What is Spring Framework? An Unorthodox Guide

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You can use this guide to understand what Spring framework is and how its core features like dependency injection or aspected oriented programming work. Also, a comprehensive FAQ.

(**Editor's note**: At ~6700 words, you probably don't want to try reading this on a mobile device. Bookmark it and come back later. And even on a desktop, ~~eat~~ read this elephant one bite at a time.)

Introduction

The complexity of the Spring ecosystem

A lot of companies are using Spring, but then you go to spring.io and see that the Spring universe actually consists of 21 different, active projects. Ouch!

Furthermore, if you started programming with Spring in the last couple of years, there is a very high chance that you went *directly* into Spring Boot or Spring Data.

However, this guide is solely about one, the most important one, of these projects: Spring Framework. Why?

Because it is essential to learn that Spring Framework is the *basis for all* other projects. Spring Boot, Spring Data, Spring Batch all build *on top* of Spring.

This has two implications:

- Without proper Spring framework knowledge, you *will* sooner or later get lost. You won't fully grok e.g. Spring Boot, no matter how unimportant you think that core knowledge is.
- Spending ~15 minutes reading this guide, which covers the most important 80% of Spring framework, will pay-off a million times in your professional career.

What is Spring Framework?

The short answer:

At its core, Spring framework is really just a dependency injection container, with a couple of convenience layers (think: database access, proxies, aspect-oriented programming, RPC, a web mvc framework) added on top. It helps you build Java application faster and more conveniently.

Now, that doesn't really help, does it?

Luckily, there's also a long answer:

The remainder of this document.

let mut author = ?

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Dependency Injection Basics

In case you already know what dependency injection is, feel free to skip straight to Spring's Dependency Injection Container. Otherwise, read on.

What is a dependency?

Imagine you are writing a Java class that lets you access a *users* table in your database. You would call these classes DAOs (data access object) or Repositories. So, you are going to write a UserDAO class.

```
public class UserDao {

    public User findById(Integer id) {
        // execute a sql query to find the user
    }
}
```

Your UserDAO has only one method which lets you find users in your database table by their respective IDs.

To execute the appropriate SQL query, your UserDAO needs a database connection. And in the Java world, you (usually) get that database connection from another class, called a DataSource. So, your code now would look something like this:

```
import javax.sql.DataSource;

public class UserDao {

    public User findById(Integer id) throws SQLException {
        try (Connection connection = dataSource.getConnecti
               PreparedStatement selectStatement = connecti
               // use the connection etc.
        }
    }

}
```

1. The question is now, where does your UserDao get its dataSource *dependency* from? The DAO obviously depends on a valid DataSource to fire those SQL queries.

How to instantiate dependencies with new()

The naive approach would be to simply create a new DataSource through a constructor, every time you need one. So, to connect to a MySQL database your UserDAO could look like this:

```
import com.mysql.cj.jdbc.MysqlDataSource;

public class UserDao {

    public User findById(Integer id) {
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");

        try (Connection connection = dataSource.getConnecti
             PreparedStatement selectStatement = connection
             // execute the statement..convert the raw jdbc
             return user;
```

```
        }
    }
}
```

1. We want to connect to a MySQL database; hence we are using a MysqlDataSource and hardcoding url/username/password here for easier reading.
2. We use our newly created DataSource for the query.

This works, but let's see what happens when we extend our UserDao class with another method, findByFirstName.

Unfortunately, that method *also* needs a DataSource to work with. We can add that new method to our UserDAO and apply some refactorings, by introducing a *newDataSource* method.

```
import com.mysql.cj.jdbc.MysqlDataSource;

public class UserDao {

    public User findById(Integer id) {
        try (Connection connection = newDataSource().getCon
               PreparedStatement selectStatement = connecti
               // TODO execute the select , handle exceptio
        }
    }

    public User findByFirstName(String firstName) {
        try (Connection connection = newDataSource().getCon
               PreparedStatement selectStatement = connecti
               // TODO execute the select ,  handle excepti
        }
    }

    public DataSource newDataSource() {
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        return dataSource;
    }
}
```

1. findById has been rewritten to use the new newDataSource() method.
2. findByFirstName has been added and also uses the new newDataSource() method.
3. This is our newly extracted method, able to create new DataSources.

This approach works, but has two drawbacks:

1. What happens if we want to create a new ProductDAO class, which also executes SQL statements? Your ProductDAO would then *also* have a DataSource dependency, which now is only available in your UserDAO class. You would then have another similar method or extract a helper class that contains your DataSource.
2. We are creating a completely new DataSource for every single SQL query. Consider that a DataSource opens up a real, socket connection from your Java program to your database. This takes time and is rather expensive. It would be much nicer if we opened just *one* DataSource and re-used it, instead of opening and closing tons of them. One way of doing this could be by saving the DataSource in a private field in our UserDao, so it can be reused between methods - but that does not help with the duplication between multiple DAOs.

How to 'manage' dependencies in a global Application class

To accommodate these issues, you could think about writing a global Application class, that looks something like this:

```
import com.mysql.cj.jdbc.MysqlDataSource;

public enum Application {

    INSTANCE;

    private DataSource dataSource;

    public DataSource dataSource() {
        if (dataSource == null) {
            MysqlDataSource dataSource = new MysqlDataSourc
            dataSource.setUser("root");
            dataSource.setPassword("s3cr3t");
            dataSource.setURL("jdbc:mysql://localhost:3306/
            this.dataSource = dataSource;
        }
        return dataSource;
    }
}
```

Your UserDAO could now look like this:

```
import com.yourpackage.Application;

public class UserDao {
    public User findById(Integer id) {
        try (Connection connection = Application.INSTANCE.d
               PreparedStatement selectStatement = connecti
               // TODO execute the select etc.
        }
    }

    public User findByFirstName(String firstName) {
        try (Connection connection = Application.INSTANCE.d
               PreparedStatement selectStatement = connecti
               // TODO execute the select etc.
        }
    }
}
```

It is an improvement in two ways:

1. Your UserDAO does not have to construct its own DataSource dependency anymore, instead it can ask the Application class to give it a fully-functioning one. Same for all your other DAOs.
2. Your application class is a singleton (meaning there will only be one INSTANCE created), and that application singleton holds a reference to a DataSource singleton.

There are however still several drawbacks to this solution:

1. The UserDAO *actively* has to know where to get its dependencies from, it has to call the application class → Application.INSTANCE.dataSource().
2. If your program gets bigger, and you get more and more dependencies, you will have one monster Application.java class, which handles all your dependencies. At which point you'll want to try and split things up into more classes/factories etc.

What is Inversion of Control?

Let's go one step further.

Wouldn't it be nice if you and the UserDAO didn't have to worry about *finding dependencies* at all? Instead of *actively* calling Application.INSTANCE.dataSource(), your UserDAO could shout (somehow) that it needs one, but has no control anymore when/how/where it gets it from?

This is what is called *inversion of control*.

Let's have a look at what our UserDAO could look like, with a brand-new constructor.

```
import javax.sql.DataSource;

public class UserDao {

    private DataSource dataSource;

    public UserDao(DataSource dataSource) { // (1)
        this.dataSource = dataSource;
    }

    public User findById(Integer id) {
        try (Connection connection = dataSource.getConnecti
                PreparedStatement selectStatement = connecti
                // TODO execute the select etc.
        }
    }

    public User findByFirstName(String firstName) {
        try (Connection connection = dataSource.getConnecti
                PreparedStatement selectStatement = connecti
                // TODO execute the select etc.
        }
    }
}
```

1. Whenever a caller creates a new UserDao through its constructor, the caller also has to pass in a valid DataSource.
2. The findByX methods will then simply use that DataSource.

From the UserDao perspective this reads much nicer. It doesn't know about the application class anymore, or how to construct DataSources itself. It only announces to the world "if you want to construct (i.e. use) me, you need to give me a datasource".

But imagine you now want to run your application. Whereas you could call "new UserService()" previously, you'll now have to make sure to call new UserDao(dataSource).

```
public class MyApplication {

    public static void main(String[] args) {
        UserDao userDao = new UserDao(Application.INSTANCE.
        User user1 = userDao.findById(1);
        User user2 = userDao.findById(2);
        // etc ...
    }
}
```

Dependency Injection Containers

Hence, the issue is that you, as a programmer are *still* actively constructing UserDAOs through their constructor and thus

setting the DataSource dependency manually.
Wouldn't it be nice if *someone* knew that your UserDAO has a DataSource constructor dependency and knew how to construct one? And then magically construct *both* objects for you: A working DataSource and a working UserDao?

That *someone* is a dependency injection container and is exactly what Spring framework is all about.

Spring's Dependency Injection Container

As already mentioned at the very beginning, Spring Framework, at its core, is a dependency injection container that manages the classes you wrote and their dependencies *for you* (see the previous section). Let's find out how it does that.

What is an ApplicationContext?

That *someone*, who has control over all your classes and can manage them appropriately (read: create them with the necessary dependencies), is called *ApplicationContext* in the Spring universe.

What we want to achieve is the following code (I described the UserDao and DataSource in the previous section, go skim it if you came right here and skipped it):

```
import org.springframework.context.ApplicationContext;
import org.springframework.context.annotation.AnnotationCon
import javax.sql.DataSource;

public class MyApplication {

    public static void main(String[] args) {
        ApplicationContext ctx = new AnnotationConfigApplic

        UserDao userDao = ctx.getBean(UserDao.class); // (2
        User user1 = userDao.findById(1);
        User user2 = userDao.findById(2);

        DataSource dataSource = ctx.getBean(DataSource.clas
        // etc ...
    }
}
```

1. Here we are constructing our Spring ApplicationContext. We'll go into much more detail on how this works in the next paragraphs.
2. The ApplicationContext can give us a fully configured UserDao, i.e. one with its DataSource dependency set.
3. The ApplicationContext can also give us the DataSource directly, which is *the same* DataSource that it sets inside the UserDao.

This is pretty cool, isn't it? You as the caller don't have to worry about constructing classes anymore, you can simply ask the ApplicationContext to give you working ones!

But how does that work?

How to create an ApplicationContext?

In the code above, we put a variable called "someConfigClass" in the AnnotationConfigApplicationContext constructor. Here's a quick reminder:

```
import org.springframework.context.annotation.AnnotationCon
public class MyApplication {

    public static void main(String[] args) {
        ApplicationContext ctx = new AnnotationConfigApplic
        // ...
    }
}
```

What you really want to pass into the ApplicationContext constructor, is a reference to a configuration class, which should look like this:

```
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration

@Configuration
public class MyApplicationContextConfiguration {  // (1)

    @Bean
    public DataSource dataSource() {  // (2)
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        return dataSource;
    }

    @Bean
    public UserDao userDao() { // (3)
        return new UserDao(dataSource());
    }

}
```

1. You have a dedicated ApplicationContext configuration class, annotated with the @Configuration annotation, that looks a bit like the Application.java class from How to 'manage' dependencies in a global Application class.
2. You have a method that returns a DataSource and is annotated with the Spring-specific @Bean annotation.
3. You have another method, which returns a UserDao and constructs said UserDao by calling the dataSource bean method.

This configuration class is already enough to run your very first Spring application.

```
import org.springframework.context.ApplicationContext;
import org.springframework.context.annotation.AnnotationCon

public class MyApplication {

    public static void main(String[] args) {
```

```
        ApplicationContext ctx = new AnnotationConfigApplic
        UserDao userDao = ctx.getBean(UserDao.class);
        // User user1 = userDao.findById(1);
        // User user2 = userDao.findById(1);
        DataSource dataSource = ctx.getBean(DataSource.clas
    }
}
```

Now, let's find out what exactly Spring and the AnnotationConfigApplicationContext do with that Configuration class you wrote.

Are there alternatives to AnnotationConfigApplicationContext?

There are many ways to construct a Spring ApplicationContext, for example through XML files, annotated Java configuration classes or even programmatically. To the outside world, this is represented through the single *ApplicationContext* interface.

Look at the MyApplicationContextConfiguration class from above. It is a Java class that contains Spring-specific annotations. That is why you would need to create an *Annotation* ConfigApplicationContext.

If, instead, you wanted to create your ApplicationContext from XML files, you would create a *ClassPathXmlApplicationContext*.

There are also many others, but in a modern Spring application, you will *usually* start out with an annotation-based application context.

What does the @Bean annotation do? What is a Spring Bean?

You'll have to think of the methods inside your ApplicationContext configuration class as factory methods. For now, there is one method that knows how to construct UserDao instances and one method that constructs DataSource instances.

These instances that those factory methods create are called *beans*. It is a fancy word for saying: I (the Spring container) created them and they are under my control.

But this leads to the question: How many *instances* of a specific bean should Spring create?

What are Spring bean scopes?

How many *instances* of our DAOs should Spring create? To answer that question, you need to learn about *bean scopes*.

- Should Spring create a *singleton*: All your DAOs share the same DataSource?
- Should Spring create a *prototype*: All your DAOs get their own DataSource?
- Or should your beans have even more complex scopes, like saying: A new DataSource per HttpRequest? Or per HttpSession? Or per WebSocket?

You can read up on a full list of available bean scopes here, but for now it is suffice to know that you can influence the scope with yet another annotation.

```
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Scope;
import org.springframework.context.annotation.Configuration

@Configuration
public class MyApplicationContextConfiguration {
```

```
    @Bean
    @Scope("singleton")
    // @Scope("prototype") etc.
    public DataSource dataSource() {
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        return dataSource;
    }
}
```

The scope annotation controls how many instances Spring will create. And as mentioned above, that's rather simple:

- Scope("singleton") → Your bean will be a singleton, there will only be one instance.
- Scope("prototype") → Every time someone needs a reference to your bean, Spring will create a new one. (There's a couple of caveats here, like injecting prototypes in singletons, though).
- Scope("session") → There will be one bean created for every user HTTP session.
- etc.

The gist: Most Spring applications almost entirely consist of singleton beans, with the occasional other bean scope (prototype, request, session, websocket etc.) sprinkled in.

Now that you know about ApplicationContexts, Beans & Scopes, let's have another look at dependencies, or the many ways our UserDAO could obtain a DataSource.

What is Spring's Java Config?

So far, you explicitly configured your beans in your ApplicationContext configuration, with the help of @Bean annotated Java methods.

This is what you would call Spring's *Java Config*, as opposed to specifying everything in XML, which was historically the way to go with Spring. Just a quick recap of what this looks like:

```
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration

@Configuration
public class MyApplicationContextConfiguration {

    @Bean
    public DataSource dataSource() {
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        return dataSource;
    }

    @Bean
    public UserDao userDao() { // (1)
        return new UserDao(dataSource());
    }

}
```

1. One question: Why do you have to explicitly call new UserDao() with a manual call to dataSource()? Cannot Spring figure all of this out itself?

This is where another annotation called @ComponentScan comes in.

What does @ComponentScan do?

The first change you'll need to apply to your context configuration is to annotate it with the additional @ComponentScan annotation.

```
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.ComponentScan
import org.springframework.context.annotation.Configuration

@Configuration
@ComponentScan  // (1)
public class MyApplicationContextConfiguration {

    @Bean
    public DataSource dataSource() {
        MysqlDataSource dataSource = new MysqlDataSource();
        dataSource.setUser("root");
        dataSource.setPassword("s3cr3t");
        dataSource.setURL("jdbc:mysql://localhost:3306/myDa
        return dataSource;
    }

    // (2)

    // no more UserDao @Bean method!
}
```

1. We added the @ComponentScan annotation.
2. Note, that the UserDAO definition is now missing from the context configuration!

What this @ComponentScan annotation does, is tell Spring: Have a look at *all* Java classes in the *same package* as the context configuration if they look like a Spring Bean!

This means if your MyApplicationContextConfiguration lives in package com.marcobehler, Spring will scan *every* package, including subpackages, that starts with com.marcobehler for potential Spring beans.

How does Spring know if something is a Spring bean? Easy: Your classes need to be annotated with a marker annotation, called @Component.

What do @Component & @Autowired do?

Let's add the @Component annotation to your UserDAO.

```
import javax.sql.DataSource;
import org.springframework.stereotype.Component;

@Component
public class UserDao {


    private DataSource dataSource;

    public UserDao(DataSource dataSource) { // (1)
        this.dataSource = dataSource;
    }
}
```

1. This tells Spring, similarly to that @Bean method you wrote before: Hey, if you find me annotated with @Component

through your @ComponentScan, then I want to be a Spring bean, managed by you, the dependency injection container!

(When you look at the source code of annotations like @Controller, @Service or @Repository later on, you'll find that they all consist of *multiple*, further annotations, *always* including @Component!).

There's only one little piece of information missing. How does Spring know that it should take the DataSource that you specified as a @Bean method and then create new UserDAOs with that specific DataSource?

Easy, with another marker annotation: @Autowired. Hence, your final code will look like this.

```
import javax.sql.DataSource;
import org.springframework.stereotype.Component;
import org.springframework.beans.factory.annotation.Autowir

@Component
public class UserDao {

    private DataSource dataSource;

    public UserDao(@Autowired DataSource dataSource) {
        this.dataSource = dataSource;
    }
}
```

Now, Spring has all the information it needs to create UserDAO beans:

- UserDAO is annotated with @Component → Spring will create it
- UserDAO has an @Autowired constructor argument → Spring will automatically inject the DataSource that is configured via your @Bean method
- Should there be no DataSources configured in any of your Spring configurations, you will receive a NoSuchBeanDefinition exception at runtime.

Constructor Injection & Autowired Revisited

I have been lying to you a tiny bit in the previous section. In earlier Spring versions (pre 4.2, see history), you needed to specify @Autowired in order for constructor injection to work.

With newer Spring versions, Spring is actually smart enough to inject these dependencies *without* an explicit @Autowired annotation in the constructor. So this would also work.

```
@Component
public class UserDao {

    private DataSource dataSource;

    public UserDao(DataSource dataSource) {
        this.dataSource = dataSource;
    }
}
```

Why did I mention @Autowired then? Because it does not hurt, i.e. makes things more explicit and because you can use @Autowired in many other different places, apart from constructors.

Let's have a look at different *ways* of dependency injection - constructor injection just being one many.

What are Field and Setter Injection?

Simply put, Spring does not have to go through a constructor to inject dependencies.

It can also directly inject fields.

```
import javax.sql.DataSource;
import org.springframework.stereotype.Component;
import org.springframework.beans.factory.annotation.Autowir

@Component
public class UserDao {

    @Autowired
    private DataSource dataSource;

}
```

Alternatively, Spring can also inject setters.

```
import javax.sql.DataSource;
import org.springframework.stereotype.Component;
import org.springframework.beans.factory.annotation.Autowir

@Component
public class UserDao {

    private DataSource dataSource;

    @Autowired
    public void setDataSource(DataSource dataSource) {
        this.dataSource = dataSource;
    }

}
```

These two injection styles (fields, setters) have the same outcome as constructor injection: You'll get a working Spring Bean. (In fact, there's also another one, called *method injection* which we won't cover here.)

But obviously, they differ from one another, which means there has been a great many debates about which injection style is best and which one you should use in your project.

Constructor Injection vs. Field Injection

There have been a great many debates online, whether constructor injection or field injection is better, with a number of strong voices even claiming that field injection is harmful.

To not add further noise to these arguments, the gist of *this* article is:

1. I have worked with both styles, constructor injection and field injection in various projects over the recent years. Based solely on personal experience, I do not truly favor one style over the other.
2. Consistency is king: Do not use constructor injection for 80% of your beans, field injection for 10% and method injection for the remaining 10%.
3. Spring's approach from the official documentation seems sensible: Use constructor injection for mandatory dependencies and setter/field injection for optional dependencies. Be warned: Be *really* consistent with that.

Most importantly, keep in mind: The overall success of your software project will not *depend on* the choice of your favorite dependency injection method (pun intended).

Summary: Spring's IoC container

By now, you should know pretty much everything you need to know about Spring's dependency container.

There is of course more to it, but if you have a good grasp of ApplicationContexts, Beans, dependencies and different methods of dependency injection, then you are already on a good path.

Let's see what else Spring has to offer, apart from pure dependency injection.

Spring's Aspect-Oriented Programming (AOP)

Dependency injection might lead to better structured programs, but injecting a dependency here and there is not what Spring's ecosystem is all about. Let's have a look at a simple ApplicationContextConfiguration again:

```
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration

@Configuration
public class MyApplicationContextConfiguration {

    @Bean
    public UserService userService() { // (1)
        return new UserService();
    }
}
```

1. Let's assume that UserService is a class that lets you find users from a database table - or save users to that database table.

Here's where Spring's hidden killer feature comes in:

Spring reads in that context configuration, containing the @Bean method you wrote and therefore Spring knows how to create and inject UserService beans.

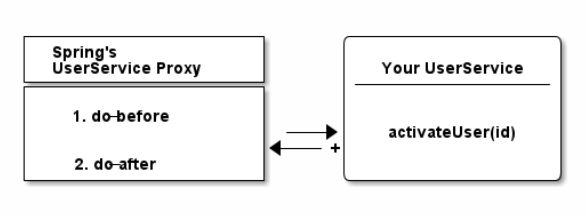
But Spring can cheat and create something *else* than your UserService class. How? Why?

Spring's Proxy Facilities

Because under the hood, any Spring @Bean method can return you something that *looks and feels like* (in your case) a UserService, but actually isn't.

It can return you a *proxy*.

The proxy will at some point delegate to the UserService you wrote, but first, will execute its *own functionality*.



More specifically, Spring will, by default, create dynamic Cglib proxies, that do not need an interface for proxying to work (like JDK's internal proxy mechanism): Instead, Cglib can proxy classes through subclassing them on the fly. (If you are unsure about the individual proxy patterns, read more about the proxies on Wikipedia.)

Why Proxies?

Because it allows Spring to give *your* beans additional features, without modifying your code. In a gist, that is what aspect-oriented (or: AOP) programming is all about.

Let's have a look at the *most popular* AOP example, Spring's @Transactional annotation.

Spring's @Transactional

Your UserService implementation above could look a bit like this:

```
import org.springframework.stereotype.Component;
import org.springframework.transaction.annotation.Transacti

@Component
public class UserService {

    @Transactional          // (2)
    public User activateUser(Integer id) {  // (1)
        // execute some sql
        // send an event
        // send an email
    }
}
```

1. We wrote an activateUser method, which, when called, needs to execute some SQL to update the User's state in the database, maybe send an email or a messaging event.
2. @Transactional on that method signals Spring that you need an open database connection/transaction for that method to work and that said transaction should also be committed at the end. And that *Spring needs to do this*.

The problem: While Spring can create your UserService bean through the applicationContext configuration, it cannot rewrite your UserService. It cannot simply inject code in there that opens a database connection and commits a database transaction.

But what it *can do*, is to create a proxy *around* your UserService that *is* transactional. So, only the proxy needs to know about how to open up and close a database connection and can then simply delegate to your UserService in between.

Let's have a look at that innocent ContextConfiguration again.

```
@Configuration
@EnableTransactionManagement // (1)
```

```
public class MyApplicationContextConfiguration {

    @Bean
    public UserService userService() { // (2)
        return new UserService();
    }
}
```

1. We added an annotation signaling Spring: Yes, we want @Transactional support, which *automatically* enables Cglib proxies under the hood.
2. With the above annotation set, Spring does *not* just create and return your UserService here. It creates a Cglib proxy of your bean, that looks, smells and delegates to your UserService, but actually wraps around your UserService and gives its transaction management features.

This might seem a bit unintuitive first, but most Spring developers encounter proxies very soon in debugging sessions. Because of the proxies, Spring stacktraces can get rather long and unfamiliar: When you step inside a method, you could very well step inside *the proxy* first - which scares people off. It is, however, completely normal and expected behavior.

Are there alternatives to CGlib proxies?

Proxies are the *default* choice when programming AOP with Spring. You are however not restricted to using proxies, you could also go the full AspectJ route, that modifies your actual bytecode, if wanted. Covering AspectJ is however outside the scope of this guide.

AspectJ allows you to change actual bytecode through load-time-weaving or compile-time-weaving. This gives you a lot more possibilities, in exchange for a lot more complexity.

You can however configure Spring to use AspectJ's AOP, instead of its default, proxy-based AOP.

Here are a couple of links if you want to get more information on this topic:

- AspectJ Homepage
- Spring AOP vs AspectJ
- Spring AOP official documentation

Spring's AOP Support: A Summary

There is of course much more to be said about aspect-oriented programming, but this guide gives you an idea of how the most popular Spring AOP use-cases like @Transactional or Spring Security's @Secured work. You could even go as far as write your own AOP annotations, if wanted.

As a consolation for the abrupt end, if you want to get more information on how Spring's @Transactional management works *in detail*, have a look at my @Transactional guide.

Spring's Resources

We've been talking about dependency injection & proxies for a while. Let's now have a first look at what I would call important *convenience utilities* in Spring framework. One of these utilities is Spring's resources support.

Think about how you would try to access a file in Java via HTTP or FTP. You could use Java's URL class and write some plumbing code.

Similarly, how would you read in files from your application's classpath? Or from a servlet context, that means from a web

applications root directory (admittedly, this gets rarer and rarer in modern, packaged.jar application).
Again, you'd need to write a fair amount of boilerplate code to get that working and unfortunately the code would differ for each use case (URLs, classpaths, servlet contexts).

But there's a solution: Spring's resource abstraction. It is easily explained in code.

```
import org.springframework.core.io.Resource;

public class MyApplication {

    public static void main(String[] args) {
            ApplicationContext ctx = new AnnotationConfigAp

            Resource aClasspathTemplate = ctx.getResource("

            Resource aFileTemplate = ctx.getResource("file:

            Resource anHttpTemplate = ctx.getResource("http

            Resource depends = ctx.getResource("myhost.com/

            Resource s3Resources = ctx.getResource("s3://my
    }
}
```

1. As always, you need an ApplicationContext to start off.
2. When you call getResource() on an applicationContext with a string that starts with *classpath:*, Spring will look for a resource on your..well..application classpath.
3. When you call getResource() with a string that starts with *file:*, Spring will look for a file on your harddrive.
4. When you call getResource() with a string that starts with *https:* (or http), Spring will look for a file on the web.
5. If you don't specify a prefix, it actually depends on what kind of applicationContext you configured. More on that here.
6. This does *not* work out of the box with Spring Framework, but with additional libraries like Spring Cloud, you can even directly access s3:// paths.

In short, Spring gives you the ability to access *resources* via a nice little syntax. The resource interface has a couple of interesting methods:

```
public interface Resource extends InputStreamSource {

    boolean exists();

    String getFilename();

    File getFile() throws IOException;

    InputStream getInputStream() throws IOException;

    // ... other methods commented out
}
```

As you can see, it allows you to execute the most common operations on a resource:

- Does it exist?
- What is the filename?

- Get a reference to the actual File object.
- Get a direct reference to the raw data (InputStream).

This lets you do everything you want with a resource, independent of it living on the web or on your classpath or your hard drive.

The resources abstraction looks like such a tiny feature, but it really shines when combined with the next convenience feature offered by Spring: Properties.

What is Spring's Environment?

A big part of any application is reading in properties, like database username & passwords, email server configuration, Stripe payment detail configuration, etc.

At its simplest form, these properties live in .properties files and there could be many of them:

- Some of them on your classpath, so you have access to some development related passwords.
- Others in the filesystem or a network drive, so a production server can have its own, secure properties.
- Some could even come in the form of operating system environment variables.

Spring tries to make it easy for you to register and automatically find properties across all these different sources, through its *environment abstraction*.

```
import org.springframework.core.env.Environment;
public class MyApplication {

    public static void main(String[] args) {
           ApplicationContext ctx = new AnnotationConfigApp
           Environment env = ctx.getEnvironment(); // (1)
           String databaseUrl = env.getProperty("database.u
           boolean containsPassword = env.containsProperty(
           // etc
    }
}
```

1. Through an applicationContext, you can always access the current program's *environment*.
2. The environment on the other hand, lets you, among other things, access properties.

Now, what is an environment exactly?

What are Spring's @PropertySources?

In a nutshell, an environment consists of one to many property sources. For example:

- /mydir/application.properties
- classpath:/application-default.properties

(Note: An environment *also* consists of profiles, i.e. "dev" or "production" profiles, but we won't go into detail on profiles in this revision of this guide).

By default, a Spring MVC web application environment consists of ServletConfig/Context parameter, JNDI and JVM system property sources. They are also hierarchical, that means they have an order of importance and override each other.

However, it is rather easy to define new @PropertySources yourself:

```
import org.springframework.context.annotation.PropertySourc
import org.springframework.context.annotation.PropertySourc

@Configuration
@PropertySources(
        {@PropertySource("classpath:/com/${my.placeholder:d
         @PropertySource("file://myFolder/app-production.pr
public class MyApplicationContextConfiguration {
    // your beans
}
```

Now it makes much more sense, why we talked about Spring's Resources before. Because both features go hand in hand.

The @PropertySource annotation works with any valid Spring configuration class and lets you define new, additional sources, with the help of Spring's resources abstraction: Remember, it's all about the prefixes: http://, file://, classpath: , etc.

Defining properties through @PropertySources is nice, but isn't there a better way than having to go through the environment to access them? Yes, there is.

Spring's @Value annotation & Property injection

You can inject properties into your beans, similarly like you would inject a dependency with the @Autowired annotation. But for properties, you need to use the @Value annotation.

```
import org.springframework.stereotype.Component;
import org.springframework.beans.factory.annotation.Value;

@Component
public class PaymentService {

    @Value("${paypal.password}")  // (1)
    private String paypalPassword;

     public PaymentService(@Value("${paypal.url}") String p
         this.paypalUrl = paypalUrl;
    }
}
```

1. The @Value annotation works directly on fields...
2. Or on constructor arguments.

There really isn't much more to it. Whenever you use the @Value annotation, Spring will go through your (hierarchical) environment and look for the appropriate property - or throw an error message if such a property does not exist.

Additional Modules

There’s even more modules that Spring Framework consists of. Let’s have a look at them now.

Spring Web MVC

You can find an extensive description of Spring MVC, Spring’s Web Framework, in this guide: Spring MVC: In-Depth Guide.

Data Access, Testing, Integration & Languages

Spring framework consists of even more convenience utilities than you have seen so far. Let’s call them *modules* and do *not* confuse these modules with the 20 other Spring projects on spring.io. To the contrary, they are all part of the Spring framework project.

So, what kind of convenience are we talking about?

You’ll have to understand that basically everything Spring offers in these modules, is also available in pure Java. Either offered by the JDK or a third-party library. Spring framework always builds *on top* of these existing features.

Here’s an example: Sending email attachments with Java’s Mail API is certainly doable, but a bit cumbersome to use. See here for a code example.

Spring provides a nice little wrapper API *on top* of Java’s Mail API, with the added benefit that everything it offers blends in nicely with Spring’s dependency injection container. It is part of Spring’s `integration` module.

```
import org.springframework.core.io.FileSystemResource;
import org.springframework.mail.javamail.JavaMailSender;
import org.springframework.mail.javamail.MimeMessageHelper;

public class SpringMailSender {

    @Autowired
    private JavaMailSender mailSender; // (1)

    public void sendInvoice(User user, File pdf) throws Exc
        MimeMessage mimeMessage = mailSender.createMimeMess

        MimeMessageHelper helper = new MimeMessageHelper(mi

        helper.setTo("john@rambo.com");
        helper.setText("Check out your new invoice!");
        FileSystemResource file = new FileSystemResource(pd
        helper.addAttachment("invoice.pdf", file);

        mailSender.send(mimeMessage);
    }
}
```

1. Everything related to configuring an email server (url, username, password) is abstracted away into the Spring specific MailSender class, that you can inject in any bean that wants to send emails.
2. Spring offers convenience builders, like the MimeMessageHelper, to create multipart emails from, say, files as fast as possible.

So, to sum it up, Spring framework’s goal is to 'springify' available Java functionality, preparing it for dependency injection and therefore making the APIs easier to use in a Spring context.

Module Overview

I'd like to give you a quick overview of the most common utilities, features and modules you might encounter in a Spring framework project. Note, however, that detailed coverage of all these tools is impossible in the scope of this guide. Instead, have a look at the official documentation for a full list.

- Spring's Data Access: *Not* to be confused with Spring Data (JPA/JDBC) libraries. It is the basis for Springs @Transactional support, as well as pure JDBC and ORM (like Hibernate) integration.
- Spring's Integration Modules: Makes it easier for you to send emails, integrate with JMS or AMQP, schedule tasks, etc.
- Spring Expression Language (SpEL): Even though this is not really correct, think about it as a DSL or Regex for Spring Bean creation/configuration/injection. It will be covered in more detail in future versions of this guide.
- Spring's Web Servlet Modules: Allows you writing web applications. Includes Spring MVC, but also support for WebSockets, SockJS and STOMP messaging.
- Spring's Web Reactive Modules: Allows you writing reactive web applications.
- Spring's Testing Framework: Allows you to (integration) test Spring contexts and therefore Spring applications, including helper utilities for testing REST services. If you want to deep dive into testing Spring (Boot) applications, have a look at this masterclass (note: I'm affiliated with Philip, the author).

FAQ

What is the difference between Spring Framework & Spring Boot?

If you have read this guide, you should understand by now that Spring Boot builds *on top* of Spring. While a comprehensive Spring Boot guide is coming up soon, here's an example what "opinionated defaults" in Spring Boot mean.