared across servlets

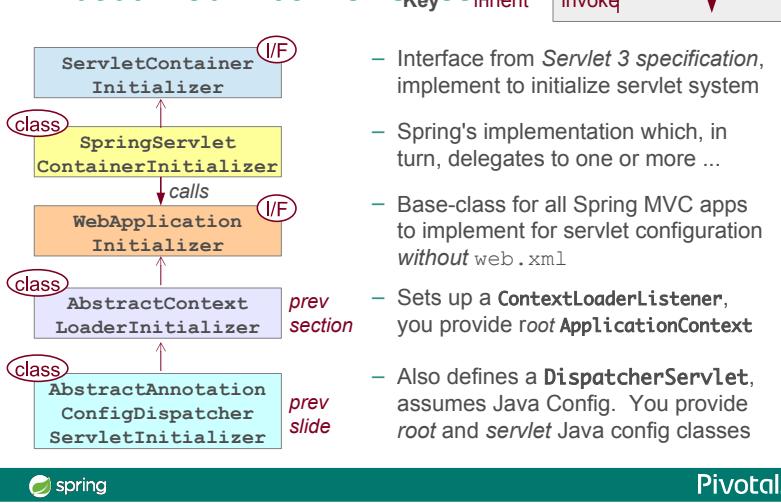


Dispatcher Servlet

Java Configuration Example



About Web Initializer Classes



Dispatcher Servlet XML Configuration Example

```
<servlet>
    <servlet-name>main</servlet-name>
    <servlet-class>
        org.springframework.web.servlet.DispatcherServlet
    </servlet-class>
    <init-param>
        <param-name>contextConfigLocation</param-name>
        <param-value>/WEB-INF/spring/web-config.xml</param-value>
    </init-param>
</servlet>

<servlet-mapping>
    <servlet-name>main</servlet-name>
    <url-pattern>/rewardsadmin/*</url-pattern>
</servlet-mapping>
```

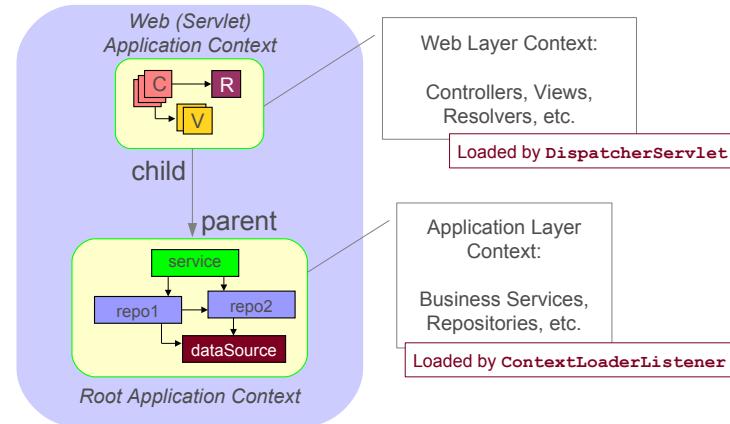
Pre-Servlet 3.0

web.xml

Beans defined in web context have access to beans defined in RootApplicationContext



Servlet Container After Starting Up



Topics in this Session

- Request Processing Lifecycle
- Key Artifacts
 - DispatcherServlet
 - **Controllers**
 - Views
- Quick Start



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Controller Implementation

- Annotate controllers with `@Controller`
 - `@RequestMapping` tells Spring what method to execute when processing a particular request



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URL-Based Mapping Rules

- Mapping rules typically URL-based, optionally using wild cards:
 - /accounts
 - /accounts/edit
 - /editAccount
 - /listAccounts.htm
 - /accounts/*
- Suffixes *ignored* by default



Controller Method Parameters

- Extremely flexible!
- You pick the parameters you need, Spring provides them
 - HttpServletRequest, HttpSession, Principal ...
 - Model for sending data to the view.
 - See [Spring Reference, Handler Methods](#)

```
@Controller  
public class AccountController {  
  
    @RequestMapping("/listAccounts")  
    public String list(Model model) {  
        ...  
    }  
}
```

View name

Model holds data for view



Extracting Request Parameters

- Use `@RequestParam` annotation
 - Extracts parameter from the request
 - Performs type conversion

```
@Controller  
public class AccountController {  
  
    @RequestMapping("/showAccount")  
    public String show(@RequestParam("entityId") long id,  
                      Model model) {  
        ...  
    }  
}
```

Example of calling URL:

`http://localhost:8080/mvc-1/rewardsadmin/showAccount.htm?entityId=123`



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URI Templates

- Values can be extracted from request URLs
 - *Based on URI Templates*
 - not Spring-specific concept, used in many frameworks
 - Use `{...}` placeholders and `@PathVariable`
- Allows clean URLs without request parameters

```
@Controller  
public class AccountController {  
  
    @RequestMapping("/accounts/{accountId}")  
    public String show(@PathVariable("accountId") long id,  
                      Model model) {  
        ...  
    }  
}
```

Example of calling URL:
`http://localhost:8080/mvc-1/rewardsadmin/accounts/123`



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Method Signature Examples

Example URLs

```
@RequestMapping("/accounts")
```

<http://.../accounts>

```
public String show(HttpServletRequest request, Model model)
```

```
@RequestMapping("/orders/{id}/items/{itemId}")
```

<http://.../orders/1234/items/2>

```
public String show(@PathVariable("id") Long id,
```

```
    @PathVariable int itemId,
```

```
    Model model, Locale locale,
```

```
    @RequestHeader("user-agent") String agent )
```

```
@RequestMapping("/orders")
```

<http://.../orders?id=1234&itemId=2>

```
public String show(@RequestParam Long id,
```

```
    @RequestParam("itemId") int itemId,
```

```
    Principal user, Map<String, Object> model,
```

```
    HttpSession session )
```

View name



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Topics in this Session

- Request Processing Lifecycle
- Key Artifacts
 - DispatcherServlet
 - Controllers
 - Views
- Quick Start



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Views

- A **View** renders web output.
 - Many built-in views available for JSPs, XSLT, templating approaches (Velocity, FreeMarker), etc.
 - View support classes for creating PDFs, Excel spreadsheets, etc.
- Controllers typically return a 'logical view name' String.
- **ViewResolvers** select View based on view name.



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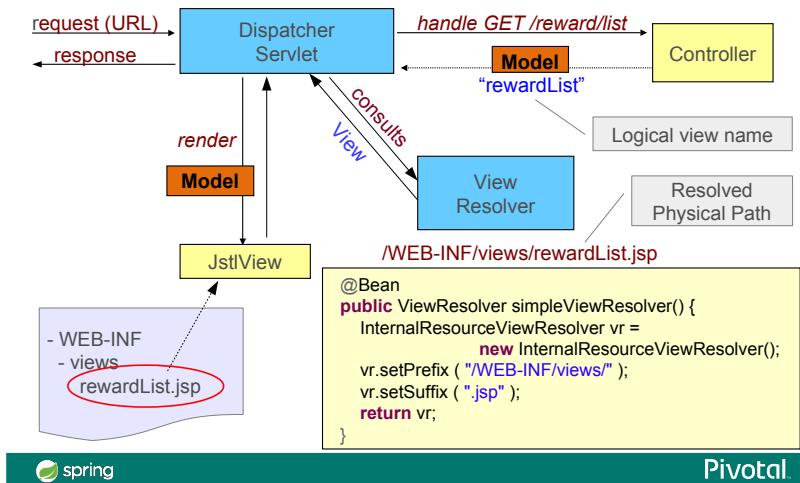
View Resolvers

- The DispatcherServlet delegates to a **ViewResolver** to obtain **View** implementation based on view name.
- The default ViewResolver treats the view name as a Web Application-relative file path
 - i.e. a JSP: `/WEB-INF/reward/list.jsp`
- Override this default by registering a ViewResolver bean with the DispatcherServlet
 - We will use **InternalResourceViewResolver**
 - Several other options available.



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Internal Resource View Resolver Example



Topics in this Session

- Request Processing Lifecycle
- Key Artifacts
 - DispatcherServlet
 - Controllers
 - Views
- Quick Start

Quick Start

Steps to developing a Spring MVC application

1. Deploy a Dispatcher Servlet (one-time only)
2. Implement a controller
3. Register the Controller with the DispatcherServlet
4. Implement the View(s)
5. Register a ViewResolver (optional, one-time only)
6. Deploy and test

Repeat steps 2-6 to develop new functionality



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1a. Deploy DispatcherServlet

```
public class WebInitializer  
    extends AbstractAnnotationConfigDispatcherServletInitializer {  
  
    // Root context:  
    @Override protected Class<?>[] getRootConfigClasses() {  
        return new Class<?>[]{ RootConfig.class };  
    }  
    // DispatcherServlet context:  
    @Override protected Class<?>[] getServletConfigClasses() {  
        return new Class<?>[]{ MvcConfig.class };  
    }  
    // DispatcherServlet mapping:  
    @Override protected String[] getServletMappings() {  
        return new String[]{ "/rewardsadmin/**" };  
    }  
}
```

Services, Repositories ...

Contains Spring MVC configuration



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1b. Deploy DispatcherServlet

- Can handle URLs like ...

```
http://localhost:8080/mvc-1/rewardsadmin/reward/list  
http://localhost:8080/mvc-1/rewardsadmin/reward/new  
http://localhost:8080/mvc-1/rewardsadmin/reward/show?id=1
```

- We will implement *show*



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Initial Spring MVC Configuration

```
@Configuration  
@EnableWebMvc  
public class MvcConfig {  
  
    // No beans required for basic Spring MVC usage.  
  
}
```

Sets up Spring MVC with convenient defaults
– see Advanced section for full details

Spring MVC *automatically* defines several beans.

Only need to provide additional beans and/or
overrides to default beans (if desired)

- For example: view resolvers



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2. Implement the Controller

```
@Controller  
public class RewardController {  
    private RewardLookupService lookupService;  
  
    @Autowired  
    public RewardController(RewardLookupService svc) {  
        this.lookupService = svc;  
    }  
  
    @RequestMapping("/reward/show")  
    public String show(@RequestParam("id") long id,  
                      Model model) {  
        Reward reward = lookupService.lookupReward(id);  
        model.addAttribute("reward", reward);  
        return "rewardView";  
    }  
}
```

Depends on application service

Automatically filled in by Spring

Selects the "rewardView" to render the reward



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3. Register the Controller

```
@Configuration  
@EnableWebMvc  
@ComponentScan("accounts.web")  
public class MvcConfig() {  
}
```

- Component-scanning very effective for MVC controllers!
- Be specific when indicating base package, avoid loading non-web layer beans
- Feel free to use <bean /> or @Configuration approaches as desired



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4. Implement the View

```
<html>
  <head><title>Your Reward</title></head>
  <body>
    Amount=${reward.amount} <br/>
    Date=${reward.date} <br/>
    Account Number=${reward.account} <br/>
    Merchant Number=${reward.merchant}
  </body>
</html>
```

References result model object by name

/WEB-INF/views/rewardView.jsp

Note: no references to Spring object / tags required in JSP.



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5. Register ViewResolver

```
@Configuration
@EnableWebMvc
@ComponentScan("accounts.web")
public class MvcConfig {

  @Bean
  public ViewResolver simpleViewResolver() {
    InternalResourceViewResolver vr =
      new InternalResourceViewResolver();
    vr.setPrefix ( "/WEB-INF/views/" );
    vr.setSuffix ( ".jsp" );
    return vr;
  }
}
```

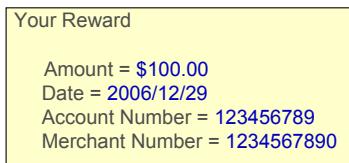
• Controller returns rewardList
• ViewResolver converts to /WEB-INF/views/rewardList.jsp



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6. Deploy and Test

`http://localhost:8080/rewardsadmin/reward/show?id=1`



Summary

- Spring MVC is Spring's web framework
 - @Controller classes handle HTTP requests
 - URL information available
 - @RequestParam, @PathVariable
 - Data returned via the Model
 - Output (HTML) generated by Views
- Multiple View technologies supported
 - ViewResolvers define where Views can be found

Learn More:
[Spring-Web – 4 day course on Spring Web Modules](#)



Lab

Adding a Web Interface

Coming Up: `@EnableWebMvc`



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MVC Additions in Spring 3.x and 4.x

- `@MVC` and legacy Controllers enabled by default
 - Appropriate Controller Mapping and Adapters registered out-of-the-box
- Newer features *not* enabled by default
 - Stateless converter framework for binding & formatting
 - Support for JSR-303 declarative validation for forms
 - `HttpMessageConverters` (for RESTful web services)
- *How do you use these features?*



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@EnableWebMvc

- Registers Controller Mapping/Adapter for @MVC only
 - You lose legacy default mappings and adapters!
 - Enables custom conversion service and validators
 - Beyond scope of this course

```
@Configuration  
@EnableWebMvc  
public class RewardConfig {  
  
    @Bean  
    public rewardController(RewardLookupService service) {  
        return new RewardController(service);  
    }  
    ...  
}
```



WebMvcConfigurerAdapter

- Optionally extend WebMvcConfigurerAdapter
 - Override methods to define/customize web-beans

```
@Configuration  
@EnableWebMvc  
public class RewardConfig extends WebMvcConfigurerAdapter {  
  
    @Bean public rewardController(RewardLookupService service) { ... }  
  
    @Override  
    public void addFormatters(FormatterRegistry registry) {  
        // Register your own type converters and formatters...  
    }  
    ...  
}
```

Example: add
custom formatters



MVC Namespace

- XML Equivalent to @EnableWebMvc

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

    <!-- Provides default conversion service, validator and message converters -->
    <mvc:annotation-driven/>
```

Learn More:
[Spring-Web – 4 day course on Spring Web Modules](#)



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Older Versions of Spring MVC

- Spring MVC is highly backwards compatible
 - Most default settings have remained unchanged since Spring 2.5 (versions 3.0, 3.1, 3.2, 4.0, 4.1, 4.2, 4.3 ... !)
- However, old default settings are no longer recommended
 - Newer styles of controllers, adapters, message convertors, validators ...
- To enable the more modern set of defaults
 - **Use Spring Boot**
 - *Or use @EnableWebMvc or <mvc:annotation-config/> explicitly*



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Spring Boot - Basics

Getting started with Spring Boot

Starter POMs, Auto-Configuration



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What is Spring Boot?

- Spring Applications typically require a lot of setup
 - Consider working with JPA. You need:
 - Datasource, TransactionManager, EntityManagerFactory ...
 - Consider a web MVC app. You need:
 - WebApplicationInitializer / web.xml, ContextLoaderListener, DispatcherServlet, ...
 - An MVC app using JPA would need all of this
- *BUT: Much of this is predictable*
 - Spring Boot can do most of this setup for you



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What is Spring Boot?

- An opinionated runtime for Spring Projects
- Supports different project types, like Web and Batch
- Handles most low-level, predictable setup for you
- It is not:
 - A code generator
 - An IDE plugin



See: [Spring Boot Reference](#)

<http://docs.spring.io/spring-boot/docs/current/reference/htmlsingle>



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Topics in this Session

- **What is Spring Boot?**
 - Definition and Hello World example
- Spring Boot Explained
 - Dependency Management
 - Auto Configuration
 - Packaging
- Web Applications with Spring Boot
- Ease of Use Features



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Opinionated Runtime?

- Spring Boot uses sensible defaults, “*opinions*”, mostly based on the classpath contents.
- For example
 - Sets up a JPA Entity Manager Factory if a JPA implementation is on the classpath.
 - Creates a default Spring MVC setup, if Spring MVC is on the classpath.
- Everything can be overridden easily
 - But most of the time not needed



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Hello World example

- Just a few files to get a running Spring Web application

pom.xml

Setup Spring Boot dependencies

HelloController class

Basic Spring MVC controller

application.properties



hello.jsp

View setup

Application class

Application launcher



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Hello World (1) – Maven descriptor

```
<parent>
  <groupId>org.springframework.boot</groupId> ← parent
  <artifactId>spring-boot-starter-parent</artifactId>
  <version>1.4.0.RELEASE</version>
</parent>
<dependencies>
  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-web</artifactId>
  </dependency>
</dependencies>
<build>
  <plugins>
    <plugin>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-maven-plugin</artifactId>
    </plugin>
  </plugins>
</build>
```

pom.xml

Spring MVC
Embedded Tomcat
Jackson...



Maven is just one option. You can also use Gradle or Ant/Ivy



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Hello World (2) – Spring MVC controller

- A minimal controller to keep this example simple
 - Returns a JSP view-name

```
@Controller
public class HelloController {
  @RequestMapping("/")
  public String hello() {
    return "hello";
  }
}
```

Controller.java

Nothing to do, just return view name



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Hello World (3) – Implement the View

```
<html>
  <head><title>Hello</title></head>
  <body>
    <p>Hello Spring Boot</p>
  </body>
</html>
```

/WEB-INF/views/hello.jsp

application.properties

```
spring.mvc.view.prefix=/WEB-INF/views
spring.mvc.view.suffix=.jsp
```

Configure an *InternalResourceViewResolver*



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Hello World (4) – Application Class

- `@SpringBootApplication` annotation enables Spring Boot
 - Runs Tomcat *embedded*

```
@SpringBootApplication
public class Application {

  public static void main(String[] args) {
    SpringApplication.run(Application.class, args);
  }
}
```

application.java

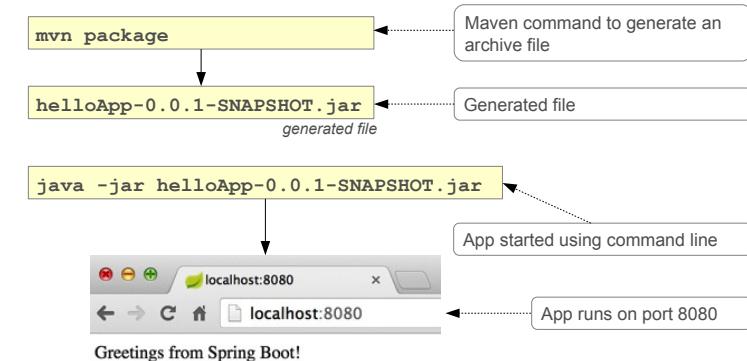


Main method will be used to run the packaged application from the command line – *old style!*



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Putting it all together



Deployment

- Our “Hello World” example bundles Tomcat inside the application
 - Runs as an executable **JAR**
- Spring Boot apps can also be deployed into an existing app server
 - As a familiar **WAR** file
 - PROs and CONs to be discussed later



Topics in this Session

- What is Spring Boot?
 - Definition and Hello World example
- **Spring Boot Explained**
 - Dependency Management
 - Auto Configuration
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- Ease of Use Features



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Spring Boot Needs Dependencies



- Auto-configuration works by analyzing the classpath
 - If you forget a dependency, Spring Boot can't configure it
 - A dependency management tool is recommended
 - Spring Boot parent and starters make it much easier
- Spring Boot works with Maven, Gradle, Ant/Ivy
 - Our content here will show Maven



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Spring Boot Parent POM

- Parent POM defines key versions of dependencies and Maven plugins

```
<parent>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-parent</artifactId>
  <version>1.4.0.RELEASE</version>
</parent>
```

Defines properties for dependencies, for example: \${spring.version} = 4.3



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Core Spring “Starter” Dependencies

- Easy way to bring in multiple coordinated dependencies
 - Including “Transitive” Dependencies

```
<dependencies>
  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter</artifactId>
  </dependency>
</dependencies>
```

Version not needed!
Defined by parent.

Resolves ~ 16 JARs!

spring-boot-*jar	spring-core-*jar
spring-context-*jar	spring-aop-*jar
spring-beans-*jar	aopalliance-*jar
...	



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Spring Web Dependencies

- Everything you need to develop a web application with Spring

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

Resolves
spring-web-*jar
spring-webmvc-*jar
tomcat-*jar
jackson-databind-*jar
...



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Test Dependencies

- Common test libraries

```
<dependencies>
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-test</artifactId>
</dependency>
</dependencies>
```

Resolves
spring-test-*jar
junit-*jar
mockito-*jar
...



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Available Starter POMs

- Not essential but *strongly* recommended
- Coordinated dependencies for common Java enterprise frameworks
 - Pick the starters you need in your project
- To name a few:
 - `spring-boot-starter-jdbc`
 - `spring-boot-starter-jpa`
 - `spring-boot-starter-batch`



See: [Spring Boot Reference, Starter POMs](http://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#using-boot-starter-poms)
<http://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#using-boot-starter-poms>



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Topics in this Session

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Spring Boot @EnableAutoConfiguration

- `@EnableAutoConfiguration` annotation on a Spring Java configuration class
 - Causes Spring Boot to automatically create beans it thinks you need
 - Usually based on classpath contents, can easily override

```
@Configuration  
@EnableAutoConfiguration  
public class AppConfig {  
    public static void main(String[] args) {  
        SpringApplication.run(AppConfig.class, args);  
    }  
}
```

Spring Boot class



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Shortcut @SpringBootApplication

- Very common to use `@EnableAutoConfiguration`, `@Configuration`, and `@ComponentScan`
 - `@ComponentScan`, with no arguments, scans the current package *and* its sub-packages

```
@Configuration  
@ComponentScan  
@EnableAutoConfiguration  
public class AppConfig {  
    ...  
}
```

 `@SpringBootApplication`

```
@SpringBootApplication  
public class AppConfig {  
    ...  
}
```

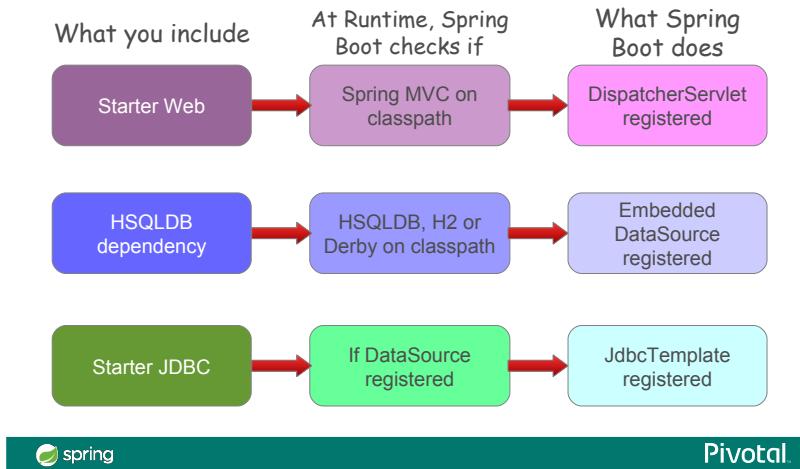


`@SpringBootApplication` was available from Spring Boot 1.2



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Auto-configuration: Examples



Topics in this Session

- What is Spring Boot?
 - Definition and Hello World example
- **Spring Boot Explained**
 - Dependency Management
 - Auto Configuration
 - **Packaging**
- Web Applications with Spring Boot
- Ease of Use Features

Packaging

- Spring Boot creates a single archive
 - JAR (or WAR)
- Gradle and Maven plugins available
 - Generate an *executable* JAR
`java -jar yourapp.jar`



Maven Packaging

- Add Boot Maven plugin to pom.xml

```
<build>
  <plugins>
    <plugin>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-maven-plugin</artifactId>
    </plugin>
  </plugins>
</build>
```



Packaging Result

- “`mvn package`” execution produces (in `target`)

```
22M  yourapp-0.0.1-SNAPSHOT.jar
5K   yourapp-0.0.1-SNAPSHOT.jar.original
```

- `.jar.original` contains only your code (a traditional JAR file)
- `.jar` contains your code *and* all libs – executable
 - Notice that it is much bigger



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Topics in this Session

- What is Spring Boot?
 - Definition and Hello World example
- Spring Boot Explained
- **Web Applications with Spring Boot**
 - Containerless Applications
 - Spring Boot inside of a Servlet Container
- Ease of Use Features



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Spring Boot as a Runtime

- Spring Boot can startup an *embedded* web server
 - You can run a web application from a JAR file!
 - Tomcat included by Web Starter

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-web</artifactId>
</dependency>
```



Simpler for running and testing, may be preferred when deploying *Cloud Native* applications



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Jetty Support

- Jetty can be used instead of Tomcat

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-web</artifactId>
  <exclusions>
    <exclusion>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-starter-tomcat</artifactId>
    </exclusion>
  </exclusions>
</dependency>
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-jetty</artifactId>
</dependency>
```

Excludes Tomcat

Adds Jetty

Jetty automatically detected and used!



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JAR vs WAR?

- Why Run a Web Application Outside of a Container?
 - No separation of container config and app config
 - Depend on each other anyway (JNDI DS names, security config ...)
 - Projects usually know which container will be used
 - Why not just include it?
 - No special IDE support needed
 - Easier debugging and profiling, hot code replacement
 - Familiar model for non-Java developers
 - Recommended for Cloud Native applications
 - 12-Factor applications #7 (see <http://12factor.net>)



 spring

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Topics in this Session

- What is Spring Boot?
 - Definition and Hello World example
- Spring Boot Explained
- **Web Applications with Spring Boot**
 - Containerless Applications
 - **Spring Boot inside of a Servlet Container**
- Ease of Use Features

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Spring Boot in a Servlet Container

- Spring Boot can also run in any Servlet 3.x container
 - e.g. Tomcat 7+, Jetty 8+
- Only small changes required
 - Change artifact type to WAR (instead of JAR)
 - Extend `SpringBootServletInitializer`
 - Override configure method
- Still no `web.xml` required



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Spring Boot WAR file

- Spring Boot produces hybrid WAR file
- Can still be executed with embedded Tomcat
 - using “`java -jar yourapp.war`”
- Traditional WAR file is produced as well
 - without embedded Tomcat
 - just drop it in your application server web app directory



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Spring Boot in a Servlet Container

```
Sub-classes Spring's WebApplicationInitializer  
– called by the web container (Servlet 3.0)
```

```
@SpringBootApplication  
public class Application extends SpringBootServletInitializer {  
  
    protected SpringApplicationBuilder configure(  
        SpringApplicationBuilder application) {  
        return application.sources(Application.class);  
    }  
  
}
```



The above requires no *web.xml* file



WAR Packaging Result

- “mvn package” execution produces:

```
22M  yourapp-0.0.1-SNAPSHOT.war  
20M  yourapp-0.0.1-SNAPSHOT.war.original
```

- .war.original is a traditional WAR file
- .war is a hybrid WAR file, additionally containing the embedded Tomcat



Servlet Container and Containerless

- Can execute: `java -jar yourapp-0.0.1-SNAPSHOT.war`

```
@SpringBootApplication  
public class Application extends SpringBootServletInitializer {
```

```
    protected SpringApplicationBuilder configure(  
        SpringApplicationBuilder application) {  
        return application.sources(Application.class);  
    }
```

WAR support

```
    public static void main(String[] args) {  
        SpringApplication.run(Application.class, args);  
    }
```

Provides main
method too

Warning: Embedded tomcat version must match version used with WAR



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It's Your Choice



- There is no force to go containerless
 - Embedded container is just one feature of Spring Boot
- Traditional WAR also benefits a lot from Spring Boot
 - Automatic Spring MVC setup, including DispatcherServlet
 - Sensible defaults based on the classpath content
 - Embedded container can be used during development



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Topics in this session

- What is Spring Boot?
 - Definition and Hello World example
- Spring Boot Explained
 - Dependency Management
 - Auto Configuration
 - Containerless Applications
 - Packaging
- Spring Boot inside of a Servlet Container
- **Ease of Use Features**



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Externalized Properties – 1

application.properties

- Developers commonly externalize properties to files
 - Easily consumable via Spring PropertySource
 - But developers name / locate their files different ways
- Spring Boot looks for **application.properties** in well-known locations
 - You can put any properties you need in here and Boot will automatically find and load them
 - Available to `Environment` and `@Value` in usual way



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Externalized Properties – 2

application.properties

- Spring Boot can be easily configured by setting any of its many, many properties
 - Set these in application.properties also
- Example: configure default **DataSource** bean

```
database.host=localhost  
database.user=admin
```

application.properties



See Appendix A of Spring Boot documentation:

<http://docs.spring.io/spring-boot/docs/current/reference/html/common-application-properties.html>



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Externalized Properties – 3

YAML Alternative

- Spring Boot also supports YAML configuration
 - More concise, indented text format (similar to JSON)
 - By default it looks for **application.yml**
 - *Do not use tabs*

```
database:  
  host: localhost  
  user: admin
```

application.yml



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Controlling Logging Level

- Boot can control the logging level
 - Just set it in `application.properties`
- Works with most logging frameworks
 - Java Util Logging, Logback, Log4J, Log4J2

```
logging.level.org.springframework=DEBUG  
logging.level.com.acme.your.code=INFO
```

application.properties



Try to stick to SLF4J in the application.

The *advanced* section covers how to change the logging framework



DataSource Configuration

- Use either `spring-boot-starter-jdbc` or `spring-boot-starter-data-jpa` and include a JDBC driver on classpath
- Declare properties

application.properties

```
spring.datasource.url=jdbc:mysql://localhost/test  
spring.datasource.username=dbuser  
spring.datasource.password=dbpass  
spring.datasource.driver-class-name=com.mysql.jdbc.Driver
```

- That's It!
 - Spring Boot will create a DataSource with properties set
 - Will even use a connection pool if the library is found on the classpath!



Web Application Convenience – 1



- Boot automatically configures
 - A `DispatcherServlet` & `ContextLoaderListener`
 - Spring MVC using same defaults as `@EnableWebMvc`
- **Plus many useful extra features:**
 - Static resources served from classpath
 - `/static`, `/public`, `/resources` or `/META-INF/resources`
 - Templates served from `/templates`
 - If Velocity, Freemarker, Thymeleaf, or Groovy on classpath
 - Provides default `/error` mapping
 - Easily overridden
 - Default `MessageSource` for I18N



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Web Application Convenience – 2



- Spring Boot automatic web configuration
 - Because `spring-boot-starter-web*.jar`
 - Such as when `spring-boot-starter-web` is used
 - You did not specify `@EnableWebMvc`
- `@EnableWebMvc` in a Spring Boot application
 - Only sets up what `@EnableWebMvc` normally does
 - No Spring Boot web extras

Bottom Line: Most Spring Boot web applications do not specify `@EnableWebMvc`



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Summary

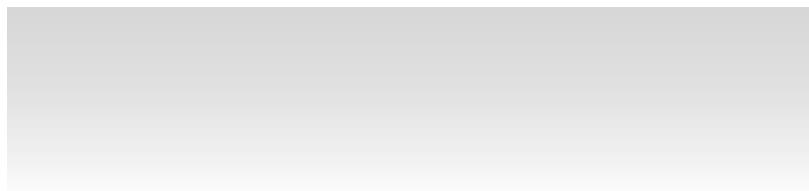
- Spring Boot speeds up Spring application development
- You always have full control and insight
- Nothing is generated
- No special runtime requirements
- No servlet container needed (if you want)
 - E.g. ideal for microservices

Advanced Section: More customization, Configuration using Properties or YAML files, Logging control, Boot-driven testing

Spring-Boot Developer – 2 day in-depth Spring Boot workshop



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Lab

Simplification using Spring Boot



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Spring Boot – Going Further

Going beyond default settings

Customization, Logging, YAML Properties, Testing



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Topics in this Session

- **Understanding Auto-Configuration**
- Customizing Spring Boot
- More on Properties
- Fine-tuning Logging
- Using YAML for Configuration
- Testing



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How Does Spring Boot Work?

- Extensive use of pre-written @Configuration classes
- Conditional on
 - The contents of the classpath
 - Properties you have set
 - Beans already defined
- @Profile is an example of conditional configuration
 - Spring Boot takes this idea to the next level



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@Conditional Annotations

- Allow conditional bean creation
 - Only create if other beans exist (or don't exist)

```
@Bean  
@ConditionalOnBean(name={"dataSource"})  
public JdbcTemplate jdbcTemplate(DataSource dataSource) {  
    return new JdbcTemplate(dataSource);  
}
```

— Or by type: @ConditionalOnBean(type={DataSource.class})

- Many others:
 - @ConditionalOnClass, @ConditionalOnProperty, ...
@ConditionalOnMissingBean, @ConditionalOnMissingClass



@Profile is a special case of @Conditional



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What are AutoConfiguration Classes

- Pre-written Spring configurations
 - `org.springframework.boot.autoconfigure` package
 - See `spring-boot-autoconfigure` JAR file
 - Best place to check what they exactly do

```
@Configuration  
public class DataSourceAutoConfiguration  
    implements EnvironmentAware {  
    ...  
    @Conditional(...)  
    @ConditionalOnMissingBean(DataSource.class)  
    @Import(...)  
    protected static class EmbeddedConfiguration { ... }  
    ... }
```



Spring Boot defines many of these configurations. They activate in response to dependencies on the classpath



Topics in this Session

- Understanding Auto-Configuration
- **Customizing Spring Boot**
- More on Properties
- Fine-tuning Logging
- Using YAML for Configuration
- Testing



Controlling What Spring Boot does

- There are several options
 - Set some of Spring Boot's properties
 - Define certain beans yourself so Spring Boot won't
 - Explicitly disable some auto-configuration
 - Changing dependencies



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1. Using Properties

- Spring Boot looks for **application.properties** in these locations (in this order):
 - `/config` sub-directory of the working directory
 - The working directory
 - `config` package in the classpath
 - classpath root
- Creates a *PropertySource* based on these files
- Many, many configuration properties available



See: [Spring Boot Reference, Appendix A. Common Application Properties](http://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#common-application-properties)
<http://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#common-application-properties>



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2. Replacing Generated Beans

- Normally beans you declare *explicitly* disable any auto-created ones.
 - Example: Your DataSource stops Spring Boot creating a default DataSource
 - Bean name often not important
 - Works with XML, Component Scanning and/or Java Config

```
@Bean  
public DataSource dataSource() {  
    return new EmbeddedDatabaseBuilder()  
        . setName("RewardsDb").build();  
}
```



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3. Selectively Disabling Auto Configuration

- Can disable some AutoConfiguration classes
 - If they don't suit your needs
- Use the `@EnableAutoConfiguration` annotation
 - List the auto-configuration classes to exclude in the “exclude” attribute

```
@EnableAutoConfiguration(exclude=DataSourceAutoConfiguration.class)  
public class ApplicationConfiguration {  
    ...  
}
```



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4a. Overriding Dependency Versions

- Spring Boot POMs preselect the versions of frameworks
 - Ensures the versions of all frameworks are consistent
 - Avoids “*dependency hell*”
- Should I override the version of a given framework?
 - Ideally no, it makes your life more complicated
- But there are good reasons to override it sometimes
 - A bug in the given version
 - Company policies



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4b. Overriding Dependency Versions

- Set the appropriate Maven property in your pom.xml

```
<properties>
  <spring.version>4.2.0.RELEASE</spring.version>
</properties>
```

- Check this POM to know all the properties names
 - <https://github.com/spring-projects/spring-boot/blob/master/spring-boot-dependencies/pom.xml>



This only works if you *inherit* from the starter. You need to redefine the artifact if you directly import the dependency



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Configuration Example: DataSource (1)

- A common example of how to control or override Spring Boot's default configuration
- Typical customizations
 - Use the predefined properties
 - Change the underlying data source connection pool implementation
 - Define your own DataSource bean (shown earlier)



Example: DataSource Configuration (2)

- Common properties configurable from properties file

```
spring.datasource.url=          # Connection settings
spring.datasource.username=
spring.datasource.password=
spring.datasource.driver-class-name=

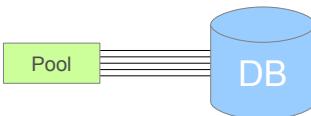
spring.datasource.schema=        # SQL scripts to execute
spring.datasource.data=

spring.datasource.initial-size=   # Connection pool settings
spring.datasource.max-active=
spring.datasource.max-idle=
spring.datasource.min-idle=
```



Example: DataSource Configuration (3)

- Spring Boot creates a pooled DataSource by default
 - If a known pool dependency is available
 - *spring-boot-starter-jdbc* or *spring-boot-starter-jpa* starters pull in *tomcat-jdbc* connection pool by default
 - Alternatives: Tomcat, HikariCP, Commons DBCP 1 & 2
 - Simply use relevant dependency



Example: Web Container Configuration

- Many settings accessible from the configuration file

```
server.port=9000
server.address=192.168.1.20
server.session-timeout=1800
server.context-path=/rewards
server.servlet-path=/admin
```

- Also available
 - SSL (keystore, truststore for client authentication)
 - Tomcat specifics (access log, compression, etc)



Topics in this Session

- Understanding Auto-Configuration
- Customizing Spring Boot
- **More on Properties**
- Fine-tuning Logging
- Using YAML for Configuration
- Testing



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Overriding Properties

Applies to Spring

or Spring Boot

- Order of evaluation of the properties (non-exhaustive)
 - Command line arguments
 - Java system properties
 - OS environment variables
 - Property file(s) – including `application.properties`
- Can access any of them using `@Value` in the usual way
- *Recommendation:*
 - Use Property files to define defaults
 - Override *externally* using one of the other 3 options



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Renaming `application.properties`

- You can override the name of this file
 - Example: to use `myserver.properties`

```
public static void main(String[] args) {  
    System.setProperty("spring.config.name", "myserver");  
    SpringApplication.run(Application.class, args);  
}
```

Application.java

Note: myserver **not**
`myserver.properties`



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Relaxed Property Binding

- No need for exact match between desired properties and names
- Intuitive mapping between java-style properties and environment variables
 - `path` equivalent to `PATH`
 - `java.home` equivalent to `JAVA_HOME`
- Easy overriding of property without changing the name!

```
@Configuration  
class AppConfig {  
  
    @Value("${java.home}")  
    String javaInstallDir;  
  
    ...  
}
```



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The Problem with Property Placeholders

- Using property placeholders is sometimes cumbersome
 - Many properties, prefix has to be repeated

```
@Configuration  
public class RewardsClientConfiguration {  
  
    @Value("${rewards.client.host}") String host;  
    @Value("${rewards.client.port}") int port;  
    @Value("${rewards.client.logdir}") String logdir;  
    @Value("${rewards.client.timeout}") int timeout;  
  
    ...  
}
```



Use @ConfigurationProperties

- Add `@ConfigurationProperties` to *dedicated* container bean
 - Will hold the externalized properties
 - Avoids repeating the prefix
 - Data-members automatically set from corresponding properties

```
@Component  
@ConfigurationProperties(prefix="rewards.client")  
public class ConnectionSettings {  
  
    private String host;  
    private int port;  
    private String logdir;  
    private int timeout;  
    ... // getters/setters  
}
```

rewards.client.host=192.168.1.42
rewards.client.port=8080
rewards.client.logdir=/logs
rewards.client.timeout=2000
application.properties



Use `@EnableConfigurationProperties`

- `@EnableConfigurationProperties` on configuration class
 - Specify and auto-inject the container bean

```
@Configuration  
@EnableConfigurationProperties(ConnectionSettings.class)  
public class RewardsClientConfiguration {  
    // Spring initialized this automatically  
    @Autowired ConnectionSettings connectionSettings;  
  
    @Bean public RewardClient rewardClient() {  
        return new RewardClient(  
            connectionSettings.getHost(),  
            connectionSettings.getPort(), ...  
        );  
    }  
}
```



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Topics in this Session

- Understanding Auto-Configuration
- Customizing Spring Boot
- More on Properties
- **Fine-tuning Logging**
- Using YAML for Configuration
- Testing



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Logging frameworks

- Spring Boot includes by default
 - SLF4J: logging facade
 - Logback: SLF4J implementation
- Best practice: stick to this in your application
 - Use the SLF4J abstraction the application code
- Other logging frameworks are supported
 - Java Util Logging, Log4J, Log4J2



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Using another logging framework

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-websocket</artifactId>
    <exclusions>
        <exclusion>
            <groupId>ch.qos.logback</groupId>
            <artifactId>logback-classic</artifactId>
        </exclusion>
    </exclusions>
</dependency>

<dependency>
    <groupId>org.slf4j</groupId>
    <artifactId>slf4j-log4j12</artifactId>
</dependency>
```

The diagram illustrates the configuration of a dependency in a build file. It shows two main sections: one for the 'spring-boot-starter-websocket' dependency and one for the 'slf4j-log4j12' dependency. In the first section, there is an exclusion for the 'logback-classic' artifact from the 'logback' group. This exclusion is annotated with a callout 'Excludes Logback'. In the second section, there is an addition of the 'slf4j-log4j12' artifact from the 'org.slf4j' group. This addition is annotated with a callout 'Includes Log4J'.



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Logging Output

- Spring Boot logs by default to the console
- Can also log to rotating files
 - Specify file OR path in application.properties

```
# Use only one of the following properties  
  
# absolute or relative file to the current directory  
logging.file=rewards.log  
  
# will write to a spring.log file  
logging.path=/var/log/rewards
```



Spring Boot can also configure logging by using the appropriate configuration file of the underlying logging framework.



Topics in this Session

- Understanding Auto-Configuration
- Customizing Spring Boot
- More on Properties
- Fine-tuning Logging
- **Using YAML for Configuration**
- Testing



What is YAML?

- *Yaml Ain't a Markup Language*
 - Recursive acronym
- Created in 2001
- Alternative to .properties files
 - Allows hierarchical configuration
- Java parser for YAML is called SnakeYAML
 - Must be in the classpath
 - Provided by spring-boot-starters



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YAML for Properties

- Spring Boot support YAML for Properties
 - An alternative to properties files



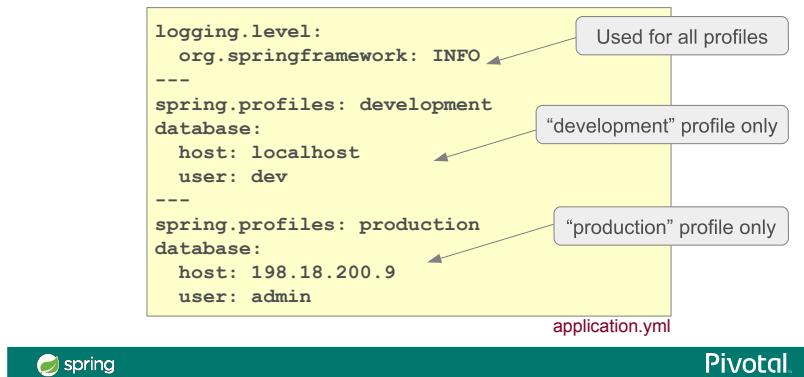
- YAML is convenient for hierarchical configuration data
 - Spring Boot properties are organized in groups
 - Examples: server, database, etc



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Multiple Profiles Inside a Single YAML File

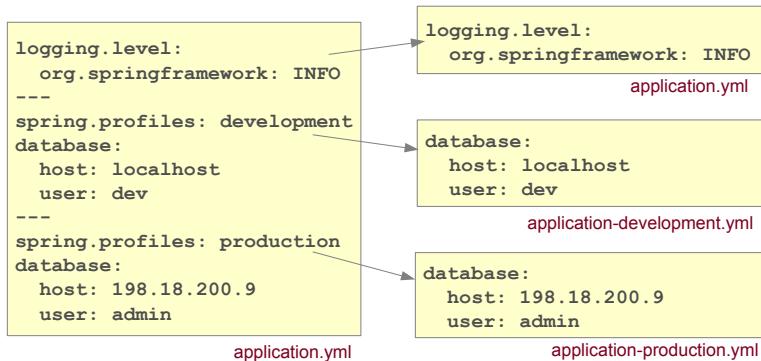
- YAML file can contain configuration for multiple profiles
 - '---' implies a separation between profiles



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Multiple Profiles Inside Multiple Files



Alternatively `application-development.properties` and `application-production.properties` can be used in same way

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Topics in this Session

- Understanding Auto-Configuration
- Customizing Spring Boot
- More on Properties
- Fine-tuning Logging
- Using YAML for Configuration
- **Testing**



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Testing: `@SpringBootTest`

```
Alias for SpringJUnit4ClassRunner
@RunWith(SpringRunner.  
@SpringBootTest(classes=TransferApplication.class)
public final class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void successfulTransfer() {
        TransferConfirmation conf = transferService.transfer(...);
        ...
    }
}
```

`@SpringBootApplication`

```
public class TransferApplication {
    public static void main(String[] args) {
        SpringApplication.run(TransferApplication.class, args);
    }
}
```

A callout box points from the `@RunWith` annotation to the `TransferServiceTests` class, with the text: "Alias for `SpringJUnit4ClassRunner`". Another callout box points from the `@SpringBootTest` annotation to the same class, with the text: "Sets up *same* configuration for the tests that the application would use".



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Web Application Testing

Can use *with or without* Spring Boot

- Spring Unit test with `@WebAppConfiguration`
 - Creates a `WebApplicationContext`
 - Can test code that uses web features
 - `ServletContext`, `Session` and `Request` bean scopes
 - Configures the location of resources
 - Defaults to `src/main/webapp`
 - Override using annotation's value attribute
 - For classpath resources use `classpath:` prefix

```
@RunWith(SpringRunner.class)
@WebAppConfiguration
public final class TransferServiceTests { ... }
```



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Summary

- Spring Boot takes care of boilerplate configuration
 - Auto-configuration can be overridden/disabled
 - Frameworks versions can be overridden too
- Spring Boot enhances Spring configuration externalization mechanisms
 - Properties/YAML files
 - Easier to override using env/Java system variables



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Spring Security

Web Application Security

Addressing Common Security Requirements



Topics in this Session

- **High-Level Security Overview**
- Motivations of Spring Security
- Spring Security in a Web Environment
- Configuring Web Authentication
- Using Spring Security's Tag Libraries
- Method security
- Advanced security: working with filters



Security Concepts

- Principal
 - User, device or system that performs an action
- Authentication
 - Establishing that a principal's credentials are valid
- Authorization
 - Deciding if a principal is allowed to perform an action
- Secured item
 - Resource that is being secured



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Authentication

- There are many authentication mechanisms
 - e.g. basic, digest, form, X.509
- There are many storage options for credential and authority information
 - e.g. Database, LDAP, in-memory (development)



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Authorization

- Authorization depends on authentication
 - Before deciding if a user can perform an action, user identity must be established
- The decision process is often based on roles
 - ADMIN can cancel orders
 - MEMBER can place orders
 - GUEST can browse the catalog



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Topics in this Session

- High-Level Security Overview
- **Motivations of Spring Security**
- Spring Security in a Web Environment
- Configuring Web Authentication
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- Method security
- Advanced security: working with filters



See: **Spring Security Reference**

<http://docs.spring.io/spring-security/site/docs/current/reference/htmlsingle/>



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Motivations - I

- Spring Security is portable across containers
 - Secured archive (WAR, EAR) can be deployed as-is
 - Also runs in standalone environments
 - Uses Spring for configuration
- Separation of Concerns
 - Business logic is decoupled from security concerns
 - Authentication and Authorization are decoupled
 - Changes to the authentication process have *no impact* on authorization



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Motivations: II

- Flexibility
 - Supports all common authentication mechanisms
 - Basic, Form, X.509, Cookies, Single-Sign-On, etc.
 - Configurable storage options for user details (credentials and authorities)
 - RDBMS, LDAP, custom DAOs, properties file, etc.
- Extensible
 - All the following can be customized
 - How a principal is defined
 - How authorization decisions are made
 - Where security constraints are stored



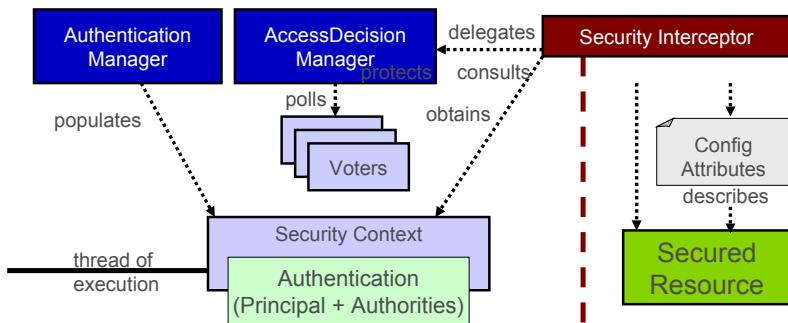
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Consistency of Approach

- The goal of authentication is *always the same regardless* of the mechanism
 - Establish a security context with the authenticated principal's information
 - Out-of-the-box this works for web applications
- The *process of authorization is always the same* regardless of resource type
 - Consult the attributes of the secured resource
 - Obtain principal information from security context
 - Grant or deny access



Spring Security – the Big Picture



Topics in this Session

- High-Level Security Overview
- Motivations of Spring Security
- **Spring Security in a Web Environment**
- Configuring Web Authentication
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- Method security
- Advanced security: working with filters



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Setup the Filter Chain

- Implementation is a *chain* of Spring configured filters
 - Requires a `DelegatingFilterProxy` called `springSecurityFilterChain`
- Use *one* of these options
 - Spring Boot does it automatically
 - Use `@EnableWebSecurity`
 - See next slide
 - For total control, subclass Spring Security's web-initializer
 - `AbstractSecurityWebApplicationInitializer`
 - Declare as a `<filter>` in `web.xml` in usual way



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Configuration in the Application Context

- Java Configuration (XML also available)
 - Extend `WebSecurityConfigurerAdapter` for more control

```
@Configuration  
@EnableWebSecurity  
public class SecurityConfig extends WebSecurityConfigurerAdapter {  
  
    @Override  
    protected void configure(HttpSecurity http) throws Exception {  
        }  
    }  
  
    @Autowired  
    public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception {  
        }  
    }  
}
```

Diagram annotations:

- A callout box labeled "Web-specific security settings" points to the first method block (`protected void configure(HttpSecurity http) throws Exception { ... }`).
- A callout box labeled "General security settings (authentication manager, ...)." points to the second method block (`public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception { ... }`).



authorizeRequests()

- Adds specific authorization requirements to URLs
- Evaluated in the order listed
 - first match is used, put specific matches first

```
protected void configure(HttpSecurity http) throws Exception {  
    http  
        .authorizeRequests()  
            .antMatchers("/css/**", "/images/**", "/javascript/**").permitAll()  
            .antMatchers("/accounts/edit**").hasRole("ADMIN")  
            .antMatchers("/accounts/account**").hasAnyRole("USER", "ADMIN")  
            .antMatchers("/accounts/**").authenticated()  
            .antMatchers("/customers/checkout**").fullyAuthenticated()  
            .antMatchers("/customers/**").anonymous();
```



Specifying login and logout

```
protected void configure(HttpSecurity http) throws Exception {  
    http  
        .authorizeRequests()  
            .antMatchers("/aaa*").hasRole("ADMIN")  
            .and() // method chaining!  
  
        .formLogin() // setup form-based authentication  
            .loginPage("/login.jsp") // URL to use when login is needed  
            .permitAll() // any user can access  
            .and() // method chaining!  
  
        .logout() // configure logout  
            .permitAll(); // any user can access  
}
```



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An Example Login Page

URL that indicates an authentication request.
Default: POST against URL used to display the page.

```
<c:url var='loginUrl' value='/login.jsp' />  
<form:form action="${loginUrl}" method="POST">  
    <input type="text" name="username"/>  
    <br/>  
    <input type="password" name="password"/>  
    <br/>  
    <input type="submit" name="submit" value="LOGIN"/>  
</form:form>
```

The expected keys for generation of an authentication request token

login-example.jsp



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Topics in this Session

- High-Level Security Overview
- Motivations of Spring Security
- Spring Security in a Web Environment
- **Configuring Web Authentication**
- Using Spring Security's Tag Libraries
- Method security
- Advanced security: working with filters



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Configure Authentication

- DAO Authentication provider is default
 - Expects a *UserDetailsService* implementation to provide credentials and authorities
 - Built-in: In-memory (properties), JDBC (database), LDAP
 - Custom
- Or define your own Authentication provider
 - *Example:* to get pre-authenticated user details when using single sign-on
 - CAS, TAM, SiteMinder ...
 - See online examples



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Authentication Provider

- Use a *UserDetailsManagerConfigurer*
 - Three built in options:
 - LDAP, JDBC, in-memory (for quick testing)
 - Or use your own *UserDetailsService* implementation

```
@Autowired  
public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception {  
    auth  
        .inMemoryAuthentication()  
            .withUser("hugie").password("hugie").roles("GENERAL").and()  
            .withUser("dewey").password("dewey").roles("ADMIN").and()  
            .withUser("louie").password("louie").roles("SUPPORT");  
}
```

Not web-specific

Adds a *UserDetailsManagerConfigurer*

login password Supported roles

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Sourcing Users from a Database

- Configuration:

```
@Autowired DataSource dataSource;  
  
public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception {  
    auth.jdbcAuthentication().dataSource(dataSource);  
}
```

Can customize queries using methods:
`usersByUsernameQuery()`
`authoritiesByUsernameQuery()`
`groupAuthoritiesByUsername()`

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Sourcing Users from a Database

Queries RDBMS for users and their authorities

- Provides default queries
 - `SELECT username, password, enabled FROM users WHERE username = ?`
 - `SELECT username, authority FROM authorities WHERE username = ?`
- Groups also supported
 - groups, group_members, groupAuthorities tables
 - See online documentation for details
- Advantage
 - Can modify user info while system is running



Password Encoding

- Can encode passwords using a hash
 - sha, md5, bcrypt, ...

```
auth.jdbcAuthentication()  
.dataSource(dataSource)  
.passwordEncoder(new StandardPasswordEncoder());
```

SHA-256 encoding

- Secure passwords using a well-known string
 - Known as a 'salt', makes brute force attacks harder

```
auth.jdbcAuthentication()  
.dataSource(dataSource)  
.passwordEncoder(new StandardPasswordEncoder("sodium-chloride"));
```

encoding with salt



Other Authentication Options

- Implement a custom UserDetailsService
 - Delegate to an existing User repository or DAO
- LDAP
- X.509 Certificates
- JAAS Login Module
- Single-Sign-On
 - OAuth, SAML
 - SiteMinder, Kerberos
 - JA-SIG Central Authentication Service

Authorization is *not* affected by changes to Authentication!



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@Profile with Security Configuration

```
public class SecurityBaseConfig extends WebSecurityConfigurerAdapter {  
    protected void configure(HttpSecurity http) throws Exception {  
        http.authorizeRequests().antMatchers("/resources/**")  
    }  
}
```

```
@Configuration  
@EnableWebSecurity  
@Profile("development")
```

Use in-memory provider

```
public class SecurityDevConfig extends SecurityBaseConfig {  
    @Autowired  
    public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception {  
        auth.inMemoryAuthentication()  
            .withUser("huglie").password("huglie").roles("GENERAL");  
    }  
}
```



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@Profile with Security Configuration

```
public class SecurityBaseConfig extends WebSecurityConfigurerAdapter {  
    protected void configure(HttpSecurity http) throws Exception {  
        http.authorizeRequests().antMatchers("/resources/**").permitAll();  
    }  
}  
  
@Configuration  
@EnableWebSecurity  
@Profile("production") Use database provider  
public class SecurityProdConfig extends SecurityBaseConfig {  
    @Autowired  
    public void configureGlobal(AuthenticationManagerBuilder auth) throws Exception {  
        auth.jdbcAuthentication().dataSource(dataSource);  
    }  
}
```



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Tag library declaration

- The Spring Security tag library is declared as follows

```
<%@ taglib prefix="security"
    uri="http://www.springframework.org/security/tags" %>
```

available since Spring Security 2.0

jsp

- Facelet tags for JSF are also available
 - You need to define and install them manually
 - See “Using the Spring Security Facelets Tag Library” in the Spring Webflow documentation
 - Principal available in SpEL: `#{}principal.username`
- Equivalent functionality for other View technologies



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Spring Security’s Tag Library

- Display properties of the Authentication object

```
You are logged in as:  
<security:authentication property="principal.username"/>
```

jsp

- Hide sections of output based on role
 - Not recommended, roles in JSP page (see next slide)

```
<security:authorize access="hasRole('ADMIN')">
    TOP-SECRET INFORMATION
    Click <a href="/admin/deleteAll">HERE</a> to delete all records.
</security:authorize>
```

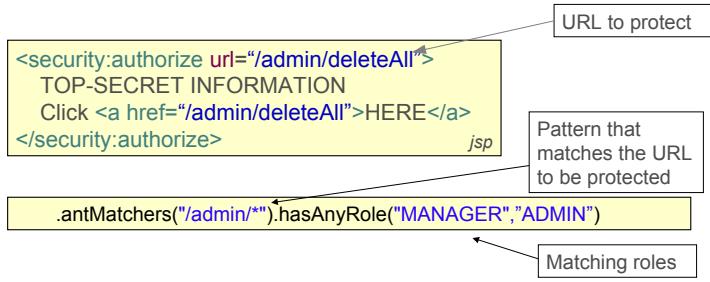
jsp



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Authorization in JSP based on intercept-url

- Role declaration can be centralized in Spring config files



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Method Security

- Spring Security uses AOP for security at the method level
 - annotations based on Spring annotations or JSR-250 annotations
 - Java configuration to activate detection of annotations
- Typically secure your services
 - Do not access repositories directly, bypasses security (and transactions)



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Method Security - JSR-250

- JSR-250 annotations should be enabled

```
@EnableGlobalMethodSecurity(jsr250Enabled = true)
```

```
import javax.annotation.security.RolesAllowed;

public class ItemManager {
    @RolesAllowed({"ROLE_MEMBER", "ROLE_USER"})
    public Item findItem(long itemNumber) {
        ...
    }
}
```



Only supports **role-based** security – hence the name



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Method Security - @Secured

- Secured annotation should be enabled

```
@EnableGlobalMethodSecurity(securedEnabled=true)
```

```
import org.springframework.security.annotation.Secured;  
  
public class ItemManager {  
    @Secured("IS_AUTHENTICATED_FULLY")  
    public Item findItem(long itemNumber) {  
        ...  
    }  
    @Secured("ROLE_MEMBER")  
    @Secured({"ROLE_MEMBER", "ROLE_USER"})
```



Spring 2.0 syntax, so *not* limited to roles. SpEL *not* supported.

spring

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Method Security with SpEL

- Use Pre/Post annotations for SpEL

```
@EnableGlobalMethodSecurity(prePostEnabled=true)
```

```
import org.springframework.security.annotation.PreAuthorize;  
  
public class ItemManager {  
    @PreAuthorize("hasRole('MEMBER')")  
    public Item findItem(long itemNumber) {  
        ...  
    }  
}
```

spring

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- Method security
- **Advanced security: working with filters**



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Spring Security in a Web Environment

- *SpringSecurityFilterChain*
 - Spring Boot does this automatically
 - Or declare in servlet configuration
- This single proxy filter delegates to a chain of Spring-managed filters
 - Drive authentication
 - Enforce authorization
 - Manage logout
 - Maintain SecurityContext in HttpSession
 - *and more*



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Example: Configuration in web.xml

- Define the single proxy filter
 - `springSecurityFilterChain` is a mandatory name
 - Refers to an existing Spring bean with same name

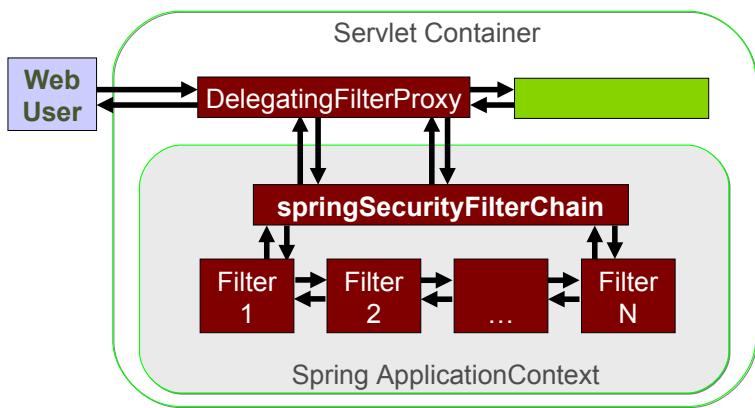
```
<filter>                                         web.xml
  <filter-name>springSecurityFilterChain</filter-name>
  <filter-class>
    org.springframework.web.filter.DelegatingFilterProxy
  </filter-class>
</filter>

<filter-mapping>
  <filter-name>springSecurityFilterChain</filter-name>
  <url-pattern>/*</url-pattern>
</filter-mapping>
```



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Web Security Filter Configuration



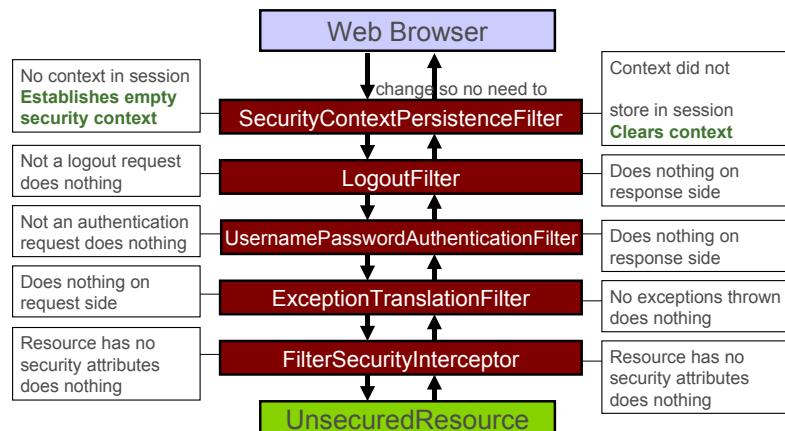
Pivotal

The Filter Chain

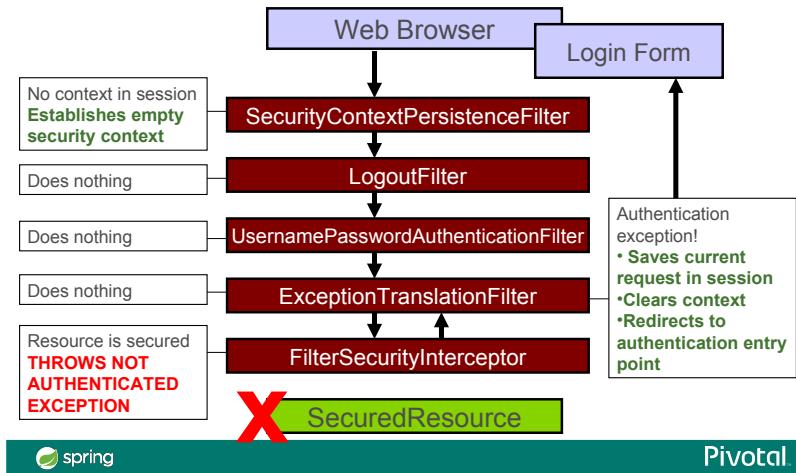
- With ACEGI Security 1.x
 - Filters were manually configured as individual <bean> elements
 - Led to verbose and error-prone XML
- Spring Security 2.x, 3.x, 4.x
 - Filters are initialized with correct values by default
 - Manual configuration is not required **unless you want to customize Spring Security's behavior**
 - It is still important to understand how they work underneath



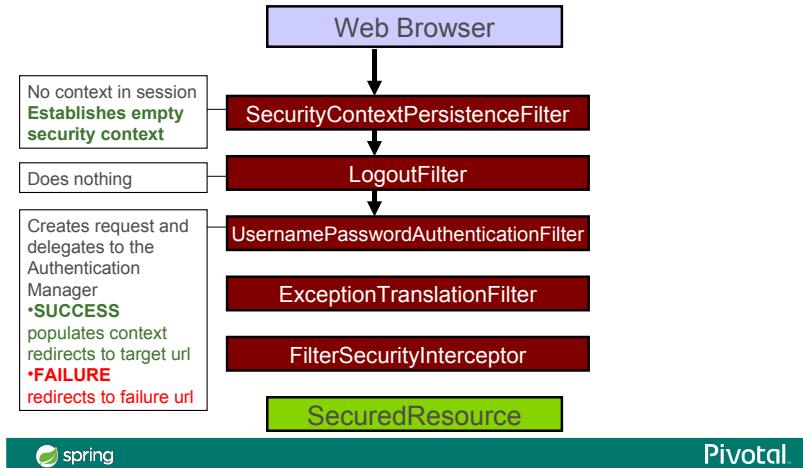
Access Unsecured Resource Prior to Login



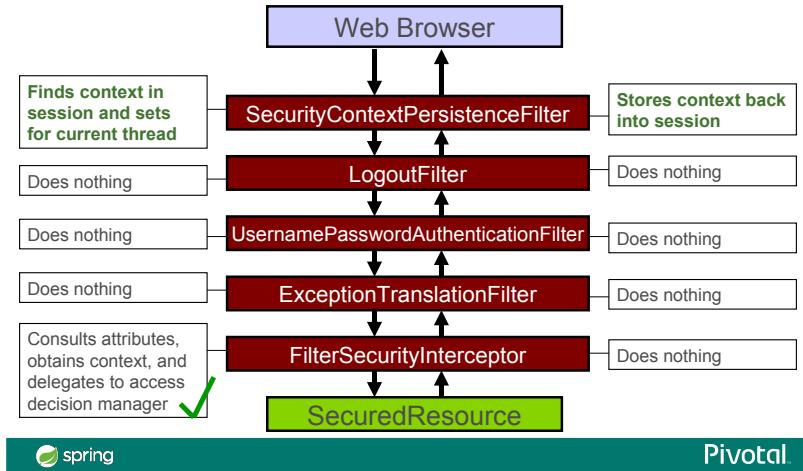
Access Secured Resource Prior to Login



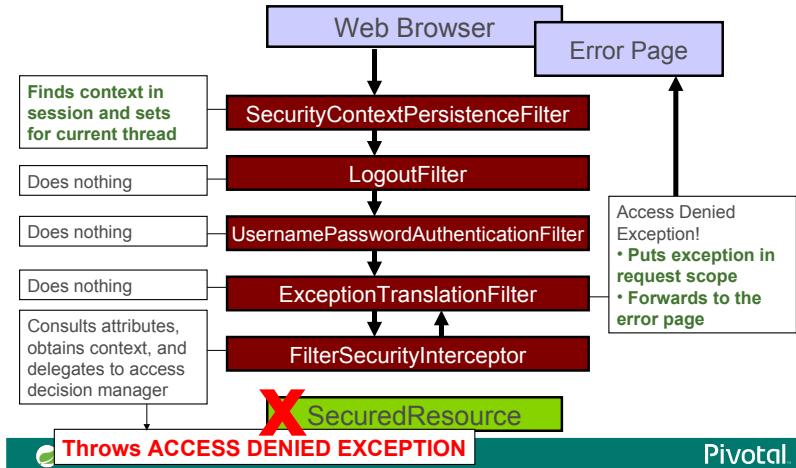
Submit Login Request



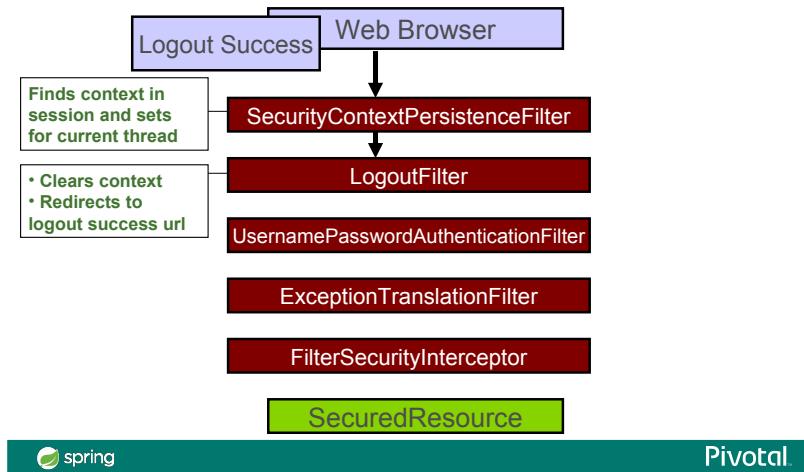
Access Resource With Required Role



Access Resource Without Required Role



Submit Logout Request



The Filter Chain: Summary

#	Filter Name	Main Purpose
1	SecurityContext IntegrationFilter	Establishes SecurityContext and maintains between HTTP requests <i>formerly: HttpSessionContextIntegrationFilter</i>
2	LogoutFilter	Clears SecurityContextHolder when logout requested
3	UsernamePassword AuthenticationFilter	Puts Authentication into the SecurityContext on login request <i>formerly: AuthenticationProcessingFilter</i>
4	Exception TranslationFilter	Converts SpringSecurity exceptions into HTTP response or redirect
5	FilterSecurity Interceptor	Authorizes web requests based on config attributes and authorities

Custom Filter Chain

- Filter can be **added** to the chain
 - Before or after existing filter

```
http.addFilterAfter ( myFilter, UsernamePasswordAuthenticationFilter.class );  
...  
@Bean  
public Filter myFilter() { return new MySpecialFilter(); }
```

- Filter on the stack may be **replaced** by a custom filter
 - Replacement must extend the filter being replaced.

```
http.addFilter ( myFilter );  
...  
@Bean  
public Filter myFilter() {  
    return new MySpecialFilter();  
}
```

```
public class MySpecialFilter  
    extends UsernamePasswordAuthenticationFilter {}
```



Summary



- Spring Security
 - Secure URLs using a chain of Servlet filters
 - And/or methods on Spring beans using AOP proxies
- Out-of-the-box setup usually sufficient – you define:
 - URL and/or method restrictions
 - How to login (typically using an HTML form)
 - Supports in-memory, database, LDAP credentials (and more)
 - Password encryption using familiar hashing techniques
 - Support for security tags in JSP views



Lab

Applying Spring Security to a Web Application



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Practical REST Web Services

Using Spring MVC to build RESTful Web Services

Extending Spring MVC to handle REST

Topics in this Session



- REST introduction
- Spring MVC support for RESTful applications
 - Request/Response Processing
 - Accessing Request/Response Data
 - Putting it all together
- RESTful Clients with the RestTemplate
- Advanced Topics

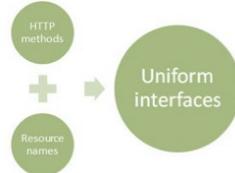
REST Introduction

- Web apps not just usable by browser clients
 - Programmatic clients can also connect via HTTP
 - Such as: mobile applications, AJAX enabled web-pages
- REST is an *architectural style* that describes best practices to expose web services over HTTP
 - REpresentational S_Tate T_Ransfer, term by Roy Fielding
 - HTTP as *application* protocol, not just transport
 - Emphasizes scalability
 - *Not* a framework or specification



REST Principles (1)

- Expose *resources* through URIs
 - Model nouns, not verbs
 - <http://springbank.io/banking/accounts/123456789>
- Resources support limited set of operations
 - GET, PUT, POST, DELETE in case of HTTP
 - All have well-defined semantics
- Example: update an order
 - PUT to </orders/123>
 - don't POST to </order/edit?id=123>



REST Principles (2)

- Clients can request particular representation
 - Resources can support multiple representations
 - HTML, XML, JSON, ...
- Representations can link to other resources
 - Allows for extensions and discovery, like with web sites
- Hypermedia As The Engine of Application State
 - *HATEOAS*: Probably the world's worst acronym!
 - RESTful responses contain the links you need – just like HTML pages do



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REST Principles (3)

- Stateless architecture
 - No HttpSession usage
 - GETs can be cached on URL
 - Requires clients to keep track of state
 - Part of what makes it scalable
 - Looser coupling between client and server
- HTTP headers and status codes communicate result to clients
 - All well-defined in HTTP Specification



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Why REST?

- Benefits of REST
 - Every platform/language supports HTTP
 - Unlike for example SOAP + WS-* specs
 - Easy to support many different clients
 - Scripts, Browsers, Applications
 - Scalability
 - Support for redirect, caching, different representations, resource identification, ...
 - Support for XML, but also other formats
 - JSON and Atom are popular choices



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REST and Java: JAX-RS



JAX-RS

- JAX-RS is a Java EE 6 standard for building RESTful applications
 - Focuses on programmatic clients, not browsers
- Various implementations
 - Jersey (RI), RESTEasy, Restlet, CXF
 - All implementations provide Spring support
- Good option for full REST support using a standard
- No support for building clients in standard
 - Although some implementations do offer it



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- Spring-MVC provides REST support as well
 - Since version 3.0
 - Using familiar and consistent programming model
 - Spring MVC does not implement JAX-RS
- Single web-application for everything
 - Traditional web-site: HTML, browsers
 - Programmatic client support (RESTful web applications, HTTP-based web services)
- RestTemplate for building programmatic clients in Java



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Topics in this Session

- REST introduction
- **Spring MVC support for RESTful applications**
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- Advanced Topics



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Spring-MVC and REST

- Will now extend Spring MVC to support REST
 - Map requests based on HTTP method
 - Define response status
 - Message Converters
 - Access request and response body data
 - Build valid Location URIs



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Request Mapping Based on HTTP Method

- Can map HTTP requests based on method
 - Allows same URL to be mapped to multiple methods
 - Often used for form-based controllers (GET & POST)
 - Essential to support RESTful resource URLs
 - incl. PUT and DELETE

```
@RequestMapping(path="/orders", method=RequestMethod.GET)
public void listOrders( ... ) {
    // find all Orders and add them to the model
}

@RequestMapping(path="/orders", method=RequestMethod.POST)
public void createOrder( ... ) {
    // process the order data from the request
}
```



Simpler Mapping Annotations

Spring 4.3

- Alternative handler mapping shortcuts
 - `@RequestMapping(path="/accounts")`
 - Or `@GetMapping("/accounts")`;
- Exist for each HTTP method
 - `@GetMapping`
 - `@PostMapping`
 - `@PutMapping`
 - `@DeleteMapping`
 - `@PatchMapping`



HTTP Status Code Support



- Web apps just use a handful of status codes
 - Success: 200 OK
 - Redirect: 30x for Redirects
 - Client Error: 404 Not Found
 - Server Error: 500 (such as unhandled Exceptions)
- RESTful applications use many additional codes
 - Created Successfully: 201
 - HTTP method not supported: 405
 - Cannot generate response body requested: 406
 - Request body not supported: 415



For a full list: https://en.wikipedia.org/wiki/List_of_HTTP_status_codes



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@ResponseStatus

place at class-level,
applies to *all* methods

Spring 4.3 – Can

- To return a status code *other* than 200
 - Use HttpStatus enumerator
- **Note:** @ResponseStatus on **void** methods
 - No longer want to return a view name - *no View at all!*
 - Method returns a response with empty body (*no-content*)

```
@RequestMapping(path="/orders/{id}",
                 method=RequestMethod.PUT)
@ResponseStatus(HttpStatus.NO_CONTENT) // 204
public void updateOrder(HttpServletRequest request) {
    Order order = getOrder(request);      // Extract from request
    orderService.updateOrder(order);
}
```



Can also set error response codes – see Advanced section



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Accessing Request/Response Data



- *The Problem*
 - HTTP `GET` needs to return data in response body
 - HTTP `POST` and `PUT` receive data in request body
 - Typically XML or JSON
 - Want to deal in Java objects
 - Want to avoid converting between formats manually
- *The Solution*
 - Use *Marshaling* via dedicated *message-converters*
 - Annotate incoming data with `@RequestBody`
 - Annotate outgoing data with `@ResponseBody`



HttpMessageConverter

- Converts HTTP request/response body data
 - XML (using JAXP Source, JAXB2 mapped object, Jackson-Dataformat-XML*)
 - Jackson JSON*, GSON*Feed data* such as Atom/RSS
 - Google protocol buffers *
 - Form-based data
 - `Byte[], String, BufferedImage`
- **Must** enable otherwise no convertors defined at all!
 - Automatic with Spring Boot
 - `@EnableWebMvc` OR `<mvc:annotation-driven/>`
 - Or define explicitly (allows you to register extra convertors)
 - Using `WebMvcConfigurer` OR `<mvc:/>`

* Requires 3rd party
libraries on classpath



@RequestBody

- To use converters for incoming request data
 - Correct converter chosen automatically
 - Based on content type of request
 - `updatedOrder` could be mapped from XML (with JAXB2) or from JSON (with Jackson)
 - Annotate Order class to help JAXB/Jackson work

```
@RequestMapping(path="/orders/{id}", method=RequestMethod.PUT)
@ResponseStatus(HttpStatus.NO_CONTENT) // 204
public void updateOrder(@RequestBody Order updatedOrder,
                        @PathVariable("id") long id) {
    // process updated order data and return empty response
    orderManager.updateOrder(id, updatedOrder);
}
```



@ResponseBody

- Use converters for response data by annotating return data with `@ResponseBody`
- Converter handles rendering a response
 - Again, no ViewResolver and View involved any more!

```
@RequestMapping(path="/orders/{id}", method=RequestMethod.GET)
@ResponseStatus(HttpStatus.OK) // 200
public @ResponseBody Order getOrder(@PathVariable("id") long id) {
    // Order class is annotated with JAXB2's @XmlRootElement
    Order order= orderService.findOrderById(id);
    // results in XML response containing marshalled order:
    return order;
}
```



What Return Format? Accept Header

```
@RequestMapping(path="/orders/{id}", method=RequestMethod.GET)
@ResponseStatus(HttpStatus.OK) // 200
public @ResponseBody Order getOrder(@PathVariable("id") long id) {
    return orderService.findOrderById(id);
}
```

```
GET /store/orders/123
Host: shop.spring.io
Accept: application/xml, ...
...
```

```
HTTP/1.1 200 OK
Date: ...
Content-Length: 1456
Content-Type: application/xml
<order id="123">
...
</order>
```

```
GET /store/orders/123
Host: shop.spring.io
Accept: application/json, ...
...
```

```
HTTP/1.1 200 OK
Date: ...
Content-Length: 756
Content-Type: application/json
{
    "order": {"id": 123,
              "items": [ ... ], ... }
}
```



@RestController Simplification

Spring 4.0

```
@Controller
public class OrderController {
    @RequestMapping(path="/orders/{id}", method=RequestMethod.GET)
    public @ResponseBody Order getOrder(@PathVariable("id") long id) {
        return orderService.findOrderById(id);
    }
}

@RestController
public class OrderController {
    @RequestMapping(path="/orders/{id}", method=RequestMethod.GET)
    public Order getOrder(@PathVariable("id") long id) {
        return orderService.findOrderById(id);
    }
}
...
```

No need for @ResponseBody on GET methods



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Accessing Request/Response Data

- Can explicitly inject `HttpServletRequest` (and `HttpServletResponse`)
 - But makes Controller methods hard to test
 - Consider Spring's `MockHttp...` classes
- Spring can *automatically* inject part of the request
 - `@RequestParam`, `@PathVariable`, `Principal`, `Locale`, `@Value`, `@RequestHeader`,
 - `@RequestBody`, `@ResponseBody`
- To perform REST we may also use
 - `HttpEntity`, `ResponseEntity`



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HttpEntity and ResponseEntity

- To build responses explicitly
 - Set headers, control content returned
 - Use `HttpEntity` or `ResponseEntity`

```
// Want to return a String as the response-body
HttpHeaders headers = new HttpHeaders();
headers.setContentType(MediaType.TEXT_PLAIN);
HttpEntity<String> entity =
    new HttpEntity<String>("Hello Spring", headers);

// ResponseEntity (since Spring 4.1) supports a "fluent" API
ResponseEntity<String> response =
    ResponseEntity.ok()
        .contentType(MediaType.TEXT_PLAIN)
        .body("Hello Spring");
```



Setting Response Data

- Can use `HttpEntity` to generate a Response
 - Avoids use of `HttpHeaders` (easier to test)

```
@RequestMapping(path="/orders/{id}", method=RequestMethod.GET)
public HttpEntity<Order> getOrder(@RequestParam("id") long id) {
    String order = orderService.find(id);

    HttpHeaders responseHeaders = new HttpHeaders();
    responseHeaders.set("Content-Type", "text/xml");

    return new HttpEntity<Order>(order, responseHeaders);
}
```

Response
body type

Response
body



Building URIs



- An HTTP POST typically returns location of newly created resource in the response header
- How to create a URI?
 - **UriComponentsBuilder**
 - Allows explicit creation of URI
 - *But* uses hard-coded URLs
 - **ServletUriComponentsBuilder**
 - Provides access to the URL that invoked the current controller method



Building URIs: UriComponentsBuilder

- Support for building URIs from templated strings
 - Escapes illegal `%20` for a space as

```
String templateUrl =  
    "http://store.spring.io/orders/{orderId}/items/{itemId}";  
  
URI location = UriComponentsBuilder.  
    fromHttpUrl(templateUrl).  
    buildAndExpand("123456","item A").  
    toUri();  
  
return ResponseEntity.created(location).build();  
  
// http://store.spring.io/orders/123456/items/item%20A
```

Use of hard-coded URL *not recommended*

Convenient way to build POST response



ServletUriComponentsBuilder

- Use in a Controller method
 - Avoids hard-coding URL

```
// Must be in a Controller method
// Example: POST /orders/{id}

URI location = ServletUriComponentsBuilder
    .fromCurrentRequestUri() ←
    .path("items/{itemId}")
    .buildAndExpand("item A")
    .toUri(); ;

return ResponseEntity.created(location).build();

// http://.../items/item%20A
```

Framework puts request URL in current thread – which builder can access



Lesson Roadmap

- REST and Java
- Spring MVC support for RESTful applications
 - Request/Response Processing
 - Accessing Request/Response Data
 - **Putting it all together**
- RESTful Clients with the RestTemplate
- Advanced Topics



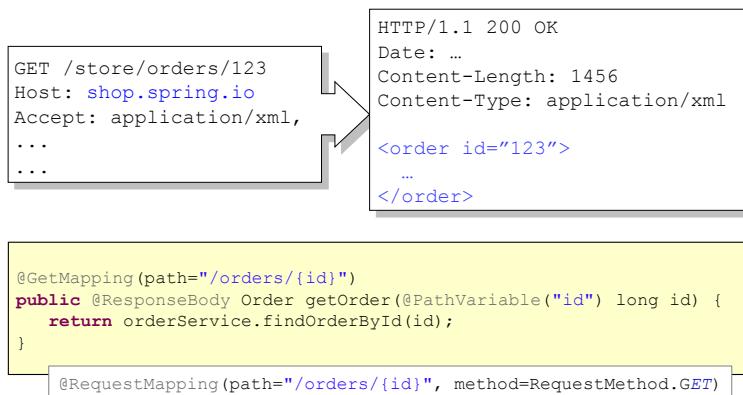
Putting it all Together



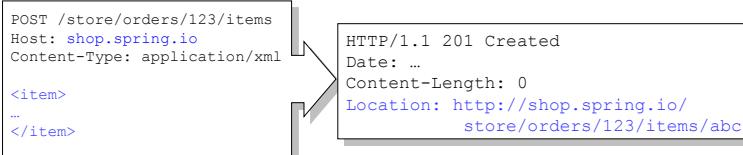
- We have covered many new concepts
 - `@ResponseStatus`
 - HTTP Message Converters
 - `@RequestBody`, `@ResponseBody`
 - `HttpEntity`, `ResponseEntity`
 - `UriComponentsBuilder`
- Let's see some typical Controller implementations for each of `GET`, `POST`, `PUT` and `DELETE`
 - Useful reference when you are writing a new Controller
 - *And for the lab!*



Retrieving a Representation



Creating a new Resource: POST (1)



- The most complicated to implement
 - “201 Created” requires `Location` header for new resource
 - Will need `ServletUriComponentsBuilder` and `ResponseEntity`



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Creating a new Resource: POST (2)

```
@PostMapping(path="/orders/{id}/items")
@ResponseStatus(HttpStatus.CREATED) // 201
public ResponseEntity<Void>
createItem(@PathVariable("id") long id, @RequestBody Item newItem) {
    // Add the new item to the order
    orderService.findOrderById(id).addItem(newItem);

    // Build the location URI of the new item
    URI location = ServletUriComponentsBuilder
        .fromCurrentRequestUri()
        .path("{itemId}")
        .buildAndExpand(newItem.getId())
        .toUri();

    return ResponseEntity.created(location).build();
}
```

`@RequestMapping(path="/orders/...", method=RequestMethod.POST)`

Assume added id to item



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Updating existing Resource: **PUT**

```
PUT /store/orders/123/items/abc  
Host: shop.spring.io  
Content-Type: application/xml  
  
<item>  
...  
</item>
```

```
HTTP/1.1 204 No Content  
Date: ...  
Content-Length: 0
```

```
@PutMapping(path="/orders/{orderId}/items/{itemId}")  
@ResponseStatus(HttpStatus.NO_CONTENT) // 204  
public void updateItem(@PathVariable("orderId") long orderId,  
                      @PathVariable("itemId") String itemId,  
                      @RequestBody Item item) {  
    orderService.findOrderById(orderId).updateItem(itemId, item);  
}  
  
@RequestMapping(path="/orders/...", method=RequestMethod.PUT)
```



Deleting a Resource:

```
DELETE /store/orders/123/items/abc  
Host: shop.spring.io  
...
```

```
HTTP/1.1 204 No Content  
Date: ...  
Content-Length: 0
```

```
@DeleteMapping(path="/orders/{orderId}/items/{itemId}")  
@ResponseStatus(HttpStatus.NO_CONTENT) // 204  
public void deleteItem(@PathVariable("orderId") long orderId,  
                      @PathVariable("itemId") String itemId) {  
    orderService.findOrderById(orderId).deleteItem(itemId);  
}  
  
@RequestMapping(path="/orders/...", method=RequestMethod.DELETE)
```



Topics in this Session

- REST introduction
- Spring MVC support for RESTful applications
- **RESTful Clients with the RestTemplate**
- Advanced Topics



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RestTemplate

- Provides access to RESTful services
 - Supports all the HTTP methods

HTTP Method	RestTemplate Method
DELETE	delete(String url, Object... urlVariables)
GET	getForObject(String url, Class<T> responseType, Object... urlVariables)
HEAD	headForHeaders(String url, Object... urlVariables)
OPTIONS	optionsForAllow(String url, Object... urlVariables)
POST	postForLocation(String url, Object request, Object... urlVariables) postForObject(String url, Object request, Class<T> responseType, Object... urlVariables)
PUT	put(String url, Object request, Object... urlVariables)



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Defining a RestTemplate

- Just call constructor in your code
 - Setups default *HttpMessageConverters* internally
 - Same as on the server, depending on classpath

```
RestTemplate template = new RestTemplate();
```



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RestTemplate Usage Examples

```
RestTemplate template = new RestTemplate();
String uri = "http://example.com/store/orders/{id}/items";
// GET all order items for an existing order with ID 1:
OrderItem[] items =
    template.getForObject(uri, OrderItem[].class, "1");
// POST to create a new item
OrderItem item = // create item object
URI itemLocation = template.postForLocation(uri, item, "1");
// PUT to update the item
item.setAmount(2);
template.put(itemLocation, item);
// DELETE to remove that item again
template.delete(itemLocation);
```

{id} = 1

{id} = 1



Also supports *HttpEntity*, for example to set HTTP request headers



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Summary



- REST is an architectural style that can be applied to HTTP-based applications
 - Useful for supporting diverse clients and building highly scalable systems
- Spring-MVC adds REST support using a familiar programming model (but *without Views*)
 - `@ResponseStatus`, `@RequestBody`, `@ResponseBody`
 - `HttpEntity`, `ResponseEntity`, `UriComponentsBuilder`
 - HTTP Message Converters
- Clients use *RestTemplate* to access RESTful servers



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Lab

Restful applications with Spring MVC

Coming Up: More on Spring MVC REST
Introduction to Spring HATEOAS



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Topics in this Session

- REST introduction
- Spring MVC support for RESTful applications
- RESTful clients with the RestTemplate
- **Advanced Topics**
 - More on Spring REST
 - Spring HATEOAS



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@ResponseStatus & Exceptions

- Can also annotate exception classes with this
 - Given status code used when an unhandled exception is thrown from *any* controller method

```
@ResponseStatus(HttpStatus.NOT_FOUND) // 404
public class OrderNotFoundException extends RuntimeException {
    ...
}

@GetMapping(value="/orders/{id}")
public String showOrder(@PathVariable("id") long id, Model model) {
    Order order = orderService.findOrderById(id);
    if (order == null) throw new OrderNotFoundException(id);
    model.addAttribute(order);
    return "orderDetail";
}
```

NOTE: this is *not* a RESTful method,
it returns a view-name.



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@ExceptionHandler

- For existing exceptions you cannot annotate, use `@ExceptionHandler` method on controller
 - Method signature similar to request handling method
 - Also supports `@ResponseStatus`

```
@ResponseStatus(HttpStatus.CONFLICT) // 409
@ExceptionHandler({DataIntegrityViolationException.class})
public void conflict() {
    // could add the exception, response, etc. as method params
}
```



Spring MVC offers several ways to handle exceptions, for more details
see <http://spring.io/blog/2013/11/01/exception-handling-in-spring-mvc>



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Mixing Views and Annotations - 1

- REST methods do not return HTML, PDF, ...
 - No message converter
 - Views better for presentation-rich representations
- How to distinguish between representations?
 - Or a RESTful POST from a HTML form submission
- Use *produces* and *consumes* attributes

```
@GetMapping(value="/orders/{id}", produces = {"application/json"})
@PostMapping(value="/orders/{id}", consumes = {"application/json"})
```



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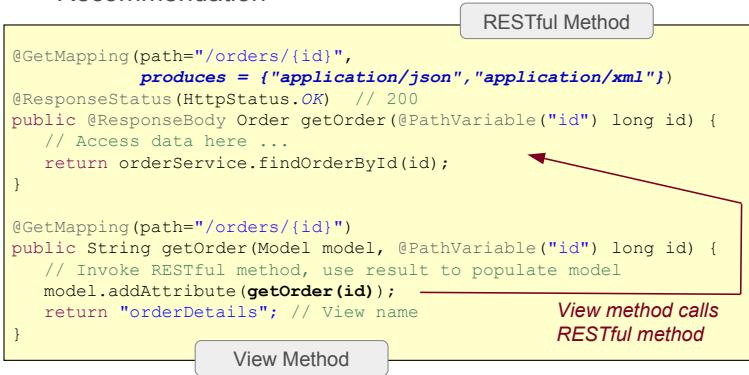
Mixing Views and Annotations – 2

- Need two methods on controller for same URL
 - One uses a converter, the other a View
 - Identify using *produces* attribute
- Recommendation
 - Mark RESTful method with *produces*
 - To avoid returning XML to normal browser request
 - Call RESTful method from View method
 - Implement all data-access logic *once* in RESTful method



Mixing Views and Annotations - 3

- Recommendation



HttpMethodFilter

- HTML forms do not support PUT or DELETE
 - Not even in HTML 5
- So use a POST
 - Put PUT or DELETE in a *hidden* form field
- Deploy a special filter to intercept the message
 - Restores the HTTP method you wanted to send
 - Appear to Spring MVC as a PUT or a DELETE



See *HttpMethodFilter* in online documentation



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Topics in this Session

- REST introduction
- Spring MVC support for RESTful applications
 - Request/Response Processing
 - Using MessageConverters
 - Putting it all together
- RESTful clients with the RestTemplate
- **Advanced Topics**
 - More on Spring REST
 - **Spring HATEOAS**



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HATEOAS - Concepts

- REST clients need *no* prior knowledge about how to interact with a particular application/server
 - SOAP web-services need a WSDL
 - SOA processes require a fixed interface defined using interface description language (IDL)
- Clients interact entirely through hypermedia
 - Provided dynamically by application servers
- Serves to *decouple* client and server
 - Allows the server to evolve functionality independently
 - Unique compared to other architectures



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HATEOAS Account Example

```
<account>
  <account-number>12345</account-number>
  <balance currency="usd">100.00</balance>
  <link rel="self" href="/account/12345"
  <link rel="deposit" href="/account/12345/deposits" />
  <link rel="withdraw" href="/account/12345/withdrawls" />
  <link rel="transfer" href="/account/12345/transfers" />
  <link rel="close" href="/account/12345/close" />
</account>
```

```
<account>
  <account-number>12345</account-number>
  <balance currency="usd">-25.00</balance>
  <link rel="self" href="/account/12345"
  <link rel="deposit" href="/account/12345/deposits" />
</account>
```

Spring HATEOAS

provides an API for generating these links in MVC Controller responses

Note: links change as state changes



There is no standard for links yet. This example uses the link style from the Hypertext Application Language (HAL), one possible representation



From: <http://restcookbook.com/Basics/hateoas/>

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Managing Links

- Use **Link** class
 - Holds an href and a rel (relationship)
 - Self implies the current resource
 - Link builder derives URL from Controller mappings

```
// A link can be built with a relationship name
// Use withSelfRel() for a self link
Link link = ControllerLinkBuilder.linkTo(AccountController.class)
    .slash(accountId).slash("transfer").withRel("transfer");

link.getRel();      // => transfer
link.getHref();    // => http://.../account/12345/transfer
```



Converting to a Resource

- Wrap return value of REST method in Resource
 - Converted by **@ResponseBody** to XML/JSON with links
 - Only HAL supported currently

```
@Controller
@EnableHypermediaSupport(type=HypermediaType.HAL)
public class OrderController {

    @GetMapping(value="/orders/{id}")
    public @ResponseBody Resource<Order>
        getOrder(@PathVariable("id") long id) {
        Links[] = ...; // Some links (see previous slide)
        return new Resource<Order>
            (orderService.findOrderById(id), links);
    }
}
```



Spring HATEOAS



- Spring Data sub-project for REST
 - For generating links in RESTful responses
 - Supports ATOM (newsfeed XML) and HAL (Hypertext Application Language) links
 - Many other features besides examples shown here
- For more information see
 - <http://projects.spring.io/spring-hateoas/>
 - <http://spring.io/guides/gs/rest-hateoas/>

Microservices with Spring

Building Cloud Native Applications

Introduction to Spring Cloud

Roadmap



- **What is Microservices Architecture?**
- Pros and Cons of Microservices
- Managing Microservices
- Tooling: Spring, Spring Cloud, Netflix
- Building a Simple Microservice System



Introduction

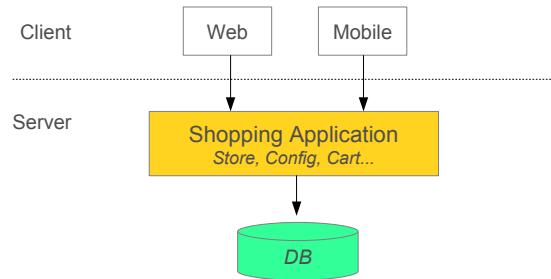
- “Microservices” is not a new word
 - Term coined in 2005 by Dr Peter Rodgers
 - Then called “*micro web services*” and based on SOAP
 - Term started to become popular since 2010
 - Proposed by a group of architects in Venice during 2011
 - Used in 2012 in a [presentation from James Lewis](#)
 - Meanwhile Adrian Cockcroft (Netflix), was describing this approach as “fine grained SOA”

<http://martinfowler.com/articles/microservices.html>



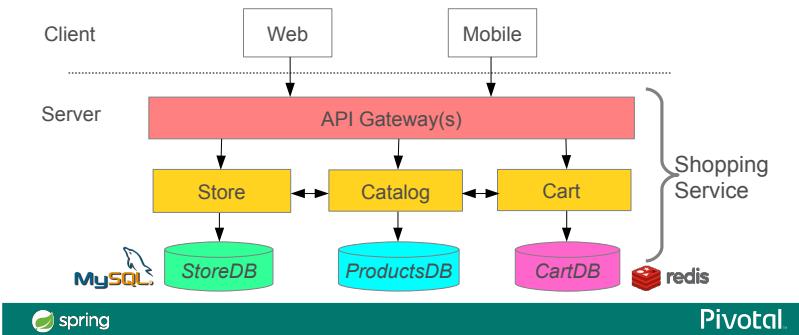
Without Microservices

- Using a “monolith” architecture
 - All-in-One application



With Microservices

- Main application has been divided in a set of sub-applications
 - Called microservices



Roadmap



- What is Microservices Architecture?
- **Pros and Cons of Microservices**
- Managing Microservices
- Tooling: Spring, Spring Cloud, Netflix
- Building a Simple Microservice System



Core Spring Concepts Applied to Application Architecture



- Spring enables *separation-of-concerns*
 - *Loose Coupling*: Effect of change is isolated
 - *Tight Cohesion*: Code performs a single well-defined task
- Microservices exhibit the same strengths
 - *Loose Coupling*
 - Applications are built from collaborating services (processes)
 - Can change independently so long as protocols unchanged
 - *Tight Cohesion*
 - An application (service) that deals with a *single* view of data
 - Also known as “Bounded Contexts” (*Domain-Driven Design*)



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Microservice Benefits



- Smaller code base is easy to maintain
- Easy to scale
 - Scale individual component
- Technology diversity
 - Mix libraries, frameworks, data storage, languages
- Fault Isolation
 - Component failure should not bring whole system down
- Better support for smaller, parallel teams
- Independent deployment



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Microservice Challenges



- Difficult to achieve strong consistency across services
 - ACID transactions *do not* span multiple processes
 - Eventual consistency, Compensating transactions
- Distributed system
 - Harder to debug/trace
 - Greater need for end-to-end testing
 - Expect, test for and handle the failure of any process
 - More components to maintain: redundancy, HA
- Typically requires “cultural” change (*Dev Ops*)
 - How applications are developed and deployed
 - Devs and Ops working *together*, even on same team!



Use a Platform to Support This



- Platforms* like *Pivotal Cloud Foundry* aid deployment
 - Easily run, scale, monitor and recover multiple processes
 - Run up a complete dev system for end-to-end testing
- Support for
 - Continuous Deployment
 - Rolling upgrades of new versions of code
 - Also termed: Blue/Green or Canary rollout
 - Quick rollback in case of defects
 - Running multiple versions of same service at same time
 - Makes migration easier for downstream projects

*Platform as a Service (PaaS)



Roadmap



- What is Microservices Architecture?
- Pros and Cons of Microservices
- **Developing Microservices**
- Tooling: Spring, Spring Cloud, Netflix
- Building a Simple Microservice System



Microservice Infrastructure

- Multiple processes working together
- Issues that now arise:

- How do they find each other? Service Discovery
- How do we decide which instance to use? Client-side Load Balancing
- What happens if a microservice is not responding Fault Tolerance
- How do we control access? OAuth, ...
- How do they communicate? Messaging REST
- To just name a few!

We cover these today



Roadmap



- What is Microservices Architecture?
- Pros and Cons of Microservices
- Managing Microservices
- **Tooling: Spring, Spring Cloud, Netflix**
- Building a Simple Microservice System



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Microservices made-easy by Spring

- Setup a new service using Spring Boot
- Expose resources via a RestController
- Consume remote services using RestTemplate
- Will leverage capabilities from *Spring Cloud Project*



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What is Spring Cloud?



- Building blocks for Cloud and Microservice applications
 - Microservices Infrastructure
 - Provides useful services such as Service Discovery, Configuration Server and Monitoring
 - Several based on other Open Source projects
 - Netflix OSS, HashiCorp's Consul, ...
 - Platform Support
 - Access platform-specific information and services
 - Available for Cloud Foundry, AWS and Heroku
 - Uses Spring Boot style starters
 - Requires Spring Boot to work

HASHICORP

NETFLIX | OSS



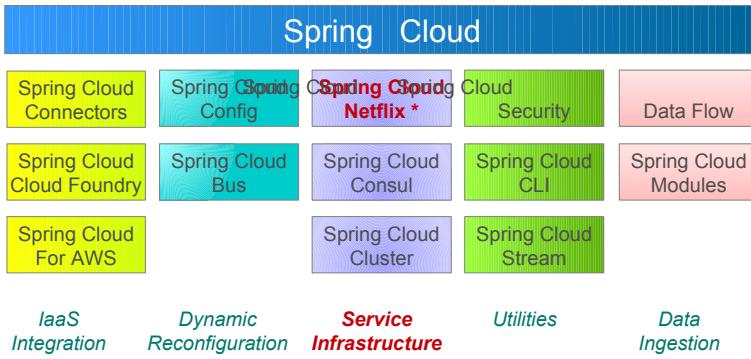
<http://projects.spring.io/spring-cloud>

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* Today we only have time

to look at the Netflix project

Spring Cloud Ecosystem



Spring Cloud is at <http://projects.spring.io/spring-cloud/>



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Spring Cloud Usage Examples

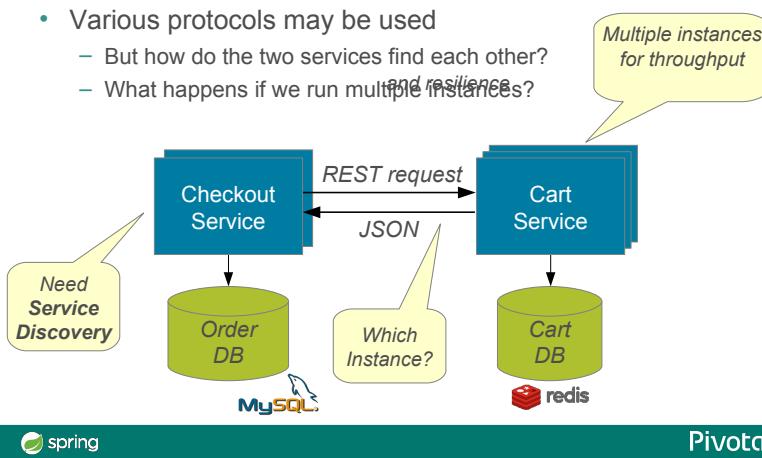


- There are *many* use-cases supported by Spring Cloud
 - Cloud Integration, Dynamic Reconfiguration, Service Discovery, Security, Data Ingestion
- Today we concentrate on *microservices* support
 - **Service Discovery**
 - How do the services find each other?
 - **Client-side Load Balancing**
 - Each service typically deployed as multiple instances
 - For fault-tolerance and load-sharing
 - How do we decide which service *instance* to use?

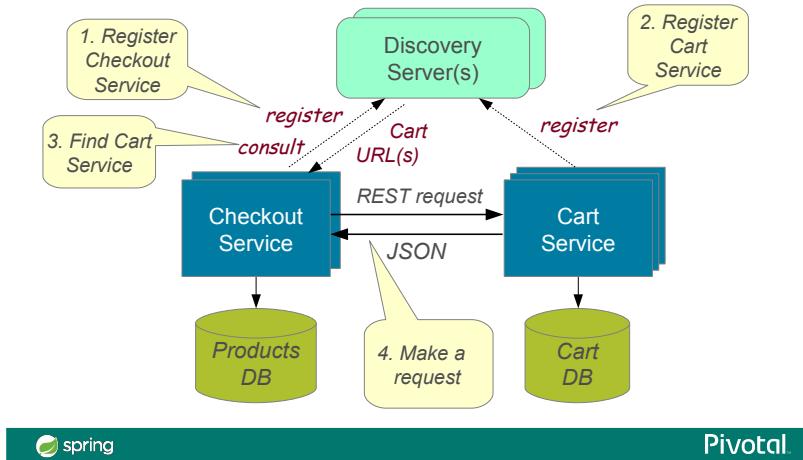


Why We Need Service Discovery – 1

- Various protocols may be used
 - But how do the two services find each other?
 - What happens if we run multiple instances?



Why We Need Service Discovery – 2



Implementing Service Discovery

- Spring Cloud supports several
 - We will use Eureka
 - Created by Netflix
 - Consul.io is another option
 - Hashicorp project (inventors of Vagrant)
- Spring Cloud makes it easy
 - To utilize either of those servers
 - Hiding their internal complexity

NETFLIX | OSS

HASHICORP



See also: <http://spring.io/blog/2015/07/14/microservices-with-spring>



Implementing Client-Side Load Balancing

- Discovery server may return the location of *multiple* instances
 - Recall: multiple instances for resilience and load-sharing
 - Client needs to pick one
- We will use Netflix Ribbon
 - Provides several algorithms for client-side load-balancing
- Spring provides a smart RestTemplate
 - Service-discovery and load-balancing built-in
 - @LoadBalanced



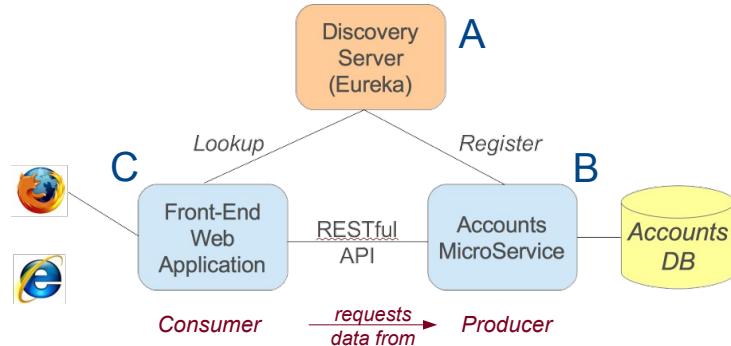
Roadmap



- What is Microservices Architecture?
- Pros and Cons of Microservices
- Managing Microservices
- Tooling: Spring, Spring Cloud, Netflix
- **Building a Simple Microservice System**



Our Simple Microservice System



spring

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Building our Simple Microservice System

- A) Run a Discovery Service
 - We will see how to create a Eureka Discovery Service
- B) Run a Microservice (the Producer)
 - Ensure it registers itself with the Discovery Service
 - Registers its *logical* service name with A
- C) How do Microservice Consumers find service B?
 - Discovery client using a “smart” RestTemplate
 - Spring performs service lookup for you
 - Uses *logical* service names in URLs

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Maven Dependencies



Dependencies for A, B & C. Spring Cloud is based on Spring Boot

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(A) Eureka Server using Spring Cloud

- All you need to implement your own registry service!

Not a client

```
@SpringBootApplication
@EnableEurekaServer
public class EurekaApplication {

    public static void main(String[] args) {
        SpringApplication.run(EurekaApplication.class, args);
    }
}
```

application.yml

```
server:
  port: 8761

eureka:
  instance:
    hostname: localhost
  client:
    registerWithEureka: false
    fetchRegistry: false
```

main.java

pom.xml

```
<dependency>
    <groupId>org.springframework.cloud</groupId>
    <artifactId>spring-cloud-starter-eureka-server</artifactId>
</dependency>
```

spring

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(B) Accounts Producer Microservice

Performs Service Registration

- Microservice declares itself as an available service
 - Using `@EnableDiscoveryClient`
 - Registers using its *application name*

```
@SpringBootApplication
@EnableDiscoveryClient
public class AccountsApplication {
    public static void main(String[] args) {
        SpringApplication.run(Application.class, args);
    }
}
spring:
  application:
    name: accounts-microservice
eureka:
  client:
    serviceUrl:
      defaultZone: http://localhost:8761/eureka/
```



(C) Consumer Service – Step 1

Enable our consumer to find the producer

- Same annotation *also* allows service *lookup*

```
@SpringBootApplication
@EnableDiscoveryClient
public class FrontEndApplication {

    public static void main(String[] args) {
        SpringApplication.run(Application.class, args);
    }

    // Will use this template to access the microservice
    // Spring will enhance this to do service discovery
    @Bean @LoadBalanced
    public RestTemplate restTemplate() {
        return new RestTemplate();
    }
}
```

Same annotation as (B) –
allows us to query Discovery
Server to *find* microservices



(C) Consumer Service – Step 2

Let our consumer use the producer

```
@Service  
public class RemoteAccountManager implements AccountService {  
  
    // Spring injects the “smart” service-aware template  
    // defined on previous slide  
    // It performs a load-balanced lookup (see next slide)  
    @Autowired  
    @LoadBalanced  
    RestTemplate restTemplate;  
  
    public Account findAccount(String id) {  
        // Fetch data  
        return restTemplate.getForObject  
            ("http://accounts-microservice/accounts/{id}",  
             Account.class, id);  
    }  
}
```

Service name



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Load Balanced RestTemplate

- Create using `@LoadBalanced` – an `@Qualifier`
 - Spring enhances it to do service lookup & load-balancing

```
@Bean @LoadBalanced  
public RestTemplate restTemplate() {  
    return new RestTemplate();  
}
```

- Must inject using same qualifier
 - If there are multiple RestTemplates you get the right one
 - Can be used to access multiple microservices

```
@Autowired  
@LoadBalanced  
RestTemplate restTemplate;
```



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Load Balancing with Ribbon

- Our “smart” RestTemplate automatically integrates *two* Netflix utilities
 - “Eureka” service-discovery
 - “Ribbon” client-side load-balancer
- End result
 - Eureka returns the URL of all available instances
 - Ribbon determines the best available service to use
- Just inject the load-balanced **RestTemplate**
 - Automatic lookup by *logical* service-name



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Spring Cloud Resources



- We have only covered a *few* Spring Cloud features
 - Project Home page
 - <http://projects.spring.io/spring-cloud>
 - Matt Stine's *free* book on Cloud Native Architectures
 - <https://pivotallabs.com/migrating-to-cloud-native-application-architectures-ebook>
 - Spring Blog article
 - <https://spring.io/blog/2015/07/14/microservices-with-spring>

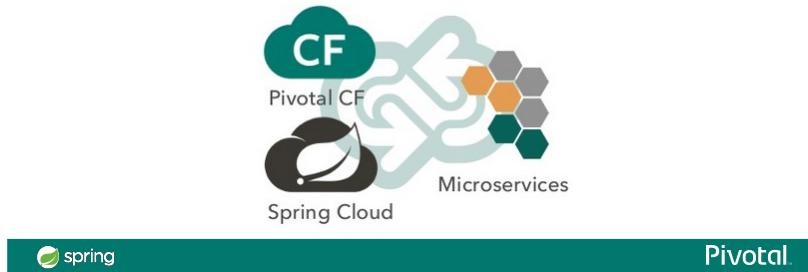
Consider taking our **Spring Cloud Services** course
See: <http://pivotallabs.com/academy>



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Summary

- After completing this lesson, you should have learned:
 - What is a Microservice Architecture?
 - Advantages and Challenges of Microservices
 - A little bit about Spring Cloud projects



Finishing Up

Course Completed

What's Next?

What's Next

- Congratulations, we've finished the course
- What to do next?
 - Certification
 - Other courses
 - Resources
 - Evaluation
- Check-out optional sections on Remoting and SOAP web-services



Certification



- Computer-based exam
 - 50 multiple-choice questions
 - 90 minutes
 - Passing score: 76% (38 questions answered successfully)
- Preparation
 - Review all the slides
 - Redo the labs
 - Study Guide available online

<https://pivotal.io/academy/certification>



Certification: Questions



Sample question

- Statements
 - a. An application context holds Spring beans
 - b. An application context manages bean scope
 - c. Spring provides many types of application context
- Pick the correct response:
 1. Only a. is correct
 2. Both a. and c. are correct
 3. All are correct
 4. None are correct



Certification: Logistics

- Where?
 - Online at PSI (Innovative Exams)
 - <https://www.examslocal.com>
- How?
 - You should receive a certification voucher by email
 - Register/sign-in and book an exam using the voucher
 - <http://it.psionline.com/exam-faqs/pivotal-faq>
 - Take the test from *any* location
- For more information, email
 - education@pivotal.io

Voucher is
valid for 3 months
– *do it soon!*



Other courses



- Many courses available
 - Spring Web
 - Enterprise Spring
 - Spring Boot Developer
 - Spring Cloud Services (Microservices with Spring)
 - Pivotal Cloud Foundry Developer
 - Pivotal Cloud Foundry Administration
 - Big Data and Analytics, Hadoop, Gemfire, ...
- See <https://pivotal.io/academy>



Spring Web



- Four-day workshop
- Making the most of Spring in the web layer
 - Spring MVC using Spring Boot
 - REST using MVC and AJAX, CORS
 - Security of Web applications
 - Mock MVC testing framework
 - Spring Web Sockets
- Spring Web Application Developer certification



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Enterprise Spring



- Building loosely coupled event-driven architectures
 - Separate processing, communications & integration
- 4 day course covering
 - Tasks, Scheduling and Concurrency
 - Advanced transaction management
 - REST Web Services with Spring MVC
 - Spring Integration
 - Spring Batch
 - Data Ingestion and Transformation



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Spring Boot Developer



- 2 day workshop covering
 - Getting started with Spring Boot
 - Spring Boot CLI
 - Configuration, auto-configuration and profiles
 - Web development and REST
 - Data Access: JDBC, JPA, Spring Data, NoSQL
 - Testing
 - Security, Messaging
 - Deployment, Metrics, Actuator
 - Microservices



Spring Cloud Services Microservices With Spring



- Course topics:
 - Introduction to Spring Boot
 - Underpins all Spring Cloud projects
 - Pushing Applications to a PaaS
 - Using Pivotal Cloud Foundry
 - What are Microservices?
 - Architecting a microservices solution
 - Cloud infrastructure services and Netflix OSS
 - Service Configuration
 - Service Registration
 - Load-balancing and fault tolerance
 - Security using OAuth



Cloud Foundry Developer



CLOUD FOUNDRY

- 3 day course covering
 - Application deployment to Cloud Foundry
 - Deployment using `cf` tool or an IDE
 - Using the PCF Application Manager
 - Cloud Foundry Concepts
 - Logging, Continuous Integration, Monitoring
 - Accessing and defining Services
 - Using and customizing Buildpacks
 - Design considerations: “12 Factor”
 - JVM application specifics, using Spring Cloud

Formerly: Developing Applications with Cloud Foundry



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Cloud Foundry Administration



CLOUD FOUNDRY

- 5 day course covering
 - Application deployment to Cloud Foundry
 - Logging, scaling, blue-green deployments
 - “Day 1 Operations”
 - Installation of PCF Ops Manager and Elastic Runtime
 - Configuring users, roles, and quotas
 - Capturing and reading logs
 - “Day 2 Operations”
 - Backing up and restoring an installation
 - Using BOSH
 - Upgrading Ops Manager and tiles.



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Pivotal Support Offerings

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- Pivotal Labs
 - Agile development experts
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Resources



- The Spring reference documentation
 - <http://spring.io/docs>
 - <http://projects.spring.io/spring-boot>
 - <http://projects.spring.io/spring-data>
 - <http://projects.spring.io/spring-security>
 - <http://projects.spring.io/spring-cloud>
- The official technical blog
 - <http://spring.io/blog>
- Stack Overflow – Active Spring Forums
 - <http://stackoverflow.com>



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Resources (2)

- You can register issues on our Jira repository
 - <https://jira.spring.io>
- The source code is available here
 - <https://github.com/spring-projects/spring-framework>



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Thank You!

- We hope you enjoyed the course
- Please fill out the evaluation form
 - Americas: <http://tinyurl.com/usa-eval>
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Don't forget the optional sections



XML Dependency Injection

Advanced Features & Best Practices

Techniques for Creating Reusable and Concise Bean Definitions

Topics in this session

- **Singletons and Factory Beans**
- Constructor Arguments
- 'p' and 'c' namespaces
- Using Bean definition inheritance
- Inner Beans
- Lab
- Advanced Features
 - SpEL, Autowiring, Collections



Advanced Bean Instantiation

- Four techniques:
 - @Bean method in @Configuration class
 - 100% Java code available, write whatever code you need
 - Beans implementing Spring's FactoryBean interface
 - Use XML factory-method attribute for Singletons
 - Define your own factories as Spring Beans in XML }?



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Using a Java Singleton

- How can Spring instantiate the following?
 - Classes with private constructors (such as Singleton pattern below)

```
public class AccountServiceSingleton implements AccountService {  
    private static AccountServiceSingleton inst = new AccountServiceSingleton();  
  
    private AccountServiceSingleton() { ... }  
  
    public static AccountService getInstance() {  
        // ...  
        return inst;  
    }  
}
```



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The factory-method Attribute

- Non-intrusive
 - Useful for existing Singletons or Factories

```
public class AccountServiceSingleton implements AccountService {  
    ...  
    public static AccountService getInstance() { // ... }  
}
```

```
<bean id="accountService" class="com.acme.AccountServiceSingleton"  
      factory-method="getInstance" />
```

Spring configuration

```
AccountService service1 = (AccountService) context.getBean("accountService");  
AccountService service2 = (AccountService) context.getBean("accountService");
```

Spring uses **getInstance()** method – so
service1 and service2 point to the *same* object

Test class



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Using Your Own Factories

- Spring allows one bean to create another
 - Create an instance of your factory as a bean
 - Use it to create another bean

```
<bean id="accountServiceFactory" class="com.acme.AccountServiceFactory">  
    <!-- any constructor-arg or property elements you need -->  
  </bean>  
  
<bean id="accountService" factory-bean="accountServiceFactory"  
      factory-method="create" />
```

Spring configuration

The **class** attribute is *illegal* here
Will be determined by the factory



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Topics in this session

- Singletons and Factory Beans
- **Constructor Arguments**
- 'p' and 'c' namespaces
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More on Constructor Args

- Constructor args matched by type
 - `<constructor-arg>` elements can be in
 - When ambiguous: indicate order with *index*

```
class MailService {  
    public MailService(String username, String email) { ... }
```

Both are Strings

```
<bean name="example" class="com.app.MailService">  
    <constructor-arg index="0" value="foo"/>  
    <constructor-arg index="1" value="foo@foo.com"/>  
</bean>
```

Index from zero



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Using Constructor Types

- Can also specify the type
 - Typically when class has multiple ambiguous constructors

```
class MailService {  
    public MailService(String username) { ... }  
    public MailService(int maxMessages) { ... }
```

```
<bean name="example" class="com.app.MailService">  
    <constructor-arg type="int" value="2000"/>  
</bean>
```

Is a String in XML
Force use of second constructor
Without type, Spring passes "2000" as the username



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Using Constructor Names

- Constructor args can have names for matching
- Must be using Java 8 or later
 - OR: Need to compile with debug-symbols enabled
 - OR: Use `@java.beans.ConstructorProperties`

```
class MailService {  
    @ConstructorProperties( { "username", "email" } )  
    public MailService(String username, String email) { ... }
```

Specify arg names in order

```
<bean name="example" class="com.app.MailService">  
    <constructor-arg name="username" value="foo"/>  
    <constructor-arg name="email" value="foo@foo.com"/>  
</bean>
```

No index needed



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Topics in this session

- Singletons and Factory Beans
- Constructor Arguments
- **'p' and 'c' namespaces**
- Using Bean definition inheritance
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The *c* and *p* namespaces

- Before

```
<bean id="transferService" class="com.acme.BankServiceImpl"
    <constructor-arg ref="bankRepository"
    <property name="accountService" ref="accountService" />
    <property name="customerService" ref="customerService" />
</bean>
```

- After

```
<bean id="transferService" class="com.acme.BankServiceImpl"
    c:bankRepository-ref="bankRepository"
    p:accountService-ref="accountService"
    p:customer-service-ref="customerService" />
```

Use camel case or hyphens



c namespace is newer, introduced in Spring 3.1



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The c and p namespaces

- c and p namespaces should be declared on top
 - Use '-ref' suffix for references

```
<beans xmlns:c="http://www.springframework.org/schema/c"
       xmlns:p="http://www.springframework.org/schema/p"
       ...>

    <bean id="transferService" class="com.acme.ServiceImpl"
          p:url="jdbc://..." p:service-ref="otherService" />
</beans>
```

Namespace declaration

Inject value for property 'url'

Inject reference to bean 'otherService'



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No schemaLocation needed

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

p and c namespace definitions

no extra schemaLocation entry required (no xsd)



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'c' and 'p' Pros and Cons

- Pros
 - More concise
 - Well supported in STS
 - CTRL+space works well
- Cons
 - Less widely known than the usual XML configuration syntax



Topics in this session

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- **Using Bean definition inheritance**
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Bean Definition Inheritance (1)

- Sometimes several beans need to be configured in the same way
- Use bean definition inheritance to define the common configuration once
 - Inherit it where needed



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Without Bean Definition Inheritance

```
<beans>
    <bean id="pool-A" class="org.apache.commons.dbcp.BasicDataSource">
        <property name="URL" value="jdbc:postgresql://server-a/transfer" />
        <property name="user" value="moneytransfer-app" />
    </bean>

    <bean id="pool-B" class="org.apache.commons.dbcp.BasicDataSource">
        <property name="URL" value="jdbc:postgresql://server-b/transfer" />
        <property name="user" value="moneytransfer-app" />
    </bean>

    <bean id="pool-C" class="org.apache.commons.dbcp.BasicDataSource">
        <property name="URL" value="jdbc:postgresql://server-c/transfer" />
        <property name="user" value="moneytransfer-app" />
    </bean>
</beans>
```

Can you find the duplication?



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Abstract Parent bean

```
<beans>
    <bean id="abstractPool"
          class="org.apache.commons.dbcp.BasicDataSource" abstract="true">
        <property name="user" value="moneytransfer-app" />
    </bean>

    <bean id="pool-A" parent="abstractPool">
        <property name="URL" value="jdbc:postgresql://server-a/transfer" />
    </bean>
    <bean id="pool-B" parent="abstractPool">
        <property name="URL" value="jdbc:postgresql://server-b/transfer" />
    </bean>
    <bean id="pool-C" parent="abstractPool">
        <property name="URL" value="jdbc:postgresql://server-c/transfer" />
        <property name="user" value="bank-app" />
    </bean>
</beans>
```

Will not be instantiated

Can override

Each pool inherits its *parent* configuration



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Default Parent Bean

```
<beans>

    <bean id="defaultPool" class="org.apache.commons.dbcp.BasicDataSource">
        <property name="URL" value="jdbc:postgresql://server-a/transfer" />
        <property name="user" value="moneytransfer-app" />
    </bean>

    <bean id="pool-B" parent="defaultPool">
        <property name="URL" value="jdbc:postgresql://server-b/transfer" />
    </bean>

    <bean id="pool-C" parent="defaultPool" class="example.SomeOtherPool">
        <property name="URL"
                  value="jdbc:postgresql://server-c/transfer" />
    </bean>

</beans>
```

Overrides URL property

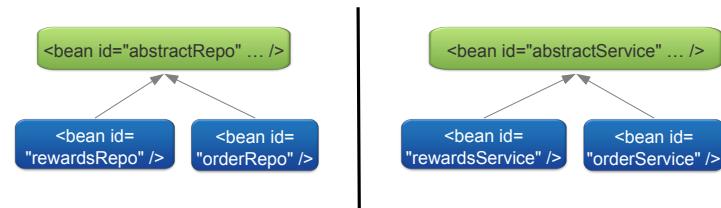
Overrides class as well



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Inheritance for service and repository beans

- Bean inheritance commonly used for definition of Repository (or DAO) beans and (less often) Services



Topics in this session

- Singletons and Factory Beans
- Constructor Arguments
- 'p' and 'c' namespaces
- Using Bean definition inheritance
- Inner Beans**
- Lab
- Advanced Features
 - SpEL, Autowiring, Collections



Inner beans

- Inner bean only visible from surrounding bean

```
<bean id="restaurantRepository"
      class="rewards.internal.restaurant.JdbcRestaurantRepository">
    <property name="benefitAvailabilityPolicy">
      <bean class="rewards...DefaultBenefitAvailabilityPolicyFactory" />
    </property>
</bean>
```

No bean id

- Cannot be accessed from the ApplicationContext

```
applicationContext.getBean(RestaurantRepository.class); ← OK
applicationContext.getBean(DefaultBenefitAvailabilityPolicyFactory.class);
```

NoSuchBeanDefinitionException!!



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Without an Inner Bean

```
<beans>
  <bean id="restaurantRepository"
        class="rewards.internal.restaurant.JdbcRestaurantRepository">
    <property name="dataSource" ref="dataSource" />
    <property name="benefitAvailabilityPolicyFactory" ref="factory" />
  </bean>
  <bean id="factory"
        class="rewards.internal.restaurant.availability.
        DefaultBenefitAvailabilityPolicyFactory">
    <constructor-arg ref="rewardHistoryService" />
  </bean>
  ...
</beans>
```

Can be referenced by other beans
(even if it should not be)



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With an Inner Bean

```
<beans>
    <bean id="restaurantRepository"
          class="rewards.internal.restaurant.JdbcRestaurantRepository">
        <property name="dataSource" ref="dataSource" />
        <property name="benefitAvailabilityPolicyFactory">
            <bean class="rewards.internal.restaurant.availability.
                DefaultBenefitAvailabilityPolicyFactory">
                <constructor-arg ref="rewardHistoryService" />
            </bean>
        </property>
    </bean>
    ...
</beans>
```

Inner bean has no id (it is anonymous)
Cannot be referenced outside this scope



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Multiple Levels of Nesting

```
<beans>
    <bean id="restaurantRepository"
          class="rewards.internal.restaurant.JdbcRestaurantRepository">
        <property name="dataSource" ref="dataSource" />
        <property name="benefitAvailabilityPolicyFactory">
            <bean class="rewards.internal.restaurant.availability.
                DefaultBenefitAvailabilityPolicyFactory">
                <constructor-arg>
                    <bean class="rewards.internal.rewards.JdbcRewardHistory">
                        <property name="dataSource" ref="dataSource" />
                    </bean>
                </constructor-arg>
            </bean>
        </property>
    </bean>
</beans>
```



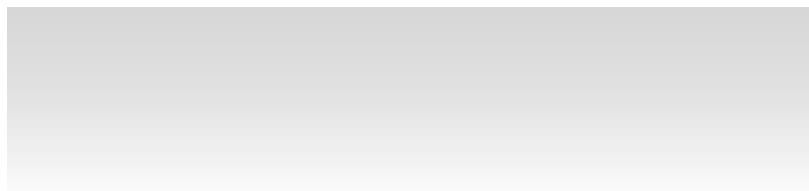
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Inner Beans: pros and cons

- Pros
 - You only expose what needs to be exposed
 - Very commonly used technique in online examples
- Cons
 - Can be harder to read
 - Avoid really deep nesting
- General recommendation
 - Use them when it makes sense
 - As for inner classes in Java
 - Complex "infrastructure beans" configuration



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Lab (Optional)

Using Bean Definition Inheritance, Property Placeholders and Namespaces



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Topics in this session

- Singletons and Factory Beans
- Constructor Arguments
- 'p' and 'c' namespaces
- More on Profiles
- Externalizing values into properties files
- Using Bean definition inheritance
- Lab
- **Advanced Features**
 - SpEL, Autowiring, Collections



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Spring Expression Language

- Can also be used in bean XML files
 - Same syntax that you have seen with @Value
 - Expressions in {} preceded by #
- Recall:
 - Can access System properties and environment
 - Properties of Spring beans



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SpEL examples – XML

```
<bean id="rewardsDb" class="com.acme.RewardsTestDatabase">
    <property name="keyGenerator"
        value="#{strategyBean.databaseKeyGenerator}" />
</bean>

<bean id="strategyBean" class="com.acme.DefaultStrategies">
    <property name="databaseKeyGenerator" ref="myKeyGenerator"/>
</bean>

<bean id="taxCalculator" class="com.acme.TaxCalculator">
    <property name="defaultLocale" value="#{ systemProperties['user.region'] }"/>
</bean>
```

Can refer a nested property

Equivalent to System.getProperty(...)



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SpEL Examples – Other Spring Projects

- In Spring Security

```
<security:intercept-url pattern="/accounts/**"
    access="isAuthenticated() and hasIpAddress('192.168.1.0/24') />
```

- In Spring Batch

```
<bean id="flatFileItemReader" scope="step"
    class="org.springframework.batch.item.file.FlatFileItemReader">
    <property name="resource" value="#{jobParameters['input.file.name']} />
</bean>
```



Spring Security will be discussed later in this course. Spring Batch is part of the "Spring Enterprise" course



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Topics in this session

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Autowiring in XML

- XML had automatic wiring (setting) of dependencies before @Autowired – it's where the name comes from
- Can select *byType* or *byName* or *byConstructor*
 - *Cannot autowire both properties and constructor-args*
 - *Is inherently confusing and limited due to this difference*

```
<!-- Autowire properties (setters) by type matching just like @Autowired -->
<bean id="rewardsDb" autowire="byType" ... />

<!-- Autowire properties by name – just like @Resource -->
<bean id="accountManager" autowire="byName" ... />

<!-- Autowire constructors only by type – just like @Autowired -->
<bean id="accountManager" autowire="byConstructor" ... />
```



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beans and *util* collections

- *beans* collections
 - From the default *beans* namespace
 - Simple and easy, legacy from Spring V1
- *util* collections
 - From the *util* namespace
 - Requires additional namespace declaration
 - More features available, since Spring V2



Both offer support for *set*, *map*, *list* and *properties* collections



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Using the *beans* namespace

```
<bean id="service" class="com.acme.service.TransferServiceImpl">
    <property name="customerPolicies">
        <list>
            <ref bean="privateBankingCustomerPolicy"/>
            <ref bean="retailBankingCustomerPolicy"/>
            <bean class="com.acme.DefaultCustomerPolicy"/>
        </list>
    </property>
</bean>
```

```
public void setCustomerPolicies(java.util.List policies) { .. }
```

Equivalent to:

```
TransferServiceImpl service = new TransferServiceImpl();
service.setCustomerPolicies(list); // create list with bean references
```

ApplicationContext

```
service -> instance of TransferServiceImpl
```



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beans collections limitation

- Can't specify the collection type
 - Example: *java.util.List* implementation is always *ArrayList*
- Collection has no bean id
 - Can't be accessed from the ApplicationContext
 - Only valid as inner beans

```
<bean id="service" class="com.acme.service.TransferServiceImpl">
    <property name="customerPolicies">
        <list> ... </list>
    </property>
</bean>
```

OK

NoSuchBeanDefinitionException!!

```
applicationContext.getBean("service");
applicationContext.getBean("customerPolicies");
```



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Injecting a Set or Map

- Similar support available for Set

```
<property name="customerPolicies">
<set>
    <ref bean="privateBankingCustomerPolicy"/>
    <ref bean="retailBankingCustomerPolicy"/>
</set>
</property>
```

- Map (through map / entry / key elements)

```
<property name="customerPolicies">
<map>
    <entry key="001-pbcn" value-ref="privateBankingCustomerPolicy"/>
    <entry key-ref="keyBean" value-ref="retailBankingCustomerPolicy"/>
</map>
</property>
```

Key can use primitive type or ref to bean

value also supported



Injecting a collection *Properties*

- Convenient alternative to a dedicated properties file
 - Use when property values are unlikely to change

```
<property name="config">
<value>
    server.host=mailer
    server.port=1010
</value>
</property>
```

```
<property name="config">
<props>
    <prop key="server.host">mailer</prop>
    <prop key="server.port">1010</prop>
</props>
</property>
```

```
public void setConfig(java.util.Properties props) { .. }
```



util collections

- **util:** collections allow:
 - specifying collection implementation-type and scope
 - declaring a collection as a top-level bean

```
<bean id="service" class="com.acme.service.TransferServiceImpl"
      p:customerPolicies-ref="customerPolicies"/>

<util:set id="customerPolicies" set-class="java.util.TreeSet">
    <ref bean="privateBankingCustomerPolicy"/>
    <ref bean="retailBankingCustomerPolicy"/>
</util:set>
```

bean id

Implementation class

Also: util:list, util:map, util:properties



beans or *util* collections?



- In most cases, the default collection elements in the beans namespace will suffice
 - But can *only* be inner beans
- Just remember the additional collection features in the **<util/>** namespace, in case you might need them
 - Declare a collection as a top-level bean
 - Specify collection implementation-type
- In the long-run, simpler to always use the **<util/>** namespace collection elements



Summary

- Spring offers many techniques to simplify XML configuration
 - We've seen just a few here
 - It's about expressiveness and elegance, just like code
- Best practices we've discussed are used widely by many existing Spring XML projects
 - Imports, Bean Inheritance, Inner Beans ...
- Other features are more specialized



Object Relational Mapping

Using OR Mapping in the Enterprise

Fundamental Concepts and Concerns

Topics in this session

- The Object/Relational mismatch
- ORM in context
- Benefits of O/R Mapping

The Object/Relational Mismatch (1)

- A domain object model is designed to serve the needs of the application
 - Organize data into abstract concepts that prove useful to solving the domain problem
 - Encapsulate behavior specific to the application
 - Under the control of the application developer



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The Object/Relational Mismatch (2)

- Relational models relate business data and are typically driven by other factors:
 - Performance
 - Space
- Furthermore, a relational database schema often:
 - Predates the application
 - Is shared with other applications
 - Is managed by a separate DBA group



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Object/Relational Mapping

- Object/Relational Mapping (ORM) engines exist to mitigate the mismatch
- Spring supports all of the major ones:
 - Hibernate
 - EclipseLink
 - Other JPA (Java Persistence API) implementations, such as OpenJPA
- This session will focus on Hibernate



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Topics in this session

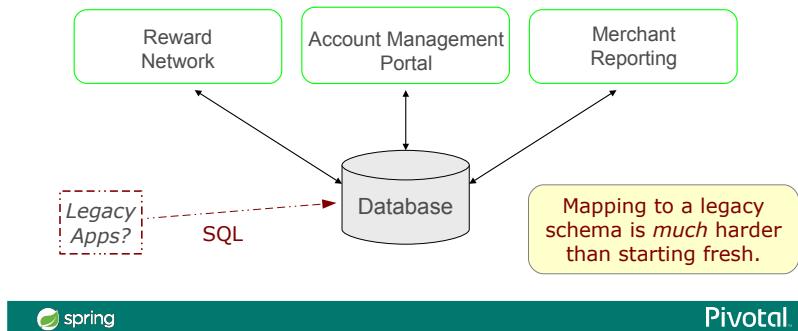
- The Object/Relational Mismatch
- **ORM in context**
- Benefits of modern-day ORM engines



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ORM in context

- For the **Reward Dining** domain
 - The database schema already exists
 - Several applications share the data



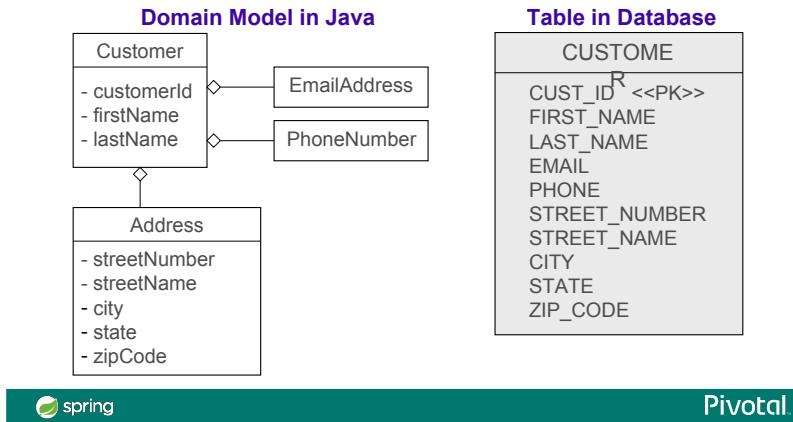
O/R Mismatch: Granularity (1)

- In an object-oriented language, cohesive fine-grained classes provide encapsulation and express the domain naturally
- In a database schema, granularity is typically driven by normalization and performance considerations



O/R Mismatch: Granularity (2)

just one example...



O/R Mismatch: Identity (1)

- In Java, there is a difference between Object identity and Object equivalence:
 - $x == y$ *identity* (same memory address)
 - $x.equals(y)$ *equivalence*
- In a database, identity is based solely on primary keys:
 - $x.getEntityId().equals(y.getEntityId())$



O/R Mismatch: Identity (2)

- When working with persistent Objects, the identity problem leads to difficult challenges
 - Two different Java objects may correspond to the same relational row
 - But Java says they are *not* equal
- Some of the challenges:
 - Implement equals() to accommodate this scenario
 - Determine when to update and when to insert
 - Avoid duplication when adding to a Collection



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O/R Mismatch: Inheritance and Associations (1)

- In an object-oriented language:
 - *IS-A* relations are modeled with inheritance
 - *HAS-A* relations are modeled with composition
- In a database schema, relations are limited to what can be expressed by *foreign keys*



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O/R Mismatch: Inheritance and Associations (2)

- Bi-directional associations are common in a domain model (e.g. Parent-Child)
 - This can be modeled naturally in each Object
- In a database:
 - One side (parent) provides a primary-key
 - Other side (child) provides a foreign-key reference
- For many-to-many associations, the database schema requires a *join table*



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Topics in this session

- The Object/Relational Mismatch
- ORM in Context
- **Benefits of O/R Mapping**



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Benefits of ORM

- Object Query Language
- Automatic Change Detection
- Persistence by Reachability
- Caching
 - Per-Transaction (1st Level)
 - Per-DataSource (2nd Level)



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Object Query Language

- When working with domain objects, it is more natural to query based on objects.
 - Query with SQL:

```
SELECT c.first_name, c.last_name, a.city, ...
      FROM customer c, customer_address ca, address a
 WHERE ca.customer_id = c.id
   AND ca.address_id = a.id
   AND a.zip_code = 12345
```

- Query with object properties and associations:

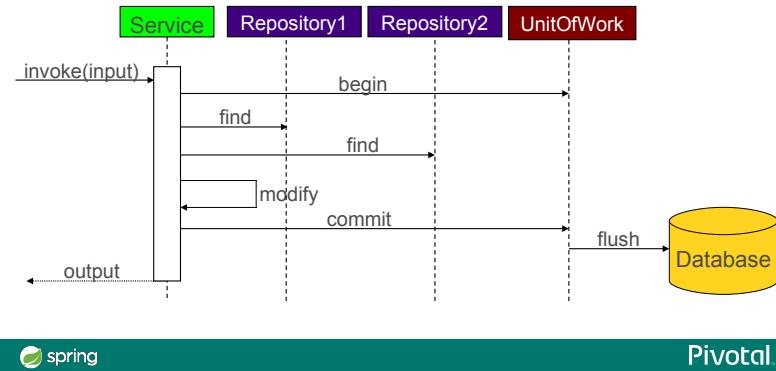
```
SELECT c FROM Customer c WHERE c.address.zipCode = 12345
```



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Automatic Change Detection

- When a unit-of-work completes, all modified state will be synchronized with the database.



Persistence by Reachability

- When a persistent object is being managed, other associated objects may become managed transparently:

```
Order order = orderRepository.findById(cid);
// order is now a managed object – retrieved via ORM

LineItem item = new LineItem(..);
order.addLineItem(item);
// item is now a managed object – reachable from order
```



(Un)Persistence by Reachability = Make Transient

- The same concept applies for deletion:

```
Order order = orderRepository.findById(cid);
// order is now a managed object – retrieved via ORM

List<LineItem> items = order.getLineItems();
for (LineItem item : items) {
    if (item.isCancelled()) { order.removeLineItem(item); }
    // the database row for this item will be deleted
}
if (order.isCancelled()) {
    orderRepository.remove(order);
    // all item rows for the order will be deleted
}
```

The diagram illustrates the state transition of objects during deletion. It shows a sequence of code within a yellow box. Annotations with arrows point to specific parts of the code:

- An annotation "Item becomes transient" points to the line `if (item.isCancelled()) { order.removeLineItem(item); }`.
- An annotation "Order and all its items now transient" points to the line `if (order.isCancelled()) { orderRepository.remove(order); }`.



Caching

- The first-level cache (1LC) is scoped at the level of a unit-of-work
 - When an object is first loaded from the database within a unit-of-work it is stored in this cache
 - Subsequent requests to load that same entity from the database will hit this cache first
- The second-level cache (2LC) is scoped at the level of the SessionFactory
 - Reduce trips to database for read-heavy data
 - Especially useful when a single application has exclusive access to the database



Summary

- Managing persistent objects is hard
 - Especially if caching is involved
 - Especially on a shared, legacy schema with existing applications
- The ORM overcomes *some* of these problems
 - Automatic change detection, queries, caching
 - Ideal if your application *owns* its database
 - It is *not* a magic-bullet
 - JDBC may still be better for some tables/queries
 - True distributed cache coherency is *very* hard
 - *Design* for it and *test* performance



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Spring Security XML Configuration

Classic configuration options for
Web Application Security

Addressing Common Security Requirements

Spring Security – XML Configuration

- Spring Security is also configurable via XML
 - Most common in older code bases
 - Some default behaviors are different.

Configuration in web.xml

- web.xml configuration remains the same
 - springSecurityFilterChain
 - May also use Servlet 3.0 initializers

```
<filter>  
    <filter-name>springSecurityFilterChain</filter-name>  
    <filter-class>  
        org.springframework.web.filter.DelegatingFilterProxy  
    </filter-class>  
</filter>  
  
<filter-mapping>  
    <filter-name>springSecurityFilterChain</filter-name>  
    <url-pattern>*</url-pattern>  
</filter-mapping>
```

web.xml



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intercept-url

- intercept-urls are evaluated in the order listed
 - first match is used, put specific matches first

```
<beans>  
    <security:http>  
  
        <security:intercept-url pattern="/accounts/edit*"  
            access="ROLE_ADMIN" />  
        <security:intercept-url pattern="/accounts/account**"  
            access="ROLE_ADMIN,ROLE_USER" />  
        <security:intercept-url pattern="/accounts/**"  
            access="IS_AUTHENTICATED_FULLY" />  
        <security:intercept-url pattern="/customers/**"  
            access="IS_AUTHENTICATED_ANONYMOUSLY" />  
  
    </security:http>  
</beans>
```



Syntax available since Spring Security 2.0



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Security EL expressions

- hasRole('role')
 - Checks whether the principal has the given role
- hasAnyRole('role1', 'role2', ...)
 - Checks whether the principal has any of the given roles
- isAnonymous()
 - Allows access for unauthenticated principals
- isAuthenticated()
 - Allows access for authenticated or remembered principals



Available from Spring Security 3.0
Previous syntax still works in Spring Security 3.0



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Intercept-url and Expression Language

- Expression Language provides more flexibility
 - Many built-in expressions available

```
<beans>
  <security:http use-expressions="true"> ←
    <!-- Expression Language needs
        to be enabled explicitly -->
    <security:intercept-url pattern="/accounts/edit**"
      access="hasRole('ROLE_ADMIN')"/>
    <security:intercept-url pattern="/accounts/account**"
      access="hasAnyRole('ROLE_ADMIN', 'ROLE_USER')"/>
    <security:intercept-url pattern="/accounts/**"
      access="isAuthenticated() and hasIpAddress('192.168.1.0/24')"/>
  </security:http>
</beans>
```



Syntax available from Spring Security 3.0



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Working with roles

- Checking if the user has one single role

```
<security:intercept-url pattern="/accounts/update*" access="hasRole('ROLE_ADMIN')"/>
```

- “or” clause

```
<security:intercept-url pattern="/accounts/update*"  
access="hasAnyRole('ROLE_ADMIN', 'ROLE_MANAGER')"/>
```

- “and” clause

```
<security:intercept-url pattern="/accounts/update*"  
access="hasRole('ROLE_ADMIN') and hasRole('ROLE_MANAGER')"/>
```

- Previous and new syntax can't be mixed

```
<security:intercept-url pattern="/accounts/update*"  
access="hasRole('ROLE_MANAGER')"/>  
<security:intercept-url pattern="/accounts/update*" access="ROLE_ADMIN"/>
```

Not correct!!



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Specifying login and logout

```
<beans ...> (Spring Security 3.1)  
"security:beans"> http pattern  
  
<security:http use-expressions="true">  
    <security:form-login login-page="/accounts/login"  
        default-target-url="/accounts/home"/>  
  
    <security:intercept-url pattern="/accounts/update*"  
        access="hasAnyRole('ROLE_ADMIN', 'ROLE_MANAGER')"/>  
  
    <security:intercept-url pattern="/accounts/**"  
        access="hasRole('ROLE_ADMIN')"/>  
  
    <security:logout logout-success-url="/home.html"/>  
...  
</security:http>
```

Exempt login page

Specify login options

Must be declared explicitly
or no logout possible
Spring configuration file



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Setting up User Login

- Default auth. provider assumes form-based login
 - This is *web* security after all
 - Must* specify form-login element
 - A basic form is provided
 - Configure to use your own login-page

```
<security:http>
  <security:form-login/>
  ...
</security:http>

<security:authentication-manager>
  <security:authentication-provider>
  ...
  </security:authentication-provider>
<security:authentication-manager>
```

Login with Username and Password

User:

Password:



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An Example Login Page

URL that indicates an authentication request

```
<form action="" method="POST">
  <input type="text" name="j_username"/>
  <br/>
  <input type="password" name="j_password"/>
  <br/>
  <input type="submit" name="submit" value="LOGIN"/>
</form>
```

The expected keys for generation of an authentication request token

login-example.jsp



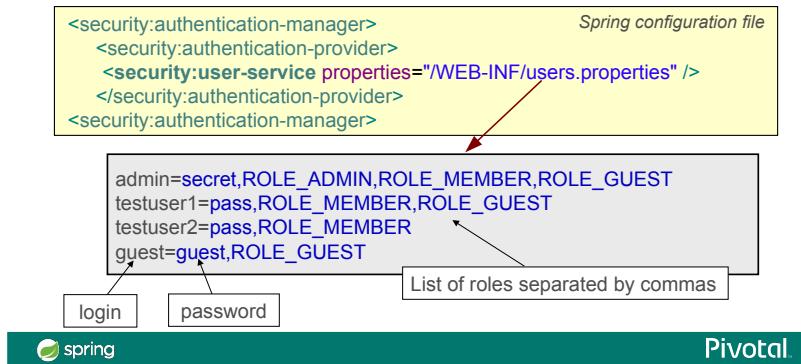
Above example shows default values (*j_spring_security_check*, *j_username*, *j_password*). All of them can be redefined using `<security:form-login/>`



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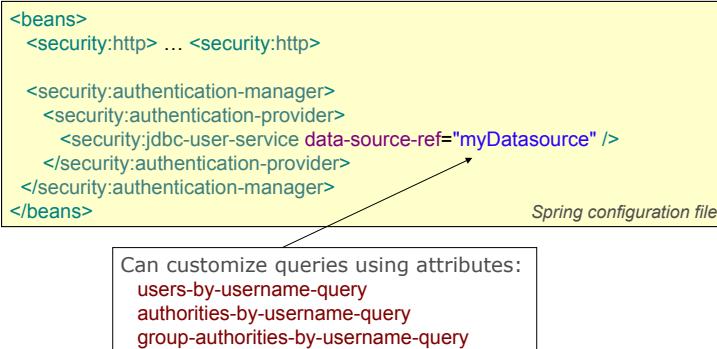
The In-Memory User Service

- Useful for development and testing
 - Note: must restart system to reload properties



The JDBC user service (2/2)

- Configuration:



Password Encoding

- Can encode passwords using a hash
 - sha, md5, ...

```
<security:authentication-provider>
    <security:password-encoder hash="sha-256" /> ← simple encoding
    <security:user-service properties="/WEB-INF/users.properties" />
</security:authentication-provider>
```

- Secure passwords using a well-known string
 - Known as a 'salt', makes brute force attacks harder

```
<security:authentication-provider>
    <security:password-encoder hash="sha-256"> ← encoding with salt
        <security:salt-source system-wide="MySalt" />
    </security:password-encoder>
    <security:user-service properties="/WEB-INF/users.properties" />
</security:authentication-provider>
```



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Method Security using XML

- Can apply security to multiple beans with only a simple declaration

```
<security:global-method-security>
    <security:protect-pointcut
        expression="execution(* com.springframework.*Service.*(..))"
        access="ROLE_USER,ROLE_MEMBER" />
</security:global-method-security>
```

Spring configuration file



Spring Security 2 syntax only. SpEL not supported here.



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Custom Filter Chain

- Filter on the stack may be **replaced** by a custom filter

```
<security:http>
  <security:custom-filter position="FORM_LOGIN_FILTER" ref="myFilter" />
</security:http>

<bean id="myFilter" class="com.mycompany.MySpecialAuthenticationFilter"/>
```

- Filter can be **added** to the chain

```
<security:http>
  <security:custom-filter after="FORM_LOGIN_FILTER" ref="myFilter" />
</security:http>

<bean id="myFilter" class="com.mycompany.MySpecialFilter"/>
```



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Spring JMS

Simplifying Messaging Applications

JmsTemplate and Spring's Listener Container

Topics in this Session

- **Introduction to JMS**
- Apache ActiveMQ
- Configuring JMS Resources with Spring
- Spring's JmsTemplate
- Sending Messages
- Receiving Messages
- Advanced Features

Java Message Service (JMS)

- The JMS API provides an abstraction for accessing Message Oriented Middleware
 - Avoid vendor lock-in
 - Increase portability
- JMS does *not* enable different MOM vendors to communicate
 - Need a bridge (expensive)
 - Or use AMQP (standard msg protocol, like SMTP)
 - See RabbitMQ



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JMS Core Components

- Message
- Destination
- Connection
- Session
- MessageProducer
- MessageConsumer



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JMS Message Types

- Implementations of the Message interface
 - TextMessage
 - ObjectMessage
 - MapMessage
 - BytesMessage
 - StreamMessage



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JMS Destination Types

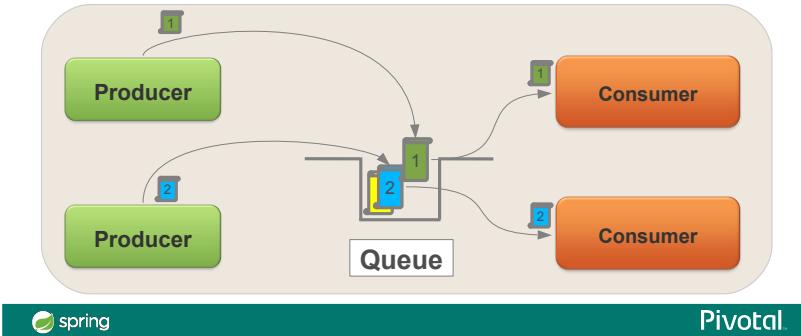
- Implementations of the Destination interface
 - Queue
 - Point-to-point messaging
 - Topic
 - Publish/subscribe messaging
- Both support *multiple* producers and consumers
 - Messages are different
 - Let's take a closer look ...



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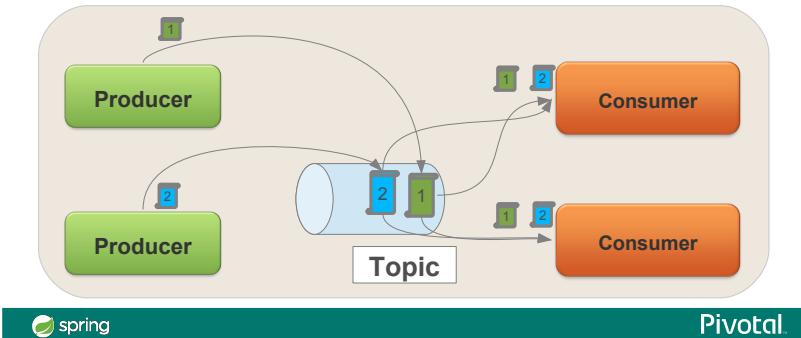
JMS Queues: Point-to-point

1. Message sent to queue
2. Message queued
3. Message consumed by *single* consumer



JMS Topics: Publish-subscribe

1. Message sent to topic
2. Message optionally stored
3. Message distributed to *all* subscribers



The JMS Connection

- A JMS Connection is obtained from a factory

```
Connection conn = connectionFactory.createConnection();
```

- Typical enterprise application:
 - ConnectionFactory is a managed resource bound to JNDI

```
Properties env = new Properties();
// provide JNDI environment properties
Context ctx = new InitialContext(env);
ConnectionFactory connectionFactory =
    (ConnectionFactory) ctx.lookup("connFactory");
```



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The JMS Session

- A Session is created from the Connection
 - Represents a unit-of-work
 - Provides transactional capability

```
Session session = conn.createSession(
    boolean transacted, int acknowledgementMode);

// use session
if (everythingOkay) {
    session.commit();
} else {
    session.rollback();
}
```



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Creating Messages

- The Session is responsible for the creation of various JMS Message types

```
session.createTextMessage("Some Message Content");

session.createObjectMessage(someSerializableObject);

MapMessage message = session.createMapMessage();
message.setInt("someKey", 123);

BytesMessage message = session.createBytesMessage();
message.writeBytes(someByteArray);
```



Producers and Consumers

- The Session is also responsible for creating instances of MessageProducer and MessageConsumer

```
producer = session.createProducer(someDestination);

consumer = session.createConsumer(someDestination);
```



Topics in this Session

- Introduction to JMS
- **Apache ActiveMQ**
- Configuring JMS Resources with Spring
- Spring's JmsTemplate
- Sending Messages
- Receiving Messages
- Advanced Features



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JMS Providers

- Most providers of Message Oriented Middleware (MoM) support JMS
 - WebSphere MQ, Tibco EMS, Oracle EMS, JBoss AP, SwiftMQ, etc.
 - Some are Open Source, some commercial
 - Some are implemented in Java themselves
- The lab for this module uses Apache ActiveMQ



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Apache ActiveMQ

- Open source message broker written in Java
- Supports JMS and many other APIs
 - Including non-Java clients!
- Can be used stand-alone in production environment
 - 'activemq' script in download starts with default config
- Can also be used *embedded* in an application
 - Configured through ActiveMQ or Spring configuration
 - *What we use in the labs*



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Apache ActiveMQ Features

Support for:

- Many cross language clients & transport protocols
 - Incl. excellent Spring integration
- Flexible & powerful deployment configuration
 - Clustering incl. load-balancing & failover, ...
- Advanced messaging features
 - Message groups, virtual & composite destinations, wildcards, etc.
- Enterprise Integration Patterns when combined with Spring Integration or Apache Camel
 - from the book by Gregor Hohpe & Bobby Woolf



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Topics in this Session

- Introduction to JMS
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Configuring JMS Resources with Spring

- Spring enables decoupling of your application code from the underlying infrastructure
 - Container provides the resources
 - Application is simply coded against the API
- Provides deployment flexibility
 - use a standalone JMS provider
 - use an application server to manage JMS resources



See: **Spring Framework Reference – Using Spring JMS**
<http://docs.spring.io/spring/docs/current/spring-framework-reference/htmlsingle/#jms>



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Configuring a ConnectionFactory

- ConnectionFactory may be standalone

```
@Bean  
public ConnectionFactory connectionFactory() {  
    ActiveMQConnectionFactory cf = new ActiveMQConnectionFactory();  
    cf.setBrokerURL("tcp://localhost:60606");  
    return cf;  
}
```

- Or retrieved from JNDI

```
@Bean  
public ConnectionFactory connectionFactory() throws Exception {  
    Context ctx = new InitialContext();  
    return (ConnectionFactory) ctx.lookup("jms/ConnectionFactory");  
}
```

```
<jee:jndi-lookup id="connectionFactory" jndi-name="jms/ConnectionFactory"/>
```



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Configuring Destinations

- Destinations may be standalone

```
@Bean  
public Destination orderQueue() {  
    return new ActiveMQQueue( "order.queue" );  
}
```

- Or retrieved from JNDI

```
@Bean  
public Destination orderQueue() throws Exception {  
    Context ctx = new InitialContext();  
    return (Destination) ctx.lookup("jms/OrderQueue");  
}
```

```
<jee:jndi-lookup id="orderQueue" jndi-name="jms/OrderQueue"/>
```



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Topics in this Session

- Introduction to JMS
- Apache ActiveMQ
- Configuring JMS Resources with Spring
- **Spring's JmsTemplate**
- Sending Messages
- Receiving Messages
- Advanced Features



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Spring's JmsTemplate

- The template simplifies usage of the API
 - Reduces boilerplate code
 - Manages resources transparently
 - Converts checked exceptions to runtime equivalents
 - Provides convenience methods and callbacks

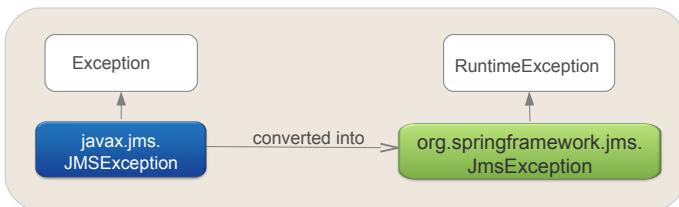
NOTE: The *AmqpTemplate* (used with RabbitMQ) has an almost identical API to the *JmsTemplate* – they offer similar abstractions over very different products



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Exception Handling

- Exceptions in JMS are checked by default
- JmsTemplate converts checked exceptions to runtime equivalents



JmsTemplate configuration

- Must provide reference to ConnectionFactory
 - via either constructor or setter injection
- Optionally provide other facilities
 - `setMessageConverter` (1)
 - `setDestinationResolver` (2)
 - `setDefaultDestination` or `setDefaultDestinationName` (3)

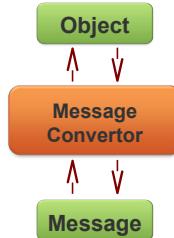
```
@Bean  
public JmsTemplate jmsTemplate () {  
    JmsTemplate template = new JmsTemplate( connectionFactory() );  
    template.setMessageConverter ( ... );  
    template.setDestinationResolver ( ... );  
    return template;  
}
```

(1), (2), (3) – see next few slides



(1) MessageConverter

- The JmsTemplate uses a **MessageConverter** to convert between objects and messages
 - You only send and receive objects
- The default **SimpleMessageConverter** handles basic types
 - String to TextMessage
 - Map to MapMessage
 - byte[] to BytesMessage
 - Serializable to ObjectMessage

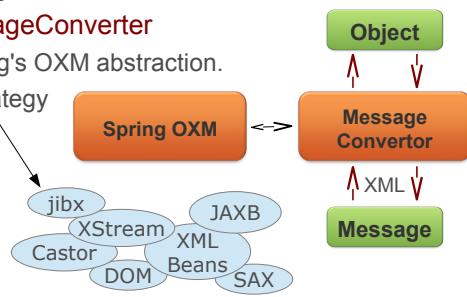


NOTE: It is possible to implement custom converters by implementing the *MessageConverter* interface



XML MessageConverter

- XML is a common message payload
 - ...but there is no "XmlMessage" in JMS
 - Use *TextMessage* instead.
- MarshallingMessageConverter**
 - Plugs into Spring's OXM abstraction.
 - You choose strategy



MarshallingMessageConverter Example

```
@Bean public JmsTemplate jmsTemplate () {  
    JmsTemplate template = new JmsTemplate( connectionFactory() );  
    template.setMessageConverter ( msgConverter() );  
    return template;  
}  
  
@Bean public MessageConverter msgConverter() {  
    MessageConverter converter = new MarshallingMessageConverter();  
    converter.setMarshaller ( marshaller() );  
    return converter;  
}  
  
@Bean public Marshaller marshaller() {  
    Jaxb2Marshaller marshaller = new Jaxb2Marshaller();  
    marshaller.setContextPath ( "example.app.schema" );  
    return marshaller;  
}
```

JAXB2 Illustrated here,
other strategies
available.



(2) DestinationResolver

- Convenient to use destination names at runtime
- DynamicDestinationResolver used by default
 - Resolves topic and queue names
 - Not their Spring bean names
- JndiDestinationResolver also available



```
Destination resolveDestinationName(Session session,  
        String destinationName,  
        boolean pubSubDomain) throws JMSEException;
```

publish-subscribe?
true q Topic
false q Queue



(3) Default Destination

- Used by default when sending *or* receiving messages

```
@Bean  
public JmsTemplate orderTemplate () {  
    JmsTemplate template = new JmsTemplate ( connectionFactory() );  
    template.setDefaultCloseOperation ( orderQueue() );  
    return template;  
}
```

Specify by Object

```
@Bean public JmsTemplate orderTemplate () {  
    JmsTemplate template = new JmsTemplate ( connectionFactory() );  
    template.setDefaultCloseOperationName ("order.queue");  
    return template;  
}
```

Specify by Name



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Topics in this Session

- Introduction to JMS
- Apache ActiveMQ
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- Sending Messages**
- Receiving Messages
- Advanced Features



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Sending Messages

- The template provides options
 - Simple methods to send a JMS message
 - One line methods that leverage the template's MessageConverter
 - Callback-accepting methods that reveal more of the JMS API
- Use the simplest option for the task at hand



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Sending POJO

- A message can be sent in one single line

```
public class JmsOrderManager implements OrderManager {  
    @Autowired JmsTemplate jmsTemplate;  
    @Autowired Destination orderQueue;  
  
    public void placeOrder(Order order) {  
        String stringMessage = "New order " + order.getNumber();  
        jmsTemplate.convertAndSend("message.queue", stringMessage );  
        // use destination resolver and message converter  
  
        jmsTemplate.convertAndSend(orderQueue, order); // use message converter  
  
        jmsTemplate.convertAndSend(order); // use converter and default destination  
    }  
}
```

No @Qualifier so Destination is wired by name



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Sending JMS Messages

- Useful when you need to access JMS API
 - eg. set expiration, redelivery mode, reply-to ...

```
public void sendMessage(final String msg) {  
    this.jmsTemplate.send( (session) -> {  
        TextMessage message = session.createTextMessage(msg);  
        message.setJMSExpiration(2000); // 2 seconds  
        return message;  
    });  
}  
  
public interface MessageCreator {  
    public Message createMessage(Session session)  
        throws JMSException;  
}
```

Lambda syntax



Topics in this Session

- Introduction to JMS
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- **Receiving Messages**
- Advanced Features



Receiving Objects

- JmsTemplate can also *receive* data
 - Automatically converted using MessageConverter
 - Underlying messages hidden

```
public void receiveData() {  
  
    // use message converter and destination resolver  
    String s = (String) jmsTemplate.receiveAndConvert("message.queue");  
    // use message converter  
    Order order1 = (Order) jmsTemplate.receiveAndConvert(orderQueue);  
    // use message converter and default destination  
    Order order2 = (Order) jmsTemplate.receiveAndConvert();  
}
```



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Receiving Messages

- Or you may access the underlying message
 - Gives you access to message properties

```
public void receiveMessages() {  
  
    // handle JMS native message from default destination  
    ObjectMessage orderMessage = (ObjectMessage) jmsTemplate.receive();  
    Order order2 = (Order) orderMessage.getObject();  
  
    // receive(destination) and receive(destinationName) also available  
}
```



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Synchronous Message Exchange

- JmsTemplate also implements a request/reply pattern
 - Using `sendAndReceive()`
 - Sending a message and blocking until a reply has been received (also uses `receiveTimeout()`)
 - Manage a temporary reply queue automatically by default

```
public void processMessage(String msg) {  
  
    Message reply = jmsTemplate.sendAndReceive("message.queue",  
        (session) -> {  
            return session.createTextMessage(msg);  
        });  
    // handle reply  
}
```



Asynchronous or Synchronous

Sync
Async

- Sending messages is asynchronous
 - The send methods return immediately
 - Even if the message takes time to be delivered
 - Recall the acknowledgement modes in `createSession()`
- But `receive()` and `receiveAndConvert()` are blocking
 - Synchronous – will wait for ever for a new message
 - optional timeout: `setReceiveTimeout()`
- How can we receive data asynchronously?
 - JMS defines *Message Driven Beans*
 - But you normally need a full JEE container to use them



Spring's MessageListener Containers

- Spring provides containers for asynchronous JMS reception
 - *SimpleMessageListenerContainer*
 - Uses plain JMS client API
 - Creates a fixed number of Sessions
 - *DefaultMessageListenerContainer*
 - Adds transactional capability
- Many configuration options available for each container type



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Quick Start

Steps for Asynchronous Message Handling

- (1) Define POJO / Bean to process Message
- (2) Define JmsListenerContainerFactory / Enable Annotations
- (3) Annotate POJO to be message-driven



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Step (1)

Define POJO / Bean to Process Message

- Define a POJO to process message

- Note: No references to JMS

```
public class OrderServiceImpl {
    @JmsListener(destination="queue.order")
    @SendTo("queue.confirmation")
    public OrderConfirmation order(Order o) { ... }
}
```

- Define as a Spring bean using XML, JavaConfig, or annotations as preferred
 - @**JmsListener** enables a JMS message consumer for the method
 - @**SendTo** defines response destination (optional)

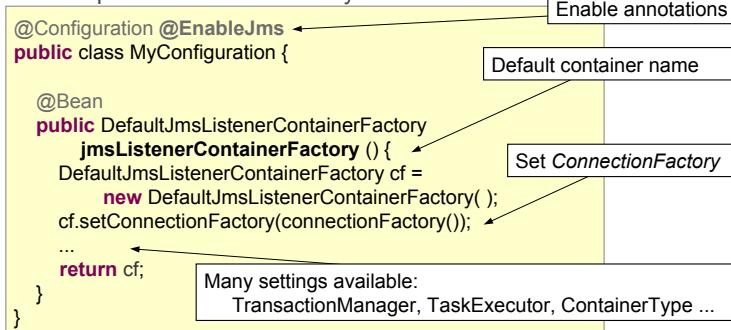
Step (2)

Define JmsListenerContainerFactory to use

- JmsListenerContainerFactory

- Separates JMS API from your POJO:

```
@Configuration @EnableJms
public class MyConfiguration {
    @Bean
    public DefaultJmsListenerContainerFactory
        jmsListenerContainerFactory() {
        DefaultJmsListenerContainerFactory cf =
            new DefaultJmsListenerContainerFactory();
        cf.setConnectionFactory(connectionFactory());
        ...
        return cf;
    }
}
```



The diagram illustrates the configuration of the `jmsListenerContainerFactory()` method. It shows the following annotations and their corresponding configurations:

- `@Configuration @EnableJms`: Points to a yellow box labeled "Enable annotations".
- `@Bean`: Points to a yellow box labeled "Default container name".
- `public DefaultJmsListenerContainerFactory`: Points to a yellow box labeled "Set ConnectionFactory".
- `jmsListenerContainerFactory()`: Points to a yellow box labeled "Many settings available: TransactionManager, TaskExecutor, ContainerType ...".
- `new DefaultJmsListenerContainerFactory()`: Points to the same yellow box labeled "Many settings available: TransactionManager, TaskExecutor, ContainerType ...".
- `cf.setConnectionFactory(connectionFactory());`: Points to the same yellow box labeled "Many settings available: TransactionManager, TaskExecutor, ContainerType ...".
- `...`: Points to the same yellow box labeled "Many settings available: TransactionManager, TaskExecutor, ContainerType ...".
- `return cf;`: Points to the same yellow box labeled "Many settings available: TransactionManager, TaskExecutor, ContainerType ...".

Step (3)

Define Receiving Method with @JmsListener

- Container with name **jmsListenerContainerFactory** is used by default

```
public class OrderServiceImpl {
    @JmsListener(containerFactory="myFactory",
                 destination="orderConfirmation")
    public void process(OrderConfirmation o) { ... }
}
```

- Can also set a custom concurrency or a payload selector

```
public class OrderServiceImpl {
    @JmsListener(selector="type = 'Order'",
                 concurrency="2-10", destination = "order")
    public OrderConfirmation order(Order o) { ... }
}
```



Using JMS: Pros and Cons

- Advantages
 - Application freed from messaging concerns
 - Resilience, guaranteed delivery (compare to REST)
 - Asynchronous support built-in
 - Interoperable – languages, environments
- Disadvantages
 - Requires additional third-party software
 - Can be expensive to install and maintain
 - More complex to use – *but not with JmsTemplate!*

Spring Enterprise – 4 day course on application integration



Lab

Sending and Receiving Messages in a Spring Application

Coming Up: Spring's Caching Connection Factory



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Topics in this Session

- Introduction to JMS
- Apache ActiveMQ
- Configuring JMS Resources with Spring
- Spring's JmsTemplate
- Sending Messages
- Receiving Messages
- **Optional Features**
 - **Using XML**



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Alternative Step (2)

Use JMS XML Namespace Support

- Equivalent Capabilities
 - The **containerId** attribute exposes the configuration of the container with that name
 - Same configuration options available
 - task execution strategy, concurrency, container type, transaction manager and more

```
<jms:annotation-driven>  
  
<jms:listener-container  
    containerId="jmsMessageContainerFactory"  
    connection-factory="myConnectionFactory"/>  
  
<bean id="orderService" class="org.acme.OrderService"/>
```



100% XML Equivalent

- Use *jms:listener-container* with embedded *jms:listeners*
 - Supports multiple listeners in a single declaration
 - Same configuration options available

```
<jms:listener-container connection-factory="myConnectionFactory">  
    <jms:listener destination="order.queue"  
        ref="orderService"  
        method="order"  
        response-destination="confirmation.queue" />  
    <jms:listener destination="confirmation.queue"  
        ref="orderService"  
        method="confirm" />  
</jms:listener-container>  
  
<bean id="orderService" class="org.acme.OrderService"/>
```

No need for `@JmsListener`



Message-Driven POJO in XML

- Listener unpacks incoming payload
 - Uses the MessageConverter
 - Invokes method on POJO
 - Return value sent to response-destination after conversion

```
public class OrderService { ①  
    public OrderConfirmation order(Order o) {  
        ②  
    } ③
```

```
<jms:listener  
    ref="orderService" ①  
    method="order" ②  
    destination="queue.orders"  
    response-destination="queue.confirmation"/>
```



CachingConnectionFactory

- JmsTemplate aggressively closes and reopens resources like Sessions and Connections
 - Lots of overhead and poor performance
 - Normally these are cached by connection factory
- Use our *CachingConnectionFactory* to add caching within the application if needed

```
<bean id="connectionFactory"  
    class="org.springframework.jms.connection.CachingConnectionFactory">  
    <property name="targetConnectionFactory">  
        <bean class="org.apache.activemq.ActiveMQConnectionFactory">  
            <property name="brokerURL" value="vm://embedded?broker.persistent=false"/>  
        </bean>  
    </property>  
</bean>
```



Performance and Operations

Management and Monitoring of Spring Java Applications

Exporting Spring Beans to JMX

Topics in this Session

J M X

- **Introduction**
- JMX
- Introducing Spring JMX
- Automatically exporting existing MBeans
- Spring Insight

Overall Goals

- Gather information about application during runtime
- Dynamically reconfigure app to align to external occasions
- Trigger operations inside the application
- Even adapt to business changes in smaller scope



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Topics in this Session

- Introduction
- **JMX**
- Introducing Spring JMX
- Automatically exporting existing MBeans
- Spring Insight



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What is JMX?

- The **Java Management Extensions** specification aims to create a standard API for adding management and monitoring to Java applications
- Management
 - Changing configuration properties at runtime
- Monitoring
 - Reporting cache hit/miss ratios at runtime



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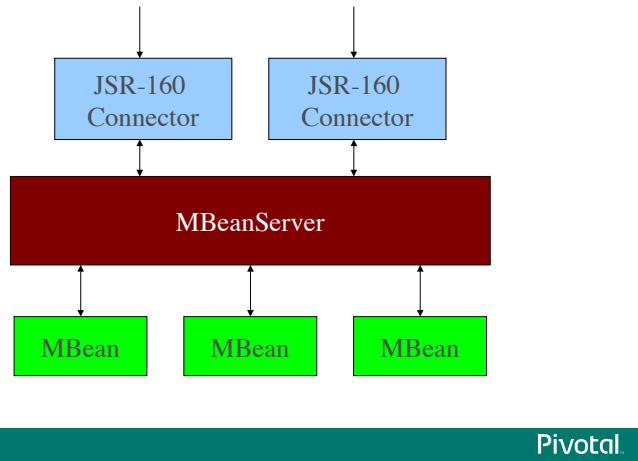
How JMX Works

- To add this management and monitoring capability, JMX instruments application components
- JMX introduces the concept of the MBean
 - An object with management metadata



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JMX Architecture



JMX Architecture

- MBeanServer acts as broker for communication between
 - Multiple local MBeans
 - Remote clients and MBeans
- MBeanServer maintains a keyed reference to all MBeans registered with it
 - *object name*
- Many generic clients available
 - JDK: jconsole, jvisualvm

JMX Architecture

- An MBean is an object with additional management metadata
 - Attributes (→ properties)
 - Operations (→ methods)
- The management metadata can be defined statically with a Java interface or defined dynamically at runtime
 - Simple MBean or Dynamic MBean respectively



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Plain JMX – Example Bean

```
public interface JmxCounterMBean {  
    int getCount(); // becomes Attribute named 'Count'  
    void increment(); // becomes Operation named 'increment'  
}
```

```
public class JmxCounter implements JmxCounterMBean {  
    ...  
    public int getCount() {...}  
    public void increment() {...}  
}
```



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Plain JMX – Exposing an MBean

```
MBeanServer server = ManagementFactory.getPlatformMBeanServer();

JmxCounter bean = new JmxCounter(...);

try {
    ObjectName name = new ObjectName("ourapp:name=counter");
    server.registerMBean(bean, name);
} catch (Exception e) {
    e.printStackTrace();
}
```



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Topics in this Session

- Introduction
- JMX
- **Introducing Spring JMX**
- Automatically exporting existing MBeans
- Spring Insight



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Goals of Spring JMX

- Using the raw JMX API is difficult and complex
- The goal of Spring's JMX support is to simplify the use of JMX while hiding the complexity of the API



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Goals of Spring JMX

- Configuring JMX infrastructure
 - Declaratively using context namespace or FactoryBeans
- Exposing Spring beans as MBeans
 - Annotation based metadata
 - Declaratively using Spring bean definitions
- Consuming JMX managed beans
 - Transparently using a proxy-based mechanism



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Spring JMX Steps

1. Configuring MBean Server
2. Configure Exporter
3. Control Attribute / Operation Exposure.



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Step 1: Creating an MBeanServer

- Use context namespace to locate or create an MBeanServer

```
<context:mbean-server />
```

XML

- Or declare it explicitly

```
@Bean  
public MBeanServerFactoryBean mbeanServer () {  
    MBeanServerFactoryBean server = new MBeanServerFactoryBean();  
    server.setLocateExistingServerIfPossible( true );  
    ...  
    return server;  
}
```

or JavaConfig



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Step 2: Exporting a Bean as an MBean

- Start with one or more existing POJO bean(s)

```
<bean id="messageService" class="example.MessageService"/>
```

- Use the MBeanExporter to export it

By default: *all public* properties exposed as attributes, *all public* methods exposed as operations.

```
@Bean  
public MBeanExporter mbeanExporter () {  
    MBeanExporter exporter = new MBeanExporter();  
    exporter.setAutodetect ( true );  
    ...  
    return exporter;  
}
```

JavaConfig

`<context:mbean-export/>`

or XML



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Step 1 & 2: JavaConfig Shortcut

- One annotation defines server and exporter:

```
@Configuration  
@EnableMBeanExport  
public class MyConfig {  
    ...  
}
```

Specific server bean
configurable if desired.



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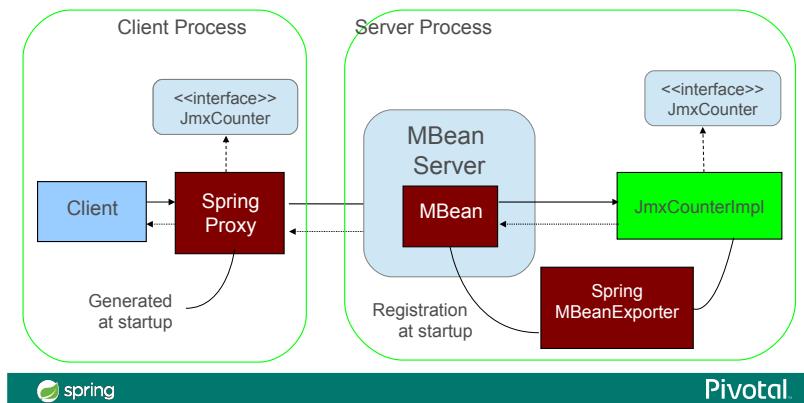
3. Control Attribute/Operation Exposure:

- Combine Annotations with Exporter:
 - Only annotated attributes/operations exposed.

```
@ManagedResource(objectName="statistics:name=counter",
                  description="A simple JMX counter")
public class JmxCounterImpl implements JmxCounter {
    @ManagedAttribute(description="The counter value")
    public int getCount() {...}
    @ManagedOperation(description="Increments the counter value")
    public void increment() {...}
}
```



Spring in the JMX architecture



Topics in this session

- Introduction
- JMX
- Introducing Spring JMX
- **Automatically exporting existing MBeans**
- Spring Insight



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Automatically Exporting Pre-existing MBeans

- Some beans are MBeans themselves
 - Example: Log4j's LoggerDynamicMBean
 - Spring will auto-detect and export them for you

```
<context:mbean-export>

<bean class="org.apache.log4j.jmx.LoggerDynamicMBean">
    <constructor-arg>
        <bean class="org.apache.log4j.Logger"
              factory-method="getLogger"/>
        <constructor-arg value="org.springframework.jmx" />
    </bean>
</constructor-arg>
</bean>
```



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Topics in this session

- Introduction
- JMX
- Introducing Spring JMX
- Automatically exporting existing MBeans
- **Spring Insight**



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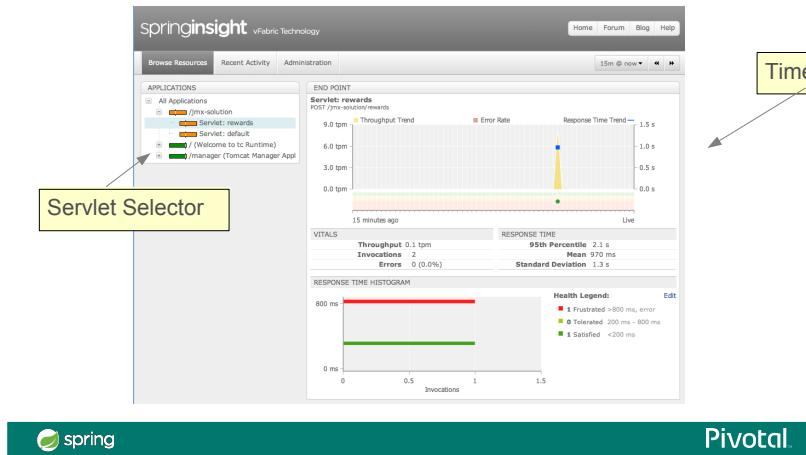
Spring Insight Overview

- Part of tc Server Developer Edition
 - Monitors web applications deployed to tc Server
 - <http://localhost:8080/insight>
- Focuses on what's relevant
 - esp. performance related parts of the application
- Detects performance issues during development
 - Commercial version for production: *vFabric APM*



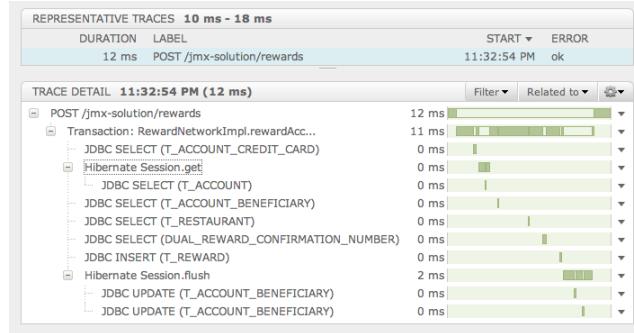
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Spring Insight Overview



Spring Insight Overview

- A request trace from HTTP POST to SQL



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- Spring JMX
 - Export Spring-managed beans to a JMX MBeanServer
 - Simple value-add now that your beans are managed
- Steps
 - Create MBean server
 - Automatically export annotated and pre-existing Mbeans
 - Use `@EnableMBeanExport` or `<context:mbean-server>` and `<context:mbean-export>`
 - Use Spring annotations to declare JMX metadata
- Spring Insight (tc Server Developer Edition)
 - Deep view into your web-application in STS



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Optional Lab

Monitoring and Managing a Java Application



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