Spring Boot in Practice

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welcome

Thanks for purchasing the MEAP edition of *Spring Boot in Practice*.

Spring Boot is the most popular Java-based web framework of the present time and there are tons of Spring Boot applications running in production. It is relatively easy to start with Spring Boot as one of the primary objectives of the framework is to provide a fast getting-started experience to the developers. However, it can sometimes be difficult to grasp what is going on behind the scenes as Spring Boot does a considerable amount of work under the hood. This book intends to provide an insight into the various underlying Spring Boot concepts that can solidify your understanding of the framework. Besides, this book also discusses numerous practical techniques that a developer can implement in their Spring Boot application. By the end of this book, you should understand:

- A thorough understanding of Spring Boot framework, auto-configuration, and actuator
- Several useful techniques that developers should be familiar with such as logging, user data validation, and configuration management
- Develop microservices with Spring Boot and various ways to communicate to the database in a Spring Boot application
- Several techniques to implement security in Spring Boot applications
- Develop reactive Spring Boot application and deploying Spring Boot applications to cloud platforms
- Using Spring Boot with Kotlin, and GraalVM

We hope that this book will assist you in your everyday Spring Boot application development and occupy an important place in your digital (and physical) bookshelf.

We also encourage you to post any comments, questions, the feedback you may have about the book in the liveBook Discussion forum. We appreciate knowing where we can make improvements and increase your understanding of the material.

—Somnath Musib

brief contents

1
Booting Spring Boot

This chapter covers

- **Introduction to Spring Boot, features and components**
- **Project structure and various elements of a generated project**
- **Creating an executable jar file and the generated jar structure**
- **Spring Boot startup events, and ways to listen to events in Spring Boot**
- **Overview of Spring Boot starter, auto-configuration, failure analyzer, and actuator**
- **Introduction to Spring Boot developer tools to increase developer productivity**

Welcome to Spring Boot! The most popular Java framework out there. It has revolutionized the way Spring applications or, more specifically, Java applications are developed these days. Spring Boot is an open-source extension of the Spring Framework designed to simplify the Spring application development. The popularity of Spring Boot is mostly attributed to its ability to create standalone, production-ready Spring-based applications in no time that you can just run without worrying much about the configuration hazards.

This chapter provides an overview of Spring Boot discussing what is Spring Boot, its purpose, project structure, and several key Spring Boot features. Are you ready? Let's *boot* our journey!"

1.1 Introducing Spring Boot

In this section, we'll introduce you to the Spring Boot framework and briefly answer few common questions around Spring Boot.

1.1.1 Why Spring Boot?

As we venture out on this beautiful voyage of getting ourselves familiar with Spring Boot, the very first question that appears in mind is that why should we learn it in the first place? To find an answer to this question, let us understand what problem Spring Boot promises to solve.

The Spring framework started its journey to simplify the Java application development. It became immensely popular due to its simplified application development strategies and the heavy-lifting nature of the framework. Further, as the use of Spring as a framework increased, the need to further simplify the Spring application development process was also amplified.

Although Spring provides a great deal of support to the developers in focusing only on solving their business problems, there is still a significant amount of work that needs to be done by the developer to make things working. For instance, the following are a few challenges you'll face once you start developing a Spring-based web application:

- You need an understanding of Servlet and the associated deployment descriptor `web.xml` concepts
- Familiarize yourself with the `WAR` and `EAR` directory structures to package the application components
- Understand application server specific concepts such as the domain, port, threads, data sources while you deploy your application
- Deal with complicated class loading strategies, application monitoring, and management concepts, and logging facilities

This is too many technical buzzwords out there. But what if instead, you can write the business logic for your application, build an executable file, and just run it in a command line. No need for complicated XML configurations, application server deployment, and other technical jugglenes. All these pieces of the puzzle are mysteriously solved by some experienced magician. Impressive, right? Well, you'll soon discover that Spring Boot is this magician.

Spring Boot was introduced as a sub-project under the Spring Framework to empower the developers with a fast getting-started experience and exempts them from most of the configuration hazards. As you proceed with your Spring Boot journey, you'll notice how seamlessly Spring Boot addresses several configuration and integration issues. For instance, in your Spring Boot project, you'll not be forced to define a deployment descriptor `web.xml` file. Besides, you also won't be forced to use an application server to run your application unless you specifically decide to run on an application server.

Most of the time, Spring Boot's default configuration can easily meet your needs.

1.1.2 What is Spring Boot

Spring Boot was introduced in April 2014 to reduce some of the burdens while developing a Java web application. It allowed developers to focus more on the business logic rather than spending time on the boilerplate technical code and the associated configurations. Spring Boot intends to create Spring-based, production-ready, standalone applications with little configuration changes on behalf of the application developer. It took an opinionated view of the Spring framework so that the application developers can quickly get started with what they need. It provides an additional layer between the Spring Framework for the user to simplify certain configuration aspects.

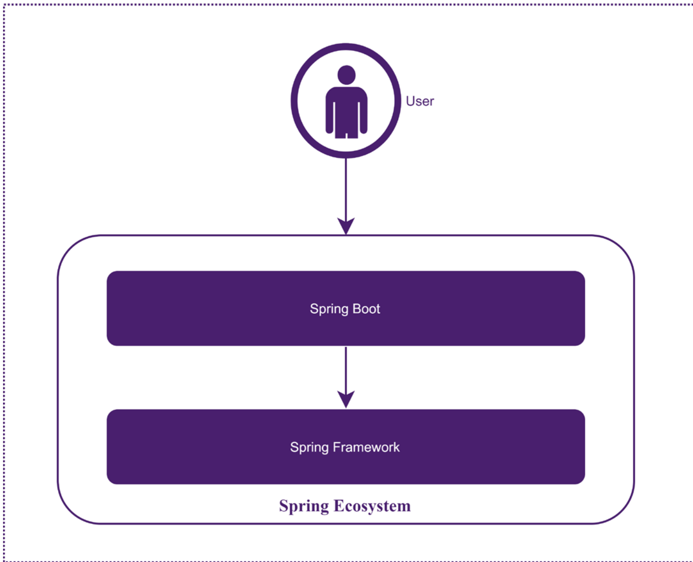


Figure 1.1 Developer view of Spring Boot. It *sandwiches* itself between the developer and the Spring framework. Several Spring framework components are automatically configured by Spring Boot based on the Spring components a developer uses.

Figure 1.1 shows how Spring Boot sandwiches itself between you as the application developer and the Spring Framework. As an intermediate layer, Spring Boot performs many configurations, which you'll otherwise need to do yourself if you interact directly with the Spring Framework.

1.1.3 Spring Boot Core Features

Spring Boot has several notable features that have made it stand out from the crowd of other frameworks:

- Fast Bootstrapping: One of the primary goals of Spring Boot is to provide a fast getting-started experience in Spring application development. Let's say you want to build a web application using Spring in a traditional approach. You'll most likely follow the steps outlined below:

    a) Configure a Maven or Gradle project with Spring MVC dependencies
    b) Configure the Spring MVC `DispatcherServlet`
    c) Package the application components into a `WAR` file
    d) Deploy the `WAR` file into a servlet container (e.g., Apache Tomcat)

With Spring Boot, you can generate an application by specifying the dependencies you need in your application, and Spring Boot takes care of the rest of the things

- Auto-configuration: Spring boot automatically configures the bare minimum components of a Spring application. It does this based on the presence of the `JAR` files in the classpath or properties configured in the various property files. For instance, if Spring Boot detects the presence of a database driver jar file (e.g., H2 in-memory database jar) in the classpath, it automatically configures the corresponding data source to connect to the database
- Opinionated: Spring Boot is opinionated. It automatically configures several components to start with a Spring application. Spring Boot does this with a set of starter dependencies. A starter dependency targets a specific area of application development and provides the related dependencies. For example, if you need to develop a `web` application, you can configure the `spring-boot-starter-web` dependency which ensures that all related dependencies to develop a web application such as `spring-web` and `spring-webmvc` are available in the application classpath
- Standalone: Spring Boot applications embed a web server so that they can run standalone and do not necessarily require an external web or application server. This enables Spring Boot applications to be packaged as an executable jar file and run with the `java -jar` command
- Production-Ready: Spring Boot provides several useful production-ready features out of the box to monitor and manage the application once it is pushed to production such as health checks, thread dumps, and other useful metrics

1.1.4 Spring Boot Components

Spring Boot consists of several components, with each component focuses on a specific area of the application development. Some of these are core components, and you'll use them often with almost every spring Boot project. For example, the `Spring Boot` is the primary component you'll use almost in every Spring Boot project. Figure 1.2 shows the Spring Boot components:

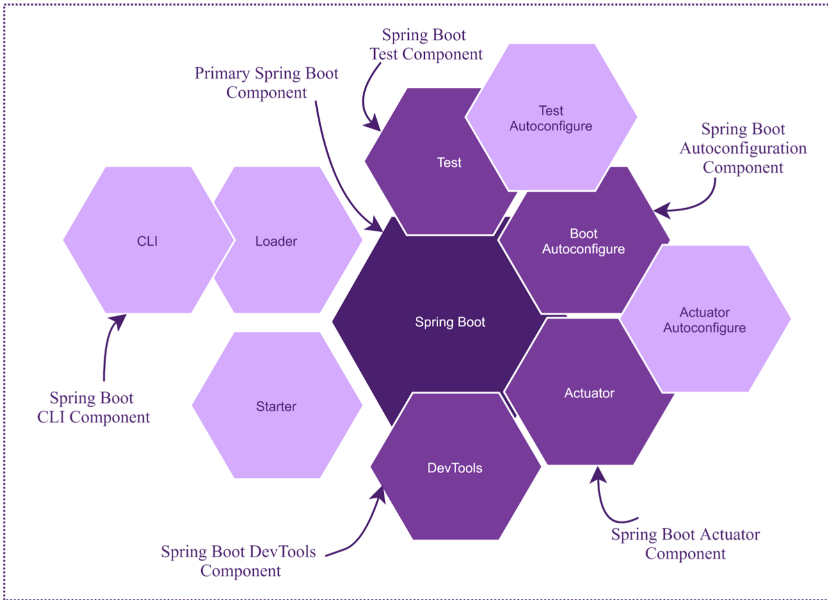


Figure 1.2 Spring Boot Components.

The following section provides a brief discussion on the Spring Boot components shown in figure 1.2.

spring-boot: This is the primary Spring boot component that provides support to other components. For example, it contains the `SpringApplication` class, which contains several static methods to create a standalone Spring Boot application. It also provides support for embedded web servers (e.g., Tomcat) and supports externalize application configurations (e.g., database details of your application), etc

spring-boot-autoconfigure: This component provides the necessary support for the automatic configuration of a Spring Boot application. Spring Boot auto-configuration guess and configure the spring beans based on the dependencies present in classpath and the properties configured. However, auto-configuration backs away from the default configuration if it detects user-configured beans with custom configurations

Spring-boot-starters: Starters are a set of pre-packaged dependency descriptors provided for developer convenience. A Spring Boot starter assists in providing a set of Spring and related technologies to the developer, which otherwise the developer needs to manage themselves.

spring-boot-CLI: This is a developer-friendly command-line utility that compiles and runs groovy codes. It can also watch files for changes so that you need not to restart your application on modifications. This CLI tool exempts you from the need for dependency management tools such as Maven or Gradle. Also, it lets you quickly prototype Spring applications without worrying much about dependency management and other builds-related stuff. Refer to Appendix A on to use the Spring Boot CLI

spring-boot-actuator: This component provides the actuator endpoints to interact, monitor, and audit a Spring Boot application. An actuator in Spring Boot can be managed through JMX or HTTP endpoints. Spring Boot provides a pre-defined list of actuator endpoints that cover a range of application aspects. If that does not satisfy your need, you can also create your custom actuator endpoints specific to your application. Spring Boot actuator also provides configurations to let you decide which actuator endpoints you want to enable and provide several means to secure them from unauthorized access

spring-boot-actuator-autoconfigure: This component provides support to auto-configure the actuator endpoints based on the classpath. For instance, if the `Micrometer` (https://micrometer.io/) dependency is present in the classpath, Spring Boot automatically configures the `MetricsEndpoint`

spring-boot-test: This module contains annotations and methods to write test cases for the Spring Boot application

spring-boot-test-autoconfigure: This component supports the auto-configuration of the test cases of your application

spring-boot-loader: This component allows a Spring Boot application to be packaged as a single fat jar file, including all dependencies and the embedded web servers that can be run standalone. You don't use this module independently; instead, it is used along with Maven or Gradle plugins

spring-boot-devtools: This component contains an additional developer toolkit for a smooth development experience of Spring Boot applications. The toolkit includes features such as automatic detection of application code changes, `LiveReload` server to automatically refresh any HTML changes to the browser. Developer tools are intended to increase developer productivity

1.2 Code Examples

In this section, we'll discuss the code examples and the technologies that we'll use to develop the examples.

1.2.1 Maven vs Gradle

Spring Boot lets you create a Spring Boot project with either Apache Maven (https://maven.apache.org/) or Gradle (https://gradle.org/) build tools. In the Spring Initializr tool, you can choose the build system of your choice and generate the project. In this book, we'll use Apache Maven as the preferred build system as most readers are familiar with Apache Maven. However, if you are a Gradle user, you will find that it is quite easy to port the code examples to Gradle seamlessly.

1.2.2 Java vs Kotlin

You can use both Java and Kotlin (https://kotlinlang.org/) programming languages in your Spring Boot project. Spring Framework 5.0 version has incorporated support for Kotlin and since then there is a constant effort to provide better support for Kotlin in the Spring Framework. For instance, In Spring Security 5.3, the Spring team has introduced a Kotlin version of their Domain Specific Language (DSL) support to Spring Security. You can read more on Spring Framework's Kotlin support at https://spring.io/.../introducing-kotlin-support-in-spring-framework-5-0.

In this book, we'll primarily use Java as our preferred language in most of the code examples. We'll cover the major Kotlin features in Spring Framework (through Spring Boot) in a later chapter.

1.2.3 Database Support

Several coding examples in this book require database access to demonstrate the concepts. Spring Boot extends support to an array of SQL and NoSQL databases. For the ease of testing of the coding examples, we'll use an H2 in-memory SQL database in all our code examples (with a few exceptions).

1.2.4 Lombok

In the Java code examples, we'll define POJO classes that define the business entities of our application. For example, to define a user, we'll define a POJO class named `User` with various user attributes such as first name, last name, username, password, etc., Besides, you'll need to provide constructors, getter, setter methods, etc. in the POJO class which is a bit verbose in the application code.

Lombok (https://projectlombok.org/) is a Java library that automatically generates the constructors, getter, setter, toString, etc. based on the presence of a few annotations in the POJO class. All you need to do is to use the appropriate annotation in the POJO class. For instance, to generate a getter method for all member variables in the POJO class, you can specify `@Getter` annotation in the class. We'll use Lombok in this book in the code examples.

If you are not interested to use Lombok, you can simply provide the getter, setter, constructors as applicable to the code. The code examples should work as expected.

1.3 Getting Started with Spring Boot

You now have an overview of Spring Boot and know the purpose of the framework. In this section, you'll learn to generate a Spring Boot project, and learn the various parts of the generated project.

1.3.1 Your First Spring Boot Project

Spring Boot provides a tool called Spring Initializr that lets you generate a skeleton Spring Boot project. You can access the Spring Initializr tool hosted at https://start.spring.io. Further, Spring Boot also provides APIs that allows the mainstream IDE vendors to integrate

Spring Initializr and provide built-in support to generate Spring Boot project in the IDE itself. If you are new to Spring Initializr, refer to Appendix A to find out various ways to create a Spring Boot project. We've generated a Spring Boot project for your reference in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/.../spring-boot-app-demo.

1.3.2 Spring Boot Project Structure

A generated Spring Boot project structure is relatively simple and consists of only the components you need to proceed with Spring Boot application development. It contains the following components:

- A `pom.xml` file that contains the dependencies you've selected during project generation
- A Maven wrapper file that lets you build the project without installing Maven in your local machine
- Package structure that contains the source and tests Java files. The source package contains a Java class with the main method and the test package has an empty test class
- A `resources` folder to maintain additional project artifacts and an empty `application.property` file

Let us discuss the key components of the generated project in detail.

THE MAVEN POM.XML FILE

The `pom.xml` file of the generated project is shown in Listing 1.1:

Listing 1.1 The pom.xml file of generated Spring Boot project

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>
    # Current project declares Spring Boot starter parent as its parent to indicate that
       this project is a child
         # Spring Boot project. This ensures several features of the application such as
       plugin and dependency management can be managed by Spring Boot
    <parent>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-starter-parent</artifactId>
        <version>2.4.1</version>
        <relativePath/> <!-- lookup parent from repository -->
    </parent>
    # Current Project's artifact details
    <groupId>com.manning.sbip.ch01</groupId>
    <artifactId>spring-boot-app-demo</artifactId>
    <version>1.0.0</version>
    <name>spring-boot-app-demo</name>
    <description>Spring Boot Demo Application</description>
    <properties>
        <java.version>15</java.version>
```

```
    </properties>

    #A list of declared Maven dependencies – Spring Boot starter web, and Spring Boot
       starter test
    <dependencies>
        <dependency>
            <groupId>org.springframework.boot</groupId>
            <artifactId>spring-boot-starter-web</artifactId>
        </dependency>
        # Spring Boot starter test dependency provides necessary support to perform testing
       Spring Boot applications with popular testing libraries such as Junit, Hamcrest and
       Mockito. This dependency excludes junit-vintage-engine dependency to leverage Junit
       5 features with junit-jupiter-engine
        <dependency>
            <groupId>org.springframework.boot</groupId>
            <artifactId>spring-boot-starter-test</artifactId>
            <scope>test</scope>
            <exclusions>
                <exclusion>
                    <groupId>org.junit.vintage</groupId>
                    <artifactId>junit-vintage-engine</artifactId>
                </exclusion>
            </exclusions>
        </dependency>
    </dependencies>
    # Spring Boot Maven plugin is a Maven plugin that provides useful goals to perform
       several application management activities. For instance, you can quickly start the
       Spring Boot application with this plugin using mvn spring-boot:run command.
    <build>
        <plugins>
            <plugin>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-maven-plugin</artifactId>
            </plugin>
        </plugins>
    </build>
</project>
```

There are three segments of the `pom.xml` you'll explore in this section:

1. The `parent` tag
2. The `dependencies` section
3. The Spring Boot Maven plugin

The `parent` tag

The `spring-boot-starter-parent` is the parent dependency for all Spring Boot starter dependencies. Besides, it also indicates that the current Spring Boot project is a child Spring Boot project and extends few details from the parent project.

A `spring-boot-starter-parent` is a special type of starter dependency that provides several default configurations such as default java version, default configurations for several Maven plugins to a Spring Boot project. For example, the `maven-war-plugin`, `maven-surefire-plugin` are automatically included by the starter parent dependency.

Further, `spring-boot-starter-parent` also assists in dependency management. Notice that there is no dependency version specified for any of the declared dependencies. The appropriate version of these libraries is specified in the `spring-boot-starter-parent`.

Does your Project already have a parent pom?

It is possible that you already have an existing maven project set up with a parent pom and you are upgrading this project to the Spring Boot. Thus, in this scenario, how can your child Spring Boot project extend the parent pom as it is already extending a custom parent pom?

You can still leverage several benefits such as the dependency management offered by Spring Boot parent pom by adding following dependency. You can specify `spring-boot-dependencies` **in the** `dependencyManagement` **section of the** `pom.xml` **file:**

```
<dependencyManagement>
   <dependencies>
      <dependency>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-dependencies</artifactId>
         <version>2.4.1</version>
         <type>pom</type>
         <scope>import</scope>
      </dependency>
   </dependencies>
</dependencyManagement>
```

Starter dependencies in the dependencies section

In the second section of the `pom.xml` file, Spring Boot starter dependencies are declared. Spring Boot starter dependencies are one of the key features of the Spring Boot framework. Refer to the Spring Boot Starter dependency sidebar for a quick overview of it.

Spring Boot Starter Dependency

A Spring Boot starter dependency is intended to make the Spring Boot application development easy, rapid, and effective. If you have previous experience developing Java applications with a build tool such as Apache Maven or Gradle, you can recall that managing dependencies is one of the key challenges for an application developer.

The first challenge is to identify the correct set of dependencies that you might need to build a specific component of your application. Once you identify them, you are in search of the right version of the provided dependencies. In this fast-paced world of application development, it is relatively easy to become out-of-sync with your dependency versions. Further to increase your issues, the dependencies you choose have their own dependencies or more precisely the transitive dependencies. In some cases, you even need to control those as well. Spring Boot Starter dependency is a solution in Spring Boot to relieve you from all the above-mentioned issues.

A starter dependency groups together a set of dependencies that you might need to develop a part of your application. If you choose to develop a web application with Spring Boot, you'll most likely choose the `spring-boot-starter-web` dependency. It ensures that all required dependencies to develop a web application are available in your application. Of course, this is opinionated, and you get the set of dependencies which Spring team recommends you need to have to develop a web application. However, the key part here is that you are relieved from the dependency versioning, upgrade, and many other issues associated with it.

A starter dependency can also depend on another starter dependency. For instance, the `spring-boot-starter-web` needs few common starter dependencies, such as the `spring-boot-starter`, `spring-boot-starter-tomcat`, and `spring-boot-starter-json` dependencies. These starters pull another set of dependencies related to Spring Boot, Tomcat, and JSON respectively. You can refer to the Spring Boot documentation for a list of Spring Boot starters available at https://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#using-boot-starter.

The concept of starter dependency is extendable. Spring Boot lets you build your starters that you can use in your application. This is useful for large applications to modularize and manage dependencies in terms of custom starters. You'll learn how to create a custom starter later in the book.

In the generated project, we've included two starter dependencies - `spring-boot-starter-web` and `spring-boot-starter-test`. The web starter dependency includes required jars to build a web application, whereas the test dependency lets to write test cases for your application.

Spring Boot Maven plugin

In the final section of the `pom.xml` presented in Listing 1.1, you can find the `spring-boot-maven-plugin`. This plugin is provided for developer convenience to simplify several application management activities. For instance, you'll often notice that it is quite straightforward to build an executable `JAR` or `WAR` file of a Spring Boot application. This is because the `repackage` goal of the `spring-boot-maven-plugin` ensures that it takes the Maven generated original `JAR` or `WAR` file (which is not an executable) and repackages it to make it executable.

Table 1.2 shows the list of available goals of `spring-boot-maven-plugin` with the syntax and a brief description:

Table 1.1 List of Spring Boot Maven Plugin Goals

Goal Name	Maven Command Syntax	Description
Build an image	`spring-boot:build-image`	Packages the application into an Open Container Initiative (OCI) (https://opencontainers.org/) image. You will learn more about images and their deployment into containers later in this book.
Generate build-info properties	`spring-boot:build-info`	Generates a `build-info.properties` file based on the current Maven project. You can find this file at `${project.build.outputDirectory}/META-INF/build-info.properties`
Display Help Information	`spring-boot:help`	Shows help the content of `the spring-boot-maven-plugin`. You can use `mvn spring-boot:help -Ddetail=true -Dgoal=<goal-name>` to view parameters allowed in a goal. For example, `mvn spring-boot:help -Ddetail=true -Dstart` shows detailed information about the start goal
Repackage Spring Boot JAR or WAR archives	`Spring-boot:repackage`	This goal intends to repackage the existing JAR or WAR file to make them executable from the command line (e.g., `java -jar somejar.jar`). By default, this goal binds itself in the Maven lifecycle `package` phase and makes the generated JAR or WAR archive executable. You can use `mvn clean install spring-boot:repackage` to see how this goal works. Alternatively, you can also use `mvn package` to generate the same executable archive.
Run a Spring Boot Application	`spring-boot:run`	Runs a Spring Boot application in place.
Start a Spring Boot Application	`spring-boot:start`	Starts a Spring Boot application
Stop a running Spring Boot Application	`spring-boot:stop`	Stops an application that was started using the 'start' goal

You can refer to table 1.1 to learn more about each of these goals. For instance, if you would like to run the current Spring Boot application, you can execute the following command in command-line or terminal from the same directory where `pom.xml` is located:

```
mvn spring-boot:run
```

You’ll see the application starts and runs on default HTTP port `8080`, as shown in figure 1.22:

```
C:\sbip\spring-boot-in-practice\Chapter01\spring-boot-app-idea>mvn spring-boot:run
[INFO] Scanning for projects...
[INFO]
[INFO] ------------< com.manning.sbip.ch01:spring-boot-app-idea >------------
[INFO] Building spring-boot-app-idea 0.0.1-SNAPSHOT
[INFO] --------------------------------[ jar ]---------------------------------
[INFO]
[INFO] >>> spring-boot-maven-plugin:2.3.4.RELEASE:run (default-cli) > test-compile @ spring-boot-app-idea >>>
[INFO]
[INFO] --- maven-resources-plugin:3.1.0:resources (default-resources) @ spring-boot-app-idea ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Copying 1 resource
[INFO] Copying 0 resource
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:compile (default-compile) @ spring-boot-app-idea ---
[INFO] Nothing to compile - all classes are up to date
[INFO]
[INFO] --- maven-resources-plugin:3.1.0:testResources (default-testResources) @ spring-boot-app-idea ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] skip non existing resourceDirectory C:\sbip\spring-boot-in-practice\Chapter01\spring-boot-app-idea\src\test\resources
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:testCompile (default-testCompile) @ spring-boot-app-idea ---
[INFO] Nothing to compile - all classes are up to date
[INFO]
[INFO] <<< spring-boot-maven-plugin:2.3.4.RELEASE:run (default-cli) < test-compile @ spring-boot-app-idea <<<
[INFO]
[INFO]
[INFO] --- spring-boot-maven-plugin:2.3.4.RELEASE:run (default-cli) @ spring-boot-app-idea ---
[INFO] Attaching agents: []
```

Spring Boot Maven Plugin *run* goal

Figure 1.3 Running a Spring Boot application using Spring Boot Maven plugin in Command Line

A careful observation of the command line output shows that this goal indeed invokes several other Maven plugins – `maven-resources-plugin` to copy resources (e.g. copying Java source files from `src/main/java` folder to the associated output directory), `maven-compiler-plugin` to compile the source code before it starts the application. The `spring-boot-maven-plugin` abstracts all these low-level tasks from the developer.

The Spring Boot Main Class

In the generated project, you can find that Spring Initializr has generated a Java class with a Java `main()` method in it. For this example, the generated Java file is available at https://github.com/spring-boot-in-practice/repo/blob/ch01/spring-boot-app-demo/src/main/java/com/manning/sbip/ch01/SpringBootAppDemoApplication.java.

Let’s examine the following components of the generated Java file:

1. The naming pattern of the Java file
2. Use of the `main()` method
3. Use of `@SpringBootApplication` annotation
4. The role of `SpringApplication` class

Naming Pattern of the Java file

You can notice that the Java file name follows a specific pattern - Spring Boot application name concatenated with the word *Application (e.g.,* `SpringBootAppDemo` (name of the Spring Boot application) + Application*).*

Use of the `main()` method

In general, to run a web application, you build and package the application components in a `WAR` or `EAR` archive file and deploy it into a web (e.g., Apache Tomcat) or application server (e.g., Red Hat JBoss). Spring Boot simplifies this process to a certain degree. It does not enforce you to build a `WAR` or `EAR` file of your application. Instead, it lets you run the Spring Boot application like a regular Java application using a conventional `main()` method.

Although Spring Boot follows a familiar approach to keep things simple for developers, it performs a decent amount of heavy lifting behind the scenes. For instance, a Servlet-based web application can run only in a Servlet Container such as Apache Tomcat or Jetty. Spring Boot enables this support by using an embedded Apache Tomcat server in the application by default. Thus, when you start your Spring Boot application using the `main()` method, Spring Boot starts an embedded instance of the Apache Tomcat server and runs the web application inside it.

If you explore the `spring-boot-starter-web` dependency further, you can find it has a transitive dependency on the `spring-boot-starter-tomcat` module. You can click on dependency in the `pom.xml` file in your IDE to explore the list of libraries it depends on.

Use of `@SpringBootApplication` annotation

You can also notice that the class in the generated Java file is annotated with the `@SpringBootApplication` annotation. This is a convenient annotation that consists of three annotations – `@EnableAutoConfiguration`, `@ComponentScan`, and `@SpringBootConfiguration`, each of which performs a specific task in the application.

Let’s understand these annotations based on their actions:

- `@EnableAutoConfiguration`: Spring Boot provides several `@Enable*` annotations to enable specific features in your Spring Boot application. The `@EnabaleAutoConfiguration` annotation provides the necessary support for Spring Boot to auto-configure your application based on the jar dependencies present in the application classpath. You’ll learn more about auto-configuration later in the book
- `@ComponentScan`: Provides support to scan the packages for Spring components in the application. A component in Spring is a Java bean that is managed by Spring and annotated with the `@Component`, `@Bean`, or specialized component annotations. With the presence of `@ComponentScan` annotation, the Spring Boot application scans for all components present in the root package and sub-packages under it to manage their lifecycle. The key point to remember with `ComponentScan` is that the scan starts from a root package and continues to all child packages. Thus, if you’ve packages that are not in the root or its sub-package, none of those components will be scanned by the component scan.
- `@SpringBootConfiguration`: This annotation indicates that the annotated class provides the Spring Boot application configuration. It is meta-annotated with Spring `@Configuration` annotation so that the configurations in the annotated class can be found automatically by Spring Boot. Thus, the beans defined in this main class can be auto-detected and loaded by Spring

Role of `SpringApplication` class

The next and final component is the use of `SpringApplication` class in the generated Java file. This class is provided by Spring Boot to conveniently bootstrap a Spring Boot application. Most of the time, you'll use the static `run()` method of `SpringApplication` to bootstrap and launch your application. Spring Boot performs several activities while it executes the `run()` method:

1. Creates an instance of an `ApplicationContext` based on the libraries present in the classpath
2. Registers a `CommandLinePropertySource` to expose command line arguments as Spring properties
3. Refreshes the `ApplicationContext` created at step 1 to load all singleton beans
4. Triggers the `ApplicationRunners` and `CommandRunners` configured in the application

Revisiting ApplicationContext

Most Java applications you develop are consist of objects. These objects interact with each other and there are dependencies among them. To effectively manage the object creation and their interdependencies, Spring uses the principles of Dependency Injection (DI). This dependency injection or the Inversion of Control (IoC) approach lets Spring create the objects (or more appropriately beans in Spring parlance) and inject the dependencies externally. The bean definitions are presented to Spring either through the XML bean definition files (e.g., applicationContext.xml) or through the annotation-based configurations (@Configuration annotation). Spring loads these bean definitions and keeps them available in the Spring IoC container.

The `ApplicationContext` **interface acts as the Spring IoC Container. Spring provides a plethora of** `ApplicationContext` **implementations based on the application type (Servlet or Reactive application), the bean definition configurations (e.g., to load from classpath or annotation), and so on. You can refer to the Java documentation of the** `ApplicationContext` **interface ((https://docs.spring.io/spring-framework/docs/current/javadoc-api/org/springframework/context/ApplicationContext.html) to know more about it and its available subtypes.**

The `SpringApplication` class attempts to create an instance of `ApplicationContext` based on the jar dependencies present in the classpath. A Spring Boot Web application can be either a Servlet-based, Reactive, or standalone (should not run as a web application) type. Leveraging Spring's class loading techniques and based on the availability of the classes in the classpath, Spring deduces the current application's type. Once the application type is known, Spring boot applies the below strategy to load the application context:

1. If the application is identified as Servlet based web application, Spring Boot attempts to create an instance of `AnnotationConfigServletWebServerApplicationContext` class
2. Alternatively, if the application is Reactive type, Spring Boot creates an instance of `AnnotationConfigReactiveWebServerApplicationContext` class

3. If the application is neither a Servlet-based nor a Reactive application, Spring Boot attempts to create an instance of `AnnotationConfigApplicationContext` class

For all three application types, if the corresponding class is not available in the classpath, Spring Boot throws an `IllegalArgumentException`.

You start a Spring Boot application using the static `run()` method of `SpringApplication` class. Although using the static `run()` method is useful, Spring Boot additionally lets you create an instance of `SpringApplication` class to customize the application bootstrap mode. For instance, if you are aware of the application type, you can directly set it in the `SpringApplication` instance as shown in Listing 1.2:

Listing 1.2 Customizing SpringApplication to select the application type as Reactive

```
package com.manning.sbip.ch02;

//imports

@SpringBootApplication
public class BootstrappingSpringBootAppApplication {

    public static void main(String[] args) {

        # Create an instance of SpringApplication
        SpringApplication springApplication = new
       SpringApplication(BootstrappingSpringBootAppApplication.class);

        # Customizing SpringApplication class to set the application type as Reactive
        springApplication.setWebApplicationType(WebApplicationType.REACTIVE);

        springApplication.run(args);
    }
}
```

`SpringApplication` also provides several setter methods so that you can control various Spring Boot features such as set additional Spring profiles, set a resource loader to load application resources. You can refer to the latest version of the Spring Boot reference manual (https://docs.spring.io/spring-boot/docs/current/reference/html/spring-boot-features.html#boot-features-spring-application) to learn more on the `SpringApplication` offerings.

CONFIGURATION MANAGEMENT WITH THE APPLICATION PROPERTIES FILE

Spring Initializr generates an empty `application.properties` file in the `src/main/resources` folder. This property file lets you externalize various application configurations (e.g., server details, database details) for your application. Although there are multiple ways to externalize application properties for a Spring Boot application, this is the most frequently used approach. This property file lets you specify the configurations in a `key-value` pair format where a key is separated from the associated value by a `=`.

Listing 1.2 shows sample configuration in the `application.properties` file to configure the server address and port of a Spring Boot application:

Listing 1.2 The application.properties contents to configure the application address and port

```
# Network address to which the server should bind
server.address=localhost
# Server HTTP port
server.port=8081
# Actuator endpoint to be enabled
management.endpoints.web.exposure.include=*
```

To see the `application.properties` file in practice, you can modify the `server.port` value in the current application to a different HTTP port value (for instance to `9090`). If you launch the application after this modification, you can see it starts on the updated HTTP port.

If you are not fond of the property file format, you can alternatively use YAML (https://yaml.org/spec/1.2/spec.html) file format to configure application properties. YAML lets you hierarchically define the properties. If you would like to use the YAML file format, you can rename the existing `application.properties` file to `application.yml` and specify the properties in YAML format. Listing 1.4 shows the equivalent YAML configuration of listing 1.3:

Listing 1.3 The application.yml content to configure the application address and port

```
server:
  address: localhost
  port: 8080
management:
  endpoints:
    web:
      exposure:
        include: '*'
```

You can refer to the common application properties on the Spring Boot website (https://docs.spring.io/spring-boot/docs/current/reference/html/appendix-application-properties.html) for a list of supported `application.properties`. As we advance in this book, you'll be surprised to observe how by simply adding an application configuration property, you can achieve a drastic change in your application behavior.

In this section, you've explored the core components of a Spring Boot application. You should now be familiar with the overall Spring Boot project structure, the `pom.xml` file components, the `@SpringBootApplication` annotation, `SpringApplication` class, and the mighty `application.properties` that give you the power to control the Spring Boot application behavior through various built-in and custom properties.

1.3.3 Creating an Executable JAR file

The easiest way to you can create an executable jar file from your Spring Boot project is to use the `mvn package` command. Recall that you've selected the packaging type while generating the project. Based on the selection, a jar file is created in the project's target directory. The generated jar file can be executed with the `java -jar` command from your command line to start the application.

By default, the Maven `package` goal does not generate an executable jar or war file on its own. It's the `spring-boot-maven-plugin's` repackage goal that binds itself in the package phase and prepares the executable file.

1.3.4 Exploring the Jar file

If you explore the generated jar file, you'll find the following structure as shown in Listing 1.4:

Listing 1.4 Spring Boot Generated Jar File Structure

```
spring-boot-app-demo.jar
  |
  +-META-INF
  |  +-MANIFEST.MF
  +-org
  |  +-springframework
  |    +-boot
  |      +-loader
  |        +-<spring boot loader classes>
  +-BOOT-INF
    +-classes
    |  +-com
    |    +-manning
    |      +-sbip
    |        +-ch01
    |          +-SpringBootAppDemoApplication.class
    +-lib
      +-classpath.idx
      +-layers.idx
      +-dependency1.jar
      +-dependency2.jar
```

We can broadly classify the structure into four sections:

- META-INF: This section contains the `MANIFEST.MF` file which contains several critical information on the jar needs to be executed. The two key parameters presented in this file are `Main-Class` and `Start-Class` details
- Spring Boot Loader components: Spring Boot Loader provides several Loader implementations that are used to load the executable file. For instance, the `JarLauncher` class is loads a Jar file, a `WarLauncher` loads a War file, and the `PropertiesLauncher` lets you customize the class loading through a set of a `loader.*` properties
- BOOT-INF\classes: All application class files are packaged in this folder
- BOOT-INF\lib: Contains all the dependencies for your application

One key point to note is the use of `Main-Class` and `Start-Class` parameters in the `MANIFEST.MF` file. The `Main-Class` contains the `Launcher` class name which uses the class specified in the `Start-Class` to start the application. In a Spring Boot executable jar, the `Start-Class` is always your Spring Boot main class.

The `classpath.idx` file is an index file that lists the dependencies with the order in which the class loader should load them. The `layer.idx` file is used for jars that allow the jar to be segregated into logical layers for Docker or the OCI image creation. You'll explore the use of `layer.idx` in detail later in this book when you create Docker images from your Spring Boot application.

1.3.5 Shutting Down a Spring Boot application

You may find shutting down and executing the Spring Boot application quite straightforward. If you are executing the jar as a foreground process through your command line, you can terminate the Java process with `Ctrl+C` (in Windows and Linux). Similarly, you can use the appropriate OS-specific command to kill the Java process if the application is running as a background process.

Without any additional configurations, the approaches discussed above terminates the Spring Boot application immediately and do not provide it any scope to serve the currently executing request if there is any. This might be an issue with your applications' user experience. Thus, you need to ensure a graceful shutdown of the application which should allow the current request to be served but no new request should be taken before it finally gets terminated. Spring Boot provides additional configurations to enable the graceful shutdown in your application. Listing 1.5 shows these configurations:

Listing 1.5 Graceful Shutdown Configuration

```
server.shutdown=graceful
spring.lifecycle.timeout-per-shutdown-phase=30s
```

The default value of the `server.shutdown` property is `immediate` which indicates an immediate shutdown of the application. Once you configure the graceful shutdown, you need to configure the grace period the application should wait for the current request to finish. In Listing 1.5, we've configured the `30s` as the grace period.

1.4 Spring Boot Additional Concepts

In this section, we'll provide a brief introduction to a few useful Spring Boot concepts. Some of these are key concepts of the framework and we'll provide a detailed discussion in the subsequent chapters.

1.4.1 Spring Boot Startup Events

Spring framework's event management mechanism promotes decoupling of event publishers and subscribers in an application. It allows you to subscribe to the framework's built-in events as well as lets you define your custom events.

The Spring Boot framework also provides several built-in events that you can subscribe to perform certain actions. For instance, there might be a requirement that you need to invoke an external REST API if your Spring Boot application initializes completely. In this section, we'll introduce several Spring Boot events which are published at various stages of an application startup and initialization:

ApplicationStartingEvent: Published at the beginning of the application startup once the Listeners are registered. Spring Boot's `LoggingSystem` uses this event to perform any action that needs to be taken up before application initialization

ApplicationEnvironmentPreparedEvent: Published when the application is starting up and the `Environment` is ready for inspection and modification. Spring Boot internally use this event to pre-initialization several services such as `MessageConverter`, `ConversionService`, Initialize Jackson, etc

ApplicationContextInitializedEvent: Published when the `ApplicationContext` is prepared, `ApplicationContextInitializers` are executed but none of the bean definitions are loaded. This event can be used to perform a task before beans are initialized in the Spring container

ApplicationPreparedEvent: Published when the `ApplicationContext` is prepared, bean definitions are loaded but not refreshed. The `Environment` is ready for use at this stage

ContextRefreshedEvent: Published when the `ApplicationContext` is refreshed. This event comes from Spring and not from Spring Boot. This event does not extend `SpringApplicationEvent`. The Spring Boot `ConditionEvaluationReportLoggingListener` listens to this event and prints the auto-configuration report once this event is published

WebServerInitializedEvent: Published when the webserver is ready. This event has two variants based on the type of the application – `ServletWebServerInitializedEvent` for Servlet-based applications, `ReactiveWebServerInitializedEvent` for Reactive applications. This event does not extend `SpringApplicationEvent`.

ApplicationStartedEvent: Published when the `ApplicationContext` is refreshed, but before the `ApplicationRunner` and `CommandLineRunners` are called

ApplicationReadyEvent: Published by `SpringApplication` to indicate the application is ready to service requests. It is not advised to change the internal state of the application as all application initialization steps are finished

ApplicationFailedEvent: Published when there are some exceptions, and the application is failed to start. This event is useful to perform tasks like script execution or notify startup failures

1.4.2 Listening Events in a Spring Boot Application

Spring Boot events at application startup provide useful information about the various stages of application initialization. These events are useful if you need programmatic control on the application startup behavior. The easiest approach is to subscribe to these events and take necessary actions. For instance, if you need to modify any parameter in the `Environment`, you can subscribe to `ApplicationEnvironmentPreparedEvent` and do so. Spring Boot uses these events internally to initialize several components of the application.

Let us discuss different approaches to subscribe to these events. The easiest way to use Spring Framework's `@EventListener` annotation. For instance, to listen to the `ApplicationReadyEvent`, you can use the code snippet as shown in Listing:

Listing 1.6 Using @EventListener annotation to listen ApplicationReadyEvent

```
@EventListener(ApplicationReadyEvent.class)
public void applicationReadyEvent(ApplicationReadyEvent applicationReadyEvent) {
       System.out.println("Application Ready Event generated at "+new
       Date(applicationReadyEvent.getTimestamp()));
}
```

The above code snippet prints the timestamp when the `ApplicationReadyEvent` was generated. Although `@EventListener` works well in most circumstances, it does not work for events that are published very early in the application start-up such as `ApplicationStartingEvent` and `ApplicationEnvironmentPreparedEvent`. In this section, we'll discuss two additional approaches to listen to events in a Spring Boot application.

Using `SpringApplication`

Typically, in the generated Spring Boot project the Application class invokes the static `run()` method of `SpringApplication` to start the application. However, the `SpringApplication` class also provides several setter methods to customize the application startup behavior. For instance, it lets you add `ApplicationContextInitializer`, set `ApplicationListener`, and many others with the various setter methods. To use `SpringApplication` to listen to events, you can create an appropriate `ApplicationListener` class and implement the `onApplicationEvent()` method. Listing 1.7 shows a custom listener that listens to the `ApplicationStartingEvent` of Spring Boot:

Listing 1.7 Creating a Custom ApplicationListener

```
public class ApplicationStartingEventListener implements
       ApplicationListener<ApplicationStartingEvent> {

       @Override
       public void onApplicationEvent(ApplicationStartingEvent applicationStartingEvent) {
         System.out.println("Application Starting Event logged at "+new
       Date(applicationStartingEvent.getTimestamp()));
       }

}
```

You can then add this listener in the `SpringApplication` so that once there is an `ApplicationStartingEvent` published, the associated listener is called. Listing 1.8 shows the `SpringApplication` implementation:

Listing 1.8 Adding Application Listener in SpringApplication

```
@SpringBootApplication
public class SpringBootEventsApplication {

       public static void main(String[] args) {
         SpringApplication springApplication = new
       SpringApplication(SpringBootEventsApplication.class);
         springApplication.addListeners(new ApplicationStartingEventListener());
         springApplication.run(args);
       }
}
```

In the listing, you've added the custom listener into the `SpringApplication` instance. The `addListeners(..)` method takes a `varargs` so that you can add any number of listeners using this method.

The `SpringApplication` approach requires you to make code changes in your Spring Boot application class. If this is not convenient, Spring Boot provides another approach through `spring.factories` property file to register the custom listeners. Let us explore this in the next section.

Using the `spring.factories` file

The `spring.factories` file provides you an extension point in the Spring Boot framework to configure and customize certain application features. For instance, you can find extensive use of this file by Spring Boot to configure the initializers, application listeners, auto-configuration, failure analyzers, the template provides, etc. The `spring.factories` file is a property file consists of key-value pairs.

In general, the `spring.factories` file exists even before the Spring Boot and it is one of the core Spring Framework features. You can find this file inside the `spring-beans` jar which is a Spring framework component.

Nonetheless, Spring Boot provides an approach to configure certain custom components such as the `ApplicationListener` through this file. Browse to your application's `src\main\resources` folder and create a folder named `META-INF`. Inside it create an empty file named `spring.factories` and add the contents shown in listing 1.9 inside it:

Listing 1.9 The spring.factories file

```
org.springframework.context.ApplicationListener=com.manning.sbip.ch01.listener.ApplicationS
       tartingEventListener
```

In listing 1.9, the key is class type of the component you are configuring, and the value is the fully qualified class name of the associated implementation. For instance, as we are configuring an `ApplicationListener`, the key is the fully qualified class type `org.springframework.context.ApplicationListener` and the value is the custom listener class `com.manning.sbip.ch01.listener.ApplicationStartingEventListener`. You can provide multiple listener implementations separated by a comma.

You'll notice the use of the `spring.factories` file in details in later chapters while configuring custom auto-configuration, failure analyzers, etc.

1.4.3 Custom Spring Boot Starters

In the earlier example, you've noticed the use of official Spring Boot starters that are developed and maintained by Spring Boot. Starters are one of the key features of Spring Boot that simplifies the dependency management in a Spring Boot application. This concept of starters can be extended to the proprietary code and configurations as well. Spring Boot extends its infrastructure to let you define your custom starters so that you can define and maintain them like other application artifacts. In the later part of the book, we'll demonstrate how to define a custom starter.

1.4.4 Custom Auto-Configuration

In the introduction of this chapter, we mentioned that Spring Boot is opinionated. At the time of application startup, Spring Boot automatically configures various application components based on available dependencies and configurations and other factors. The auto-configuration strategy lets Spring Boot express its opinion about certain application components and plays a major role in Spring Boot application initialization and execution. As starters, the auto-configuration feature is also extendable, and you can define your auto-configuration. In the later part of the book, we'll demonstrate how to define custom auto-configuration

1.4.5 Failure Analyzers

Spring Boot uses the notion of failure analyzers that analyzes application failures and provides a detailed diagnostic report about the failure. A `FailureAnalyzer` accepts an exception and provides a detailed `FailureAnalysis`. Figure 1.4 shows the `FailureAnalysis` report printed in the console for the `PortInUseException`. This exception occurs if the port you are using to start the Spring Boot application is not available for use.

```
***************************
APPLICATION FAILED TO START
***************************

Description:

Web server failed to start. Port 8080 was already in use.

Action:

Identify and stop the process that's listening on port 8080 or configure this application to listen on another port.
```

Figure 1.4 Failure Analyzer diagnostic report if the port is not available for use

You can extend the concept of `FailureAnalyzer` and define your custom exception and failure analyzers. For instance, it is quite useful along with custom auto configurations to define your domain-specific exception and define failure analyzer implementation with a detailed failure analysis report. You'll explore how to create a custom `FailureAnalyzer` later in the book.

1.4.6 Spring Boot Actuator

Spring Boot actuator lets you monitor and interact with your Spring Boot application. It is quite common to monitor several health parameters in any production application. For instance, you can perform a health check in an application to determine whether the application is up. Besides, you can also capture thread dump or heap dump of your application to perform a variety of analyses. Spring Boot provides a plethora of production-ready features with the actuator. To enable the Spring Boot actuator, you need to include the `spring-boot-starter-actuator` dependency in the pom.xml. Listing 1.10 shows this dependency:

Listing 1.10 Spring Boot Starter Actuator dependency

```
<dependency>
   <groupId>org.springframework.boot</groupId>
   <artifactId>spring-boot-starter-actuator</artifactId>
</dependency>
```

By default, Spring Boot exposes the `/actuator` as the base endpoint to access the other endpoints. Only the `/health` and `/info` endpoints are enabled for HTTP by default. For instance, if you access the http://localhost:8080/actuator, you'll see the page as shown in Listing 1.11:

Listing 1.11 Spring Boot Actuator Endpoints

```
{
   "_links":{
      "self":{
         "href":"http://localhost:8080/actuator",
         "templated":false
      },
      "health":{
         "href":"http://localhost:8080/actuator/health",
         "templated":false
      },
      "health-path":{
         "href":"http://localhost:8080/actuator/health/{*path}",
         "templated":true
      },
      "info":{
         "href":"http://localhost:8080/actuator/info",
         "templated":false
      }
   }
}
```

If you access http://localhost:8080/actuator/health, you can find the application status as `UP` if the application is running. We'll discuss the Spring Boot actuator in detail in a later chapter.

1.4.7 Spring Boot Developer Tool

To increase developer productivity, Spring Boot provides a set of tools that make the development experience more pleasant. For instance, it monitors the classpath changes and automatically builds the application for any change. Besides, it also provides an embedded LiveReload server that can be used to trigger a browser refresh when a resource is modified. To include developer tools in your Spring Boot project, you need to include the spring-boot-devtools dependency in the `pom.xml` as shown in Listing 1.12:

Listing 1.12 Spring Boot Developer Tools

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-devtools</artifactId>
    <optional>true</optional>
</dependency>
```

1.5 Chapter Summary

Spring Boot enables you to create standalone, production-ready applications that you can run without worrying much about the configuration aspects. Its auto-configuration and starter-based dependency management perform the heavy-lifting of application configuration and let you focus on the business aspect of your application.

In this chapter, we've started with an overview of the various Spring Boot features and components. Some of the main areas we explored in this chapter were:

- What is Spring Boot, and the benefits it offers over a traditional Spring application
- Spring Boot features and its various components
- Explored the structure and the components of a generated Spring Boot project
- How to create an executable JAR file from a Spring Boot project and explored the structure of the generated JAR file
- How to gracefully shutdown a running Spring Boot application
- Spring Boot startup events and various ways to listens to the events
- Overview of custom starter, auto-configuration, failure analyzers, and actuator
- Introduction to Spring Boot developer tools to increase development productivity

The remainder of this book is dedicated to presenting the real-world techniques for solving common problems you'll encounter when working with Spring Boot. You'll be introduced to a broad spectrum of subject areas, starting with Spring Boot application development, security, reactive application development, and cloud-based deployments.

2

Spring Boot common tasks

This chapter covers

- **Managing Configurations in a Spring Boot application**
- **Creating Custom configuration with** `@ConfigurationProperties`
- **Exploring** `CommandLineRunner` **interface to execute initialization code**
- **Understanding Spring Boot default logging and configuring** `Log4j2` **logging**
- **How to validate user data in a Spring Boot application using Bean Validation**

By this point, we've learned a bit about what Spring Boot is and learned its purpose to improve the application development experience by abstracting specific low-level configurations. In this chapter, you'll extend this understanding further by learning few core concepts such as how to manage application configuration and create a custom configuration for your application. You'll also use Spring Boot to perform several commonly used tasks that you'll frequently perform while developing Spring Boot applications.

2.1 Managing Configurations

Managing application configuration is a key part of any application, and Spring Boot applications are no exception to it. Based on how you develop and manage applications, you can have multiple environments (e.g., dev, test, staging, and prod) for an application in your organization. For instance, you can have one environment for development, one for testing, one for staging, and one for production. For all these environments, your application code mostly remains the same and you need to manage a lot of different configurations based on the environment. As an example, the database configurations, or the security configurations are different in all these environments. Besides, as the application grows, and you incorporate new features, it becomes more tedious to manage the configurations.

Spring Boot provides several approaches to let you externalize application configurations without altering the application source code. The various approach includes property files, YAML files, environment variables, and command-line arguments.

In the next sections, you'll explore these approaches and learn how you can configure the application configurations in your Spring Boot application.

2.1.1 Using SpringApplication

You can use the `SpringApplication` class to define configurations in your Spring Boot application. This class provides a method named `setDefaultProperties()` that accepts a `java.util.Properties` or a `java.util.Map<String, Object)` instance to let you set the configurations. You can configure all your application properties in the Properties or the Map instance. This approach is useful for configurations that are one-time configurations. Let us explain this through an example.

In your `application.properties` file, you can import other configuration files (e.g., properties or yml files containing the configurations) using the Spring Boot's `spring.config.import` property. For instance, you can configure `spring.config.import=classpath:additional-application.properties` in your `application.properties` file so that Spring Boot can load the configuration present in the `additional-application.properties` file. However, if this file does not exist in the classpath, Spring Boot throws a `ConfigDataLocationNotFoundException`.

Based on your application configuration, you may choose to ignore some configuration files and continue with the application bootstrap. To achieve this, you can configure a property named `spring.config.on-not-found` to `ignore`. Listing 2.1 shows this in practice:

Listing 2.1 Using SpringApplication's setDefaultProperties method

```
package com.manning.sbip.ch02;

import java.util.Properties;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class SpringBootAppDemoApplication {

       public static void main(String[] args) {

         Properties properties = new Properties();
         properties.setProperty("spring.config.on-not-found", "ignore");

         SpringApplication application = new
       SpringApplication(SpringBootAppDemoApplication.class);
         application.setDefaultProperties(properties);
         application.run(args);
       }
}
```

In Listing 2.1 you've created an instance of `SpringApplication` class and set the `spring.config.on-not-found` property with a `java.util.Properties` instance through the `setDefaultProperties(..)` method.

You can download the Spring Boot project used in this section available at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/spring-application.

2.1.2 Using @PropertySource

In your Spring configuration classes, you can specify the `@PropertySource` annotation with the location of the property file to load configurations. Listing 2.2 shows this:

Listing 2.2 The DbConfiguration Class

```
package com.manning.sbip.ch02;

//imports

@Configuration
@PropertySource("classpath:dbConfig.properties")
public class DbConfiguration {

	@Autowired
	private Environment env;

	@Override
	public String toString() {
	  return "Username: "+env.getProperty("user") +", Password:
	"+env.getProperty("password");
	}
}
```

The code snippet in Listing defines a Spring configuration class that has `@PropertySource` annotation on it that reads properties from `dbConfig.properties` file available in the classpath. Listing 2.3 shows a sample `dbConfig.properties` file:

Listing 2.3 dbConfig.properties file

```
user=sa
password=password
```

Besides, you've autowired the Spring `Environment` instance that lets you access the properties available in the `dbConfig.properties` file. Let us now access the `DbConfiguration` class to get the configured properties as shown in Listing 2.4:

Listing 2.4 Accessing DbConfiguration Instance

```
package com.manning.sbip.ch02;

//imports

@SpringBootApplication
public class SpringBootAppDemoApplication {
```

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

          ConfigurableApplicationContext applicationContext =
        SpringApplication.run(SpringBootAppDemoApplication.class, args);
          DbConfiguration dbConfiguration =
        applicationContext.getBean(DbConfiguration.class);
          System.out.println(dbConfiguration);
        }
}
```

If you start the application, you'll notice that it prints the database username and password in the application console. You can download the Spring Boot project used in this section available at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/property-sources.

@PropertySource

1. YML or YAML files are not supported with this annotation like properties files. You need to write additional code to support YML files

2. If you are using Java 8 and above, you can repeat @PropertySource annotation with other configuration files. If you are using below Java 8, you can use @PropertySources annotation to specify multiple @PropertySource annotations. The following code snippet shows @PropertySource Java 8 configuration that loads properties from dbConfig.properties and redisConfig.properties files:

```
@Configuration
@PropertySource("classpath:dbConfig.properties")
@PropertySource("classpath:redisConfig.properties")
public class DbConfiguration {
//
}
```

2.1.3 Config Data File

Spring Boot lets you specify the application configuration properties in the `application.properties` or the `application.yml` file. This is the most widely used approach to provide a configuration in a Spring Boot file. You'll notice the Spring Initializr generated project includes an empty `application.properties` file. In case you are comfortable with YAML or YML files, you can provide an `application.yml` file in your application. Configurations specified in the properties or the YML file are loaded into Spring `Environment` and you can access the Environment instance in your classes. Besides, you can also use them with the `@Value` annotation.

Properties or YML File

Spring Boot lets you specify the application configurations in the properties as well as the YML file. In a property file, you can specify the properties in a key-value pair as shown below where the property key is separated from the values with a = separator:

```
server.port=8081
spring.datasource.username=sa
spring.datasource.password=password
```

The similar properties can be configured in a YML in the following manner:

```
server:
  port: 8081
spring:
  data source:
    username: sa
    password: password
```

Whether to use properties or YML files is a developer preference. Spring Boot works similarly with both these file types (with a few exceptions). Some people prefer to use YML due to its better clarity, and ability to represent hierarchical data more naturally. Besides, it is less repetitive and has enhanced capabilities to support data structures such as lists, maps, etc.

However, if you choose to use YML files in your application, you should exercise caution to be mindful of its syntax. It is relatively easy to miss an extra space or define an incorrect indentation in the YML file.

If you need to change the file name from the application to any other name, you can do it easily. You can customize the file name from `application.properties` with the `spring.config.name` Spring Boot property. In your Spring Boot application, let's create a file named `sbip.yml` file in `src\main\resources` folder and place the `server.port` configuration with value `8081`. You can build the application using the `mvn install` command from the location of your pom file. Post-build, run the executable jar using the `java -jar <jarName>` command as shown in Listing 2.5:

Listing 2.5 Executing the application Jar file

```
java -jar config-data-file-0.0.1-SNAPSHOT.jar
```

You'll notice the application starts in default HTTP port `8080`. Stop the application with the `Ctrl+C` command and restart it with the command shown in Listing 2.6:

Listing 2.6 Running a Spring Boot application with a different configuration file name

```
java -jar config-data-file-0.0.1-SNAPSHOT.jar --spring.config.name=sbip
```

You'll notice the application starts with HTTP port `8081`. This is because the Spring Boot has read the `server.port` property from the `sbip.yml` file and started the application in HTTP port `8081`.

By default, Spring Boot reads the `application.properties` or the `application.yml` file from the following locations:

1. The classpath root
2. The classpath `/config` package
3. The current directory
4. The `/config` subdirectory in the current directory
5. Immediate child directories of the `/config` subdirectory

We leave it as an exercise to try out these configurations in your Spring Boot project. Apart from the above locations, you can also specify a custom location using the `spring.config.location` property. For instance, the `java` command in Listing 2.7 reads the configuration file from the path `C:\sbip\repo\ch02\config-data-file\data\sbip.yml` of my Windows machine:

Listing 2.7 Executing Spring Boot Application with spring.config.location property

```
java -jar target\config-data-file-0.0.1-SNAPSHOT.jar
--spring.config.location=C:\sbip\repo\ch02\config-data-file\data\sbip.yml
```

The command in Listing starts the Spring Boot application in HTTP port 8081. Starting from version 2.4 onwards, Spring Boot throws an error if it could not find any property file you specified. You can use the `optional` prefix to indicate the configuration file is optional. For instance, the command in Listing 2.8 continues to start the Spring Boot application even though the property file `sbip1.yml` is not available in `C:\sbip\repo\ch02\config-data-file\data\` location:

Listing 2.8 Starting Spring Boot application with optional property file

```
java -jar target\config-data-file-0.0.1-SNAPSHOT.jar
--spring.config.location=optional:C:\sbip\repo\ch02\config-data-file\data\sbip1.yml
```

Note on spring.config.name and spring.config.location properties

Spring Boot loads `spring.config.name` **and** `spring.config.location` **in the early phases of application startup. Thus, you can't provide these configurations in the** `application.properties or application.yml` **file. You can use the** `SpringApplication.setDefaultProperties()` **method, OS environment variable, or command-line arguments to configure these properties. In the above examples, we've used the command-line arguments options.**

Spring Boot also lets you specify the property files for a specific profile. Spring Profiles let you segregate parts of your application configuration and make it available only in a certain environment (e.g., a profile for the `test` environment, a profile for the `production` environment). You can refer to Spring Boot documentation to read more on profiles available at https://docs.spring.io/.../spring-boot-features.html#boot-features-profiles. In this section, we'll keep ourselves focused on the profile features for config data files.

You can specify one or more config data files dedicated to a profile. You can maintain the application-specific property files with the `application-{profile}.properties` (or .yml). For instance, if you have two profiles, dev, and test, you can maintain two different applications.properties files with the name `application-dev.properties` and `application-test.properties`. Let us see this in practice.

In the Spring Boot project, let us create these two property files in the `src\main\resources` folder. For `application-dev.properties`, specify `server.port=9090` and for `application-test.properties`, specify `server.port=9091`. Thus, if you select profile as the `dev`, the application should start on HTTP port 9090, and for the `test`, it should be HTTP port 9091. You can activate a profile (e.g., dev or test) using the `spring.profiles.active` Spring Boot property. You can specify it in your `application.properties` file. For instance, if you specify `spring.profiles.active=dev`, then profile dev is active, and the properties specified in `application-dev.properties` are loaded.

Config data files are loaded in the following order:

- The application properties (properties or the `YML` file) files packaged inside the application jar
- Profile specific application properties packaged inside the application jar
- The application properties (properties or the `YML` file) files packaged outside the application jar
- Profile specific application properties packaged outside the application jar

You can find the Spring Boot project used in this example available at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/config-data-file.

2.1.4 OS Environment Variable

You can specify the configurations as an environment variable and use the variable name in the config data file. Let us demonstrate this with an example. In the `application.properties` file, we've declared the following properties as shown in Listing 2.9:

Listing 2.9 Spring Boot Datasource username and password property configuration

```
spring.datasource.username=${DB_USERNAME}
spring.datasource.password=${DB_PASSWORD}
```

The `DB_USERNAME` and `DB_PASSWORD` are two environment variables configured with values `sa` and `password` respectively. In Windows, you can set an environment variable using the `set VAR=value` command through the command prompt. In Linux-based OS, you can use `export VAR=value` through terminal. Setting the environment variables with this approach makes the variables available only for that command prompt/terminal session. Thus, you need to run the Spring Boot application in the same command prompt/terminal window.

Let us now access the `spring.datasource.username` and `spring.datasource.password` properties from the application code as shown in Listing 2.10:

Listing 2.10 Accessing the Spring Boot properties

```
package com.manning.sbip.ch02;

//imports

@SpringBootApplication
public class SpringCloudDemoApplication {

       public static void main(String[] args) {
         ConfigurableApplicationContext applicationContext =
       SpringApplication.run(SpringCloudDemoApplication.class, args);
         Environment env = applicationContext.getBean(Environment.class);
         System.out.println("Database
       Username:"+env.getProperty("spring.datasource.username"));
        System.out.println("Database
       Password:"+env.getProperty("spring.datasource.password"));
       }
}
```

In Listing, we've accessed the `ConfigurableApplicationContext` instance and then accessed the Environment bean from it. The Environment stores the properties configured in the `application.properties` file. We then access and print the properties in the application console. You'll notice it prints `sa` and `password` values respectively. Notice that Spring Boot has accessed the environment variable for you and replaced the placeholders with the actual value at run time. This approach is useful to store application secrets such as database passwords, key information, etc.

2.1.5 Command Line Arguments

Spring Boot lets you specify the configuration as command-line arguments as well. You can create a JAR file of the application and specify the properties as command-line arguments while executing the jar file. For instance, in the 2.1.3 Config Data File section, you have specified the `spring.config.name` and `spring.config.location` properties as the command line arguments.

In this section, you've learned various approaches to configure application properties in a Spring Boot application. Let us wrap this discussion by understanding the order in which the properties are loaded if a property is present in multiple places. For instance, what happens if you have configured the server.port property in the application.properties config data file as well as pass it through as a command-line argument. Following is the order in which properties get precedence. The higher sequence number overrides the properties of the lower sequence number:

1. `SpringApplication`
2. `@PropertySource`
3. `Config Data File`
4. `OS Environment Variable`
5. `Command Line Arguments`

Thus, a property specified in the command line arguments has the highest precedence over a property specified in the config data file.

You can refer to Spring Boot documentation available at https://docs.spring.io/spring-boot/docs/current/reference/htmlsingle/#boot-features-external-config for an in-depth understanding of various features on configuration management in your Spring Boot application.

2.2 Creating Custom Properties with @ConfigurationProperties

In the previous section, you've seen several approaches to configure properties in a Spring Boot application. The configurations that we use can be classified into two categories – Spring Boot built-in properties and custom properties. Spring Boot provides a myriad number of properties to configure various features of your Spring Boot application. The easiest example is the `server.port` property that you've used in the previous section to configure on which HTTP port your Spring Boot application should execute. The `server.port` property is a Spring Boot built-in property. You can find a list of Spring Boot built-in properties in Spring Boot reference documentation available at https://docs.spring.io/spring-boot/docs/current/reference/html/appendix-application-properties.html.

In this section, we'll discuss custom properties that are specific to your application. Based on the complexity and features available in your application, you may need to configure custom properties. For instance, you can configure an external REST web service URL, or configure a `boolean` flag to control a feature in your application. The good part is that you can configure any number of properties in your application configuration file(s) and Spring Boot will ensure that it is loaded and available to you at runtime. In the previous section, you've seen how Spring Boot binds the configured properties in the Spring's `Environment` instance that you can autowire to your class and access the values.

Although this approach works perfectly well, it has several drawbacks:

- There is no type-safety of the configured properties and we encounter issues at runtime. For instance, let's assume you are capturing an URL or an email address in your property file. You can't enforce the type-safety of these properties as there is no validation
- You need to access the property values individually with the `@Value` annotation or through the Spring `Environment` instance

Spring Boot provides you an alternative approach that lets you define strongly typed bean definitions that manage the type-safety as well as validate your application configuration. Let us discuss this in the next technique.

TECHNIQUE DEFINE CUSTOM PROPERTIES WITH @CONFIGURATIONPROPERTIES IN A SPRING BOOT APPLICATION

Problem

You need to define custom properties in your Spring Boot application that is type-safe and can be validated.

Solution

In this technique, we'll discuss how to define custom properties in your Spring Boot application and access these properties in your application classes without using `@Value` annotation or from `Environment` instance. To continue with this technique, you can use the Spring Boot project you've created previously. You need to add the following additional configuration in the `pom.xml` file as shown in Listing 2.11:

Listing 2.11 Spring Boot Configuration Processor

```
<dependency>
	<groupId>org.springframework.boot</groupId>
	<artifactId>spring-boot-configuration-processor</artifactId>
	<optional>true</optional>
</dependency>
```

You need a Spring Boot configuration processor to generate metadata about classes that are annotated with `@ConfigurationProperties` annotation. This metadata is then used by the IDEs to provide auto-completion and documentation support for the properties in the `application. properties` or `application.yml` file. You'll learn more about `@ConfigurationProperties` annotation shortly.

Next, we'll need to use the following custom properties in our Spring Boot application as shown in Listing 2.12:

Listing 2.12 Custom application properties

```
app.sbip.ct.name=CourseTracker
app.sbip.ct.ip=127.0.0.1
app.sbip.ct.port=9090
app.sbip.ct.security.enabled=true
app.sbip.ct.security.token=asddf998hhyqthgtYYtggghg9908jjh7ttr
app.sbip.ct.security.roles=USER,ADMIN
```

Notice that these are not Spring Boot properties and specific to our application. You need to specify these properties in your config data file. Let us define a Java class that represents these properties as shown in Listing 2.13:

Listing 2.13 AppProperties Class

```
package com.manning.sbip.ch02.configurationproperties;

import java.util.List;

import org.springframework.boot.context.properties.ConfigurationProperties;
import org.springframework.boot.context.properties.ConstructorBinding;

@ConstructorBinding
@ConfigurationProperties("app.sbip.ct")
public class AppProperties {

       /**
        * Application Name
        */
       private final String name;

       /**
        * Application IP
        */
       private final String ip;

       /**
        * Application IP
        */
       private final int port;

       /**
        * Application Security configuration
        */
       private final Security security;

       public String getName() {
         return name;
       }

       public String getIp() {
         return ip;
       }

       public int getPort() {
         return port;
       }

       public Security getSecurity() {
         return security;
       }

       public AppProperties(String name, String ip, int port, Security security) {
         this.name = name;
         this.ip = ip;
         this.port = port;
         this.security = security;
       }

       @Override
       public String toString() {
         return "AppProperties{" +
```

```
                    "name='" + name + '\'' +
                    ", ip='" + ip + '\'' +
                    ", port='" + port + '\'' +
                    ", security=" + security +
                    '}';
    }

    public static class Security {

      /**
       * Enable Security. Possible values true/false
       */
      private boolean enabled;

      /**
       * Token Value
       */
      private final String token;

      /**
       * Available roles
       */
      private final List<String> roles;

      public Security(boolean enabled, String token, List<String> roles) {
              this.enabled = enabled;
              this.token = token;
              this.roles = roles;
      }

      public boolean isEnabled() {
              return enabled;
      }

      public String getToken() {
              return token;
      }

      public List<String> getRoles() {
              return roles;
      }

      @Override
      public String toString() {
              return "Security{" +
                              "enabled=" + enabled +
                              ", token='" + token + '\'' +
                              ", roles=" + roles +
                              '}';
      }
    }

}
```

Let us explain the changes in the AppProperties class of Listing 2.13:

- This class is annotated with the `@ConstructorBidning` and `@ConfigurationProperties` annotations. We'll provide more details regarding these two annotations in the Discussion section. Besides you've set the prefix for the properties as the `app.sbip.ct`
- You've defined few variables with the name of the properties (e.g., name, ip, port). For a few of the properties, we've used a static class inside the `AppProperties` class. This is because as our properties are nested in this fashion
- You have provided Java documentation to these variables so that IDEs can show this documentation in the property or the `YML` file

So far, we've defined our properties and the associated class that maps to the properties. Let us now define another class that uses the configured properties as shown in Listing 2.14:

Listing 2.14 AppService Class

```java
package com.manning.sbip.ch02;

import com.manning.sbip.ch02.configurationproperties.AppProperties;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.stereotype.Service;

@Service
public class AppService {

    @Autowired
    private AppProperties appProperties;

    public AppProperties getAppProperties() {
        return this.appProperties;
    }
}
```

The class defined in Listing is annotated with Spring `@Service` annotation to define it as a service and should be auto-scanned by Spring Boot. The most notable change is that we've autowired the `AppProperties` instance in this class. Spring Boot ensures that all configured properties are read, validated, and binds to the `AppProperties` instance. This instance is then autowired to the service class.

Let us use this service class and access the `AppProperties` instance as shown in Listing 2.15:

Listing 2.15 Spring Boot Application Class

```java
package com.manning.sbip.ch02;

import com.manning.sbip.ch02.configurationproperties.AppProperties;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.context.properties.EnableConfigurationProperties;
import org.springframework.context.ConfigurableApplicationContext;
```

```
@SpringBootApplication
@EnableConfigurationProperties(AppProperties.class)
public class SpringBootAppDemoApplication {

       public static void main(String[] args) {
         ConfigurableApplicationContext applicationContext =
       SpringApplication.run(SpringBootAppDemoApplication.class, args);
         AppService appService = applicationContext.getBean(AppService.class);
         System.out.println(appService.getAppProperties());

       }
}
```

In Listing 2.15, we've used the `@EnableConfigurationProperties(AppProperties.class)` annotation. This annotation ensures that classes with `@ConfigurationProperties` are registered in the Spring container. One drawback with this annotation is that you need to specify your `@ConfigurationProperties` annotated classes with the annotation. If you have more classes annotated with `@ConfigurationProperties`, you can use the alternative `@ConfigurationPropertiesScan` and specify a base package so that Spring Boot can scan and find the classes annotated with `@ConfigurationProperties`. In this case, you need not explicitly specify the `@ConfigurationProperties` classes. Note that this annotation does not pick classes that are additionally annotated or meta-annotated with the `@Component` annotation.

If you start the application, you can find that configured properties are printed in the application console. You can find the completed version of this project available at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/configuration-properties.

Discussion

Spring Boot's `@ConfigurationProperties` provides a type-safe and structured approach to configure custom application properties. You've already noticed how easily you can configure, validate, and use a set of properties in your Spring Boot application. Along with `spring.config.import` and `@ConfigurationProperties` annotation you can logically segregate your application properties into various files based on their category.

The `@ConfigurationProperties` annotation lets you externalize configurations in a type-safe and structured fashion. You can add this annotation to class definition (demonstrated in this technique), or to a method annotated with `@Bean` annotation in a Spring `@Configuration` class. The property binding to the class can be done either with setter methods for the member variables or through constructor binding. In this example, you've provided a prefix named `app.sbip.ct`. This prefix is used along with the properties you've defined in the class. Thus, the property name is used as an `app.sbip.ct.name`.

In this example, you've used the `@ConstructorBinding` by explicitly specifying this annotation in the POJO class. In case you need to use the setter binding, you can provide the setter methods for the member variables. However, you are looking for the immutability of your property configuration class, you should use `@ConstrcutorBinding` without providing the setter methods. Thus, once the properties bind to the POJO instance, there is no way to modify them.

You can optionally use the `@DefaultValue` annotation in the parameter if you need to define a default value for one or more properties. Listing 2.16 shows this:

Listing 2.16 AppProperties class constructor with @DefaultValue annotation

```
public AppProperties(String name, String ip, @DefaultValue("8080") int port, Security
       security) {
       this.name = name;
       this.ip = ip;
       this.port = port;
       this.security = security;
}
```

In Listing 2.16, you've provided a default value of 8080 for the property port. Thus, if this if `app.sbip.ct.port` property is not configured in the application, this default value is used. To learn more about `@ConfigurationProperties` annotation, you can refer to Spring Boot documentation available at https://docs.spring.io/.../#boot-features-external-config-typesafe-configuration-properties.

2.3 Executing Code on Spring Boot Application Startup

At times you'll need to execute custom code at Spring Boot application startup. For instance, you may want to execute a database initialization script before the application finishes its initialization or consume a REST service to load data for your application.

The `CommandLineRunner` and `ApplicationRunner` are two Spring Boot interfaces that provide a single `run(..)` method and are invoked just before the `SpringApplication.run()` finishes its execution. These methods are invoked only once at the time of the Spring Boot application startup. In this section, you'll explore the use of the `CommandLineRunner` interface in a Spring Boot application. The `ApplicationRunner` interface is quite similar to the `CommandLineRunner` interface and we leave it as an exercise to the reader to try by themselves.

TECHNIQUE: USE COMMANDLINERUNNER TO EXECUTE CODE AT SPRING BOOT APPLICATION STARTUP

Problem

You want to use `CommandLineRunner` to execute some application initialization code at the Spring Boot application startup

Solution

You can configure `CommandLineRunner` in several ways. The following list shows the approaches to configure a `CommandLineRunner` in a Spring Boot application:

- In the Spring Boot main class that implements the `CommandLineRunner` interface
- By providing the `CommandLineRunner` implementation as a bean definition using the `@Bean` annotation

- By providing the `CommandLineRunner` as a Spring Component using the `@Component` annotation

In this technique, you'll see the above-mentioned `CommandLineRunner` configuration approaches with examples. To continue with this technique, you can continue with the Spring Boot project you've created earlier. Alternatively, if you are using Maven, you can download the base Spring Boot project for this technique in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/command-line-runner/spring-boot-app-start.

After creating or importing the project, implement the `CommandLineRunner` interface in your Spring Boot main class, as shown in Listing 2.17:

Listing 2.17 The CommandLineRunner implementation in Spring Boot Main Class

```
package com.manning.sbip.ch02;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class CourseTrackerApplication implements CommandLineRunner  {

    protected final Log logger = LogFactory.getLog(getClass());

    public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApplication.class, args);
    }
    # Provides an implementation of the run(..) method of ComandLineRunner interface.
       Prints a log statement in the console
    @Override
    public void run(String... args) throws Exception {
        logger.info("CourseTrackerApplication CommandLineRunner has executed");
    }
}
```

To keep the example simple, you are logging a statement in the console. Once the Spring Boot application starts, it logs the statement in the console as shown in Figure 2.1:

```
PID 8840 (C:\sbip\repo\ch02\command-line-runner\spring-boot-app-final\target\classes started by musib in C:\sbip\repo\ch02\command-line-runner\spring-boot-app-final)
2021-02-17 09:14:12.422  INFO 8840 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : No active profile set, falling back to default profiles: default
2021-02-17 09:14:13.221  INFO 8840 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat initialized with port(s): 8080 (http)
2021-02-17 09:14:13.239  INFO 8840 --- [           main] o.apache.catalina.core.StandardService   : Starting service [Tomcat]
2021-02-17 09:14:13.239  INFO 8840 --- [           main] org.apache.catalina.core.StandardEngine  : Starting Servlet engine: [Apache Tomcat/9.0.41]
2021-02-17 09:14:13.349  INFO 8840 --- [           main] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring embedded WebApplicationContext
2021-02-17 09:14:13.349  INFO 8840 --- [           main] w.s.c.ServletWebServerApplicationContext : Root WebApplicationContext: initialization completed in 858 ms
2021-02-17 09:14:13.539  INFO 8840 --- [           main] o.s.s.concurrent.ThreadPoolTaskExecutor  : Initializing ExecutorService 'applicationTaskExecutor'
2021-02-17 09:14:13.694  INFO 8840 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2021-02-17 09:14:13.706  INFO 8840 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : Started CourseTrackerApplication in 1.693 seconds (JVM running for 2.048
)
2021-02-17 09:14:13.709  INFO 8840 --- [           main] ication$$EnhancerBySpringCGLIB$$aeb30474 : CourseTrackerApplication CommandLineRunner has executed
2021-02-17 09:14:13.709  INFO 8840 --- [           main] ication$$EnhancerBySpringCGLIB$$aeb30474 : CommandLineRunner executed as a bean definition with 0 arguments
```

Figure 2.1 The log statement define in the CommandLineRunner is printed in the IntelliJ IDEA console log

You can also define a `CommandLineRunner` as a Spring `@Bean` definition, as shown in Listing 2.18:

Listing 2.18 CommandLineRunner implementation as a Spring Bean

```
package com.manning.sbip.ch02;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.context.annotation.Bean;

@SpringBootApplication
public class CourseTrackerApplication {

    protected final Logger logger = LoggerFactory.getLogger(getClass());

    public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApplication.class, args);
    }

    #Defiens a CommandLineRunner bean. Once the application starts, this bean is loaded and
       prints the log statement in the console
    @Bean
    public CommandLineRunner commandLineRunner() {
        return args -> {
            logger.info("CommandLineRunner executed as a bean definition with
       "+args.length+" arguments");
            for(int i=0; i<args.length;i++){
                logger.info("Argument: "+args[i]);
            }
        };

    }
}
```

In Listing 2.18, you've defined a Spring bean that provides an implementation of the `CommandLineRunner` interface through a Java lambda expression. This is possible because `CommandLineRunner` is a functional interface with a single method called `run(String… args)`. The run(..) method accepts a `varargs`. You can supply the command line arguments and access these inside the `commandLineRunner` bean implementation.

This `@Bean` implementation produces the same result as the previous "implements" alternative shown in Listing 2.17. The benefit of this approach is that you are not forced to implement the `CommandLineRunner` interface.

So far, you've provided the `CommandLineRunner` implementation in the Spring Boot main class. However, you can also provide a `CommandLineRunner` implementation in a separate class and annotate it with Spring's `@Component` annotation. This approach ensures that the

`CommandLineRunner` specific code is segregated in a separate Java file and not cluttered in the Spring Boot main class.

Both `@Bean` and `@Component` annotation lets you instruct Spring to create instances of the annotated class. But their usage is slightly different. You typically use `@Bean` annotation for the classes to which you don't have access to the source code. Thus, you define a bean and return a new instance of the class. For `@Component` annotation, as you have access to the source Java file, you can simply annotate the class with this annotation.

For example, Listing 2.19 shows a simple `CommandLineRunner` implementation that logs a statement in the console log:

Listing 2.19 CommandLineRunner implementation as a Spring Component

```
package com.manning.sbip.ch02.commandline;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.stereotype.Component;

# The Order annotation defines the sorting order of the annotated component. For instance,
       if you have multiple CommandLineRunner instances, you can use the Order annotation to
       specify their execution order.
@Order(1)
@Component
public class MyCommandLineRunner implements CommandLineRunner {

    protected final Log logger = LogFactory.getLog(getClass());

    @Override
    public void run(String... args) throws Exception {
        logger.info("MyCommandLineRunner executed as a Spring Component");
    }
}
```

The Spring Boot component scan can detect this component and creates an instance of `MyCommandLineRunner` class. If you start the application, you can see the configured log statement in the console.

You can also configure multiple `CommandLineRunner` implementations and decide the execution order based on the `@Order` annotation. Recall that the `Order(1)` annotation is specified in Listing 2.19. For instance, Listing 2.20 shows another `CommandLineRunner` implementation which is ordered with order value two:

Listing 2.11 CommandLineRunner implementation with execution order two

```
package com.manning.sbip.ch02.commandline;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.core.annotation.Order;
import org.springframework.stereotype.Component;
```

```
@Order(2)
@Component
public class AnotherCommandLineRunner implements CommandLineRunner {

    protected final Log logger = LogFactory.getLog(getClass());

    @Override
    public void run(String... args) throws Exception {
        logger.info("AnotherCommandLineRunner executed as a Spring Component");
    }
}
```

If you start the application, you can see that both the log statements are printed in the console based on their defined order, as shown in Figure 2.2:

```
2021-02-17 09:19:30.643  INFO 2204 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : No active profile set, falling back to default profiles: default
2021-02-17 09:19:31.243  INFO 2204 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat initialized with port(s): 8080 (http)
2021-02-17 09:19:31.243  INFO 2204 --- [           main] o.apache.catalina.core.StandardService   : Starting service [Tomcat]
2021-02-17 09:19:31.259  INFO 2204 --- [           main] org.apache.catalina.core.StandardEngine  : Starting Servlet engine: [Apache Tomcat/9.0.41]
2021-02-17 09:19:31.337  INFO 2204 --- [           main] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring embedded WebApplicationContext
2021-02-17 09:19:31.337  INFO 2204 --- [           main] w.s.c.ServletWebServerApplicationContext : Root WebApplicationContext: initialization completed in 654 ms
2021-02-17 09:19:31.459  INFO 2204 --- [           main] o.s.s.concurrent.ThreadPoolTaskExecutor  : Initializing ExecutorService 'applicationTaskExecutor'
2021-02-17 09:19:31.568  INFO 2204 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2021-02-17 09:19:31.584  INFO 2204 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : Started CourseTrackerApplication in 1.214 seconds (JVM running for 1.462
)
2021-02-17 09:19:31.584  INFO 2204 --- [           main] c.m.s.c.commandline.MyCommandLineRunner  : MyCommandLineRunner executed as a Spring Component
2021-02-17 09:19:31.584  INFO 2204 --- [           main] c.m.s.c.c.AnotherCommandLineRunner       : AnotherCommandLineRunner executed as a Spring Component
2021-02-17 09:19:31.584  INFO 2204 --- [           main] ication$$EnhancerBySpringCGLIB$$d8dc8824 : CourseTrackerApplication CommandLineRunner has executed
2021-02-17 09:19:31.584  INFO 2204 --- [           main] ication$$EnhancerBySpringCGLIB$$d8dc8824 : CommandLineRunner executed as a bean definition with 0 arguments
```

Figure 2.2 Log statements printed in the IntelliJ IDEA console log as defied in multiple CommandLineRunner implementations

Discussion

The `CommandLineRunner` is a useful feature and frequently used to perform several application initialization activities. In a `CommandLineRunner` implementation, you also have access to the command line arguments through the `args` parameter. Thus, you can control the `CommandLineRunner` implementation behavior externally through the supplied arguments.

Besides, in a `CommandLineRunner` implementation, you can also autowire any dependency using Spring's dependency injection mechanism. Since a `CommandLineRunner` implementation runs when the Spring Boot application almost finishes its initialization, all bean definitions are available for autowire. Hence, you can autowire any bean dependency in your `CommandLineRunner` implementation.

As an example, in the upcoming techniques when you'll learn the Spring Data Repository, you'll see the use of the `CourseRepository` interface as a dependency on the `CommandLineRunner` implementation. Listing 2.21 shows an example:

Listing 2.21 CommandLineRunner implementation from Spring Boot main class

```
#A CommandLineRunner implements in which CourseRepository is injected by Spring dependency
       injection
@Bean
public CommandLineRunner printCourses(CourseRepository courseRepository) {
    return args -> {
```

```
        System.out.println("============= Course Details =================");
        courseRepository.findAll().forEach(System.out::println);
    };
}
```

We'll explain the Spring Data repository in detail in chapter 3. For now, understand that an instance of `CourseRepository` will be automatically provided by Spring Boot in `printCourses(..)` method.

You can find the completed version of the Spring Boot project of this technique at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/command-line-runner/spring-boot-app-final.

Summary

In this technique, you've seen three variations on the usage of a `CommandLineRunner` implementation:

1. By implementing the `CommandLineRunner` interface directly in the Spring Boot application and provided an implementation of the `run(..)` method
2. By defining the `CommandLineRunner` as a Spring bean definition using the `@Bean` annotation
3. By defining the `CommandLineRunner` as a Spring component using the `@Component` annotation

The first approach is limited as it lets you define only one `CommandLineRunner` implementation and there are no execution ordering capabilities. The other two approaches are flexible as they let you specify the execution order. Besides, the third approach lets you segregate the `CommandLineRunner` implementation away from the Spring Boot main class and provides better code organization.

2.4 Customizing logging Logging in a Spring Boot Application

Logging is an essential aspect of an application. A log contains important events of application activity and provides useful information on application behavior. Based on the logging configuration, log statements can be logged in various mediums such as in the console, files, and database. However, console and file-based logging are the dominant logging types and are most frequently used in an application. Refer to https://logging.apache.org/log4j/2.x/manual/appenders.html for a list of appenders available in Log4j2.

In this section, you'll first understand and explore the default Spring Boot logging mechanism and then examine how to customize the logging in your Spring Boot application with other popular logging frameworks such as Log4j2.

TECHNIQUE: UNDERSTAND AND CUSTOMIZE DEFAULT SPRING BOOT LOGGING IN A SPRING BOOT APPLICATION

Problem

You want to understand and customize the default logging in a Spring Boot application

Solution

By default, Spring Boot provides a console logging facility for all Spring Boot applications. This console log prints the log statements in the command prompt or terminal at application startup, or when you perform any other activity in the application for which logging is enabled.

Spring Boot uses the Apache commons logging framework (https://commons.apache.org/proper/commons-logging/) for its internal logging purposes. It also supports other popular logging frameworks such as Logback (http://logback.qos.ch/), Log4j2 (https://logging.apache.org/log4j/2.x/), and Java Util Logging.

If you are using any of the Spring Boot starter dependencies, then by default Spring Boot uses the `Logback` logging framework for logging. This is because Spring Boot starter dependencies have a transitive dependency with `spring-boot-starter-logging` starter dependency which includes the Logback dependencies. Listing 2.22 shows the Logback dependencies internally used by Spring Boot:

Listing 2.22 Spring Boot Starter Logging Dependencies

```
# Spring Boot Starter Logging dependencies
<dependencies>
    <dependency>
        <groupId>ch.qos.logback</groupId>
        <artifactId>logback-classic</artifactId>
    </dependency>
    <dependency>
        <groupId>org.slf4j</groupId>
        <artifactId>jul-to-slf4j</artifactId>
    </dependency>
    <dependency>
        <groupId>org.slf4j</groupId>
        <artifactId>log4j-over-slf4j</artifactId>
    </dependency>
</dependencies>
```

As usual, to proceed with this technique, you can continue with the same Spring Boot project you've used in the previous technique. You can find the base Spring Boot project for this technique in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/spring-boot-default-logging/spring-boot-app-start.

Once the project setup is done, you can start the application using the IDE's launch option or by using the `mvn spring-boot:run` Maven command. You can see the startup log in the console, as shown in Figure 2.3:

```
  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
 :: Spring Boot ::                (v2.4.2)

2021-02-17 09:26:21.099  INFO 19472 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : Starting CourseTrackerApplication using Java 15 on DESKTOP-VBH5P79 with
 PID 19472 (C:\sbip\repo\ch02\spring-boot-default-logging\spring-boot-app-final\target\classes started by musib in C:\sbip\repo\ch02\spring-boot-default-logging\spring-boot
-app-final)
2021-02-17 09:26:21.101  INFO 19472 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : No active profile set, falling back to default profiles: default
2021-02-17 09:26:21.614  INFO 19472 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat initialized with port(s): 8080 (http)
2021-02-17 09:26:21.629  INFO 19472 --- [           main] o.apache.catalina.core.StandardService   : Starting service [Tomcat]
2021-02-17 09:26:21.629  INFO 19472 --- [           main] org.apache.catalina.core.StandardEngine  : Starting Servlet engine: [Apache Tomcat/9.0.41]
2021-02-17 09:26:21.692  INFO 19472 --- [           main] o.a.c.c.C.[Tomcat].[localhost].[/]       : Initializing Spring embedded WebApplicationContext
2021-02-17 09:26:21.692  INFO 19472 --- [           main] w.s.c.ServletWebServerApplicationContext : Root WebApplicationContext: initialization completed in 553 ms
2021-02-17 09:26:21.795  INFO 19472 --- [           main] o.s.s.concurrent.ThreadPoolTaskExecutor  : Initializing ExecutorService 'applicationTaskExecutor'
2021-02-17 09:26:21.920  INFO 19472 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2021-02-17 09:26:21.936  INFO 19472 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : Started CourseTrackerApplication in 1.139 seconds (JVM running for 1.35
3)
```

Figure 2.3 Various components of Spring Boot startup logs logged in the console

This console log should be familiar to you if you are following any of the techniques discussed so far. Let us now understand various parts of the console log. Figure 2.3 shows the different parts of the logged message.

Following are the various parts of a log statement:

- Date and Time: Date and time of logging
- Log Level: Logging level. Possible values `FATAL`, `ERROR`, `WARN`, `INFO`, `DEBUG`, and `TRACE`. A logging level demonstrates the importance of the log statement. For instance, any log statement logged with `FATAL` or `ERROR` indicates some serious issues in the application processing. Whereas `INFO` or `DEBUG` for example indicates typical regular application activities which you probably could ignore
- Process ID: Process Id of the application
- Separator: A separator (`---`) to indicate the start of the actual log messages
- Thread Name: Name of a thread performing the logging. A Spring Boot application contains multiple threads. Some of the threads could be application threads, and few threads you might be starting for various reasons. For instance, if you are executing asynchronous processing capabilities of Spring Boot, you can create a `TaskExecutor` and assign a name for the threads of the underlying thread pool. Thus, in such cases, you'll see the custom thread name as you've configured.
- Logger Name: Abbreviated source class name
- Message: The actual log message

Now that you've seen various parts of a log statement. Let's understand how these parts are configured. Listing 2.23 shows the logging pattern used the Figure 2.3:

Listing 2.23 Default Logging Pattern

```
# Default logging pattern used in Spring Boot console logging
%clr(%d{${LOG_DATEFORMAT_PATTERN:yyyy-MM-dd HH:mm:ss.SSS}}){faint}
       %clr(${LOG_LEVEL_PATTERN:-%5p}) %clr(${PID:- }){magenta} %clr(---){faint}
       %clr([%15.15t]){faint} %clr(%-40.40logger{39}){cyan} %clr(:){faint}
       %m%n${LOG_EXCEPTION_CONVERSION_WORD:%wEx}
```

The `%clr` is a conversion word that is used to configure the color-coding. Spring Boot uses `org.springframework.boot.logging.logback.ColorConverter` class for this purpose. For example, `%clr(${PID:- }){magenta}` prints the process ID in `magenta` colour. This default logging pattern is specified in the Spring Boot Logback logging configuration file.

You can customize the default logging pattern with a different logging format. For example Listing 2.24 shows a custom logging pattern by configuring the `logging.pattern.console` property in the `application.properties` file:

Listing 2.24 Custom Logging Pattern in the application.properties file

```
# Configuring a custom logging pattern in a Spring Boot application
logging.pattern.console=%clr(%d{dd-MM-yyyy HH:mm:ss.SSS}){yellow} %clr(${PID:- }){green}
       %magenta([%thread]) %highlight([%-5level]) %clr(%-40.40logger{39}){cyan} %msg%n
```

If you restart the application, you will notice a different logging format printed in the console.

Appender and Logger in Logging

In case you are new to logging, there are few terminologies that you should be aware of:

Logger: A logger is a logging framework component that is responsible for logging the log messages using one or more appenders. You can define several loggers with various logging levels based on your need.

Appender: An appender in a logging framework primarily decides two main things – where the log messages should go, and what should be the logging format. Based on the destination of the log messages, there are several appender types. For example, a console appender logs the messages in the underlying application's console. A file appender lets the log messages be written into a file. A special type of file appender, the RollingFile appender performs additional tasks such as managing the log file by rolling it over based on time and date. An SMTP appender lets you email the log messages to an email address.

By default, Spring Boot log statements with `INFO`, `WARN`, and `ERROR` levels. If you need other logging levels such as `TRACE`, or `DEBUG`, you can configure the associated properties in the `application.properties` file. For instance, to enable debug statements, you can configure `debug=true` in the `application.properties` file.. Similarly, you can enable trace mode by configuring `trace=true` in the `application.properties` file.

Although console logging works well in development time, in a production application, you need the log the application log statements in a file so that the file can be referred to in the future. Moreover, logging into a file is not enough. You also need to maintain the log files based on the file size and duration, i.e., what should be the size of a log file and how long you would continue writing into an existing log file. Besides, you don't want to run out of disk space while debugging your application! Isn't it?

There are the size and time-based policies to roll over the log file to a new file. For example, you may decide to roll over to a new log file once your current log file reaches a size of ten Megabytes. Or, you also would like to roll over to a new log file daily. You'll see an example of such policies shortly, but before that let's see how to write the log contents into a file in a Spring Boot application.

The easiest way to configure logging in a file by configuring the `logging.file.name` or `logging.file.path` properties in the `application.properties` file. The `logging.file.name` property lets you specify a log file name where the logging should be made. Let's configure `logging.file.name=application.log` in the `application.properties` file.

If you want to configure the log file into a different directory other than the project root directory, you can specify the `logging.file.path` property with the path value. For example, configuring `logging.file.path=C:/sbip/logs` generates a log file named `spring.log` into `C:/sbip/logs` directory. Note that, you can configure either `logging.file.name` or `logging.file.path` property at any point in time. Let's configure the `logging.file.path` in the `application.properties` file as shown in Listing 2.25:

Listing 2.25 Updated application.properties file

```
#Custom logging pattern
logging.pattern.console=%clr(%d{dd-MM-yyyy HH:mm:ss.SSS}){yellow} %clr(${PID:- }){green}
      %magenta([%thread]) %highlight([%-5level]) %clr(%-40.40logger{39}){cyan} %msg%n

#Log file path
logging.file.path=C:\\sbip\\logs
```

By default, Spring Boot backs up the current log file and rolls over to the next log file when the file size reaches ten MB, or if the log file is seven days old. You can control these behaviors using the `logging.logback.rollingpolicy.max-file-size` and `logging.logback.rollingpolicy.max-history` properties, respectively. We encourage you to configure these parameters in the `application.properties` file and notice the changes in the log file.

You can find the completed version of the Spring Boot project of this technique at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/spring-boot-default-logging/spring-boot-app-final.

Discussion

In this technique, you've learned the default logging configurations in Spring Boot. You've seen how to configure and manage file-based logging with Spring Boot provided parameters. You can read more on Spring Boot logging features on Spring Boot documentation available at https://docs.spring.io/.../spring-boot-features.html#boot-features-logging.

Although Logback logging works fine with a Spring Boot project, you might be interested to configure other major logging frameworks in your Spring Boot application. There could be various reasons to do this. For instance, you are comfortable and familiar with other logging frameworks such as Log4j2, or your organization might have a preference towards a specific logging framework. Let us demonstrates how you can exclude the default Logback configuration and configure an alternate logging framework. In the next technique, you'll configure the Log4j2 logging framework in your Spring Boot application.

TECHNIQUE USE LOG4J2 TO CONFIGURE LOGGING IN A SPRING BOOT APPLICATION

In the previous technique, you've seen to configure and customize logging with Spring Boot. You've learned that Spring Boot uses Logback as the default logging configuration if you include any of the Spring Boot starter dependency in your `pom.xml` file. In this technique, you'll learn to configure Log4j2 as the logging provider in a Spring Boot application.

Problem

You need to configure Log4j2 as the logging framework in your Spring Boot application

Solution

Configuring Log4j2 in a Spring Boot application is straightforward. To start with, you need to exclude the default `spring-boot-starter-logging` dependency and provide Log4j2 starter dependency in your build configuration file. You can then provide the Log4j2 logging configuration either in properties, XML, YAML, or in JSON format for Spring Boot to load and configure the logging. In this technique, we'll use XML to define the logging configuration.

As usual, to proceed with this technique, you can continue with the same Spring Boot project you've used in the previous technique. Alternatively, you can find the base Spring Boot project for this technique in the book's companion GitHub repository at https://github.com/.../spring-boot-app-start.

If you are continuing with the Spring Boot project from previous technique, then you need to perform two additional changes to start with the Log4j2 logging configuration:

- Remove all the logging configurations you've added to the `application.properties` file. You can remove all properties that start with the logging prefix
- You also need to exclude the `spring-boot-starter-logging` dependency from the `spring-boot-starter-web` dependency in the `pom.xml` file. You then need to add the `spring-boot-starter-log4j2` dependency. Listing 2.26 shows these configuration changes:

Listing 2.26 Adding Log4j2 starter dependency and excluding default starter logging

```
# Excluding the default Logback dependency and including Log4j2 dependency
<dependencies>
       <dependency>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-web</artifactId>
         <exclusions>
                  <exclusion>
                           <groupId>org.springframework.boot</groupId>
                           <artifactId>spring-boot-starter-logging</artifactId>
                  </exclusion>
         </exclusions>
       </dependency>
       <dependency>
         <groupId>org.springframework.boot</groupId>
```

```
        <artifactId>spring-boot-starter-log4j2</artifactId>
       </dependency>

       // Other dependencies
</dependencies>
```

The above pom.xml changes ensure that Logback related dependencies are removed, and Log4j2 dependencies are available in the classpath.

You can provide log4j2 configurations such as appender, loggers, and associated configurations in an XML file or a YML file. This XML configuration needs to be created in the src\main\resources folder with the name log4j2.xml or log4j2-spring.xml. This configuration file wraps the complete logging configuration to be used in your Spring Boot application. Although Spring Boot provides both the options to define the configurations with either log4j2.xml or log4j2-spring.xml files, it recommends using the latter one wherever possible. This is because Spring Boot can have better control over the logging initialization[1].

Listing 2.27 shows a sample log4j2.xml configuration:

Listing 2.27 Sample Log4j2 XML configuration

```
<?xml version="1.0" encoding="UTF-8"?>
#The root element of a Log4j2 configuration file. The status attribute represents the level
       of internal log4j2 events. It is set to WARN in this configuration
<Configuration status="WARN">
    #Defines common placeholders that can be used in other places in the XML file. You've
       defined the LOG_PATTERN property here.
    <Properties>
        <Property name="LOG_PATTERN">
            %d{yyyy-MM-dd HH:mm:ss.SSS} [%5p] [%15.15t] %-40.40c{1.} : %m%n%ex
        </Property>
    </Properties>
    #List of appenders
    <Appenders>
         #A console appender configuration that logs the log statements in
       console/terminal/command prompt
        <Console name="ConsoleAppender" target="SYSTEM_OUT">
            <PatternLayout pattern="${LOG_PATTERN}" />
        </Console>
        # A file appender configuration that logs the log statements in a file with
       provided file name and pattern.
         It also provides additional configuration such as how to manage the file over a
       period
        <RollingFile name="FileAppender"
                    # Log file name (along with the relative path)
                    fileName="logs/application-log4j2.log"
                    # Log file name once it rolls over. Log file name appended with date
       and a sequence
                    filePattern="logs/application-log4j2-%d{yyyy-MM-dd}-%i.log">
            <PatternLayout>
                <Pattern>${LOG_PATTERN}</Pattern>
            </PatternLayout>
            <Policies>
                 # Rolls the current log file once its size reaches 10 MB
```

[1] https://github.com/spring-projects/spring-boot/issues/15649

```
                <SizeBasedTriggeringPolicy size="10MB" />
                # Rolls the current log file after 7 days
                <TimeBasedTriggeringPolicy interval="7" />
            </Policies>
            # Maximum 10 back up log files can be kept
            <DefaultRolloverStrategy max="10"/>
        </RollingFile>
    </Appenders>
    # The list of loggers that logs the log statements using the provide appender
    <Loggers>
         # A logger that runs in DEBUG logging level. It uses the underlying file appender
       to log all log events generated from com.manning.sbip and its subpackages
        <Logger name="com.manning.sbip" level="debug" additivity="false">
            <AppenderRef ref="FileAppender"/>
        </Logger>
        # A logger that runs in INFO logging level and logs events from
       org.springframeworg.boot and its subpackages
        <Logger name="org.springframework.boot" level="info" additivity="false">
            <AppenderRef ref="ConsoleAppender"/>
        </Logger>
        # Root logger runs in INFO logging level
        <Root level="info">
            <AppenderRef ref="FileAppender"/>
            <AppenderRef ref="ConsoleAppender"/>
        </Root>
    </Loggers>
</Configuration>
```

You can refer to the inline documentation to understand various configuration parameters. Log4j2 is a powerful and feature-rich logging framework. The above configuration represents the basic logging configuration that is needed to demonstrate Log4j2 integration with Spring Boot.

Let us add the `CommandLineRunner` implementation in the Spring Boot main class to include log statements instead of the system out statements. Listing 2.28 shows the modified Spring Boot main class:

Listing 2.28 Spring Boot main class with updated CommandLineRunner implementation

```
package com.manning.sbip.ch02;

import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class CourseTrackerApplication {

    private static Logger logger = LoggerFactory.getLogger(CourseTrackerApplication.class);

    public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApplication.class, args);
        logger.info("CourseTrackerApplication started successfully with Log4j2
       configuration");
    }
}
```

You can find the modified code highlighted in bold font.

- The first change you've done is that you've created a logger instance using the `getLogger` method of `LoggerFactory` class. If you look into the import statements, you can find that the imported `LoggerFactory` class is from the SLF4j library. Simple Logging Facade for Java (SLF4J) provides an abstraction for various logging frameworks that allows you to plug-in the preferred logging framework (e.g., Log4j2) at build time. You can learn more about SLF4j at http://www.slf4j.org/.
- The next change is that, instead of using the system out statements, you are using the newly created logger instance to log the messages

If you start the application, you can find the `application-log4j2.log` log file is generated in the `logs` folder of your project's root directory. You can see that the configured log message is printed along with other application startup log statements.

You can find the completed version of the Spring Boot project for this technique at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/spring-boot-logging-with-log4j2/spring-boot-app-final.

Discussion

In this technique, you've learned to configure one of the most popular and widely used logging frameworks of the Java ecosystem. The Log4j2 logging framework is one of the stable logging frameworks and offers a lot of useful features. You can refer to the Log4j2 reference manual (https://logging.apache.org/log4j/2.x/manual) to learn more about this logging framework.

As an exercise, we encourage you to play around with the Log4j2 configuration, its various parameters such as log levels, various other appender types (e.g., JDBC appender), filters, and other offerings. For instance, to see how the size-based trigger policy and default rollover strategy works, you can change the `SizeBasedTriggeringPolicy` size to a smaller size in the Log4j2 XML configuration file. You can then generate more log messages from your Java files. You'll notice how log files are rolled over once they meet the defined criteria.

2.5 Validate User Data using Bean Validation

It is often a requirement to validate the user input data to make sure it meets the business requirement. For instance, you would like to validate certain fields for non-empty or check the minimum and the maximum lengths of the values allowed for that field. Besides, you can also want to implement a custom validation on the user data. For example, it might be possible that you want to implement a custom password validation rule for the user-supplied password.

Bean Validation (https://beanvalidation.org/) is the de-facto standard for implementing such validations in the Java ecosystem. This Java specification lets you express validations in terms of simple annotations. Moreover, it also lets you define custom validators in an extensible manner. Hibernate Validator (http://hibernate.org/validator/) is the reference implementation of the Bean Validation specification.

Spring Boot provides seamless integration with the Bean Validation framework with a Spring Boot starter dependency. It provides a `spring-boot-starter-validation` dependency that lets you use Hibernate Validator in your application.

TECHNIQUE: USE BUILT-IN BEAN VALIDATION ANNOTATIONS TO VALIDATE BUSINESS ENTITY IN A SPRING BOOT APPLICATION

Problem

You want to validate business entities using the Java Bean Validation framework in your Spring Boot application.

Solution

Let us demonstrate the usage of bean validation in Spring Boot with an example. To start with, you can either use the Spring Boot project used in the previous technique or download the base Spring Boot project available at https://github.com/.../spring-boot-app-start. In this Maven project, we've additionally added the `spring-boot-bean-validation` dependency as shown in Listing 2.29:

Listing 2.29 Spring Boot Starter Validation Maven Dependency

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-validation</artifactId>
</dependency>
```

To start with, let us add a new business model named `Course`. A course contains an id, name, category, rating, and a course description as shown in Listing 2.30:

Listing 2.30 The Course Entity

```
package com.manning.sbip.ch02.model;

import javax.validation.constraints.Min;
import javax.validation.constraints.Max;

public class Course {

    private long id;
    private String name;
    private String category;

    @Min(value = 1, message = "A course should have a minimum of 1 rating")
    @Max(value = 5, message = "A course should have a maximum of 5 rating")
    private int rating;

    private String description;

    // Constructor, Getter, and Setters
}
```

We've additionally added two validations for the `rating` field. A rating can have a minimum value of 1 and a maximum value of 5. If these constraints are not satisfied, then the message defined in the annotation is displayed as an error message.

Let us validate these constraints by defining a `CommandLineRunner` as shown in Listing 2.31:

Listing 2.31 The Spring Boot Main Class with CommandLineRunner implementation

```
package com.manning.sbip.ch02;

import com.manning.sbip.ch02.model.Course;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

import javax.validation.ConstraintViolation;
import javax.validation.Validation;
import javax.validation.Validator;
import java.util.Set;

@SpringBootApplication
public class CourseTrackerApplication implements CommandLineRunner {

    private static Logger logger = LoggerFactory.getLogger(CourseTrackerApplication.class);
    public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApplication.class, args);
    }

    @Override
    public void run(String... args) throws Exception {
        Course course = new Course();
        course.setId(1);
        # Create a course with a rating of 0 which violates the minimum constraint defined
       for the rating field
        course.setRating(0);
                  # Get an instance of Validator that validates the bean instances. In this
       example, it will validate the course entity
        Validator validator = Validation.buildDefaultValidatorFactory().getValidator();
          # Validates all defined constraints in the course object and returns the
       constraint violations if any
        Set<ConstraintViolation<Course>> violations = validator.validate(course);
        # Logs each constrant violation in the console
        violations.forEach(courseConstraintViolation -> logger.error("A constraint
       violation has occurred. Violation details: [{}].", courseConstraintViolation));
    }
}
```

In Listing 2.31, you've created a course and set the course rating value to 0. Besides, you are obtaining an instance of the validator and supplying the course instance to it for constraint validation. The validator validates and returns the set of constraint violations in the supplied object. In this example, the `@Min` constraint validation is violated and the associated `ConstraintViolation` is returned. We then log this validation error in the console.

If you run the application, you can find that once the application starts successfully, the `CommandLineRunner` is executed and the `ConstraintViolation` error message is logged in the console as shown in Figure 2.4:

```
2021-02-17 09:28:52.323  INFO 272 --- [           main] o.s.s.concurrent.ThreadPoolTaskExecutor  : Initializing ExecutorService 'applicationTaskExecutor'
2021-02-17 09:28:52.432  INFO 272 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2021-02-17 09:28:52.448  INFO 272 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : Started CourseTrackerApplication in 1.129 seconds (JVM running for 1.359)

2021-02-17 09:28:52.479 ERROR 272 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : A constraint violation has occurred. Violation details: [ConstraintViolat
ionImpl{interpolatedMessage='Course name field can't be empty', propertyPath=name, rootBeanClass=class com.manning.sbip.ch02.model.Course, messageTemplate='Course name fiel
d can't be empty'}].
2021-02-17 09:28:52.479 ERROR 272 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : A constraint violation has occurred. Violation details: [ConstraintViolat
ionImpl{interpolatedMessage='Course description field can't be empty', propertyPath=description, rootBeanClass=class com.manning.sbip.ch02.model.Course, messageTemplate='Co
urse description field can't be empty'}].
2021-02-17 09:28:52.495 ERROR 272 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : A constraint violation has occurred. Violation details: [ConstraintViolat
ionImpl{interpolatedMessage='A course should have a minimum of 1 rating', propertyPath=rating, rootBeanClass=class com.manning.sbip.ch02.model.Course, messageTemplate='A co
urse should have a minimum of 1 rating'}].
2021-02-17 09:28:52.495 ERROR 272 --- [           main] c.m.sbip.ch02.CourseTrackerApplication   : A constraint violation has occurred. Violation details: [ConstraintViolat
ionImpl{interpolatedMessage='Course category field can't be empty', propertyPath=category, rootBeanClass=class com.manning.sbip.ch02.model.Course, messageTemplate='Course c
ategory field can't be empty'}].
```

Figure 2.4 The @Min Constraint Violation Error message

You can download the completed version of this Spring Boot project at https://github.com/.../spring-boot-app-final.

Discussion

Bean Validation lets you specify and validate application constraints. You've already noticed how it allows you to specify the constraints in terms of annotations with the ability to configure custom error messages. Table 2.2 provides some of the commonly used annotations defined in the Hibernate Validator API:

Table 2.2 Hibernate Validator annotations to validate field-level constraints

Annotation	Purpose
`@NotBlank`	Checks for non-null of the annotated character sequence. Supported only in a `CharSequence` field
`@NotEmpty`	Checks for non-null or empty of the annotated character sequence. Supported only in `CharSequence`, Collection, Map, and arrays
`@NotNull`	Checks whether the annotated value is not null. Supported in any data type
`@Min(value=)`	Checks whether the annotated value is higher than or equal to the specified minimum value
`@Max(value=)`	Checks whether the annotated value is lower than or equal to the specified maximum value
`@Pattern(regex=, flags=)`	Checks if the annotated string matches the regular expression `regex` considering the given `flags` match
`@Size(min=, max=)`	Checks if the annotated element's size is between min and max (inclusive) value
`@Email`	Checks whether the specified character sequence is a valid email address

Refer to https://docs.jboss.org/…/#section-builtin-constraints for a list of supported Hibernate Validator constraints and their usage.

Although built-in annotations work well in most of the scenarios, sometimes you might need custom constraint validations. For instance, you might need to check whether a supplied character sequence is a valid IP address. You can also apply additional constraints for a password supplied by your application users. In the next technique, you'll learn how to implement and use a custom constraint using the Bean Validation framework in your Spring Boot application.

TECHNIQUE: DEFINE AND USE CUSTOM BEAN VALIDATION ANNOTATION TO VALIDATE A POJO IN A SPRING BOOT APPLICATION

Problem

You want to define a custom annotation and use it to validate a POJO in a Spring Boot application.

Solution

In the previous technique, you've used the built-in Bean Validation annotations to apply constraints in business entities. In this technique, you'll learn how to implement a custom annotation with a custom validator to implement business-specific constraints in your entities.

To demonstrate how to define a custom constraint, you'll use a `User` POJO that has a username and a password. Typically, organizations define custom password policies that their users need to adhere to. In this example, you'll implement a custom annotation that validates the passwords against the predefined password policy. In this example, you'll use the Passay (https://www.passay.org/) library to enforce the password rules.

To follow along with this example, you can continue with the Spring Boot project used in the previous technique or download the base Spring Boot project available in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/…/spring-boot-app-start to continue with this technique.

In this project, we've added the Passay Maven dependency in the `pom.xml` as shown in Listing 2.32:

Listing 2.32 Passay Maven Dependency

```
<dependency>
    <groupId>org.passay</groupId>
    <artifactId>passay</artifactId>
    <version>1.6.0</version>
</dependency>
```

Before defining the custom validation annotation, you need to define the `ConstraintValidator` that is invoked to enforce the constraint. Let us define the `PasswordRuleValidator` class that contains the actual password validation logic as shown in Listing 2.33:

Listing 2.33 The PasswordRuleValidator

```
package com.manning.sbip.ch02.validation;

import org.passay.*;

import javax.validation.ConstraintValidator;
import javax.validation.ConstraintValidatorContext;
import java.util.ArrayList;
import java.util.List;

public class PasswordRuleValidator implements ConstraintValidator<Password, String> {

    private static final int MIN_COMPLEX_RULES = 2;
    private static final int MAX_REPETITIVE_CHARS = 3;
    private static final int MIN_SPECIAL_CASE_CHARS = 1;
    private static final int MIN_UPPER_CASE_CHARS = 1;
    private static final int MIN_LOWER_CASE_CHARS = 1;
    private static final int MIN_DIGIT_CASE_CHARS = 1;

    @Override
    public boolean isValid(String password, ConstraintValidatorContext context) {
        List<Rule> passwordRules = new ArrayList<>();
        passwordRules.add(new LengthRule(8, 30));
        CharacterCharacteristicsRule characterCharacteristicsRule  =
                new CharacterCharacteristicsRule(MIN_COMPLEX_RULES,
                        new CharacterRule(EnglishCharacterData.Special,
       MIN_SPECIAL_CASE_CHARS),
                        new
       CharacterRule(EnglishCharacterData.UpperCase,MIN_UPPER_CASE_CHARS),
                        new
       CharacterRule(EnglishCharacterData.LowerCase,MIN_LOWER_CASE_CHARS),
                        new
       CharacterRule(EnglishCharacterData.Digit,MIN_DIGIT_CASE_CHARS));
        passwordRules.add(characterCharacteristicsRule);
        passwordRules.add(new RepeatCharacterRegexRule(MAX_REPETITIVE_CHARS));
        PasswordValidator passwordValidator = new PasswordValidator(passwordRules);
        PasswordData passwordData = new PasswordData(password);
        RuleResult ruleResult = passwordValidator.validate(passwordData);
        return ruleResult.isValid();
    }
}
```

Let us discuss the code snippet shown in Listing 2.26:

- This class implements the `ConstraintValidator` interface and provided an implementation of the `isValid(..)` method that contains the custom password validation logic. The `ConstraintValidator` interface is typed and accepts two arguments. The first argument defines the annotation (e.g., Password) on which the custom validator should be used. The second argument takes the data type of the value on which the custom annotation is applied. Thus, we've defined the `ConstraintValidator<Password, String>`
- In the `isValid(..)` method, you've defined the custom policy against which the password should be validated. We've kept the password policy fairly simple. There is a length-based rule that enforces that the password length should be a minimum of 8 characters and a maximum of 30 characters. Besides, the policy expects the password

should contain an upper case, a lower case, a digit, and there should not be repetitive of a character more than three times

- The `isValid(..)` method returns either `true` or `false` based on the defined validation logic

Let us now define the `@Password` annotation that uses the `PasswordRuleValidator` as shown in Listing 2.34:

Listing 2.34 The @Password Annotation

```
package com.manning.sbip.ch02.validation;

import javax.validation.Constraint;
import javax.validation.Payload;
import java.lang.annotation.ElementType;
import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;
import java.lang.annotation.Target;

@Target({ElementType.METHOD, ElementType.FIELD})
@Retention(RetentionPolicy.RUNTIME)
@Constraint(validatedBy = PasswordRuleValidator.class)
public @interface Password {
    String message() default "Password do not adhere to the specified rule";
    Class<?>[] groups() default {};
    Class<? extends Payload>[] payload() default {};
}
```

Let us explore various parts of this annotation definition:

- The `@Target` annotation defines that this annotation applies to the `Method` and `Field`
- The `@Retention` annotation defines how the `@Password` annotation is store. You've used `RUNTIME` so that it can be used by the runtime environment
- The `@Constraint` indicates that this annotation is a Bean Validation constraint. The element `validatedBy` specifies the classes implementing the constraint
- The `message()` defines the message that needs to be displayed if the input data validation fails
- The `Class<?>[] groups()` allow the developer to select to split the annotations into different groups to apply different validations to each group. We haven't defined any groups in this example
- The `Class<? extends PayLoad>[] payLoad()` is typically used to carry metadata information consumed by a validation client. We haven't defined any payload in this example

Let us now define the business model on which the `@Password` annotation is applied. Listing 2.35 shows the `User` POJO:

Listing 2.35 The User business entity

```
package com.manning.sbip.ch02.model;

import com.manning.sbip.ch02.validation.Password;

public class User {

    private String userName;

    @Password
    private String password;

    public User(String userName, String password) {
        this.userName = userName;
        this.password = password;
    }

    public String getUserName() {
        return userName;
    }

    public String getPassword() {
        return password;
    }

    @Override
    public String toString() {
        return "User{" +
                "userName='" + userName + '\'' +
                ", password='" + password + '\'' +
                '}';
    }
}
```

The `User` business entity has two fields a username and a password. The password field is annotated with the custom `@Password` annotation. Let us now create a few users and see how the custom annotation works. Listing 2.36 shows a `CommandLineRunner` implementation that creates several users:

Listing 2.36 Spring Boot main class with A CommandLineRunner implementation

```
package com.manning.sbip.ch02;

import com.manning.sbip.ch02.model.User;
import com.manning.sbip.ch02.validation.PasswordRuleValidator;
import org.slf4j.Logger;
import org.slf4j.LoggerFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

import javax.validation.ConstraintViolation;
import javax.validation.Validation;
import javax.validation.Validator;
import java.util.Set;
```

```
@SpringBootApplication
public class CourseTrackerApplication implements CommandLineRunner {

    private static Logger logger = LoggerFactory.getLogger(CourseTrackerApplication.class);

    public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApplication.class, args);
    }

    @Override
    public void run(String... args) throws Exception {
        User user1 = new User("sbip01", "sbip");
        Validator validator = Validation.buildDefaultValidatorFactory().getValidator();
        Set<ConstraintViolation<User>> violations = validator.validate(user1);
        logger.error("Password for user1 do not adhere to the password policy");
        violations.forEach(constraintViolation -> logger.error("Violation details: [{}].",
      constraintViolation.getMessage()));

        User user2 = new User("sbip02", "Sbip01$4UDfg");
        violations = validator.validate(user2);
        if(violations.isEmpty()) {
            logger.info("Password for user2 adhere to the password policy");
        }

        User user3 = new User("sbip03", "Sbip01$4UDfgggg");
        violations = validator.validate(user3);
        logger.error("Password for user3 violates maximum repetitive rule");
        violations.forEach(constraintViolation -> logger.error("Violation details: [{}].",
      constraintViolation.getMessage()));

        User user4 = new User("sbip04", "Sbip014UDfgggg");
        violations = validator.validate(user4);
        logger.error("Password for user4 violates special character rule");
        violations.forEach(constraintViolation -> logger.error("Violation details: [{}].",
      constraintViolation.getMessage()));

    }
}
```

In Listing 2.36, you've created four users. Apart from `user2`, all other users do not adhere to the defined password policy. For instance, there are multiple password policy violations for `user1`. For `user3` and `user4` there are maximum repetitive rules and special character rule violations. Let us start the application to see these validation issues. Figure 2.5 shows the error message for password violations:

```
2021-02-17 09:30:06.480  INFO 11576 --- [           main] o.s.b.w.embedded.tomcat.TomcatWebServer  : Tomcat started on port(s): 8080 (http) with context path ''
2021-02-17 09:30:06.480  INFO 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Started CourseTrackerSpringBootApplication in 1.114 seconds (JVM runnin
g for 1.345)
2021-02-17 09:30:06.527 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Password for user1 do not adhere to the password policy
2021-02-17 09:30:06.527 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Violation details: [Password do not adhere to the specified rule].
2021-02-17 09:30:06.527  INFO 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Password for user2 adhere to the password policy
2021-02-17 09:30:06.527 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Password for user3 violates maximum repetitive rule
2021-02-17 09:30:06.527 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Violation details: [Password do not adhere to the specified rule].
2021-02-17 09:30:06.527 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Password for user4 violates special character rule
2021-02-17 09:30:06.542 ERROR 11576 --- [           main] m.s.c.CourseTrackerSpringBootApplication : Violation details: [Password do not adhere to the specified rule].
```

Figure 2.5 The Custom Constraint Violation Error message

You can find the completed version of the Spring Boot project used in the technique at https://github.com/spring-boot-in-practice/repo/tree/main/ch02/bean-validation-custom-annotation/spring-boot-app-final.

Discussion

In this technique, you've seen how to define a custom annotation to implement business-specific constraints in your Spring Boot application. To implement a custom constraint, you need to implement the `ConstraintValidator` interface and define the `isValid(..)` method. In this method, you need to define the business logic that decides whether the input data is valid or not. Once the validator is defined, you need to define the custom annotation that uses the defined validator.

You can then use the annotation in the fields which need to be validated. In this example, we've explicitly used the validator from the `ValidatorFactory` to validate the objects. Later in the book, you'll see much better and effective use of the Bean Validation's built-in and custom annotations while designing the REST API with a Spring Boot application.

2.6 Chapter Summary

In this chapter, you've explored several core techniques that need to be mastered by any Spring Boot developer. Some of the major topics that we've explored in this chapter were:

- Discussed several approaches to manage application properties in a Spring Boot application
- How to use `@ConfigurationProperties` to define properties in a type-safe manner
- How to configure `CommandLineRunner` to execute one-time executable code at Spring Boot application startup
- Default Spring Boot console logging, additional configurations, and how to use Log4j2 logging in a Spring Boot application
- How to use Bean Validation API to validate POJOs in your Spring Boot application with built-in annotations as well as with custom annotations

In Chapter 3, the next stop of your Spring Boot journey, you'll learn to access the database from a Spring Boot application.

3

Database Access with Spring Data

This chapter covers

- **Introduction to Spring Data, its needs, and various Spring Data Modules**
- **Configuring a relational database, NoSQL database (MongoDB), and access data in a Spring Boot Application**
- **Enabling Spring Data JPA to manage business domain objects with relational database**
- **Various techniques to access data from a relational database using** `@NamedQuery`**,** `@Query`**,** `Criteria API` **and** `Querydsl`

You've already explored a variety of topics on Spring Boot in the last two chapters. With a solid overview of Spring Boot, you've learned a few common tasks that you may use in your Spring Boot quite frequently. Now, what's next? In today's world, most applications are just incomplete without a database that stores the application data. Spring Boot applications are no exception to it. In this chapter, you'll boot your journey by interacting with the database from your Spring Boot application. You'll explore how seamless it is to perform database configuration, initialization, access data, and manage business objects in the database with Spring Boot!

3.1 Introducing Spring Data

Spring Data (https://spring.io/projects/spring-data) lets you access data from a variety of data sources (e.g., relational and non-relational databases, map-reduce databases, and cloud-based data services). It attempts to provide a uniform, easy-to-use, and familiar programming model through the Spring Framework.

It is an umbrella project under the Spring Framework that contains several subprojects each of which targets a specific database. For instance, the Spring Data JPA module is specific to relational databases (e.g., H2, MySQL, PostgreSQL). Similarly, the Spring Data MongoDB aims to provide support for the MongoDB database.

Java Persistence API (JPA)

Most applications in today's world need to communicate to the database to store and retrieve application data. And to achieve this interaction developers generally need to write a lot of boilerplate code. For instance, in the standard Java Database Connectivity (JDBC) approach, you need to obtain a database connection, define a `PreparedStatement`, set the bind variables, execute the query, and perform resource management.

The Java Persistence API (JPA) takes away most of these burdens and provides the developers a bridge between the Java object model (e.g., business objects) and the relational database model (e.g., database tables). This mapping between Java objects and the relational model is popularly known as Object Relational Mapping (ORM).

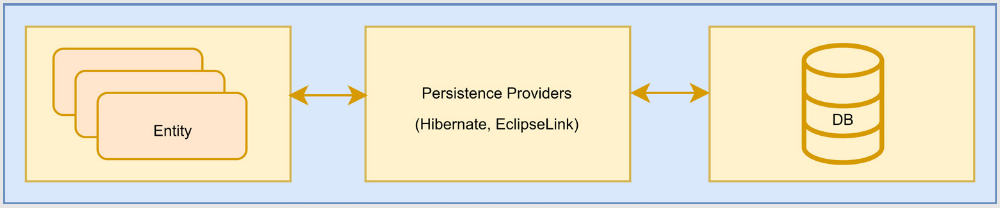


Figure 3.1 An overview of Object Relational Mapping. An entity represents a business object to be persisted. A persistence provider implements the JPA specification.

Java Persistence API (JPA) is a specification that provides a set of interfaces, classes, and annotations to persist and retrieve application objects easily and concisely. Note that it is just a specification and outlines the standards for the ORM techniques. There are several third-party vendors such as Hibernate (https://hibernate.org/orm/), EclipseLink (https://www.eclipse.org/eclipselink/#jpa) which provides a concrete implementation of this specification.

3.1.1 Why Spring Data

One of the core themes of Spring Data is to provide a consistent programming model to access various data sources. Thus, it provides a convenient API that lets you specify the metadata to the domain objects that need to be persisted and ensures that business domain objects are eligible to be persisted in the specific datastore. For instance, you can use a relational database and Spring Data JPA to manage business objects. You can provide the JPA annotations in business objects and Spring Data JPA ensures that the domain object is persisted in the database table. Later in this chapter, you'll see many of these annotations and their use in business objects.

Besides, Spring Data modules also expose APIs in form of templates similar to popular `JdbcTemplate`, `JmsTemplate` template design patterns. For instance, if you use MongoDB, you can use MongoTemplate to perform various operations in the MongoDB database. These template classes provide several helper methods that manage store-specific resource management and exception translations.

Spring Template

Spring Templates eliminates the need for boilerplate code that is otherwise required to correctly use some of the commonly used APIs such as Java Database Connectivity (JDBC), Java Message Service (JMS), Java Naming, and Directory Interface (JNDI). The boilerplate code is typically the setup, error handling, and resource management code that you additionally need to write to achieve the task. For instance, in the previously discussed JDBC example, you need to obtain a database connection, create a `PreparedStatement`, execute the query, handle the exception, and close the `PreparedStatement` and database connection.

The Spring templates take care of most of these boilerplate codes and let you only focus on the actual business logic. For example, the `JdbcTemplate` lets you supply the query that you need to run, and the rest is managed by the template.

Spring Data provides a Repository abstraction layer across the supported databases as a common programming model. The abstraction is contained in the Spring Data Commons module and it provides several useful interfaces that let you perform the standard Create, Read, Update, Delete (known as CRUD operations) operations as well as executing queries. This abstraction layer is the topmost layer and acts as the foundation for other Spring Data modules.

3.1.2 Spring Data Modules

In the previous section, you've seen the role of Spring Data. In this section, you'll learn more about Spring Data modules. You can refer to the Spring Data Modules sidebar for the list of major sub-projects available under Spring Data.

Spring Data Modules

Spring Data is an umbrella project that provides support for several mainstream data stores. Table 1 summarizes a few of the commonly used modules:

Module Name	Purpose
Spring Data Commons	It contains the foundational components used in all Spring Data projects
Spring Data JDBC	This module provides repository support for JDBC
Spring Data JPA	It provides repository support for JPA
Spring Data MongoDB	It provides support for document-based MongoDB database
Spring Data REDIS	It provides the necessary support for Redis datastore
Spring Data REST	It lets you access Spring data repositories as REST resources
Spring Data for Apache Cassandra	This module provides the necessary support for Apache Cassandra

Table 1: Spring Data Modules and their purposes

You can refer to the Spring Data reference document (https://spring.io/projects/spring-data) for a full list of Spring Data projects.

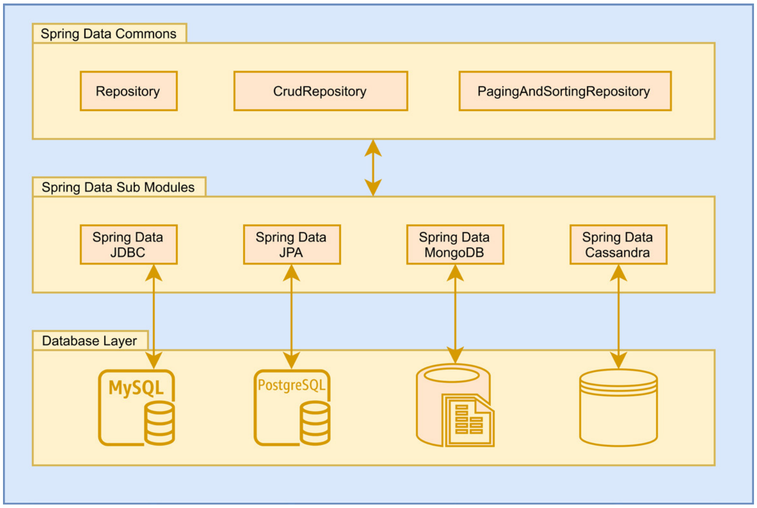


Figure 3.2 Spring Data Modules. Spring Data Commons module provides a foundation upon which other submodules are based on. Each submodule targets a specific type of database. The Repository, CrudRepository, and PagingAndSortingRepository are interfaces of the Spring Data Commons module

Out of all Spring Data modules, the Spring Data Commons module is one of the important modules. It consists of foundational and data source agnostic components of Spring Data that are used in other Spring Data modules. For instance, the Spring Data JPA module relies on the interfaces defined in the Spring Data Commons module. Spring Data JPA's `JpaRepository` interface is a sub-interface of the Spring Data Commons module's `PagingAndSortingRepository` interface and inherits CRUD, Pagination, and Sorting support from the Spring Data Commons module.

As shown in Figure 3.2, the Spring Data Commons module provides three core repository interfaces – `Repository`, `CrudRepository`, and `PagingAndSortingRepository`. As the name suggests, the `CrudRepository` interface lets you use the CRUD operations. Similarly, the `PagingAndSortingRepository` interface, which is a sub-interface of `CrudRepository`, allows you to perform CRUD operations as well as the pagination and sorting of data returned from the database. You'll explore these interfaces in detail in section 3.3.

The Spring Data sub-modules contain database technology-specific Spring Data implementations that provide supports for specific database families (e.g. Spring Data JDBC or Spring Data JPA focuses on relational databases) or vendor-specific databases (e.g. Spring Data MongoDB focuses on MongoDB database). These sub-modules leverage the core framework features offered in the Spring Data Commons module.

3.2 Configuring a Database in a Spring Boot Application

Configuring and accessing a database is one of the fundamental operations in any application, and Spring Boot applications are no exception to it. Spring Boot provides various techniques to configure and access a database from your Spring Boot application. Let's understand how to configure and access a relational database in a Spring Boot application.

TECHNIQUE CONFIGURE A RELATIONAL DATABASE IN A SPRING BOOT APPLICATION

Problem

Most applications need to interact with a database to store and retrieve application data. However, before communicating with the database, you need to configure the database in the application. You need to configure and access a relational database in your Spring Boot application

Solution

To configure a relational database with Spring Boot, you can add spring-boot-starter-data-jpa and the relational database driver dependency in the `pom.xml` of your application. Additionally, you need to supply the database details such as database username, password, driver class, and connection URL.

Which Relational Database to Use?

In the demonstration, you'll use an in-memory relational database named H2 (https://www.h2database.com/html/main.html).

However, you can use any relational database to continue with this technique. For example, you can use MySQL (https://www.mysql.com/), Oracle (https://www.oracle.com/in/database/technologies/appdev/xe.html), or PostgreSQL (https://www.postgresql.org/) databases as well. In case you are using a different database other than H2, the configuration technique will be all same and only the database driver and other supporting configuration parameters will change.

Besides, you need to ensure you have a running instance of the database you are using so that the Spring Boot application can connect to the database. You can either install and configure the database in your development machine or use a database instance from the cloud service providers such as AWS or Azure. In the latter case, ensure that you have connectivity to the database from your machine. Note that whatever approach (local or cloud) you use, only the database connection URL changes, and the rest all the configuration remains the same. In this example, we are using the embedded version of the H2 in-memory database.

Source Code

You can find the base version of the Spring Boot project used in this technique in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/configuring-relational-database/course-tracker-start.

The finished version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/configuring-relational-database/course-tracker-final.

To configure a relational database, you need to add two additional dependencies in the existing `pom.xml` file as shown in Listing 3.1. You can copy and paste these dependencies anywhere inside the `dependencies` tag in the `pom.xml` file.

Listing 3.1 Spring Data JPA Starter and H2 dependency

```
# Spring Boot Data JPA dependency for JPA support
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-data-jpa</artifactId>
</dependency>
# H2 database driver dependency. This dependency is configured with runtime scope to ensure
       it is available at the application runtime and not needed at the time of
       compilation.
<dependency>
       <groupId>com.h2database</groupId>
       <artifactId>h2</artifactId>
       <scope>runtime</scope>
</dependency>
```

In Listing 3.1, the first dependency incorporates Spring Data JPA, and the other one includes the H2 database driver into the Spring Boot project. If you are using a database other than H2, you need to use the associated database driver dependency in the `pom.xml` file. For instance, if you are using MySQL or PostgreSQL database, you can find the corresponding Maven dependency in the Maven central repository.

Among the dependencies, Spring Data JPA lets you manage your business domain objects through Object Relational Mapping (ORM) techniques without defining SQL queries explicitly. The H2 in-memory dependency lets you use an embedded H2 database in the Spring Boot application. As this is an in-memory database, the data inside this database is lost each time you restart the application.

Let’s now proceed with the H2 database details in the Spring Boot application. If you recall, every Spring Boot application contains an `application.properties` file that lets you configure various application properties to control its behavior. Let’s add the H2 database configurations to the `application.properties` file. Listing 3.2 shows the configuration needed to do this:

Listing 3.2 Application Properties with H2 database configuration

```
# Database URL. We are using schema named sbipdb in this demonstration
spring.datasource.url=jdbc:h2:mem:sbipdb
# H2 Driver class
spring.datasource.driverClassName=org.h2.Driver
# Database Username
spring.datasource.username=sa
# Database Password
spring.datasource.password=password
# Enable H2 console. This property is specific to H2 database only
spring.h2.console.enabled=true
```

In Listing 3.2, you've provided the H2 database connection URL, driver class, username, password and enabled the H2 console. The H2 console provides you a UI that lets you execute SQL queries in the in-memory H2 database. The provided details are sufficient for Spring Boot to configure the data source in the application.

To validate the created data source, you'll define a test case that asserts the data source type and the underlying database as shown in Listing 3.3. If you are not familiar with the test, you can refer to the book's companion GitHub wiki page at https://github.com/spring-boot-in-practice/repo/wiki/Beginners-Guide-to-Unit-Testing-with-Spring-Boot.

Listing 3.3 Unit test to validate the data source details

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private DataSource dataSource;

    @Test
    public void givenDatasourceAvailableWhenAccessDetailsThenExpectDetails() throws
       SQLException {

       assertThat(dataSource.getClass().getName()).isEqualTo("com.zaxxer.hikari.HikariDataS
       ource");

       assertThat(dataSource.getConnection().getMetaData().getDatabaseProductName()).isEqua
       lTo("H2");
    }
}
```

In this test case, you've autowired the `DataSource` instance and asserted that the data source class name is `com.zaxxer.hikari.HikariDataSource` and the database product name is `H2`. You'll learn more about the role of `HikariCP` in the discussion section of this technique. If you execute this test case, you can see both assertions are true as shown in Figure 3.3:

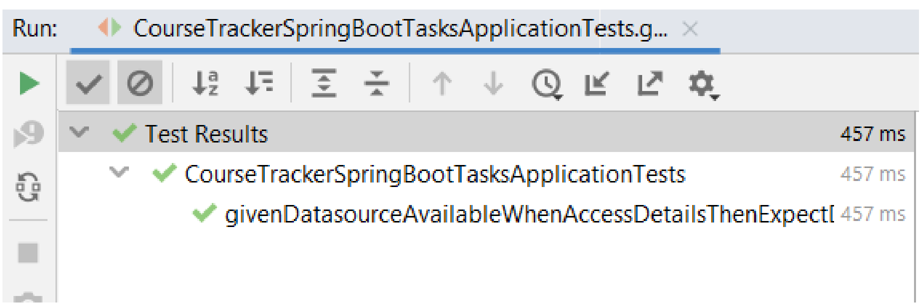


Figure 3.3 Unit Test case executed successfully in IntelliJ IDEA

Discussion

In this technique, you've learned how you can configure a relational database in your Spring Boot application with a few configurations. For instance, the presence of database configuration details in the `application.properties` file and the Spring Data JPA and H2 driver jars in the classpath enables Spring Boot to configure an H2 data source in the application. You can use this data source for database communication.

As part of the database configuration, Spring Boot automatically configures `HikariCP` (https://github.com/brettwooldridge/HikariCP) database connection pool. A database connection pool contains one or more database connections that are generally created at the time of application startup and available for use by the application. The benefit of a database connection pool is that a set of database connections are created at the application startup and available for use by the application. Thus, you don't create a new connection each time you need a database connection and close it once done. The application can take a connection from the pool, use it, and return to the pool. Spring Boot uses `HikariCP` as the default database connection pool library.

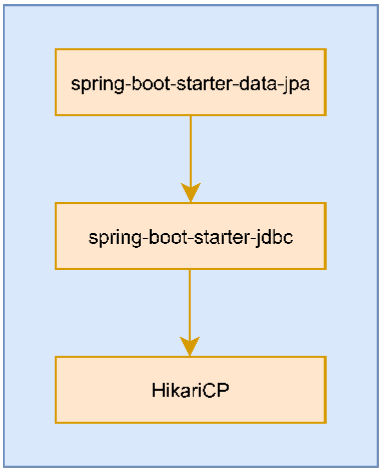


Figure 3.4 HikariCP connection pool library transitive dependency

If you are curious to know where is `HikariCP` dependency located, you can inspect the `spring-boot-starter-data-jpa` dependency by looking at its associated `pom.xml` file. Browse to the `pom.xml` file of the sample application in your IDE and click on the `spring-boot-starter-data-jpa` dependency. You can observe that `spring-boot-starter-data-jpa` has a dependency on `spring-boot-starter-jdbc` and that in turn has a dependency on the `HikariCP` library. Figure 3.4 shows this dependency hierarchy.

If you need to use a database connection pooling library other than `HikariCP`, you can achieve this by excluding `HikariCP` dependency from the `spring-boot-starter-data-jpa` dependency and include your preferred database connection pooling library (e.g., Oracle UCP, Tomcat JDBC, DBCP2, etc). Listing 3.4 shows the configuration to exclude `HikariCP` and use the `tomcat-jdbc` connection pooling library:

Listing 3.4 POM XML changes to exclude HikariCP and include Tomcat connection pool

```
…
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-data-jpa</artifactId>
    <exclusions>
         # Default connection pool HikariCP is excluded from Spring Data JPA dependency
        <exclusion>
            <groupId>com.zaxxer</groupId>
            <artifactId>HikariCP</artifactId>
        </exclusion>
    </exclusions>
</dependency>
# Tomcat JDBC connection pool is added explicitly as the connection pool of choice
<dependency>
    <groupId>org.apache.tomcat</groupId>
    <artifactId>tomcat-jdbc</artifactId>
</dependency>
…
```

Spring Boot uses the following strategies to detect the database connection pool library based on the configuration defined in Listing 3.4:

1. If `HikariCP` is not available, then Spring Boot attempts to use Apache Tomcat database connection pooling if it is available in the classpath
2. If both `HikariCP` and Apache Tomcat connection pool dependencies are not available, then Spring Boot attempts to use Apache Commons DBCP2 library (https://commons.apache.org/proper/commons-dbcp/)
3. If DBCP2 is also not available, Spring Boot configures the JDK's default data source (`javax.sql.DataSource`)

In this technique, you've configured the `H2` database in your Spring Boot application by configuring a few parameters in the `application.properties` file. In this demonstration, you've used only a handful of parameters to enable the database configuration. Spring Boot provides several additional configuration parameters to finetune the database configuration.

For instance, if you are using the default HikariCP configuration, you might want to customize the `HikariCP` connection pool configuration. For instance, you can configure a custom maximum number of connections per pool, namely the maximum connection pool size by configuring the `spring.datasource.hikari.maximum-pool-size` property in the `application.properties`. If you are using a connection pool library other than `HikariCP`, you need to the property specific to the library.

If you are curious to explore the available database configuration parameters, you can browse Spring Boot `application.properties` documentation at https://docs.spring.io/spring-boot/docs/current/reference/html/appendix-application-properties.html#data-properties.

TECHNIQUE CONFIGURE MONGODB DATABASE IN A SPRING BOOT APPLICATION

Problem

You've already explored configuring a relational database in a Spring Boot application. Apart from relational databases, NoSQL databases are also gaining popularity. You need to configure the popular NoSQL database MongoDB in a Spring Boot application

Solution

MongoDB is a popular NoSQL database that stores the data as documents in JSON-like format. Spring Boot provides an easy approach to integrate with MongoDB database through `spring-boot-starter-data-mongodb` dependency. In this technique, you'll learn how to connect to a MongoDB database from your Spring Boot application.

Source Code

You can find the base version of the Spring Boot project used in this technique in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/configuring-mongodb-database/course-tracker-start.

The finished version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/configuring-mongodb-database/course-tracker-final.

To configure MongoDB in a Spring Boot application, you've included the following dependencies in your Spring Boot application as shown in the Listing 3.5:

Listing 3.5 MongoDB Maven Dependencies

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-data-mongodb</artifactId>
</dependency>
<dependency>
    <groupId>de.flapdoodle.embed</groupId>
    <artifactId>de.flapdoodle.embed.mongo</artifactId>
</dependency>
```

The first dependency provides Spring Data MongoDB support in the Spring Boot application. The second dependency adds an embedded MongoDB in our application[1].

If you are using a real MongoDB instance, then you don't need the embedded MongoDB database dependency.

Let us define a test case to validate how to use MongoDB as shown in Listing 3.6:

[1]You can find more details on this embedded MongoDB database at https://github.com/flapdoodle-oss/de.flapdoodle.embed.mongo

Listing 3.6 Unit test to validate the use of MongoDB in Spring Data

```
package com.manning.sbip.ch03;

// Import statements are excluded as a matter of readability

import static org.assertj.core.api.Assertions.assertThat;

@DataMongoTest
@ExtendWith(SpringExtension.class)
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private MongoTemplate mongoTemplate;

    @Test
    public void givenObjectAvailableWhenSaveToCollectionThenExpectValue() {
        // given
        DBObject object = BasicDBObjectBuilder.start().add("Manning", "Spring Boot In
       Practice").get();
        // when
        mongoTemplate.save(object, "collection");
        // then
        assertThat(mongoTemplate.findAll(DBObject.class, "collection"))
                .extracting("Manning")
                .containsOnly("Spring Boot In Practice");

    }
}
```

Let us explore the activities performed in this test case:

- You've autowired the `MongoTemplate` in the test class. An instance of `MongoTemplate` is Created by Spring Boot. `MongoTemplate` is a helper class that lets you perform various MongoDB operations
- You then create a document as the key-value pair with the key as *Manning* and the value as *Spring Boot In Practice*. MongoDB stores the documents as part of collections. Thus, you add the document to a collection named *Collection*
- Finally, you find the document and extract the key and assert the returned value

Discussion

A relational database stores data in a tabular format in terms of rows and columns. However, not all data is suitable to be stored in a tabular format. There are several use cases where data is unstructured and treated as a document. The NoSQL databases store the data in terms of a document and are popularly known as a document database. MongoDB is one of the popular and leading document databases.

In this technique, you've used an in-memory instance of MongoDB. An in-memory instance lets you quickly bootstrap the application and does not require a local or remote database installation.

If you've a local or remote instance (e.g., in a remote server or cloud provider), you can remove the embedded configuration and provide your actual database configuration. Listing

3.7 shows the MongoDB database configurations that you can provide in the `application.properties` file to customize the database details:

Listing 3.7 MongoDB properties

```
# Authentication database name.
spring.data.mongodb.authentication-database=<Authentication database name>
# Database name.
spring.data.mongodb.database=<Database name>
# Fully qualified name of the FieldNamingStrategy to use.
spring.data.mongodb.field-naming-strategy=<Field Naming Strategy>
# GridFS database name.
spring.data.mongodb.gridfs.database=<Gridfs database>
# Mongo server host.
spring.data.mongodb.host=<Database Hostname>
# Login password of the mongo server.
spring.data.mongodb.password=<Database password>
# Mongo server port (27017 is the default MongoDB port).
spring.data.mongodb.port=<Database Port>
# Mongo database URI. When set, host and port are ignored.
spring.data.mongodb.uri=<Database URI>
# Login user of the mongo server.
spring.data.mongodb.username=<Database Username>
```

Note

You can refer to Spring Boot reference documentation available at https://docs.spring.io/spring-boot/docs/current/reference/html/appendix-application-properties.html for all supported properties.

If you are new to MongoDB, you can refer to the book's companion GitHub wiki page for a beginner's guide on MongoDB available at https://github.com/spring-boot-in-practice/repo/wiki/Beginners-Guide-to-MongoDB.

TECHNIQUE INITIALIZE A RELATIONAL DATABASE SCHEMA WITH A SPRING BOOT APPLICATION

Problem

In the technique *Configure a relational database in a spring boot application*, you've seen how to configure a relational database in your Spring Boot application. However, before you start accessing the database, you need to ensure the database schema is initialized properly. For instance, all the required tables and indexes are created, and associated insert scripts are executed. You need to initialize the database schema at the application startup.

Solution

Spring Boot lets you initialize a database schema with built-in solutions as well as third-party libraries (ORM solutions). In this technique, you'll learn how to initialize the database using Spring's built-in `schema.sql` and `data.sql` scripts.

Spring Boot can load the SQL scripts from the classpath (e.g. `src/main/resources` folder) or a pre-configured location. By default, you define the `schema.sql` file to provide all DDL scripts and define the `data.sql` file to include the DML scripts and place it inside the src\main\resources folder for Spring Boot to detect and execute these files. Further, you can also use the `spring.datasource.schema` and `spring.datasource.data` properties to customize the default behavior. You'll examine this in this technique.

DDL and DML in a nutshell

DDL stands for Data Definition Language and it is used to define database structures such as database users, schemas, tables, indexes, constraints in a relational database. For example, in H2 you can use the following DDL statement to create a table named AUTHORS:

```
create table AUTHORS (
  id bigint not null,
  name varchar(255),
  primary key (id)
);
```

DML stands for Data Manipulation Language and it is used to manipulate data. For example, DML statements let you INSERT, UPDATE, and DELETE data in relational database tables. For example, the following DML script INSERTS data into the AUTHORS table:

```
INSERT INTO AUTHORS(id, name) VALUES(1, 'John Doe') ;
```

Source Code

To start with this technique, you can use the base Spring Boot project from the book's GitHub repository available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/initialize-relational-database-with-schema/course-tracker-start The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/initialize-relational-database-with-schema/course-tracker-final

To begin with, let's configure the `spring.datasource.initialization-mode` property to `always` in the `application.properties` file. This property instructs Spring Boot to always initialize the database schema. It supports three values - `embedded`, `always`, and `never`. By default, this property is set to the value `embedded`. This means Spring Boot automatically initializes the database schema for embedded database types (e.g., H2 in-memory database - https://www.h2database.com/html/main.html). To initialize the MySQL or other actual databases, you need to explicitly configure the value to `always`. Since you are using the H2 database in this technique, you may ignore this property.

In this schema initialization-based approach, Spring Boot re-creates the schema each time you restart the application. There is no database schema versioning done by Spring Boot. For example, in the above example, Spring Boot drops and re-create the `COURSES` table in each application restart and executes the DML statements provided in the `data.sql` script.

Listing 3.8 shows the updated `application.properties` file:

Listing 3.8 Updated application.properties file

```
# This is to instruct Spring Boot to initialize the database schema. Supported values are
       embedded, always, and never. By default,  it is set to embedded which means if you
       use an embedded database then automatically the database is initialized. For other
       database types, always needs to be configured to configure the database
.
spring.datasource.initialization-mode=always

# Other data source properties such as username, password, driver name, and connection URL
```

Let us now define the `schema.sql` and the `data.sql` files. However, before that let us recap the business model we are working on within this application. In this example, you are managing Course details in the sample application. Thus, the `Course` is the business domain object in the application. The `schema.sql` creates the `COURSES` table and the `data.sql` inserts few sample courses into the `COURSES` table.

Listing 3.9 shows the database schema configuration located at `src/main/resources/schema.sql`:

Listing 3.9 Database schema.sql configuration

```
CREATE TABLE COURSES
(
    id int(15) NOT NULL,
    name varchar(100) NOT NULL,
    category varchar(20) NOT NULL,
    rating int(1) NOT NULL,
    description varchar(1000) NOT NULL,
    PRIMARY KEY (id)
);
```

Listing 3.10 shows the database initialization SQL script provided in the `data.sql` configuration file located at `src/main/resources/data.sql`: This is a DML script that contains the `INSERT` statements to populate the `COURSES` table.

Listing 3.10 Database initialization scripts

```
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION) VALUES(1, 'Rapid Spring Boot
       Application Development', 'Spring', 4, 'Spring Boot gives all the power of the
       Spring Framework without all of the complexities');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION) VALUES(2, 'Getting Started
       with Spring Security DSL','Spring', 3,  'Learn Spring Security DSL in easy steps');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION) VALUES(3, 'Scalable, Cloud
       Native Data Applications', 'Spring', 4,  'Manage Cloud based applications with
       Spring Boot');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION) VALUES(4, 'Fully Reactive:
       Spring, Kotlin, and JavaFX Playing Together', 'Spring', 3, 'Unleash the power of
       Reactive Spring with Kotlin and Spring Boot');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION) VALUES(5, 'Getting Started
       with Spring Cloud Kubernetes', 'Spring', 5, 'Master Spring Boot application
       deployment with Kubernetes');
```

Database Specific Schema and Data SQL files

In addition to the `schema.sql` and `data.sql` files, Spring Boot also supports database-specific SQLs. For instance, if your application supports multiple database types, and there are SQL syntax differences, you can use `schema-${platform}.sql` and `data-${platform}.sql` files. Thus, you can define a `schema-h2.sql` and `data-h2.sql` if you need to support the `h2` database. You can specify the database platform by defining `spring.datasource.platform=h2` in the `application.properties` file. Note that at any point only one database is active. Thus, you can maintain multiple `schema-${platform}.sql` and `data-${platform}.sql` files but you can configure the `spring.datasource.platform` to a specific database at any time.

To validate whether Spring Boot initializes the database schema, let us write a test case. This simple test case counts the number of courses available in the `COURSES` table in the database. Listing 3.11 shows this:

Listing 3.11 Unit test to validate database schema initialization

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private DataSource dataSource;

    @Test
    public void whenCountAllCoursesThenExpectFiveCourses() throws SQLException {
        ResultSet rs = null;
        int noOfCourses = 0;
        try(PreparedStatement ps = dataSource.getConnection().prepareStatement("SELECT
       COUNT(1) FROM COURSES")) {
            rs = ps.executeQuery();
            while(rs.next()) {
                noOfCourses = rs.getInt(1);

            }
            assertThat(noOfCourses).isEqualTo(5L);
        }
        finally {
            if(rs != null) {
                rs.close();
            }
        }
    }
}
```

In listing 3.11, you've autowired the `DataSource` and use basic JDBC code to count the courses from the `COURSES` table. Don't be scared by all this boilerplate code as in the next section, you'll learn how to perform SQL queries with JPA repositories. In this example, you've created five courses using the `INSERT` queries defined in the `data.sql` file. Thus, in the test case you are asserting for five courses.

You can also specify a different schema and data file name with a different location. For instance, the listing 3.12 shows the configuration for `sbip-schema.sql` and `sbip-data.sql` files available at `src\main\resources\sql\schema` and `src\main\resources\sql\data` folders respectively:

Listing 3.12 Custom Schema and Data file location

```
# Specifying a different schema file location
spring.datasource.schema=classpath:sql/schema/sbip-schema.sql

# Specifying a different data file location
spring.datasource.data=classpath:sql/data/sbip-data.sql
```

Other than classpath, you can also provide a file system location (with file://<absolute path>) if your schema and data files are in the file system. Further, you can specify more than one schema or data file separated by the comma.

Discussion

In this technique, you've learned how to use Spring Boot's built-in techniques to initialize a database by defining a few SQL files. To recap, you can define the `schema.sql` file to provide all your DDL scripts that define the database schema. Furthermore, you can use the `data.sql` file to provide the DML scripts that populate the database. Besides, you've also learned to maintain database platform-specific SQLs in the same application. This is useful if your application supports multiple databases.

So far, you've used the basic Spring Boot techniques to configure and communicate to the database. In the next section, you'll learn to use Spring Data JPA to manage your database communication in a much concise and effective manner. Let's proceed to discuss Spring Data's `CrudRepository` interface which provides support for standard CRUD operations as well as upon which most of the Spring Data sub-modules are based.

3.3 Understanding the CrudRepository Interface

Before starting with the `CrudRepository` interface, you need to know about the `Repository` interface. Spring Data repository uses this generic interface as the primary abstraction for a data source. It takes a business domain class that needs to be managed and an identifier type of the class as the type attribute. A business domain class is a Java class that represents a business entity and needs to be persisted. For instance, in the `CourseTracker` application, you are managing the course details which are represented in the `Course` class and have an identifier of the `long` data type.

The `Repository` is a marker interface and is primarily used to capture the domain class and its ID type information. A marker interface has no methods or constants and provides run-time type information about objects. Listing 3.13 shows the `Repository` interface from the `spring-data-commons` module:

Listing 3.13 Spring Data Repository Interface

```
public interface Repository<T, ID> {}
```

The `CrudRepository` is a sub-interface of the `Repository` interface and provides CRUD operations. Listing 3.14 shows the `CrudRepository` interface from the `spring-data-commons` module. You can find the source code of this interface at https://github.com/spring-projects/spring-data-commons/blob/master/src/main/java/org/springframework/data/repository/CrudRepository.java.

Listing 3.14 Spring Data CrudRepository methods

```
# The interface definition. The Generic type T represents the domain class and the ID type
       represents the identifier of the domain class
public interface CrudRepository<T, ID> extends Repository<T, ID> {

       # Saves a given entity
       <S extends T> S save(S entity);

       # Finds an entity by the given id
       Optional<T> findById(ID id);

       # Finds all entities
       Iterable<T> findAll();

       # Returns the number of entities available
       long count();

      # Deletes the entity with the given id
      void deleteById(ID id);

    // Additional Methods excluded for brevity
}
```

In addition to the `CrudRepository`, Spring Data also provides a `PagingAndSortingRepository` which extends `CrudRepository` and provides additional support for *pagination* and *sorting* of the entities. Figure 3.5 shows the relationship between the core interfaces of the Spring Data Commons module:

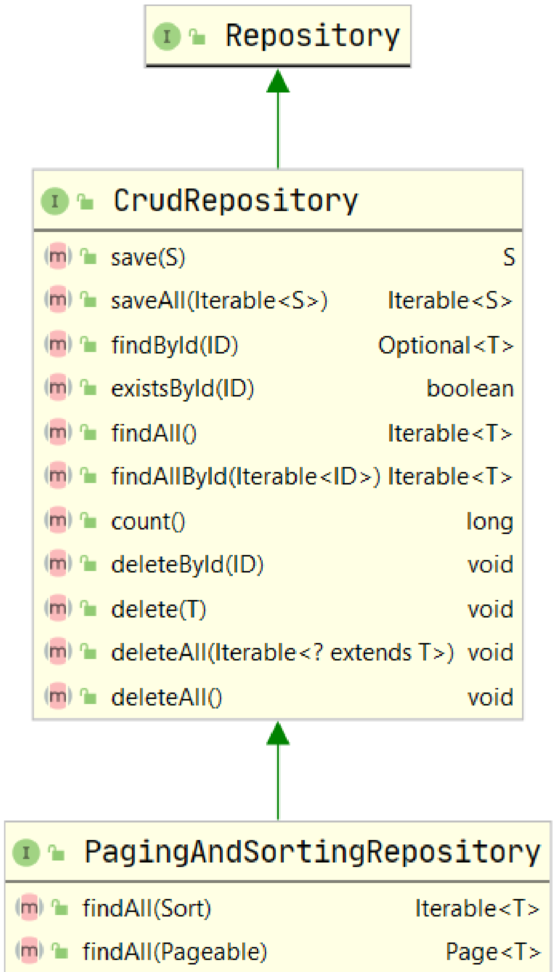


Figure 3.5 Spring Data Commons repository hierarchy class diagram

To manage a business domain class persistence, you typically create an interface that extends either `CrudRepository` or the `PagingAndSortingRepository` interface and provides the entity class and its identifier type information. The custom repository interface (e.g., `CourseRepository`) extends all the methods available in the extended interface (e.g., `CrudRepository`). Let us explore the use of the `CrudRepository` interface in the next technique.

TECHNIQUE MANAGE DOMAIN OBJECTS IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

You need to use Spring Data JPA to manage domain objects in a relational database in your Spring Boot application.

Solution

In the previous section, you've learned the Spring Data repository interfaces `Repository`, `CrudRepository`, and `PagingAndSortingRepository` that lets you manage domain objects in a Spring Boot application. In this technique, you'll learn how to use the `CrudRepository` interface to perform the Create, Read, Update, and Delete operations in an application.

Source Code

You can find the base Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/manage-domain-objects-with-jpa/course-tracker-start.
The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/manage-domain-objects-with-jpa/course-tracker-final.

Let us start by modifying the `Course` domain class by providing few JPA annotations so that Spring Data JPA can manage this class. This is shown in Listing 3.15:

Listing 3.15 The Course entity with @Id, @Column, and @GeneratedValue annotations

```
import javax.persistence.*;

@Entity
@Table(name = "COURSES")
public class Course {

        @Id
        @Column("ID")
        @GeneratedValue(strategy = GenerationType.IDENTITY)
        private Long id;

        @Column(name = "NAME")
        private String name;

        @Column(name = "CATEGORY")
        private String category;

        @Column(name = "RATING")
        private int rating;

        @Column(name = "DESCRIPTION")
        private String description;
        // Constructor, Getter/setters, and toString is omitted
```

Let's discuss the changes you've done:

- Annotated the class with the `@Entity` and the `@Table` annotations. The first annotation marks the Java class as a JPA entity, and the other annotation provides the database table details in which the entity needs to be managed

- You have also annotated the Java fields with the `@Column` annotation. This provides mapping information between the Java fields and the associated column name in the table
- You have annotated the id field with the `@Id` annotation to indicate that this field is the primary key of the table. You've also provided details to indicate that the values for this field should be generated using the provided strategy. Refer to the discussion section for more information on the available strategies

You'll now define a custom Spring Data repository by extending the `CrudRepository` interface that lets you manage the `Course` details. Recall that the `CrudRepository` interface provides support for the standard CRUD operations. Thus, `CourseRepository` inherits the CRUD operation support from this extended interface. Listing 3.16 shows the `CourseRepository` interface:

Listing 3.16 The CourseRepository interface

```
package com.manning.sbip.ch03.repository;

import org.springframework.data.repository.CrudRepository;
import org.springframework.stereotype.Repository;

import com.manning.sbip.ch03.model.Course;

@Repository
public interface CourseRepository extends CrudRepository<Course, Long> {
       // The interface body is actually empty
}
```

You've annotated the `CourseRepository` interface with the `@Repository` annotation to indicate this is a Spring repository. Notice that although it seems to be an empty interface, at runtime its concrete method implementation is provided by Spring Data JPA which is then used to perform the CRUD operations.

The last change you need to perform to update the `application.properties` file with `spring.jpa.hibernate.ddl-auto` property with `create` value. This property instructs the Hibernate (It is the default JPA provider in Spring Data JPA) to manage the database tables for the entities. Let us now write a test case to see the CRUD operations in practice as shown in Listing 3.17:

Listing 3.17 Unit test to validate CrudRepository methods

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
```

```
    private CourseRepository courseRepository;

    @Test
    public void givenCreateCourseWhenLoadTheCourseThenExpectSameCourse() {
        Course course = new Course("Rapid Spring Boot Application Development", "Spring",
       4, "'Spring Boot gives all the power of the Spring Framework without all of the
       complexities");
        Course savedCourse = courseRepository.save(course);
        assertThat(courseRepository.findById(savedCourse.getId()).get()).isEqualTo(course);
    }

    @Test
    public void givenUpdateCourseWhenLoadTheCourseThenExpectUpdatedCourse() {
        Course course = new Course("Rapid Spring Boot Application Development", "Spring",
       4, "'Spring Boot gives all the power of the Spring Framework without all of the
       complexities");
        courseRepository.save(course);
        course.setRating(5);
        Course savedCourse = courseRepository.save(course);
assertThat(courseRepository.findById(savedCourse.getId()).get().getRating()).isEqualTo(5);
    }

    @Test
    public void givenDeleteCourseWhenLoadTheCourseThenExpectNoCourse() {
        Course course = new Course("Rapid Spring Boot Application Development", "Spring",
       4, "'Spring Boot gives all the power of the Spring Framework without all of the
       complexities");
        Course savedCourse  = courseRepository.save(course);
    assertThat(courseRepository.findById(savedCourse.getId()).get()).isEqualTo(course);
    courseRepository.delete(course);
    assertThat(courseRepository.findById(savedCourse.getId()).isPresent()).isFalse();
   }
}
```

In the unit test of Listing 3.17, you've autowired the `CourseRepository` and defined three test cases:

- The first test case creates a new course and saves it into the database. We then find the course by its id and asserts that it is the same course we've created
- The second test case creates and saves a course in the database. It then updates the course rating of the course and asserts whether the update is successful
- The last test case creates and deletes a course. It asserts whether the course deletion is successful

Discussion

In this technique, you've learned to manage business domain objects through Spring Data JPA. To start with, you've updated the business domain class with JPA annotations. Spring Data JPA uses these annotations to manage the domain objects. Let's explore the JPA annotations in detail:

- **@Entity:** You've annotated the `Course` class with the `@Entity` annotation to indicate that this class is a JPA entity. A JPA entity is a POJO class representing the business domain object that needs to be persisted in a database table. As a default configuration, Spring Data uses the class name as the entity name. However, you can specify a custom entity name with the name attribute of `@Entity` annotation (e.g., `@Entity(name = "COURSE")`)

- **@Table:** By default, the entity class name also represents the name of the database table in which the entity data should be persisted. Thus, the `Course` POJO class name (i.e., `Course`) ensures that course details should be persisted in a table named `COURSE` in the database. Spring Data uses this as the default strategy if there is no table information provided in the class. However, in this example, you've customized the table name to `COURSES` with the `@Table` annotation. You can also specify several other tables related information such as the database schema name, unique constraints and indexes for the table, and a custom table name.
- **@Id:** An entity requires an identifier to identify each row in the underlying database table uniquely. The `@Id` annotation on a Java field in the business domain class specifies the property as the primary key of the table. Based on the application, a primary key can be a simple id with a single field, or it can be a composite id with multiple fields. To see the use of the composite key in Spring Data JPA, you can refer to https://github.com/spring-boot-in-practice/repo/wiki/Using-Composite-Key-with-JPA.
- **@Column:** By default, Spring Data uses the class field names as the column names in the database table. For example. the field name `id` represents the column `ID` in the database table. Besides, if you have a property with more than one word in the `camelCase` format in your Java class, then the `camelCase` property name in the class is represented as the `camel_case` in the database table field. The words in the field are connected by an underscore (_). Thus, if you've defined a property named `courseId`, it is represented as `course_id` in the table column.

Although the default column naming strategy works well in most of the scenarios, you can't use it all the time. For example, your organization might have a pre-defined column naming convention for the database table columns. Thus, you have a database column name different than the generated column name. You can address this name mismatch by specifying the corresponding database column name in the `@Column` annotation in the POJO field. For instance, `@Column(name= "COURSE_ID")` uses `COURSE_ID` as the column name in the `COURSES` table, instead of the default generated name `ID`. Besides, you have also noticed that the `id` field is annotated with the `@GeneratedValue` annotation. This annotation indicates that the value of the annotated property is generated. The `GeneratedValue` annotation accepts a `GenerationType` strategy that defines how the property value should be generated. The supported values are `Table`, `Identity`, `Sequence`, and `Auto`. Let us discuss these options briefly:

- **Table**: This option indicates that the persistence provider should assign primary keys for an entity using a database table
- **Identity**: Identity indicates that the persistence provider should assign the primary keys for an entity using a database identity column
- **Sequence**: As the name suggests, this option lets the persistence provider assign the primary keys using a database sequence

- **Auto**: This option lets the persistence provider decide on the Id generation scheme

You've annotated the `CourseRepository` interface with the `@Repository` annotation. This annotation serves two important purposes:

- **Auto Detection**: The `@Repository` annotation is meta annotated with the `@Component` annotation. Thus, the Spring component scan can autodetect the repository interfaces through the classpath scanning and you can autowire in other classes
- **Exception Translation:** One major benefit of using Spring Data JPA is that it provides flexibility to switch the underlying persistence provider. For instance, you can instruct Spring Boot to use `EclipseLink` as the JPA provider instead of `Hibernate`. However, this also brings the overhead of handling `EclipseLink` specific exceptions.

The `@Repository` annotation assists you to manage this overhead through its support for exception translation. An exception translation in this context means converting a technology-specific exception type (e.g., `SQLException`, `EclipseLinkException`, or `HibernateException`) to a generic Spring exception type (e.g., `DataAccessException`). Spring Data provides `DataAccessException` and a set of its child exception classes which are runtime exceptions. These exceptions wrap the original technology-specific checked exceptions and enables you to define a consistent exception handling strategy through the `DataAccessException`

SERVICE AND DATA ACCESS OBJECT (DAO) LAYER

Typically, you don't use a repository or the DAO implementations directly in the application. There should be a business service layer that acts as a bridge between the controller and the repository or the DAO layer. However, for simplicity and teaching purposes, in this demonstration, we've directly used the repository inside the test case.

JPA provides you the flexibility to automatically infer the DDLs from the `@Entity` classes and execute them in a database. The `spring.jpa.hibernate.ddl-auto` property decides how to manage the DDLs in your application. The possible values for this property are `none`, `validate`, `update`, `create`, and `create-drop`. The following list provides a brief discussion on these options:

- **none**: Disables the automatic DDL management. The default value for non-embedded databases
- **validate**: Validates the schema but does not make any changes to the database. Spring Boot throws an error if the database schema is not in expected structure
- **update**: Updates the already existing schema if necessary
- **create**: Creates the schema and destroys already existing data
- **create-drop**: Creates the schema and destroys at the end of the session. The default value for embedded databases

The property `spring.jpa.hibernate.ddl-auto` is specific to Hibernate which is the default persistence provider in Spring Boot. If you are using another Persistent provider, you can use the more generic property `spring.jpa.generate-ddl` which accepts a `boolean` value.

schema.sql or spring.jpa.hibernate.ddl-auto

In the previous technique, you've explored that you can use the `schema.sql` to create the database schema. In the current technique, you've learned the `spring.jpa.hibernate.ddl-auto` property that can also instruct Spring Data JPA to create the database schema based on the JPA annotations.

You've to ensure that you choose either of the approaches to create the database schema. If you choose to use `schema.sql`, then configure `spring.jpa.hibernate.ddl-auto` property to `none`.

In this technique, you've explored that you can use the `CrudRepository` interface to perform the CRUD operations in your application. However, at times you might need control to control the exposure of the CRUD methods. For instance, you may not want to expose the `delete(..)` method that deletes business entities due to your application design. For instance, many organizations won't delete the application data and instead choose to update the details as inactive in the database.

In the next technique, you'll learn to control the exposure of the CRUD methods by defining a custom Spring Data repository.

TECHNIQUE CREATE CUSTOM SPRING DATA REPOSITORY WITH SPRING DATA JPA TO MANAGE DOMAIN OBJECTS IN A RELATIONAL DATABASE

Problem

You want to use Spring Data repository interfaces to manage your application domain objects but don't want to expose all CRUD methods.

Solution

Spring Data repository interfaces provide an excellent and easy way to manage the business domain objects. It also lets you define your custom repository interfaces if the framework provided does not meet your need. In this technique, you'll define a custom Spring Data repository interface and use it in your Spring Boot application.

Source Code

You can find the base version of the Spring Boot project available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/creating-custom-spring-data-repository/course-tracker-start.

The completed version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/creating-custom-spring-data-repository/course-tracker-final.

To create a custom repository, you need to define a base repository interface that extends the Spring Data's `Repository` interface. You can then selectively specify the

`CrudRepository` methods that you want to expose. Let us define an interface called `BaseRepository` that exposes only the `save()` and `findAll()` methods of the `CrudRepository` interface as shown in the Listing 3.18:

Listing 3.18 Defining BaseRepository interface

```
package com.manning.sbip.ch03.repository;

import org.springframework.data.repository.NoRepositoryBean;
import org.springframework.data.repository.Repository;

@NoRepositoryBean
public interface BaseRepository<T, ID> extends Repository<T, ID> {

    <S extends T> S save(S entity);

    Iterable<T> findAll();

}
```

You've annotated this interface with `@NoRepositoryBean` annotation. As this is a base interface, you don't want Spring Data infrastructure to pick up this interface and create a concrete instance of it. The `@NoRepositoryBean` annotation ensures that the `BaseRepository` interface is excluded from the proxy object creation. You've also provided the `CrudRepository` method signatures that you want to expose in the `BaseRepository` interface. For these method invocations, Spring Data routes the runtime calls to the actual JPA implementation class as they match the `CrudRepository` method signature.

Let us define a custom interface that extends the `BaseRepository` interface as shown in listing 3.19. This ensures that the custom repository has access to only the methods defined in the `BaseRepository` interface.

Listing 3.19 Defining CustomizedCourseRepository interface

```
package com.manning.sbip.ch03.repository;

import com.manning.sbip.ch03.model.Course;
import org.springframework.stereotype.Repository;

@Repository
public interface CustomizedCourseRepository extends BaseRepository<Course, Long> {
}
```

The `CustomizedCourseRepository` interface is similar to the `CourseRepository` interface with the exception that it extends the `BaseRepository` interface and lets you access only the `save(..)` and `findAll(..)` methods.

Let's define a test case that uses the custom `CustomizedCourseRepository` interface as shown in Listing 3.20. Notice that you can only invoke the `save(..)` and `findAll(..)` methods. Trying to access other `CrudRepository` methods will result in a compile-time error since that method signature is not available in the `BaseRepository` interface.

Listing 3.20 Unit test to validate custom repository

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@DataJpaTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CustomizedCourseRepository customizedCourseRepository;

    @Test
    public void givenCreateCourseWhenFindAllCoursesThenExpectOneCourse() {
        Course course = new Course("Rapid Spring Boot Application Development", "Spring",
       4, "'Spring Boot gives all the power of the Spring Framework without all of the
       complexities");
        customizedCourseRepository.save(course);

       assertThat(Arrays.asList(customizedCourseRepository.findAll()).size()).isEqualTo(1);
    }
}
```

In Listing 3.20, you've autowired the `CustomizedCourseRepository` and use it to create a course. You then assert that one course has been created.

Discussion

In this technique, you've learned how to define a custom repository interface in your application. Although the `CrudRepository` interface is suitable in most of the scenarios, sometimes it is useful to control the CRUD operations. With the `@NoRepositoryBean` annotation, Spring Data lets you achieve this.

@SpringBootTest vs @DataJpaTest

In the previous technique, we've used the `@DataJpaTest` annotation instead of the `@SpringBootTest`. The `@SpringBootTest` annotation is useful when you need to bootstrap the entire Spring IoC container. Thus, this annotation creates the `ApplicationContext` that is used in the tests. However, at times loading the complete container is overkill. For instance, when you test the DAO layer, you are only interested to load the related beans, not the entire `ApplicationContext`. To achieve this, Spring Boot provides several annotations to *slice* the testing into different layers and tests only the layer you are interested in. For instance, the `@DataJpaTest` annotation is provided to test only the JPA components. Similarly, the `@WebMvcTest` focuses only on the Spring MVC components. It is recommended that you use these feature-specific annotations wherever applicable. You can find more information about feature-specific testing at https://docs.spring.io/spring-boot/docs/current/reference/html/spring-boot-features.html#boot-features-testing.

3.4 Retrieve Data from a Database using Spring Data

In the previous sections, you've learned how to configure databases and manage business domain objects or entities. In this section, you'll learn several techniques to efficiently access data from a database in a Spring Boot application.

3.4.1 Defining Query Methods

In previous techniques, you've seen how to use the `CrudRepository` interface to manage business domain objects. Although this interface provides standard CRUD operations, sometimes these generic methods are not sufficient. Instead, you may need more fine-grain control to manage domain objects. For instance, you might need to query entities based on entity properties instead of only relying on the entity Id (i.e., default `findById(..)` method).

Besides, you may also need to query entities after applying some *conditions* on the entity properties (e.g., `Like`, `StartsWith`, `Containing`, etc.). Further, you may also be interested to order (i.e., ascending or descending) the fetched entities based on one or more entity properties.

Spring Data JPA provides two ways to define custom query methods that can meet most of these custom requirements:

- Define custom methods in the repository interfaces with specific naming patterns. Spring Data can internally parse these methods and generate the query from it
- Define custom methods and provide a SQL query that is directly used by the Spring Data to query the entities

In this section, you'll learn the first option to define query method signatures so that the Spring Data can parse the provided methods and generate the queries. Spring Data has a pre-defined method naming pattern that is understood by its method parser. It supports the following commonly used patterns:

- **Query**: For querying entities, it lets you define `find..By`, `read..By`, `get..By`, `query..By`, `stream..By`, `search..By` methods
- **Count**: This pattern is used to define `count..By()` methods to count the entities
- **Exists**: This pattern is used to define `exists..By()` methods that checks the existence of an entity
- **Delete**: To delete entities, it lets you define `delete..By()` and `remove..By()` methods

Additionally, you can also use additional clauses to fine-tune the methods. For instance, you can use `Distinct` or `All` expression in the method. Further, you can also use the `And`, and `Or` expressions to concatenate additional entity properties.

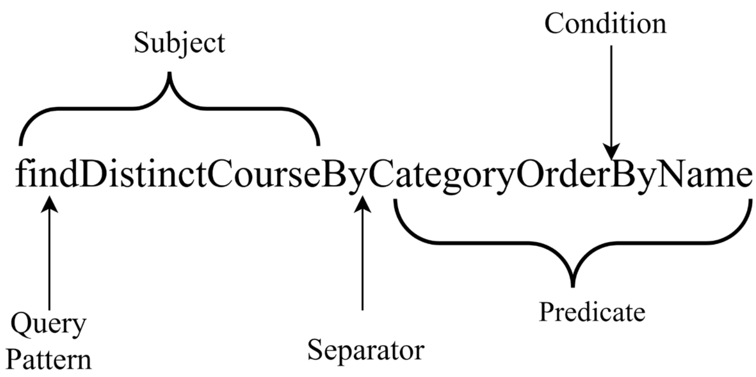


Figure 3.6 Query Method Structure

Spring Data uses the concept of a `Subject` and `Predicate` to parse the methods. It splits the method signature based on the `By` clause and treats the first half as the subject, and the remaining part as the predicate. Thus, if you define a method named `findDistinctCourseByCategoryOrderByName()` then the part `DistinctCourse` is the subject and the `CategoryOrderByName` is the predicate. This is demonstrated in Figure 3.6.

Let us use a technique to learn how you can define query methods to retrieve data from the database.

TECHNIQUE DEFINE CUSTOM QUERY METHODS TO RETRIEVE DOMAIN OBJECTS FROM A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

You need to use Spring Data JPA to define custom query methods to retrieve entities from a relational database in your Spring Boot application.

Solution

Spring Data JPA lets you define custom query methods to retrieve business entity details from the database. In this exercise, you'll learn to use this technique by defining a few custom query methods in the `CourseTracker` application.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/custom-query-methods/course-tracker-start. The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/custom-query-methods/course-tracker-final.

In the previous technique, you've used the `CourseRepository` interface to extend the `CrudRepository` interface and accessed methods defined in it. Let us modify the

CourseRepository interface to provide a few query method signatures as shown in Listing 3.21:

Listing 3.21 CourseRepository Interface with custom query methods

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface CourseRepository extends CrudRepository<Course, Long> {

    # Finds all courses by category. A find query returns an Iterable type
    Iterable<Course> findAllByCategory(String category);

    # Finds all courses by category and order the entities by name
    Iterable<Course> findAllByCategoryOrderByName(String category);

    # Checks if a course with the supplied name exists. Returns true if course exists,
       false otherwise. Exists queries return the boolean type
    boolean existsByName(String name);

    # Returns the count of courses for the supplied category. Count queries can return an
       integer or long type
    long countByCategory(String category);

    # Finds all courses that match the supplied course name OR the course category
    Iterable<Course> findByNameOrCategory(String name, String category);

    # Finds all courses that start with the supplied course name string
    Iterable<Course> findByNameStartsWith(String name);

    # Finds all courses by category and returns a Java 8 Stream
    Stream<Course> streamAllByCategory(String category);
}
```

You've defined seven custom query methods that find the course details and related information from the database. Let us explain these methods in detail. Note that you've only defined the method signatures and not provided any implementation for these methods. Spring Data JPA parses the method signatures and ensures to provide a concrete implementation internally.

1. `findAllByCategory`: This is the simplest query method you've defined in the `CourseRepository` interface. You can relate it with the `findById(..)` method defined in the `CrudRepository` interface that finds an entity with the supplied entity ID. This method takes the same concept a step further and lets you define a custom method that finds a list of entities that belongs to a category. You can define more custom query methods that use other entity properties. For instance, to find a course that matches the supplied course description, you can define a method named `findByDescription(String description)`
2. `findAllByCategoryOrderByName`: This is an extension to the `findAllByCategory(..)` method with the exception that it returns courses in ascending order of the course name

3. `existsByName`: This method checks if a course with the supplied name exists. Returns true if course exists, false otherwise
4. `countByCategory`: This method returns the count of courses for the supplied category
5. `findByNameOrCategory`: Finds all courses that match the supplied course name OR the course category. Like the `OR` clause, you can also use the `AND` clause if you need to define a query that requires both properties to be available
6. `findByNameStartsWith`: Finds all courses that start with the supplied course name string. The supplied course name method parameter can be a substring of the actual course name
7. `streamAllByCategory`: Finds all courses by category and returns a Java 8 Stream. A `Stream` return type is different than the `Iterable` return type which you've seen in the previous methods. An `Iterable` is a data structure and contains the returned data that you can iterate. A Stream is not a data structure, instead, it points to a data source from which the data can be streamed.

Let us define a test case to use these query methods in practice as shown in Listing 3.22:

Listing 3.22 Unit test to validate custom query methods

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CourseRepository courseRepository;

    @Test
    public void givenCreateCourseWhenLoadTheCourseThenExpectSameCourse() {
        // Saving a list of courses
        courseRepository.saveAll(getCourseList());
        assertThat(courseRepository.findAllByCategory("Spring")).hasSize(3);
        assertThat(courseRepository.existsByName("JavaScript for All")).isTrue();
        assertThat(courseRepository.existsByName("Mastering JavaScript")).isFalse();
        assertThat(courseRepository.countByCategory("Python")).isEqualTo(2);
        assertThat(courseRepository.findByNameStartsWith("Getting Started")).hasSize(3);
    }

    private List<Course> getCourseList() {
        // Get Course List
    }
}
```

In the test case of Listing 3.22, you have created a few courses and save them into the database table. You then used the custom query methods and asserts their outcome. If you execute this test case, you'll find that all assertions are true.

Discussion

In this section, you've learned a couple of important concepts of Spring Data JPA. Let us summarize the concepts you've explored so:

- You have seen how to define custom repository query methods based on the entity properties. Besides, you've also seen how you can use various patterns such as `Or`, `StartsWith`, and `OrderBy` to control the query and the returned result ordering. These are only a few expressions we've demonstrated in this example. You can refer to https://docs.spring.io/spring-data/jpa/docs/current/reference/html/#jpa.query-methods to learn more about the other expressions that you can use in the query method name
- You've seen how to define a repository method with a Java 8 Stream in the repository interface, and subsequently use the returned stream in your application. This contrasts with the `Iterable` return type through which you return a collection. You can leverage the Stream features such as `map-filter-reduce` techniques using the defined repository Stream method. Refer to the Java 8 `Stream` to learn more on how to leverage the Stream features

3.4.2 Implementing Pagination with PagingAndSortingRepository

Pagination is a technique to break a large set of data into multiple pages. It is an effective and server-friendly way to return the results to your user. Typically, application users will not look beyond the first few results irrespective of the number of results shown to them. Thus, retrieving, processing, and a large set of data at times results in a waste of bandwidth and CPU time. Besides, if the returned data contains resources such as images, it can slow down the application loading and impact the user experience. Imagine showing a product catalog with hundreds of items with each catalog item containing an image.

Spring Data provides the `PagingAndSortingRepository` interface that provides you the ability to page and sort the returned data. And, since this interface extends `CrudRepository`, you can also access the core CRUD features provided in the `CrudRepository` interface. Let us explore the use of the `PagingAndSortingRepository` interface in the next technique.

TECHNIQUE: USING PAGINGANDSORTINGREPOSITORY INTERFACE TO PAGINATE AND SORT THE DATA

Problem

Loading, sorting, and returning a large set of data to the application users waste the server resources and impact the application user experience. You need to return the data into a smaller subset in terms of pages

Solution

Pagination is the technique to split the data into a smaller chunk known as a page. You can configure the size of the page that determines the number of records or data contains in a page. Besides, for a better user experience, you can optionally sort the data in ascending or descending order.

In this technique, you'll use Spring Data's built-in `PagingAndSortingRepository` to implement pagination. In this technique, we'll load a few courses and return the courses to the users in terms of pages.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-paging-and-sorting-repository/course-tracker-start.

The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-paging-and-sorting-repository/course-tracker-final

Let us define the `CourseRepository` interface that extends the `PagingAndSortingRepository` interface as shown in Listing 3.23. We'll look into the `PagingAndSortingRepository` interface shortly.

Listing 3.23 Extending PagingAndSortingRepository

```
@Repository
public interface CourseRepository extends PagingAndSortingRepository<Course, Long> {

}
```

Next, let us define a test case that uses the `PagingAndSortingRepository` interface as shown in the Listing 3.24:

Listing 3.24 Unit test to use PagingAndSortingRepository

```
@Test
void givenDataAvailableWhenLoadFirstPageThenGetFiveRecords() {
    Pageable pageable = PageRequest.of(0,5);
    assertThat(courseRepository.findAll(pageable)).hasSize(5);
    assertThat(pageable.getPageNumber()).isEqualTo(0);

    Pageable nextPageable = pageable.next();
    assertThat(courseRepository.findAll(nextPageable)).hasSize(4);
    assertThat(nextPageable.getPageNumber()).isEqualTo(1);
}
```

We are performing the following activities:

- Created a `PageRequest` instance using the static `of` method by specifying the page number and the number of records in the page. You've specified the page number zero and the record size in the page as five
- Next, you've the used pageable instance in the `findAll()` method of the `CourseRespository` to load the first page. This `findAll()` method is from `PagingAndSortingRepository` interface
- Using the various methods of Pageable instances to assert on the values such as next page and page number

Let us now explore the use of Sorting facilities provided in the `PagingAndSortingRepository` interface as shown in Listing 3.25:

Listing 3.25 Pagination usage example

```
@Test
void givenDataAvailableWhenSortsFirstPageThenGetSortedSData() {
    Pageable pageable = PageRequest.of(0,5, Sort.by(Sort.Order.asc("Name")));
    Condition<Course> sortedFirstCourseCondition = new Condition<Course>() {
        @Override
        public boolean matches(Course course) {
            return course.getId() == 4 && course.getName().equals("Cloud Native Spring Boot
       Application Development");
        }
    };
    assertThat(courseRepository.findAll(pageable)).first().has(sortedFirstCourseCondition);
}

@Test
void givenDataAvailableWhenApplyCustomSortThenGetSortedResult() {
    Pageable customSortPageable = PageRequest.of(0,5,
       Sort.by("Rating").descending().and(Sort.by("Name")));
    Condition<Course> customSortFirstCourseCondition = new Condition<Course>() {
        @Override
        public boolean matches(Course course) {
            return course.getId() == 2 && course.getName().equals("Getting Started with
       Spring Security DSL");
        }
    };

       assertThat(courseRepository.findAll(customSortPageable)).first().has(customSortFirst
       CourseCondition);
}
```

In the above code snippet, you've performed sorting of the data:

- The first one with the custom sort order with the course name in ascending order
- Second, defined a custom sorting order with descending sorting order on course rating and ascending sorting on the course name

Discussion

The `PagingAndSortingRepository` is a useful interface that lets you achieve a custom pagination and sorting feature in your application. Listing 3.26 shows this interface from the Spring Data codebase:

Listing 3.26 The PagingAndSortingRepository interface definition

```
@NoRepositoryBean
public interface PagingAndSortingRepository<T, ID> extends CrudRepository<T, ID> {

      Page<T> findAll(Pageable pageable);

       Iterable<T> findAll(Sort sort);

}
```

The first `findAll(..)` method takes an instance of `Pageable`. The `Pageable` interface provides several useful methods to construct page requests as well as access the page information. For instance, you've used the `of(..)` method to construct the page request that lets you specify the page number with the number of records in it. Further, it also lets you access the previous, and next pages.

The second `findAll(..)` method takes an instance of `Sort`. The `Sort` class is flexible and provides a myriad way to construct a sorting order. For instance, in the second test case, you have constructed a custom sort order with rating in descending and name in ascending order.

3.4.3 Specifying Query using @NamedQuery

In the Defining Query Methods section 3.4.1, you've seen there are two approaches to define query methods. You've learned the first approach in technique *Define custom query methods to retrieve domain objects from a relational database with Spring Data JPA* where we explained how to define custom query method signatures from which Spring Data generates the queries. In this section, you'll learn the other approach to manually define custom queries directly in your repository methods so that Spring Data can use them as is instead of deriving through the names of the methods.

Although the method name-based query approach works fine in most circumstances, sometimes you would like to define the queries explicitly that should be used by Spring Data. Let us understand the scenarios when you might want to use this alternative approach:

- You might have defined a fine-tuned query and leveraged datastore specific features
- There might be a requirement to access more than one table with table joins. Thus, you might have defined a query with joins multiple tables

In this section, you'll learn the several features to manually specify the query using Spring Data's NamedQuery, Query, and QueryDSL features. In this section, let's start with the `NamedQuery` feature.

A `NamedQuery` is a predefined query that is associated with a business entity. It uses Jakarta Persistence Query Language (JPQL - https://eclipse-ee4j.github.io/jakartaee-tutorial/persistence-querylanguage.html) to define the query. You can define a `NamedQuery` in an entity or its superclass. You'll see an example of this shortly.

You can define a Named Query with the `@NamedQuery` annotation in your entity class. This annotation has four arguments – `name`, `query`, `lockMode`, and `hints`. The `name` and the `query` attributes of the `@NamedQuery` annotations are mandatory, whereas the remaining two attributes are optional.

Let's start with the next technique that shows you the usage of `NamedQuery` in your Spring Boot application.

TECHNIQUE USE A NAMED QUERY TO MANAGE DOMAIN OBJECTS IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

You need to use Named Query with Spring Data JPA to define custom queries in repository interface methods to manage domain objects in a relational database

Solution

Although the query methods with query method signature definition approach work fine in most scenarios, there are cases when it has some limitations. For instance, if you need to join multiple tables and retrieve the data, there is no easy way to define the method signatures. With the Named Query, you can provide the query along with the method signature so that the same can be used to retrieve the data.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/named-query-method/course-tracker-start. The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/named-query-method/course-tracker-final.

To begin with, let's modify the `Course` class to add the `@NamedQuery` annotation as shown in Listing 3.27:

Listing 3.27 Course interface with @NamedQuery annotation

```
package com.manning.sbip.ch03.model;

import javax.persistence.*;

@Entity
@Table(name = "COURSES")
# The @NamedQuery annotation lets you specify the query for the repository method in JPQL
       format
@NamedQuery(name = "Course.findAllByCategoryAndRating", query = "select c from Course c
       where c.category=?1 and c.rating=?2")
public class Course {

       @Id
       @GeneratedValue(strategy = GenerationType.IDENTITY)
       private long id;
       private String name;

       // Remaining parts omitted for brevity
}
```

In the `Course` POJO, you've provided the query details that fetches all courses by the supplied category in the `@NamedQuery` annotation. The `name` attribute contains the entity name and the method name concatenated with a dot(.). Besides, in the query, you've provided the query along with two positional parameters `?1` and `?2`. It uses the supplied parameter values when the repository method is invoked.

Further, you can use `@NamedQuery` annotation more than once in the entity if you need to define more than one repository methods for which you want to use the `@NamedQuery` feature. Listing 3.28 shows this:

Listing 3.28 Use of @NamedQueries annotation to include multiple @NamedQuery annotation

```
@Entity
@Table(name = "COURSES")
@NamedQueries({
    @NamedQuery(name = "Course.findAllByRating", query = "select c from Course c where
       c.rating=?1"),
    @NamedQuery(name = "Course.findAllByCategoryAndRating", query = "select c from Course c
       where c.category=?1 and c.rating=?2"),
})
public class Course {

// other members are excluded as a matter of readability
}
```

Let us re-define the `CourseRepository` interface which now contains a custom method with the same method name provided in the `@NamedQuery` annotation in the `Course` entity. Listing 3.29 shows the updated `CourseRepository` interface:

Listing 3.29 CourseRepository interface with the method defined in @NamedQuery annotation

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface CourseRepository extends CrudRepository<Course, Long> {
    # The repository method is defined in the @NamedQuery annotation. Defined here so that
       you can use it with CourseRepository instance
    Iterable<Course> findAllByCategoryAndRating(String category, int rating);
}
```

Let us validate the use of the `findAllByCategoryAndRating(..)` method by defining a test case as shown in Listing 3.30:

Listing 3.30 Unit test to use @NamedQuery annotation

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CourseRepository courseRepository;

    @Test
    public void givenCoursesCreatedWhenLoadCoursesBySpringCategoryThenExpectThreeCourses(){
        courseRepository.saveAll(getCourseList());
        assertThat(courseRepository.findAllByCategoryAndRating("Spring", 4)).hasSize(1);
```

```
    }

    private List<Course> getCourseList() {
        // get course list
    }
}
```

If you run the test case, you'll see it executes successfully. In the next section, let's discuss the `@Query` annotation.

3.4.4 Specifying Query using @Query

Although the named queries to declare queries in the entity class works fine, it unnecessarily adds persistence information in the business domain class (recall that you added the `@NamedQuery` annotation in the Course class). This can be a concern as it tightly couples the persistence details in the business domain classes.

As an alternative, you can provide the query information in the repository interface. This co-locates the query method and the JPQL query together. You can use the `@Query` annotation in the repository interface methods to do this. Besides, the benefit of using the `@Query` annotation over the named queries is that the `@Query` annotation lets you use the native SQL queries as well. Thus, you can use both JPQL as well as native SQL queries with the `@Query` annotation. Let us explore the use of `@Query` annotation in the next technique:

TECHNIQUE USE @QUERY ANNOTATION TO DEFINE QUERIES AND RETRIEVE DOMAIN OBJECTS IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

You want to use `@Query` annotation with Spring Data JPA to define custom queries in repository interface methods to manage domain objects in a relational database

Solution

The `@Query` annotation lets you provide the queries along with the method signature in the repository interface. This is considered a better approach as the business domain objects are kept free from the persistence-related information.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-query-annotation/course-tracker-start
The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-query-annotation/course-tracker-final

Let us re-define the `CourseRepository` interface in which you'll provide three repository methods using the `@Query` annotation as shown in Listing 3.31:

Listing 3.31 Updated CourseRepository with custom query methods with @Query annotation

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface CourseRepository extends CrudRepository<Course, Long> {

    # The repository method that finds all the courses belongs to the supplied category.
       The @Query annotation lets you specify the JPQL Query. You have used a positional
       argument with ?1 which is replaced by the supplied category in this example
    @Query("select c from Course c where c.category=?1")
    Iterable<Course> findAllByCategory(String category);

          # The repository method finds all the courses that belong to the supplied
       category and has a rating value greater than the one supplied in the rating
       parameter. You have used named parameters in this example. These named parameters
       are replaced by the supplied category and rating values in this example.
    @Query("select c from Course c where c.category=:category and c.rating >:rating")
    Iterable<Course> findAllByCategoryAndRatingGreaterThan(@Param("category") String
       category, @Param("rating") int rating);

    # The repository method that finds all the courses for a given rating. This is not a
       JPQL query and we've set the nativeQuery to true to indicate this query is a native
       SQL database query
    @Query(value = "select * from COURSE where rating=?1", nativeQuery = true)
    Iterable<Course> findAllByRating(int rating);

    # The repository method that lets you update a course rating. The @Modifying annotation
       indicates that the query specified in the @Query annotation is a modifying query.
       The @Transactional annotation bounds the method execution in a transaction context
       as it is performing a database update
    @Modifying
    @Transactional
    @Query("update Course c set c.rating=:rating where c.name=:name")
    int updateCourseRatingByName(@Param("rating") int rating, @Param("name") String name);
}
```

There is a quite lot happening in the updated `CourseRepository` interface. Let us examine these in detail:

- You've used the `@Query` annotation to define the JPQL query that should be used by Sprig Data to fetch the courses. This query is similar to what you've used in the named queries technique in section 3.4.3. Besides, this query also uses positional arguments to use the supplied argument. In this query, you are retrieving all courses that belong to the provided category
- In the next query also, you've used the `@Query` annotation to define the query to be used by Spring Data. However, there are few notable differences in the syntax. Instead of the positional argument-based approach, you've used **named parameters**. Although the positional based approach works well, at times it is error-prone if the position of the parameter changes while performing code refactoring. To avoid this issue, you are using the `@Param` annotation to provide the parameter a name and binding the name in the query

- In the third query, you've specified a SQL query and set the `nativeQuery` flag to true to indicate the query is a native SQL query. Typically, different database vendors offer database-specific features that are native to the specific database. Thus, if you need to leverage database-specific features, you can define the SQL query with `nativeQuery` flag set to `true`
- The last query is quite interesting. So far, most of the queries in the earlier demonstrations have been used to retrieve data from the database. Unlike those queries, the third query is a data manipulation query that updates content in the database. Along with the `@Query` annotation, this method also specified two additional annotations and a different return type. Let us explain these in detail:
- The `@Transactional` annotation is used to bound the method execution in a transaction context as it is performing a database update. Note that we are not performing any transaction explicitly, instead, Spring is managing the transaction through Aspect-Oriented programming.
- The `@Modifying` annotation is to indicate that the query specified in the `@Query` annotation is a modifying query. This annotation only works in conjunction with the `@Query` annotation. In addition to the `UPDATE` statements, you can also specify `INSERT` and `DELETE`, and other DDL statements in the `@Query` annotation. Note that we'll get an `InvalidDataAccessApiUsageException` if this annotation is not specified

    - The return type of the query must be either `int/Integer` or `void` as it is a modifying query. If the return type is `int/Integer`, it returns the number of rows modified by the query

To understand the supported return types in the query methods, you can refer to Spring Data JPA documentation at https://docs.spring.io/spring-data/jpa/docs/current/reference/html/#repository-query-return-types for a list of supported return types. Let us now define a test case to see these methods in practice as shown in Listing 3.32:

Listing 3.32 Unit test to examine the use of the @Query annotation

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@DataJpaTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CourseRepository courseRepository;

    @Test
    public void givenCoursesCreatedWhenLoadCoursesWithQueryThenExpectCorrectCourseDetails()
       {
        saveMockCourses();
        assertThat(courseRepository.findAllByCategory("Spring")).hasSize(3);
        assertThat(courseRepository.findAllByRating(3)).hasSize(2);
        assertThat(courseRepository.findAllByCategoryAndRatingGreaterThan("Spring",
       3)).hasSize(2);
```

```
        courseRepository.updateCourseRatingByName(4, "Getting Started with Spring Cloud
       Kubernetes");
        assertThat(courseRepository.findAllByCategoryAndRatingGreaterThan("Spring",
       3)).hasSize(3);
    }

    private void saveMockCourses() {
       // Save List of Courses
    }
}
```

If you execute this test case, you'll find that all the assertions are true.

Description

The `@Query` mechanism is an excellent feature that lets you specify the JPQL and the SQL queries directly in the repository query methods. It offers several benefits compared to the other two approaches (e.g., Query Methods, Named Query). The Spring Data Query method has a limitation when you need to fetch data from multiple tables as well as if you wish to use any native database feature. The Query approach is extremely useful if you need to fetch data from multiple tables with a complex table join query. You can define the query and let the Spring Data repository use the query to retrieve the data. Besides, you can also use native SQL features of the underlying database if required.

Although similar, the Named Query approach introduces persistence details with `@NamedQuery` annotation which is not always considered a best practice. An attentive reader might counter that the `@Query` approach also specifies native SQL queries inside the Java class which also is not considered as a best practice. To overcome this problem, Spring Data lets you externalize the queries in a property file. You can create a folder named `META-INF` inside the `src\main\resources` folder. Add a file named `jpa-named-queries.properties` inside the `META-INF` folder. You can then externalize the queries in the `Entity.finderMethod=Query` format. For example, you can externalize the query for the `findAllByCategory(..)` method as shown below:

```
Course.findAllByCategory = select c from Course c where c.category=?1
```

Spring Data automatically refers to this externalized query when it needs to execute the `findAllByCategory(..)` method.

Although the named query and the query approaches seem an excellent alternative to control how to fetch data, both techniques suffer from a major drawback. In these approaches, there is no syntax check of the provided query at compile-time and any syntax issue in the query only surfaces at run time. In the next section, you'll learn two different techniques to programmatically define queries in a type-safe manner.

3.4.5 Using Criteria API with Spring Data JPA

One of the major drawbacks of using JPQL is the lack of its type safety and absence of static query checking. This is because JPQL queries are not validated at compile time. Thus, any error in the query can only be detected at the execution time.

The Criteria API (https://docs.oracle.com/javaee/7/tutorial/persistence-criteria.htm#GJITV) introduced in JPA 2.0 adds a type-safe way to create queries. It lets you express a query in a programmatic and type-safe manner. The type safety of a query is achieved using the interfaces and classes that represent various parts of the query such as the select clause, order-by, etc. The type-safety is also achieved in terms of referencing attributes of an entity. Let us define a technique to see the use of Criteria API in conjunction with Spring Data JPA.

TECHNIQUE USE CRITERIA API TO MANAGE DOMAIN OBJECTS IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

Previously you've used the JPQL or native SQL queries to access data from the database. However, both JPQL and SQL do not provide any mechanism to validate the correctness of the queries at compile time. Instead, all query syntax issues are detected at runtime. You need to implement a technique that let you define queries programmatically in a type-safe manner to reduce execution-time errors in the queries

Solution

Criteria API is a native API of JPA specification. Thus, you don't need additional libraries to use in your Spring Boot application and use it directly in your Spring Boot application.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-criteria-api/course-tracker-start.
The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-criteria-api/course-tracker-final.

Most of the components in the `CourseTracker` application require no change to use Criteria API. Thus, the previously defined `Course` class, `CourseRepository` interface, and other configurations remain unchanged.

Let us define a test case to see the use of Criteria API in practice as shown in Listing 3.33:

Listing 3.33 Unit test to demonstrate the use of Criteria API

```
package com.manning.sbip.ch03;

// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CourseRepository courseRepository;

    @Autowired
    private EntityManager entityManager;

    @Test
    public void givenCoursesCreatedWhenLoadCoursesWithQueryThenExpectCorrectCourseDetails()
```

```
        {
         courseRepository.saveAll(getCourseList());

         CriteriaBuilder criteriaBuilder = entityManager.getCriteriaBuilder();

         CriteriaQuery<Course> courseCriteriaQuery =
        criteriaBuilder.createQuery(Course.class);

         Root<Course> courseRoot = courseCriteriaQuery.from(Course.class);

         Predicate courseCategoryPredicate =
        criteriaBuilder.equal(courseRoot.get("category"), "Spring");

         courseCriteriaQuery.where(courseCategoryPredicate);

         TypedQuery<Course> query = entityManager.createQuery(courseCriteriaQuery);

         Assertions.assertThat(query.getResultList().size()).isEqualTo(3);

    }

    private List<Course> getCourseList() {
        // Get Courses
    }
}
```

You are performing the following activities in the test case:

- Autowired the `EntityManager` in the test class and used it to create an instance of `CriteriaBuilder`. An `EntityManager` instance is associated with a persistence context which is a set of entity instances. Within the persistence context, the entity instances and their lifecycle are managed. The `CriteriaBuilder` instance lets you construct criteria queries, selections, ordering, etc.
- The returned `CriteriaBuilder` is used to define a `CriteriaQuery` and its type is bound to the Course type
- You then define the Root of the query using the returned `CriteriaQuery`
- Subsequently, you define a Predicate that defines a condition. In this example, the predicate represents the category as Spring
- Lastly, you used the predicate in the previously defined `CriteriaQuery` and define a `TypedQuery` which provides the query output

Discussion

To use Criteria API in your application, you need to follow a series of steps to construct the query. At first, you define an instance of `CriteriaBuilder` instance through the `EntityManager`. Subsequently, you use this `CriteriaBuilder` instance to create either of the `CriteriaQuery`, `CriteriaUpdate`, `CriteriaDelete` instances based on the need. `CriteriaQuery` provides you the functionalities to construct a query. The `CriteriaUpdate` and `CriteriaDelete` let you define queries to perform bulk updates and deletes, respectively.

You then use the `CriteriaQuery` to construct various query parts using the methods such as `from(..)`, `where(..)`, `groupBy()`, `orderBy()`, etc. A `CriteriaQuery` instance is typed as you use the entity type in the `CriteriaBuilder` interface to create it. For instance, in the test case shown earlier, you've used the `Course` type to bound the type. You use `CriteriaQuery` to define the query root which is always the reference entities (e.g. Course in our example).

The obtained `Root` is used to define the expressions. For instance, we have defined the expression that the course category is Spring. This expression is used to define a Predicate which is used in the `CriteriaQuery`. You use the `EntityManager` instance to create a `TypedQuery` from the already created `CriteriaQuery`. The `TypedQuery` interface controls the execution of the types of queries. You used the methods provided in the `TypedQuery` instance to obtain the query result. For example, we've used the `getResultList(..)` method to execute the query and retrieved the result.

Providing an in-depth guide of Criteria API is beyond the scope of this book. You can refer to Chapter 6 of the JPA specification available at https://download.oracle.com/otn-pub/jcp/persistence-2_1-fr-eval-spec/JavaPersistence.pdf to learn more about this API.

3.4.6 Using QueryDsl with Spring Data JPA

In section 3.4.5, you've explored the use of Criteria API with Spring Data JPA. Although Criteria API is a native JPA API, one of the major challenges with it is that its verbose nature. To execute even a simple SELECT query, you need to write quite a few lines of code.

The `Querydsl` (http://www.querydsl.com/) is an alternative third-party library that also lets you build type-safe queries using its fluent API more concisely. Like Criteria API, it also ensures that the following checks are done at the compilation time:

- Entity types specified in a query exist and can be persisted in the database
- All properties used in a query exists in the entity and can be persisted in the database
- All SQL operators receive values of expectant type
- Finally, the resulting query is syntactically correct

Spring Data provides a `QuerydslPredicateExecutor` interface to leverage Querydsl features in Spring Data modules. In the next technique, let's see the use of `Querydsl` with JPA.

TECHNIQUE USE QUERYDSL TO MANAGE DOMAIN OBJECTS IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

Criteria API is a native JPA API and provides a means to build queries in a type-safe manner. However, this API is often criticized for being verbose as you need to perform too many tasks to even execute a simple query. You need a relatively simple alternative.

Solution

Querydsl is an alternative to Criteria API that provides a fluent and concise API. Similar to Criteria API, it also lets you define the queries programmatically in a type-safe manner. In this technique, you'll see the use of Querydsl API with Spring Data JPA to manage domain objects in a relational database.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-query-dsl/course-tracker-start. The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/using-query-dsl/course-tracker-final.

To use Querydsl, we need to add the `querydsl-apt`, `querydsl-jpa` maven dependencies and the `apt-maven-plugin` plugin in the `pom.xml` to enable the `Querydsl` capabilities in the application as shown in the Listing 3.34:

Listing 3.34 Updated pom.xml file with Querydsl dependencies and apt-maven-plugin

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>

    // Other pom.xml components

    <dependencies>
        // Other dependencies
        <dependency>
            <groupId>com.querydsl</groupId>
            <artifactId>querydsl-apt</artifactId>
        </dependency>
        <dependency>
            <groupId>com.querydsl</groupId>
            <artifactId>querydsl-jpa</artifactId>
        </dependency>
    </dependencies>

    <build>
        <plugins>
            <plugin>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-maven-plugin</artifactId>
            </plugin>
            <plugin>
                <groupId>com.mysema.maven</groupId>
                <artifactId>apt-maven-plugin</artifactId>
                <version>1.1.3</version>
                <executions>
                    <execution>
                        <phase>generate-sources</phase>
                        <goals>
                            <goal>process</goal>
                        </goals>
                        <configuration>
```

```
                            <outputDirectory>target/generated-
       sources/java</outputDirectory>

       <processor>com.querydsl.apt.jpa.JPAAnnotationProcessor</processor>
                        </configuration>
                    </execution>
                </executions>
            </plugin>
        </plugins>
    </build>

</project>
```

Let us explore the use of these additional Maven dependencies and the plugin:

- The `querydsl-apt` library is an annotation processing tool (APT) that enables the processing of the annotation in the source files before they move to the compilation stage. This tool generates the so-called `Q-types` classes that are related to the entity classes present in the application. These Q-types are classes that are directly related to the entity classes of your application but are prefixed with the letter `Q`. For example, for the `Course` entity, you'll see a `QCourse.java` source file created by this tool.
- The `querydsl-jpa` is the `Querydsl` library designed to be working alongside a JPA application. Similarly, if you would like to use Querydsl with MongoDB database, you need to use `querydsl-mongodb` maven dependency
- The `apt-maven-plugin` ensures that the Q-types are generated at the time of the process goal of Maven build. Besides, as the name indicates, the `outputDirectory` property is the place where the generated `Q-types` are kept. Furthermore, this directory needs to be included as the source folder of the project as you'll use these generated Java files in your application.

Let us now focus on the `CourseRepository` interface as shown in Listing 3.35:

Listing 3.35 Updated CourseRepository interface with QuerydslPredicateExecutor

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface CourseRepository extends CrudRepository<Course, Long>,
       QuerydslPredicateExecutor<Course> {
}
```

You can notice that along with the `CrudRepository` interface, `CourseRepository` now also extends the `QuerydslPredicateExecutor` interface. Although this interface is not compulsory to be implemented to use `Querydsl`, it provides several overloaded methods that let you use `Querydsl` instances with the familiar query methods (e.g. `Iterable<T> findAll(OrderSpecifier<?>... orders);`). Note that the query method from the `CrudRepository` interface does not take any argument. You'll see the usage of the methods from this interface shortly.

For this demonstration, there is no change in the `Course` POJO. Since the common IDEs are automatically configured to process annotations, you should find the generated `QCourse.java` Java file in the configured `outputDirectory` as configured in the `apt-maven-plugin` plugin in the `pom.xml` file. For this demonstration, you've configured the `target/generated-sources/java` directory where this `QCourse.java` file is generated. If the sources are not generated automatically, then you can run the `mvn generate-sources` command from the root directory of your project to generate the source code.

Ensure that the root package of the generated java file is marked as the source directory. Otherwise, you won't be able to use this Java file in your application. In IntelliJ IDEA, you can right-click on the `java` folder inside the `generated-sources` folder and click on `Mark Directory as` and then `Generated Sources Root` options.

You'll now use the generated `QCourse` class to define the queries in our application codebase. Typically, you'll use the Q-classes inside the service layer to define the queries. To keep things simple, we will define a test case and use the `QCourse` class to define the queries. Listing 3.36 shows a test case that demonstrates this:

Listing 3.36 Unit test to examine the use of Querydsl

```
package com.manning.sbip.ch03;

// Imports excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private CourseRepository courseRepository;

    @Autowired
    private EntityManager entityManager;

    @Test
    public void givenCoursesCreatedWhenLoadCoursesWithQueryThenExpectCorrectCourseDetails()
       {
        courseRepository.saveAll(getCourseList());

        # Defines a course instance
        QCourse course = QCourse.course;
        # Creates a JPA query instance
        JPAQuery query1 = new JPAQuery(entityManager);


        # Builds the query using the from and where clauses. Notice the use of DSL (e.g.
       the use of from and where)
        query1.from(course).where(course.category.eq("Spring"));

        # Executes the query and retrieves the courses
        assertThat(query1.fetch().size()).isEqualTo(3);

        JPAQuery query2 = new JPAQuery(entityManager);
        query2.from(course).where(course.category.eq("Spring").and(course.rating.gt(3)));
        assertThat(query2.fetch().size()).isEqualTo(2);
```

```
        # OrderSpecifier represents the order-by instance in  the Course. In this case,we
        are creating a descending order-by instance with the Course rating
         OrderSpecifier<Integer> descOrderSpecifier = course.rating.desc();

        assertThat(Lists.newArrayList(courseRepository.findAll(descOrderSpecifier)).get(0).g
        etName()).isEqualTo("Getting Started with Spring Security DSL");
    }

    private List<Course> getCourseList() {
         # getCourseList implementation goes here. Method body is excluded as a matter of
        readability
    }
}
```

Let us discuss the test case in detail:

- It has a dependency on the `CourseRepository` and the `EntityManager`. The `EntityManager` is used to create the JPA query instances
- You have defined a local variable named course and initialize it with QCourse.course static instance
- Subsequently, you have created an instance of JPAQuery using the entityManager. It is the default implementation of the `JPQLQuery` interface for JPA in `Querydsl`
- You then start building the query using Querydsl's fluent API. You pass the course instance to the from() method of JPAQuery and build the conditional clause of the query using the where() method
- Following that, you invoke the `fetch()` method on the created query to fetch courses from the database and asserts the result
- Subsequently, in the next `JPAQuery` (query2), you've used the and(..) method in the where() method to provide additional criteria in the query
- You then invoke fetch() on the generated query and asserts the result
- Lastly, you've created an instance of OrderSpecifier which represents the order-by instance in the Course. It defines the descending order based on the rating property of the Course entity
- You then use the `findAll(..)` method of CourseRepository that accepts the `OrderSpecifier` instance. It returns all courses ordered as per the `OrderSpecifier` instance

Note that this `findAll(..)` method is from `QuerydslPredicateExecutor`. Since `CourseRepository` extends this interface, you can invoke using the `CourseRepository` instance.

Discussion

In this technique, you've seen the use of `Querydsl` API with Spring Data JPA. `Querydsl` is a popular framework that enables you to construct statically typed SQL-like queries for several data sources. One of the major reasons for this library's popularity is its static type checking, fluent API, and concise nature. This static type check ensures that queries are syntactically correct at compilation time.

Querydsl was introduced to maintain Hibernate Query Language (HQL) queries in a type-safe way. Incorrect string concatenation and reference to domain types and properties in HQL queries often lead to runtime query execution issues. Querydsl reduces these errors by performing static type-checking at query compilation time. In Querydsl, queries are constructed based on the generated query types which are essentially the properties of the business domain class. Besides, in the Querydsl method invocations are also done in a type-safe manner.

You can refer to the Querydsl reference manual available at http://www.querydsl.com/static/querydsl/latest/reference/html/index.html for further details.

Criteria API vs Querydsl

In the previous two techniques, you've seen the usage of both Criteria API and the Querydsl library. The next question that appears to mind is which one you should use in your application? Well, both APIs are popular and widely used. Following are a few points to consider while deciding the API to use:

1) The Criteria API is a native JPA library and thus has native support in JPA. Whereas the Querydsl is an open-source third-party library

2) The Criteria API is criticized for its verbosity and complex nature the API. You need to write more to even execute a simple query. The Querydsl has a more approachable API due to the simpler and English-like API

3) Criteria API is only applicable for JPA. Querydsl has integration with other data stores such as MongoDB, Lucene, JDO apart from JPA

3.5 Managing Domain Object Relationships

Accessing data from a single table is relatively simple, but this is seldom the case for modern enterprise applications. In most scenarios, you are likely to use more than one table to retrieve the required data.

In the relational database nomenclature, retrieving the required columns from different tables is known as `Projection`. Spring Data lets you use projections either through **interface-based projection** or **class-based projection**.

An interface-based projection lets you limit the attributes of an entity by declaring an interface that exposes accessor methods for the properties to be read. For instance, if you want to read only the description field of the `Course` entity when finding the courses by course name, you can first define an interface that returns the only description as shown in Listing 3.37:

Listing 3.37 Interface Based Projection

```
package com.manning.sbip.ch03.ibp;

public interface DescriptionOnly {
    String getDescription();
}
```

You can then add a query method in the `CourseRepository` interface that returns a collection of `DescriptionOnly` type as shown in Listing 3.38:

Listing 3.38 Query method with Interface Based Projection

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface CourseRepository extends CrudRepository<Course, Long> {

    Iterable<DescriptionOnly> getCourseByName(String name);
}
```

The test case presented in Listing 3.39 validates the interface-based-projection:

Listing 3.39 Unit test to validate Interface Based Projection

```
@Test
public void givenACourseAvailableWhenGetCourseByNameThenGetCourseDescription() {
    Iterable<DescriptionOnly> result = courseRepository.getCourseByName("Rapid Spring Boot
       Application Development");

       assertThat(result)
            .extracting("description").contains("Spring Boot gives all the power of the
       Spring Framework without all of the complexity");
}
```

The `getCourseByName(..)` method returns an `Iterable` of type `DescriptionOnly` and we retrieve the description. We then assert that the returned description with the actual description.

A class-based projection is also referred to as `Data Transfer Objects` (DTOs). A DTO is a Java POJO class that contains the selected properties returned by the query. As the name suggests, the main purpose of this object is to transfer data from the DAO layer to a higher layer such as the Service layer. You can recall that as a best practice a service layer bridges the DAO layer, and the Spring controllers and DAO layers are not accessed directly. You'll examine an example of class-based projection shortly.

Another important concept to understand while dealing with more than one entity is the relationship among them. Based on their association, this relationship is classified into the following categories:

- `One-to-One`**:** It indicates that one entity is associated with exactly one entity of the other type. For example, in our Course entity example, let us assume we've another entity named CourseDetails that captures the additional details about a Course. Thus, we can say that the Course and CourseDetails entities have a One-To-One relationship as a Course can have only one CourseDetails
- `One-To-Many`**:** This relationship type indicates that one entity is associated with more than one entity of the other type. For instance, an entity Person can have more than one Address. Thus, the relationship between the Person and the Address is one to

many

- `Many-To-One`**:** This relationship type indicates that many entities of one type are associated with one entity of the other type. For instance, the relationship between the entity Book and entity Publisher is of Many-To-One. As multiple Books can be published by a Publisher
- `Many-To-Many`**:** This relationship type indicates that more than one entity of one type of is associated with more than one type of the other entity type. For instance, in the course management example, one course may be authored by multiple authors. Similarly, one author can author multiple courses. The relationship in this context is many-to-many between the author and course entities

Let us demonstrate the use of DTO and the implementation of a many-to-many relationship in the following technique.

TECHNIQUE MANAGE DOMAIN OBJECTS WITH MANY-TO-MANY RELATIONSHIP IN A RELATIONAL DATABASE WITH SPRING DATA JPA

Problem

While managing object relationships in your application, you often encounter scenarios when objects maintain Many-To-Many relationships. For instance, in the `CourseTracker` application, entities `Author` and `Course` maintain a Many-To-Many relationship. You need to manage the Many-To-Many relationship among two entities using Spring Data JPA.

Solution

Many-to-many relationships are one of the most used relationships that you often need to manage between entities. For instance, the `Course` and `Author` entities have a many-to-many relationship among them. In such a scenario, you must maintain the author and course details along with the relationship between course and author. For example, an author can author multiple courses, and many authors can collaborate on a course. Thus, in this case, you need to maintain the author and course information as well as their relationship details. Hence, you need to maintain three tables – one for the `Author` details, another for the `Course` details, and one for their related information. Figure 3.7 shows the Entity-Relationship (ER) diagram:

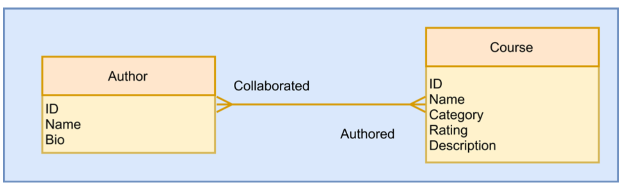


Figure 3.7 Author and Course Entity-Relationship diagram. In an E-R diagram, the relationship table is represented by the relationship arrow itself. Thus, the relationship table is not present in the diagram

Before continuing further let us understand the data model you'll use in this technique. The `Author` entity is represented by the `AUTHOR` table in the database.

Source Code

You can find the base version of the Spring Boot project in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/managing-many-to-many-relationship/course-tracker-start. The final version of the project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch03/managing-many-to-many-relationship/course-tracker-final

The mapping table between the `Author` and the `Course` entities is represented by the `AUTHORS_COURSES` table. To represent a relationship on RDBMS, the rule is to use relationship tables where the relationship between author and course is represented with a DB entry containing the corresponding unique identifiers of the two tables. For example, the `AUTHORS_COURSES` table contains the mapping information of authors and courses based on `author_id` and `course_id`. Listing 3.40 shows the `schema.sql` DDL scripts used in this technique:

Listing 3.40 The Schema.sql

```
CREATE TABLE authors (
  id   BIGINT NOT NULL,
  bio  VARCHAR(255),
  name VARCHAR(255),
  PRIMARY KEY (id)
);

CREATE TABLE authors_courses (
  author_id BIGINT NOT NULL,
  course_id BIGINT NOT NULL,
  PRIMARY KEY (author_id, course_id)
);

CREATE TABLE courses (
  id          BIGINT NOT NULL,
  category    VARCHAR(255),
  description VARCHAR(255),
  name        VARCHAR(255),
  rating      INTEGER NOT NULL,
  PRIMARY KEY (id)
);

# A foreign key constraint to ensure that the course_id in the authors_courses table is a
       valid course ID from the courses table
ALTER TABLE authors_courses
  ADD CONSTRAINT course_id_fk FOREIGN KEY (course_id) REFERENCES courses (id);

# A foreign key constraint to ensure that the author_id in the authors_courses table is a
       valid author ID from the authors table

ALTER TABLE authors_courses
  ADD CONSTRAINT author_id_fk FOREIGN KEY (author_id) REFERENCES authors (id);
```

Let us now define the INSERT scripts in the `data.sql` file as shown in Listing 3.41. We've created three courses and two authors. Besides, we've added the author and course relationship by mapping courses one and two with author 1 and course one, two, and three with author 2. Thus, courses one and two are co-authored by both author 1 and author 2.

Listing 3.41 The data.sql script

```
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION)  VALUES(1, 'Rapid Spring Boot
       Application Development', 'Spring', 4, 'Spring Boot gives all the power of the
       Spring Framework without all of the complexity');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION)  VALUES(2, 'Getting Started
       with Spring Security DSL', 'Spring', 5, 'Learn Spring Security DSL in easy steps');
INSERT INTO COURSES(ID, NAME, CATEGORY, RATING, DESCRIPTION)  VALUES(3, 'Getting Started
       with Spring Cloud Kubernetes', 'Python', 3, 'Master Spring Boot application
       deployment with Kubernetes');
INSERT INTO AUTHORS(ID, NAME, BIO)  VALUES(1, 'John Doe', 'Author of several Spring Boot
       courses');
INSERT INTO AUTHORS(ID, NAME, BIO)  VALUES(2, 'Steve Muller', 'Author of several popular
       Spring and Python courses');
INSERT INTO AUTHORS_COURSES(AUTHOR_ID, COURSE_ID) VALUES(1, 1);
INSERT INTO AUTHORS_COURSES(AUTHOR_ID, COURSE_ID) VALUES(1, 2);
INSERT INTO AUTHORS_COURSES(AUTHOR_ID, COURSE_ID) VALUES(2, 1);
INSERT INTO AUTHORS_COURSES(AUTHOR_ID, COURSE_ID) VALUES(2, 2);
INSERT INTO AUTHORS_COURSES(AUTHOR_ID, COURSE_ID) VALUES(2, 3);
```

To automatically execute the `schema.sql` and the `data.sql` we have added the following additional properties in the `application.properties` file as shown in Listing 3.42:

Listing 3.42 Additional properties in the application.properties file

```
# We are using schema.sql to initialize schema, thus, we are instructing JPA not to manage
       the schema
spring.jpa.hibernate.ddl-auto=none
# This is to indicate Spring Boot to execute the schema.sql in our H2 database
spring.datasource.initialization-mode=always
```

Let us now start by defining the `Author` entity as shown in Listing 3.43:

Listing 3.43 The Author Entity

```
package com.manning.sbip.ch03.model;

// Import Statements are excluded as a matter of readability

@Entity(name = "AUTHOR")
@Table(name="AUTHORS")
public class Author {

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    private long id;
    private String name;
    private String bio;

    @ManyToMany
    @JoinTable(name = "AUTHORS_COURSES",
            joinColumns = {
      @JoinColumn(name="author_id", referencedColumnName = "id", nullable = false,
       updatable = false)},
```

```
            inverseJoinColumns = {
      @JoinColumn(name="course_id", referencedColumnName = "id", nullable = false,
       updatable = false)}
    )
    private Set<Course> courses = new HashSet<>();

    public Author() {}

    public Author(String name, String bio) {
        this.name = name;
        this.bio = bio;
    }

    public long getId() {
        return id;
    }

    public String getName() {
        return name;
    }

    public String getBio() {
        return bio;
    }

    public Set<Course> getCourses() {
        return courses;
    }

    @Override
    public String toString() {
        return "Author{" +
                "id=" + id +
                ", name='" + name + '\'' +
                ", bio='" + bio + '\'' +
                '}';
    }
}
```

In the Author class, you've initialized an empty set of courses to store the relationship between Author and Course. Listing 3.44 shows the `Course` entity:

Listing 3.44 The updated Course entity

```
package com.manning.sbip.ch03.model;

// Import Statements are excluded as a matter of readability

@Entity(name = "COURSE")
@Table(name = "COURSES")
public class Course {

       @Id
       @GeneratedValue(strategy = GenerationType.IDENTITY)
       private long id;
       private String name;
       private String category;
       private int rating;
```

```
    private String description;
          # The mappedBy attribute of @ManyToMany annotation in the non-owning side of
    the relationship
    @ManyToMany(mappedBy = "courses")
    private Set<Author> authors = new HashSet<>();

    // Constructor, getter, setters are excluded as a matter of readability

}
```

The `Course` entity contains information related to a course and specifies the many-to-many relationship with the authors. Note that you've specified the `mappedBy` attribute of `@ManyToMany` annotation in the non-owning side of the relationship.

We can create the courses and map to the authors created it as shown in Listing 3.45:

Listing 3.45 Mapping Course details with Authors

```
Course rapidSpringBootCourse = new Course("Rapid Spring Boot Application Development",
    "Spring", 4,"Spring Boot gives all the power of the Spring Framework without all of
    the complexity");

Course springSecurityDslCourse = new Course("Getting Started with Spring Security DSL",
    "Spring", 5, "Learn Spring Security DSL in easy steps");

Author author1 = new Author("John Doe", "Author of several Spring Boot courses");

author1.getCourses().addAll(Arrays.asList(rapidSpringBootCourse, springSecurityDslCourse));
```

Also, besides the core annotations such as `@Entity`, `@Table`, and `@Id`, there are other annotations specified to capture the relationship information with the `Course` entity. Let us explain these annotations:

@ManyToMany

The `@ManyToMany` annotation specifies the many-valued association with Many-To-Many multiplicity. Each such association has two sides – the owning side and the non-owning side. The owning side indicates the entity which owns the relationship, and a non-owning side is the inverse side of the relationship.

In the case of a One-To-Many relationship, the "Many" part is the owning side. This is because every object of the many sides can easily have a reference to the "one" side. Otherwise, you need to maintain many references from the single object (i.e. the one part) to the many objects.

For Many-To-Many relationships, you can choose which side should be declared as the owning side as both sides can own the relationship. For instance, in this demonstration, we have selected the Author entity as the owning side. This is done based on the understanding that an author *owns* its courses.

You additionally specify the `@JoinTable` annotation on the owning side of the relationship. As discussed, since an author owns a course, you have specified `@JoinTable` annotation on the Author entity. In the case of the non-owning side, you specify the `mappedBy` parameter in

`@ManyToMany` annotation to specify the field of the owning side. The use of the `mappedBy` parameter you'll see in the `Course` entity.

@JoinTable

This annotation is specified on the owning side of the relationship and is typically used in the mapping of many-to-many and unidirectional one-to-many associations. You've specified this annotation to define the `AUTHORS_COURSES` join table. If this annotation is not provided, then the default values of the annotation are applied. For example, if the table name is not provided, then the table names of the entities are concatenated together with an underscore character where the owning side table is used first. Besides, you have specified the `joinColumns` and `inverseJoinColumns` attributes with `@JoinTable` annotation. The `joinColumns` specifies the foreign key columns of the join table (e.g., `AUTHORS_COURSES`) which references the primary table (e.g., `AUTHORS`) which owns the association. The `inverseJoinColumns` specify the foreign key columns of the join table which reference the primary table (e.g., `COURSES`) of non-owning side.

@JoinColumn

This annotation lets you specify a column for joining an entity association. To recap, the following is the usage of the `JoinColumn` attribute:

```
@JoinColumn(name="author_id", referencedColumnName = "id", nullable = false, updatable =
       false)
```

The name attribute specifies the name of the foreign key column of the relationship table. The `referencedColumnName` attribute lets you specify the database column that should be referenced by the foreign key column. The `nullable` attribute indicates whether the foreign column is nullable. The `updatable` attribute specifies whether the column is included in SQL UPDATE statements of the relationship table generated by the persistence provider.

Let us define the `AuthorCourse` entity as shown in Listing 3.46:

Listing 3.46 The AuthorCourse entity

```
package com.manning.sbip.ch03.model;

// Import Statements are excluded as a matter of readability

@Entity(name = "AUTHOR_COURSE")
@Table(name = "AUTHORS_COURSES")
public class AuthorCourse {
    @Id
    @Column(name = "author_id")
    private long authorId;
    @Column(name = "course_id")
    private long courseId;

    // Constructor, Getter, and Setters excluded as a matter of readability
}
```

This class stores the relationship information of `Author` and `Course` entities and contains the primary keys of both the tables. Besides, this entity also represents the `AUTHORS_COURSES` table as you've annotated it with the `@Table` entity. You'll see the use of this `AUTHORS_COURSES` table when we define join query to retrieve data in our repository interface.

Let us now discuss the `AuthorCourseDto` DTO class presented in Listing 3.47

Listing 3.47 The AuthorCourseDto entity

```
package com.manning.sbip.ch03.dto;

public class AuthorCourseDto {

       private long id;
       private String authorName;
       private String courseName;
       private String description;

       public AuthorCourseDto(long id, String authorName, String courseName, String
       description) {
         this.id = id;
         this.authorName = authorName;
         this.courseName = courseName;
         this.description = description;
       }

       @Override
       public String toString() {
         return "{" +
                          "id=" + id +
                          ", authorName='" + authorName + '\'' +
                          ", courseName='" + courseName + '\'' +
                          ", description='" + description + '\'' +
                          '}';
       }
}
```

If you recall, a DTO class (the class-based projection) lets you retrieve data from different tables through projection that might not be represented by an existing entity. Thus, a DTO is an object-oriented representation of the tuple data projection from the repository method. You can use a DTO class as the repository return type for queries with joins.

Listing 3.48 The AuthorRepository Interface

```
package com.manning.sbip.ch03.repository;

// Import Statements are excluded as a matter of readability

@Repository
public interface AuthorRepository extends CrudRepository<Author, Long> {

       @Query("SELECT new com.manning.sbip.ch03.dto.AuthorCourseDto(c.id, a.name, c.name,
       c.description) from AUTHOR a, COURSES c, AUTHORS_COURSES ac where a.id = ac.authorId
       and c.id=ac.courseId and ac.authorId=?1")
```

```
    Iterable<AuthorCourseDto> getAuthorCourseInfo(long authorId);
}
```

In the AuthorRepository interface presented in Listing 3.48, there is a query method that fetches data from AUTHORS, COURSES, and AUTHORS_COURSES tables. Since the data contains obtained through the projection do not represent either Author or the Course entity, it is represented with the AuthorCourseDto class.

The AuthorRepository interface extends the CrudRepository to access the basic CRUD features. Besides, it also defines a custom finder method to fetch the course details authored by an author through the authorId. As you've seen in the earlier techniques, the @Query annotation lets you specify the query that should be used to fetch the data from the database tables. Notice the query specified in the @Query annotation is not a SQL query. It is a JPQL query that joins all three tables to fetch the data and map to the provided DTO instance. In figure 3.8, you've three tables namely – AUTHORS, AUTHORS_COURSES, and COURSES. You've defined a query method with the query that joins AUTHORS, COURSES, and AUTHORS_COURSES tables and fetches data based on the criteria specified in the query. Thus, you've created the AuthorCourseDto Java POJO that represents the columns in the returned projection.

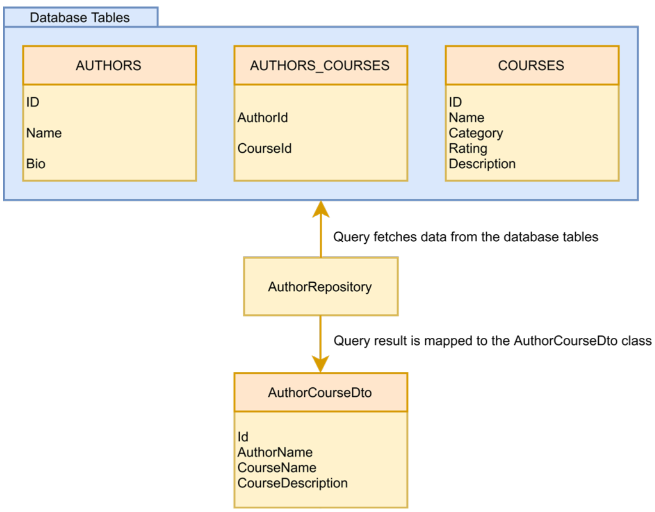


Figure 3.8 Author, Course, and Authors_Courses tables with AuthorCourseDto POJO

Let us now add a test case to see the usage of the getAuthorCourseInfo(..) method of AuthorRepository in practice as shown in Listing 3.49:

Listing 3.49 Unit test to validate Many-to-Many relationship

```
package com.manning.sbip.ch03;
```

```
// Import Statements are excluded as a matter of readability

@SpringBootTest
class CourseTrackerSpringBootApplicationTests {

    @Autowired
    private AuthorRepository authorRepository;

    @Test
    public void whenCountAllCoursesThenExpectFiveCourses() {
        assertThat(authorRepository.getAuthorCourseInfo(2)).hasSize(3));
    }
}
```

In Listing 3.49 you've defined a test case that fetches courses authored by author id 2. In this example, the author id has authored three courses. Thus, you've asserted the number of courses to three. If you execute this test case, you'll see that it run successfully and asserts that three courses are authored by author Id 2.

Discussion

In this section, you've seen an example of how to manage the Many-To-Many relationship among the entities. Although the presented example is a very basic one, it demonstrated the features offered by Spring Data JPA to establish and maintain Many-To-Many relationships between your business domain objects. For instance, you've seen the use of `@ManyToMany` annotation in both the entities maintaining the many-to-many relationship.

Besides, you've also learned the concept of projection. We've explored both the interface and class-based projections with examples. An interface-based projection lets you selectively fetch columns from an entity. Whereas a class-based projection with the notion of Data Transfer Objects lets you access data that belongs to multiple entities.

Discussing all the relationship types with code examples is beyond the scope of the book. We encourage you to implement the other relationship types once you are comfortable with the concepts described in this technique.

3.6 Chapter Summary

In this chapter, you've explored a variety of topics related to database communication from a Spring Boot application. Many of these features are used extensively in Spring Boot application development. Let's quickly summarize these concepts you've learned in this chapter:

- You have an introduction to Spring Data, its need, and various Spring Data modules
- You can configure a relational database and NoSQL databases with Spring Boot
- You can initialize the database schema with `schema.sql` and `data.sql` as well as through Spring Data JPA
- Understand Spring Data `CrudRepository` and `PagingAndSortingRepository` interfaces and their use in a Spring Boot application
- You can access data from a relational database using query methods, `@NamedQuery`,

`@Query`, Criteria API, and `Querydsl`

- You know how to manage the Many-To-Many relationship between domain objects in a Spring Boot application

In Chapter 4, you'll dive into two important concepts of Spring Boot – auto-configuration and actuator. Spring Boot auto-configuration performs a lot of automatic configuration under the hood for us and makes it relatively simple to start developing applications. Spring Boot Actuator provides an infrastructure that lets you monitor and interact with a Spring Boot application. Let's discuss these in the next chapter!

4 Spring Boot – autoconfiguration and actuator

This chapter covers

- **Introduction to Spring Boot auto-configuration, various types of Conditional annotation, and in-depth discussion**
- **An overview of Spring Boot devtools, how to configure, and its various purposes**
- **Introduction to Spring Boot FailureAnalyzer, and how to define a custom application-specific FailureAnalyzer**
- **An in-depth discussion on Spring Boot Actuator, and how to define custom metrics**

You've already learned so much about Spring Boot in the last three chapters. With a solid foundation on Spring Boot, you've already seen various features of the framework, several common tasks that you need to perform on daily basis. Besides, you've also learned how to communicate and use a database in a Spring boot application.

In this chapter, you'll explore two major concepts of Spring Boot – the Spring Boot auto-configuration and Spring Boot actuator. You'll learn various building blocks of Spring Boot auto-configuration and explore how it works in an application. We'll explore the various conditional annotation which is the foundation of Spring Boot auto-configuration. You'll then explore the Spring Boot actuator which lets you monitor your application health and let you interact with it.

4.1 Understanding Spring Boot Auto-configuration

Spring Boot auto-configuration is probably the single most important feature of the framework and one of the main reasons behind Spring Boot's popularity. As the name suggests, auto-configuration automatically configures application components that you would require while developing a Spring application. It makes a sensible guess about the application components and attempts to provide a default configuration with which it initializes the application. For instance, if you include `spring-boot-starter-web` dependency in your build configuration file, then Spring Boot assumes that you need a webserver to run the web application. Thus, it automatically configures the Apache Tomcat web server for you.

Another interesting feature of auto-configuration is its flexibility. If the auto-configuration determines that the developer has explicitly configured an application component, then it simply backs away from automatically configuring the specific application component and uses the configuration provided by the developer. For instance, when you use the `spring-boot-starter-web` dependency, Spring Boot uses Apache Tomcat as the default web server. However, if you configure a different web server, Spring Boot backs off its default configuration and configures the user-defined web server. Listing 4.1 shows the configuration to configure Jetty web server in a Spring Boot application over Spring Boot default Tomcat:

Listing 4.1 Configuring Jetty Web Server in a Spring Boot application

```
<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>
```

4.1.1 Motivation

Imagine you are working in an organization where development teams are working on various projects using the Spring framework. At one point, one of the developers notices that few Spring configuration beans are used by all the teams and are duplicated across the teams. Hence the developer decided to extract those duplicate configurations into a common application context configuration as shown in Listing 4.2:

Listing 4.2 CommonApplicationContextConfiguration Class

```
package com.manning.sbip.ch04;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
#The @Configuration annotation indicates this is a Spring configuration class
@Configuration
public class CommonApplicationContextConfiguration {

    #Creates a Spring Bean of type RelationalDataSourceConfiguration
    @Bean
    public RelationalDataSourceConfiguration dataSourceConfiguration() {
```

```
        return new RelationalDataSourceConfiguration();
    }

    // Other commonly used Spring bean definitions
}
```

Listing 4.2 shows a sample configuration of the `CommonApplicationContextConfiguration`:

- The `CommonApplicationContextConfiguration` configuration class resides in a separate project and is published as an independent Maven or Gradle component. Thus, other teams can use this as a dependency in their projects
- The `RelationalDataSourceConfiguration` class provides a relational data source configuration that initializes the database and returns a data source. Since most of the teams use a relational database, it makes sense to extract and keep this as a separate configuration. Also, for simplicity, we've provided only one configuration, but the `CommonApplicationContextConfiguration` class can contain other common configurations such as Spring transaction manager bean definition

Other teams that need to use `CommonApplicationContextConfiguration` can import this common configuration in their specific configuration classes as shown in Listing 4.3:

Listing 4.3 CommonPaymentContextConfiguration uses CommonApplicationContextConfiguration Class

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

@Configuration
#Imports the Spring beans defined in the CommonApplicationContextConfiguration class
@Import(CommonApplicationContextConfiguration.class)
public class CommonPaymentContextConfiguration {

      // Payment teams bean definitions
}
```

The teams can define project-specific bean definitions in their respective configuration files. This approach works fine in most of the scenarios, but there is one problem. What if a team wishes to use all the beans defined in the `CommonApplicationContextConfiguration`, except a specific bean definition? For instance, one team wishes to use all beans defined in the `CommonApplicationContextConfiguration` but not the `RelationalDataSourceConfiguration` as they don't use a relational database. Thus, there should be some way to tell Spring that importing the `CommonApplicationContextConfiguration` configuration is fine but doesn't create the `RelationalDataSourceConfiguration` bean. How can you achieve this? Spring's `@Conditional` annotation has an answer to this question. Let's see it in detail in the next section.

4.1.2 Understanding @Conditional annotation

Spring framework provides a `@Conditional` annotation that you can place in the `@Bean`, `@Component`, and `@Configuration` to influence the creation of the Spring-managed components. The `@Conditional` annotation accepts a `Condition` class parameter. The `Condition` interface has a method name `matches(..)` that return a `boolean` value. A value `true` indicates to further evaluate or create a `@Bean`, `@Component`, or a `@Configuration`. A value `false` means not to proceed with the `@Bean`, `@Component`, or a `@Configuration` creation. In your custom Condition implementations, you implement the `Condition` interface and define the `matches(..)` method.

Let us now examine how to use the `@Conditional` annotation in the `RelationalDataSourceConfiguration` bean. Figure 4.4 shows the modified `CommonApplicationContextConfiguration` configuration class that uses the `@Conditional` annotation:

Listing 4.4 Updated CommonApplicationContextConfiguration

```
import org.springframework.context.annotation.*;
import org.springframework.core.type.AnnotatedTypeMetadata;

@Configuration
public class CommonApplicationContextConfiguration {

    #The Conditional annotation ensures that the bean is only created if the
       RelationalDatabaseCondtion evaluates to true
    @Bean
    @Conditional(RelationDatabaseCondition.class)
    public RelationalDataSourceConfiguration dataSourceConfiguration() {
        return new RelationalDataSourceConfiguration();
    }
}
```

This configuration is similar to what you've seen in Listing 4.2 with the exception that now the `dataSourceConfiguration` bean creation depends on the `RelationDatabaseCondition` condition. Listing 4.5 defines this condition:

Listing 4.5 Condition to check relational database

```
public class RelationDatabaseCondition implements Condition {
    #This method returns true if the MySQL database driver class is present in the
       classpath
    @Override
    public boolean matches(ConditionContext conditionContext, AnnotatedTypeMetadata
       annotatedTypeMetadata) {
        return isMySQLDatabase();
    }
    # Evaluates if the MySQL driver class is present in the classpath. Availability of the
       class indicates that the MySQL database is being used in the application. We’ve used
       MySQL Driver for demonstration purpose only.
    private boolean isMySQLDatabase() {
        try {
            Class.forName("com.mysql.jdbc.Driver");
            return true;
```

```
        }
        catch(ClassNotFoundException e) {
           return false;
        }
    }
}
```

In Listing 4.5, you've done the following changes:

- You've provided an implementation of the `Condition` interface. This interface has a `matches(..)` method that returns a `boolean` value
- Besides, you are validating whether the MySQL driver class is present in the application classpath. If the driver class is available, then the condition returns `true` to indicate that a relational database is available

For simplicity, we've kept the `RelationDatabaseCondition` straightforward with only one validation. This one validation should be enough to convey the idea behind the `@Condition` annotation. You can implement more such checks to evaluate a condition and return the boolean value accordingly. Typically, you can implement a condition to create beans in two different ways:

- First, evaluate the classpath for the presence of specific libraries
- Second, validate if certain properties are configured in the application. In the `matches(..)` method, you've got an instance of `ConditionContext` which gives access to the configured application properties. Thus, you can access all of the properties configured in the `application.properties` file

Although `@Conditional` annotation works just fine, it is a low-level annotation. Spring Boot provides several high-level `@Conditional` annotations that target a specific type of condition. Table 4.1 summarizes a few of the popular `@Conditonal` annotation (most frequently used ones are highlighted in bold):

Table 4.1 List of Spring Boot Conditional annotations. Refer to the Spring Boot API documentation at https://docs.spring.io/spring-boot/docs/current/api/org/springframework/boot/autoconfigure/condition/package-summary.html for the list of annotations.

Annotation	Example	Example Explanation
@ConditionalOnBean	**@ConditionalOnBean(DataSource.class)**	**This condition is true if the user specifies a DataSource bean in a configuration**
@ConditionalOnClass	**@ConditionalOnClass(DataSource.class)**	**This condition is true if the class Datasource is available in the classpath**
@ConditionalOnProperty	**@ConditionalOnProperty("some.property")**	**This condition is true if some.property is configured**
@ConditionalOnCloudPlatform	**@ConditionalOnCloudPlatform(Clo**	**This condition is true if the**

	udPlatform.KUBERNETES)	CloudPlatform is set to KUBERNETES
@ConditionalOnExpression	@ConditionalOnExpression("SPEL Expression")	This condition is true if the SPEL expression is true
@ConditionalOnJava	@ConditionalOnJava(JavaVersion.EIGHT)	This condition is true if the supported Java version is eight
@ConditionalOnJndi	@ConditionalOnJndi("java:/comp/env/jdbc/MyLocalDB")	This condition is true if the specified JNDI context exists
@ConditionalOnMissingBean	@ConditionalOnMissingBean(DataSource.class)	This condition is true if there is no DataSource bean in any configuration
@ConditionalOnMissingClass	@ConditionalOnMissingClass(DataSource.class)	This condition is true if there is no DataSource class present in the classpath
@ConditionalOnNotWebApplication	@ConditionalOnNotWebApplication	This condition is true if the application is not a web application
@ConditionalOnResource	@ConditionalOnResource("classpath:some.properties")	This condition is true if some.properties file is present in the classpath
@ConditionalOnSingleCandidate	@ConditionalOnSingleCandidate(DataSource.class)	Matches if there is exactly one primary DataSource bean present in the application
@ConditionalOnWebApplication	@ConditionalOnWebApplication	This condition is true if the application is a web application

In the next section, you'll explore the use of some of these annotations in detail.

4.1.3 Deep Dive into Auto-configuration

Now that you've learned about the various `@Conditional` annotation, let us explore how Spring Boot uses these annotations in practice. Every Spring Boot project has a dependency on the `spring-boot-autoconfigure` module. It contains the key to Spring Boot's auto-configuration magic. This jar contains a file called `spring.factories`, under the `META-INF` folder. Listing 4.6 shows a few of the auto-configuration classes:

Listing 4.6 Auto Configuration classes in the spring.factories file

```
# Auto Configure
org.springframework.boot.autoconfigure.EnableAutoConfiguration=\
org.springframework.boot.autoconfigure.admin.SpringApplicationAdminJmxAutoConfiguration,\
org.springframework.boot.autoconfigure.aop.AopAutoConfiguration,\
org.springframework.boot.autoconfigure.amqp.RabbitAutoConfiguration,\
org.springframework.boot.autoconfigure.batch.BatchAutoConfiguration,\
org.springframework.boot.autoconfigure.cache.CacheAutoConfiguration,\
org.springframework.boot.autoconfigure.cassandra.CassandraAutoConfiguration,\
```

```
org.springframework.boot.autoconfigure.context.ConfigurationPropertiesAutoConfiguration,\
org.springframework.boot.autoconfigure.context.LifecycleAutoConfiguration,\
org.springframework.boot.autoconfigure.context.MessageSourceAutoConfiguration,\
org.springframework.boot.autoconfigure.context.PropertyPlaceholderAutoConfiguration,\
org.springframework.boot.autoconfigure.couchbase.CouchbaseAutoConfiguration,\
org.springframework.boot.autoconfigure.dao.PersistenceExceptionTranslationAutoConfiguration
       ,\
org.springframework.boot.autoconfigure.data.cassandra.CassandraDataAutoConfiguration,\

// Other auto-configuration classes
```

If you explore the `spring.factories` file, you'll find a section named ***Auto Configure*** which contains auto-configuration details for several Spring Boot components and the third-party libraries Spring Boot integrates with. These auto-configuration classes are Spring configuration files with the `@Conditional` annotations which you have seen in Table 4.1.

To understand this concept further, let us analyze one of the auto-configuration configurations. In the next section, you'll explore the `DataSourceAutoConfiguration` that configures a data source in a Spring Boot application. Listing 4.7 shows a code snippet from the `DataSourceAutoConfiguration` class. This class is available at https://github.com/spring-projects/spring-boot/blob/main/spring-boot-project/spring-boot-autoconfigure/src/main/java/org/springframework/boot/autoconfigure/jdbc/DataSourceAutoConfiguration.java

Listing 4.7 DataSourceAutoConfiguration Class

```
@Configuration
#This configuration is loaded if DataSource and EmbeddedDatabaseType classes are present in
       the classpath
@ConditionalOnClass({ DataSource.class, EmbeddedDatabaseType.class })
@EnableConfigurationProperties(DataSourceProperties.class)
# DataSourceAutoConfiguration also imports DataSourcePoolMetadataProvidersConfiguration and
       DataSourceInitializationConfiguration classes
@Import({ DataSourcePoolMetadataProvidersConfiguration.class,
       DataSourceInitializationConfiguration.class })
public class DataSourceAutoConfiguration {

       @Configuration
       #This configuration is loaded if the EmbeddedDatabaseCondtion evaluates to true and
       there are no beans of type DataSource and XADataSource
       @Conditional(EmbeddedDatabaseCondition.class)
       @ConditionalOnMissingBean({ DataSource.class, XADataSource.class })
       @Import(EmbeddedDataSourceConfiguration.class)
       protected static class EmbeddedDatabaseConfiguration {

       }

       @Configuration
       #This configuration is loaded if the PooledDataSourceCondition evaluates to true and
       there are no beans of type DataSource and XADataSource
@Conditional(PooledDataSourceCondition.class)
       @ConditionalOnMissingBean({ DataSource.class, XADataSource.class })
       @Import({ DataSourceConfiguration.Hikari.class,
       DataSourceConfiguration.Tomcat.class,
                 DataSourceConfiguration.Dbcp2.class,
```

```
        DataSourceConfiguration.Generic.class,
                  DataSourceJmxConfiguration.class })
        protected static class PooledDataSourceConfiguration {

        }
// Additional Code
```

There are many annotations configured in the `DataSourceAutoConfiguration` class shown in Listing 4.7. Let us explore these annotations one by one:

1. This `DataSourceAutoConfiguration` class is configured with `@Configuration` annotation. This indicates that this is a standard Spring configuration class
2. It uses `@ConditionalOnClass` annotation to indicate that `DataSourceAutoConfiguration` configuration should only be evaluated if `DataSource.class` and `EmbeddedDatabaseType.class` are present in the classpath
3. The `@EnableConfigurationProperties(DataSourceProperties.class)` ensures that data source specific properties provided in the `application.properties` file should automatically be converted to an instance of the `DataSourceProperties` class. For instance, the `spring.datasource.*` properties configured in the `application.properties` file are automatically mapped to `DataSourceProperties`. In section 2.2 of chapter 2, we had discussed the use of the `@EnableConfigurationProperties` annotation in detail
4. The `@Import` annotation pulls two additional configurations into the current class – `DataSourcePoolMetadataProvidersConfiguration` and `DataSourceInitializationConfiguration` to the `DataSourceAutoConfiguration`
5. In the `DataSourceAutoConfiguration` class, there are two inner configurations – `EmbeddedDatabaseConfiguration` and `PooledDataSourceConfiguration`. The first one creates an embedded database configuration if `EmbeddedDatabaseCondition` evaluates to `true` and if you haven't configured a `DataSource` or `XADataSource` bean explicitly. The `PooledDataSourceConfiguration` creates a database connection pool if `PooledDataSourceCondition` is evaluated to `true` and there is no `DataSource` or `XADataSource` bean configured
6. The `PooledDataSourceConfiguration` imports other data store specific configurations for the supported connection pool libraries – HikariCP, Tomcat, DBCP2, and Generic

You can explore these configurations to understand further how the auto-configuration is implemented. However, the above example demonstrates the foundational concept behind Spring Boot auto-configuration. As an exercise, you can explore the `EmbeddedWebServerFactoryCustomizerAutoConfiguration`, `JpaRepositoriesAutoConfiguration` and `H2ConsoleAutoConfiguration` classes for further understanding.

4.2 Using Spring Boot DevTools

Spring Boot provides a developer toolkit that provides an additional set of development time features. These tools can be used for a more pleasant Spring Boot application development experience and increased developer productivity. In short, this toolkit is popularly known as Spring Boot DevTools. You can enable DevTools support in your application by adding the following dependency in the `pom.xml` file as shown in the listing 4.8:

Listing 4.8 The Spring Boot DevTools Maven dependency

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-devtools</artifactId>
    <optional>true</optional>
</dependency>
```

Notice that DevTools is added as an optional dependency. This is to prevent DevTools dependency from being transitively applied to other modules that depend on your project. In the remainder of this section, you'll explore various features offered by DevTools.

Property Defaults

Spring Boot and some of its supporting libraries support caching for improved performance. For instance, the Thymeleaf template engine can cache the HTML templates to avoid re-parsing. Although caching works well in production applications, it can be counter-productive at development time as you need to see your latest changes. Spring Boot DevTools disables all the caching options by default. You can find a list of items for which Spring Boot disables caching in the `DevToolsPropertyDefaultsPostProcessor` class available in the `org.springframework.boot.devtools.env` package of the `spring-boot-devtools` jar.

Automatic Restart

In a typical development set up you make changes to your application, and to view those changes, you restart the application. Spring Boot Devtools makes developer life a little easier by automatically restarting the application whenever there is an application classpath change. This provides a quick feedback loop for the code changes as you can almost immediately validate your latest changes.

Spring Boot uses two separate class loaders to implement automatic restart functionality. The first one, known as the base class loader loads classes which are less likely to change. For instance, the third-party libraries on your application have a dependency that does not change. The other class loader known as the restart class loader loads the classes that you are developing. This restart class loader is discarded whenever there is a class change and a new one is created.

Live Reload

Spring Boot DevTools provides an embedded `LiveReload` server that can be used to trigger a browser refresh when a resource is changed. To use this feature, the browser needs to have the `LiveReload` extension installed.

For a detailed discussion on Spring Boot DevTools, refer to the documentation available at https://docs.spring.io/spring-boot/docs/current/reference/html/using-spring-boot.html#using-boot-devtools.

4.3 Creating Custom Failure Analyzer

In chapter 1, you've learned the concept of a `FailureAnalyzer` in Spring Boot. As the name indicates, it detects a failure/exception in the application and provides a detailed message that is useful for the developer to further understand the issue. For instance, it is a common occurrence that we try to start multiple instances of a Spring Boot application that uses the same HTTP port. In this case, Spring Boot provides a nicely formatted error message stating you can't start the second instance on the same HTTP port as it is already in use. Spring Boot does this with the help of a built-in failure analysis infrastructure. Further, it also lets you extend the concept of a failure analyzer so that you can leverage the benefit of it.

There are two reasons a failure analyzer is useful:

- First, it lets you provide a detailed error message on the actual error, what action you can take to resolve the issue and the root cause of the issue
- Second, it also provides an opportunity to perform validations at application start-up and report any error as early as possible. For instance, let's assume that your application is depending upon an external REST service that provides critical business data for your application to function. Thus, it may be useful to validate the accessibility of the service at the application start-up and ensure your application can operate as expected. However, if the service is not reachable, you may choose not to start the application as without the REST service your application might not function in an expected manner

In the next technique, let us demonstrate how to create a custom failure analyzer in a Spring Boot application.

TECHNIQUE CREATE A CUSTOM SPRING BOOT FAILUREANALYZER

Problem

Your application has a dependency on an external REST service. You need to ensure its reachability at the time of application startup. Besides, you need to provide a detailed message if the service is not accessible

Solution

Spring Boot provides a failure analysis infrastructure that lets you define custom logic to perform your business-specific validations and also lets you report the validation errors. Thus, you can leverage this infrastructure to perform the accessibility of the REST API and report any error at the application start-up.

To demonstrate how to create a custom failure analyzer, you'll use the following scenario. Let's assume your application fetches dog details from an external API called https://dog.ceo/dog-api/ and displays them in the application UI. You would like to validate if this URL is accessible at the application start-up. You'll perform the following activities:

- Use Spring Boot's `ContextRefreshedEvent` to trigger the validation. Spring Boot publishes this event once the `ApplicationContext` is refreshed
- If the API is not accessible, you'll throw a custom `RuntimeException` called `UrlNotAccessibleException`
- Subsequently, define a custom `FailureAnalyzer` called `UrlNotAccessibleFailureAnalyzer` that should be invoked if `UrlNotAccessibleException` occurs
- Lastly, you'll register `UrlNotAccessibleFailureAnalyzer` through the `spring.factories` file so that Spring Boot registers the custom `FailureAnalyzer`. The `spring.factories` is a special file that is located at the `src\main\java\META-INF` folder of your application and automatically loaded by Spring on application boot time. This file contains a reference to many configuration classes.

Source Code

To start with this technique, you can use any of the Spring Boot projects you've used previously. You can also find the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-failure-analyzer/course-tracker-custom-failure-analyzer-start.

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-failure-analyzer/course-tracker-custom-failure-analyzer-final

Let us begin with by defining the `UrlNotAccessibleException` exception as shown in Listing 4.9:

Listing 4.9 The UrlNotAccessibleException Exception

```
package com.manning.sbip.ch04.exception;

import lombok.Getter;

@Getter
public class UrlNotAccessibleException extends RuntimeException {

	private String url;

	public UrlNotAccessibleException(String url) {
	  this(url, null);
	}

	public UrlNotAccessibleException(String url, Throwable cause) {
	  super("URL " + url + " is not accessible", cause);
	  this.url = url;
	}
}
```

In the listing, you are defining a `RuntimeException` that you'll use in case the URL is not accessible. Next, let us define the `UrlAccessibilityHandler` class as shown in the listing 4.10:

Listing 4.10 The UrlAccessiblityHandler Class

```
package com.manning.sbip.ch04.listener;

//imports

@Component
public class UrlAccessibilityHandler {

       @Value("${api.url:https://dog.ceo/}")
       private String url;

       @EventListener(classes = ContextRefreshedEvent.class)
       public void listen() {
         // For demonstration purpose, we are throwing
         // the exception assuming the site is not reachable
         throw new UrlNotAccessibleException(url);
       }
}
```

In listing 4.10, you've defined the class `UrlAccessibilityHandler` as a Spring component. Further, you've defined an event listener that is invoked once Spring Boot publishes the `ContextRefreshedEvent` event. For simplicity and demonstration purpose, you are throwing the `UrlNotAccessibleException` assuming it is not reachable.

Let us now define the `UrlNotAccessibleFailureAnalyzer` class as shown in the listing 4.11:

Listing 4.11 The UrlNotAccessibleFailureAnalyzer Class

```
package com.manning.sbip.ch04.exception;

//imports

public class UrlNotAccessibleFailureAnalyzer extends
       AbstractFailureAnalyzer<UrlNotAccessibleException> {

       @Override
       protected FailureAnalysis analyze(Throwable rootFailure, UrlNotAccessibleException
       cause) {
         return new FailureAnalysis("Unable to access the URL "+cause.getUrl(),
                           "Validate the URL and ensure it is accessible", cause);
       }

}
```

Spring Boot invokes this `FailureAnalyzer` instance when an `UrlNotAccessibleException` occurs. However, you need to indicate Spring Boot that you've defined a `FailureAnalyzer` to handle the exception. You can do this by adding the `META-INF\spring.factories` file in the `src\main\java` directory. Listing 4.12 shows the content of this file:

Listing 4.12 Registering the FailureAnalyzer through spring.factories file

```
org.springframework.boot.diagnostics.FailureAnalyzer=\
com.manning.sbip.ch04.exception.UrlNotAccessibleFailureAnalyzer
```

In the listing, you specify the type of the class i.e., `FailureAnalyzer` in this case, and specify the fully qualified class name of the `FailureAnalyzer` implementation. The type of the class indicates which type of configuration the associated value refers to. If you configure more than one failure analyzers, you can configure a comma-separated list as shown in Listing 4.13:

Listing 4.13 Registering the FailureAnalyzer through spring.factories file

```
org.springframework.boot.diagnostics.FailureAnalyzer=\
com.manning.sbip.ch04.exception.UrlNotAccessibleFailureAnalyzer,
com.manning.sbip.ch04.exception.AdditionalFailureAnalyzer,
com.manning.sbip.ch04.exception.AnotherFailureAnalyzer
```

You can start the application and find that it failed to start. In the console log, you can notice the nicely formatted failure message as shown in figure 4.1:

```
***************************
APPLICATION FAILED TO START
***************************

Description:

Unable to access the URL https://dog.ceo/dog-api/

Action:

Validate the URL and ensure it is accessible
```

Figure 4.1 Custom FailureAnalyzer with the error description and the action message

Discussion

Spring Boot uses `FailureAnalyzer` internally to perform several types of failure analysis. For instance, the `NoSuchBeanDefinitionFailureAnalyzer` is invoked when a `NoSuchBeanDefinitionException` exception occurs. Similarly, there is another analyzer such as `DataSourceBeanCreationFailureAnalyzer` which is invoked whenever a `DataSourceBeanCreationException` occurs.

Spring Boot exposes this infrastructure and lets the developer use it to define application-specific analyzers. In this technique, you've seen an example of it. The steps to use a failure analyzer are as follows:

- Define a custom exception with the required fields that can carry the relevant error messages
- Define a `FailureAnalyzer` by extending the `AbstractFailureAnalyzer` class. This class has a type parameter that accepts any subclass of Throwable

- In the `FailureAnalyzer` implementation return a `FailureAnalysis` that contains the issue, possible resolution, and the issue root cause details
- Subsequently, you need to register this `FailureAnalyzer` instance so that Spring Boot is aware of it
- Lastly, you need to perform the validation at an appropriate phase of the application start-up. You can use various Spring Boot lifecycle events to invoke your application's failure analyzers. For instance, in this technique, we've used the `ContextRefreshedEvent` to invoke the `UrlNotAccessibleFailureAnalyzer`

This summarizes the discussion on `FailureAnalyzer` and how you can define a custom one in your application. In the next section, let us discuss Spring Boot Actuator.

4.4 Spring Boot Actuator

In addition to the core features to develop applications, Spring Boot also provides a set of additional features for your application's operational support. An application is considered operational when it is in production and serving your customers/users. To manage a seamless service to your customers, you need to monitor and manage your application. This monitoring and managing include understanding application health, performance, inbound outbound traffic, auditing, various application metrics (more on this later), restarting the application, changing application log level, etc. The various monitoring inputs and metric details let you analyze application behaviour and let you act on a need basis.

Spring Boot actuator brings these monitoring and managing capabilities to your Spring Boot application. The main benefit of Spring Boot Actuator is that you get a lot of production-ready features in your application without explicitly implementing those in your application.

4.4.1 Configuring Spring Boot Actuator

Let us now demonstrate how to configure the Spring Boot actuator in a Spring Boot application.

TECHNIQUE CONFIGURE SPRING BOOT ACTUATOR IN A SPRING BOOT APPLICATION

Problem

You need to configure Spring Boot Actuator in your Spring Boot application.

Solution

You can enable Spring Boot actuator support in your Spring Boot application by adding the `spring-boot-starter-actuator` dependency in the application `pom.xml` configuration file as shown in the listing 4.14:

Listing 4.14 The Spring Boot Starter Actuator dependency

```
<dependency>
       <groupId>org.springframework.boot</groupId>
       <artifactId>spring-boot-starter-actuator</artifactId>
</dependency>
```

The dependency shown in Listing 4.14 incorporates `spring-boot-actuator-autoconfigure` and `micrometer-core` dependencies to the application. The first dependency provides the core actuator support and the other one provides additional support for Micrometer (https://micrometer.io/) to capture various matrices. We'll discuss more on Micrometer later in this chapter.

Source Code

To start with this technique, you can find the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator/spring-boot-app-demo-start.

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator/spring-boot-app-demo-final

Start the application and browse the following URL at http://localhost:8080/actuator/health either through your web browser or the terminal to access the application `/health` endpoint. Figure 4.2 shows the output:

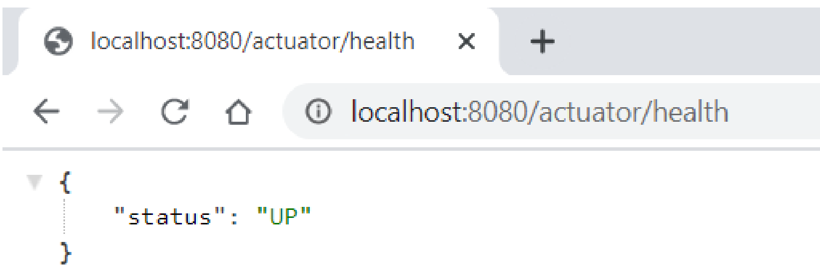


Figure 4.2 The /health endpoint outcome

The health endpoint returns with status as `UP`. The status `UP` indicates the overall health status of the application is good and all components of the application are accessible. Later in this chapter, we'll discuss more on the other health statuses and how to write custom `HealthIndicator` in a Spring Boot application.

You'll learn more about the other available endpoints and various other customizations in the subsequent sections.

4.4.2 Understanding Spring Boot Actuator Endpoints

An actuator endpoint lets you monitor and manage your application. In the previous technique, you've seen the usage of the `health` actuator endpoint that lets you monitor the health status of the application. Spring Boot provides several built-in endpoints that you can use out-of-the-box. Besides, you can also add your custom endpoint specific to your application.

The actuator endpoints can be accessed either over the web (HTTP) or JMX (Java Management Extensions) and you can make the endpoints enabled, disabled, or exposed. The enabled or disabled options indicate that you can control whether to allow a specific actuator endpoint in the application. For instance, by default, the `shutdown` endpoint that lets you shut down a running application is disabled due to security reasons. You can override this default behaviour and enable it in your application. The expose option indicates whether a specific endpoint is exposed to be accessed through an access mode (e.g., over the HTTP or JMX). For instance, by default, only `health` and `info` endpoints are exposed over HTTP, and the rest of all other endpoints are not exposed over HTTP. However, all Spring Boot built-in actuator endpoints are exposed over JMX by default. JMX is considered more secure than HTTP and is the reason built-in endpoints are exposed by default over JMX.

Spring Boot provides a discovery page that contains all available actuator endpoints. By default, this discovery page is available at `/actuator` and always accessible. Thus, you can get the list of available actuator endpoints by accessing the URL http://localhost:8080/actuator/. Figure 4.3 shows this:

Figure 4.3 The Spring Boot Actuator discovery page. This page contains a list of endpoints that you can access. The templated field is true if the endpoint URL has a template that needs to be replaced with an appropriate

value. For instance, in the URL http://localhost:8080/actuator/caches/{cache}, you can retrieve details of a particular cache by replacing the {cache} with the actual cache name

Table 4.2 shows the built-in Spring Boot actuator endpoints:

Table 4.2 Spring Boot Actuator built-in endpoints

Endpoint Id	Purpose	Expose over HTTP	Expose Over JMX
auditevents	Security audit information such as user login/logout	No	Yes
beans	Lists all available beans in the BeanFactory	No	Yes
caches	Lists all the caches in the application	No	Yes
conditions	Reports all the auto-configuration conditions	No	Yes
configprops	Shows all @ConfigurationProperties beans	No	Yes
env	Shows current environment properties	No	Yes
flyway	Shows details of Flyway https://flywaydb.org/ database configurations if Flyway is configured in the application	No	Yes
health	Health status of the application	Yes	Yes
heapdump	Build and return the heap dump of the JVM used by the application	No	Yes
httptrace	Provides the details of HTTP requests and responses. To view the HTTP traces you need to configure a HttpTraceRepository bean.	No	Yes
info	General application information such as custom data, buid information, and latest commit details	Yes	Yes
integrationgraph	Exposes a graph containing all Spring Integration components	No	Yes
logfile	Provides access to the contents of the application's log file	No	N/A
loggers	Provides access to the application's loggers and the configuration of their levels	No	Yes
liquibase	Provides detail of Liquibase https://www.liquibase.org/ database configurations if Liquibase is configured in the application	No	Yes
metrics	Provides details of various application metrics	No	Yes
mappings	Provides information about the application's request mappings	No	Yes
prometheus	provides Spring Boot application's metrics in the format required for scraping by a Prometheus server	No	N/A
scheduledtasks	Provides information about the application's scheduled tasks	No	Yes
sessions	Provides information about the application's HTTP sessions that	No	Yes

	are managed by Spring Session		
shutdown	Let shutdown the application	No	Yes
startup	Provides information about the application's startup sequence	No	Yes
threaddump	Provides a thread dump from the application's JVM	No	Yes

4.4.3 Managing Spring Boot Actuator Endpoints

In section 4.4.2, you've seen by default Spring Boot exposes the `health` and `info` endpoints over the HTTP. You can expose other built-in endpoints by configuring the `management.endpoints.web.exposure.include` property in the `application.properties` file. You can selectively specify the endpoint names that you wish to expose over the web, or you can use the wildcard character `*` to expose all the actuator endpoints. Listing 4.15 shows the configurations to enable actuator endpoints over the web:

Listing 4.15 Actuator Web Endpoints Include Property

```
management.endpoints.web.exposure.include=beans,threaddump
management.endpoints.web.exposure.include=*
```

In Listing 4.15, the first configuration enables only `beans` and `threaddump` endpoints over the web (HTTP). The second configuration enables all available actuator endpoints over the web (HTTP).

Further, you can also use the exclude property to control the exposure of actuator endpoints. For instance, you may wish to expose all actuator endpoints except the `threaddump`, `heapdump`, and `health` endpoints. Listing 4.16 shows this configuration:

Listing 4.16 Actuator Web Endpoints Include and Exclude Property

```
management.endpoints.web.exposure.include=*
management.endpoints.web.exposure.exclude=threaddump,heapdump,health
```

In listing 4.16, you've exposed all actuator endpoints with wildcard the `*` but excluded the `threaddump`, `heapdump` and `health` endpoints.

In the previous sections, you've seen that the context root of all actuator endpoints is always set to the `actuator`. For instance, to access the `health` actuator endpoint, you used the URL http://localhost:8080/actuator/health. Spring Boot lets you customize the endpoint context root with the custom values. This is useful if you already use the `/actuator` endpoint for some other purposes and need to choose a different context root. For instance, configuring the `management.endpoints.web.base-path=/sbip` property in the `application.properties` file changes the actuator context root from `actuator` to `sbip`.

Besides, you can change the management server port to a different HTTP port than the actual application HTTP port. For instance, our Spring Boot application is running on HTTP port 8080 and by default, this is used as the management port for actuator endpoints. You can change the management port to `8081` by configuring the property `management.server.port=8081` in the `application.properties` file. The figure 4.4 shows this:

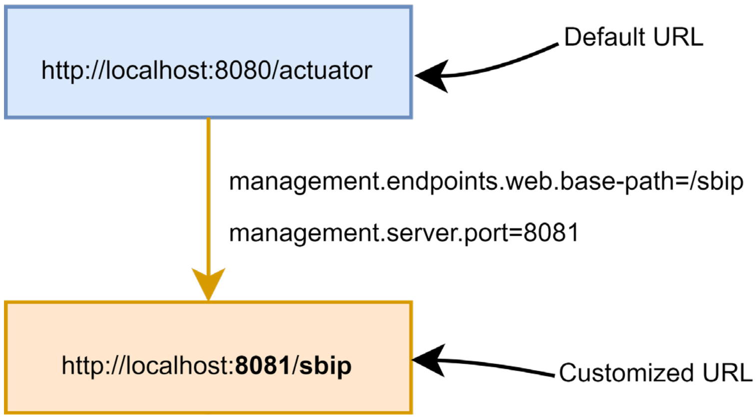


Figure 4.4 Customizing the Spring Boot actuator URL with different HTTP port and context root

You can also customize the specific actuator endpoint name to a custom name. For instance, you can customize the default `/health` endpoint to `/apphealth` by configuring the `management.endpoints.web.path-mapping.health=apphealth` property in the `application.properties` file. Figure 4.5 shows this:

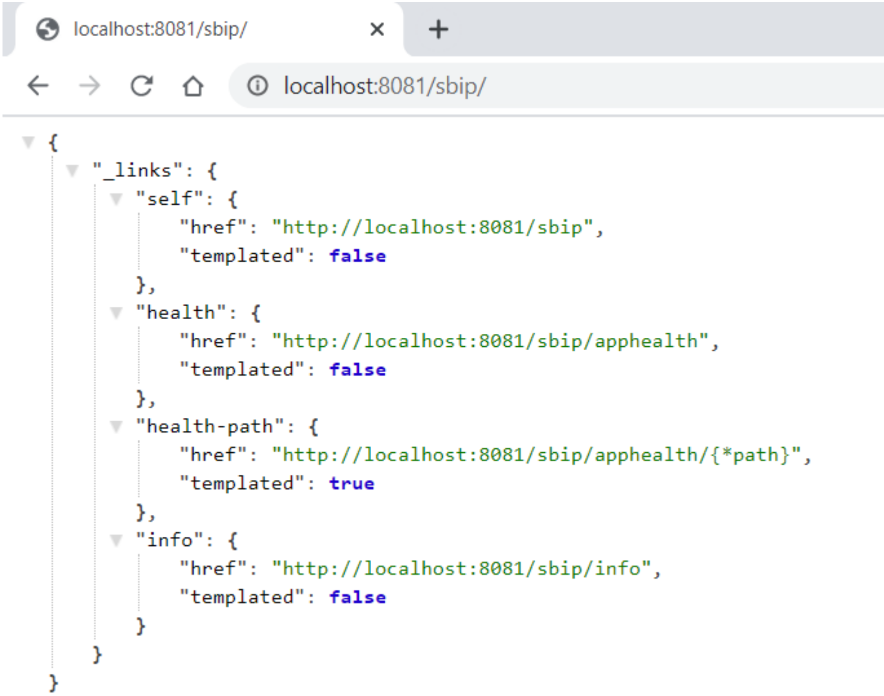


Figure 4.5 Spring Boot Actuator endpoint discovery page with custom content. In this example, the /actuator context is customized to /sbip. The management server port is 8081, whereas the application port is 8080

4.4.4 Health Endpoint Deep Dive

In section 4.4.2, you've noticed the use of the `health` Spring Boot actuator endpoint. As the name indicates, it provides the health status of the application and various other components of it. For instance, you can retrieve the health status of the database component of the application through the `health` actuator endpoint.

Out of the box, Spring Boot provides several `HealthIndicator` implementations that provide the health status of a particular application component. Some of these `HealthIndicators` are provided by Spring Boot and are always configured. For instance, Spring Boot always configures the `DiskSpaceHealthIndicator` and `PingHealthIndicator`.

Earlier, you've noticed that the `health` endpoint only provides the aggregated health status (e.g., `UP`). Let us configure the following property to retrieve the disk space and the ping status along with the aggregated application health status. Let us configure the following property in the `application.properties` file as shown in the listing 4.17:

Listing 4.17 Property to display detailed health status

```
management.endpoint.health.show-details=always
```

The property in the listing can be configured with the following three values:

- `always`: Indicates that always display the detailed health status
- `never`: Indicates only to provide the health status without any additional details. This is the default value
- `when-authorized`: Indicates only to provide details if the user or API is authorized to access the health endpoint. A user is considered authorized if she is authenticated in the application and has the roles as defined in the `management.endpoint.health.roles` property in the `application.properties` file.

If you restart the application and access the http://localhost:8080/actuator/health URL, you'll notice that the diskspace and ping health status are also provided as shown in figure 4.6:

Figure 4.6 Spring Boot Actuator health endpoint with show-details *always* configuration

Sometimes, Spring Boot enables `HealthIndicator` conditionally. These conditions could be due to the presence of a particular dependency in the application classpath. For instance, if you are using a relational database, Spring Boot automatically configures the `DataSourceHealthIndicator` and provides the underlying database health status. Note that these additional details are made available under the health endpoint only if `management.endpoint.health.show-details` property is configured to `always` as shown in listing 4.17. Let us include the `H2` database dependency in the application `pom.xml` file as shown in the listing 4.18:

Listing 4.18 The H2 database dependency

```
<dependency>
       <groupId>com.h2database</groupId>
       <artifactId>h2</artifactId>
       <scope>runtime</scope>
</dependency>
```

If you restart the application and access the `/health` endpoint, you'll notice that database health status is also included along with other component's health status. Figure 4.7 shows this:

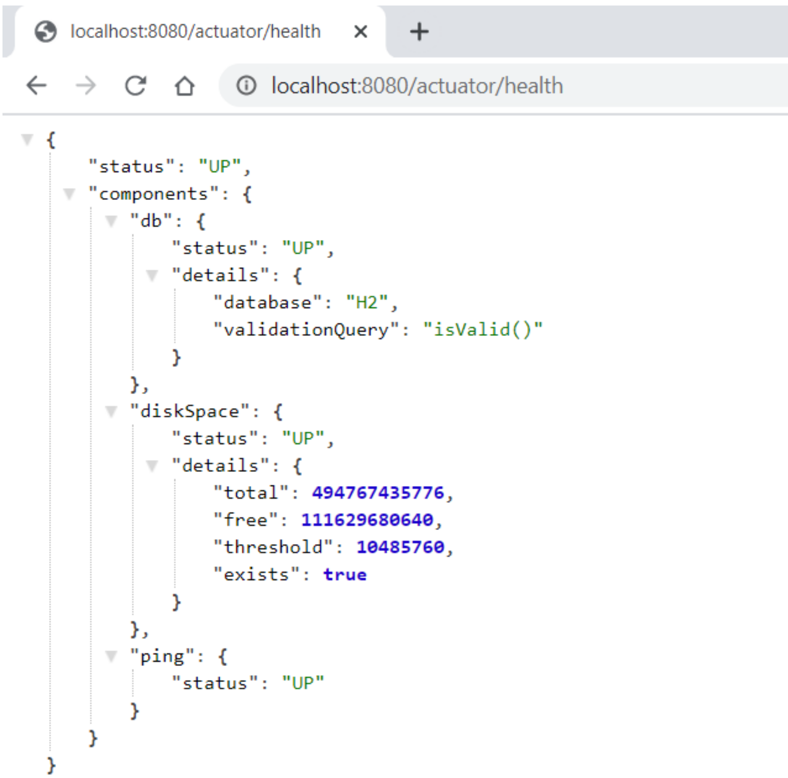


Figure 4.7 Spring Boot Actuator /health endpoint with database health status

In the figure, the root status shows the aggregated health status of your application. Aggregated healthy status aggregates the health status of all available application components and provides the aggregated health status. By default, Spring Boot provides the following four health statuses:

1. DOWN: The component is not available
2. OUT-OF-SERVICE: The component is temporarily out of service
3. `UP`: The component is working as expected
4. `UNKNOWN`: The component status is unknown

If you need other statuses in your application, you can define custom status as well. You can use the `status(..)` method of `Health` class to define custom status. Listing 4.19 creates a new status named `FATAL`. You'll learn more about this in the next section.

Listing 4.19 Creating a custom Health status

```
public Health health() {
       return Health.status("FATAL").build();
}
```

Spring Boot uses the specified status order to determine the aggregated health status of the application. Thus, the status `DOWN` has the highest priority and `UNKNOWN` has the lowest. If any one of the `HealthIndicator` returns the health status as `DOWN`, the aggregated application status is `DOWN`.

You can customize this order with the `management.endpoint.health.status.order` property. For instance, listing 4.20 shows a custom status order where the custom status `FATAL` is configured with the highest order:

Listing 4.20 Defining Custom Health Status Order

```
management.endpoint.health.status.order=FATAL,DOWN,OUT-OF-SERVICE,UNKNOWN,UP
```

These health statuses affect the `HTTP` status code of the endpoint. For instance, by default, Spring Boot maps the `DOWN` and `OUT-OF-SERVICE` status code to the `HTTP` status code 503 (Service Unavailable). The `UP` and other statuses are mapped to the `HTTP` status code 200 (`OK`).

If you need to customize the health status mapping to different HTTP status code, you can configure the `management.endpoint.health.status.http-mapping.<status>` property. Listing 4.21 shows the mapping for the `down` and `out_of_service` statuses:

Listing 4.21 Health Status Mapping

```
management.endpoint.health.status.http-mapping.down=500
management.endpoint.health.status.http-mapping.out_of_service=503
```

You can also customize the mapping programmatically by providing an implementation of the `HttpCodeStatusMapper` interface and define the `getStatusCode()` method.

Source Code

You can refer to the Spring Boot available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator-custom-status-mapper for more details

4.4.5 Creating a Custom Spring Boot HealthIndicator

In the previous section, you've explored the use of the `health` actuator endpoint. You've seen some of the Spring Boot built-in `HealthIndicator` such as `DiskSpaceHealthIndicator` and `DataSourceHealthIndicator` that provides the disk space and data source status respectively. Looking at these, you may wonder that it would have great if you could define your custom `HealthIndicator` that may provide health status to your application or any sub-system your application is integrated with. As an example, your application can load data from an external REST API. You may want to validate the health status of the REST API system. As you may correctly guess, Spring Boot lets you define custom `HealthIndicator` and automatically integrates the health status through the `health` endpoint. Let us explore this in the next technique.

TECHNIQUE DEFINE A CUSTOM SPRING BOOT ACTUATOR HEALTHINDICATOR

Problem

Spring Boot built-in `HealthIndicator` does not let you enquire about the health status of your application-specific components. You need to define a custom `HealthIndicator` that lets you monitor the health status of the critical REST API system that your application is integrated with.

Solution

Spring Boot provides the `HealthIndicator` interface that lets you define any number of custom `HealthIndicator` for your application. These `HealthIndicator` implementations are treated as regular Spring components and automatically discovered by the Spring Boot component scanning and automatically integrated with the Spring Boot actuator `/health` endpoint data. To demonstrate how to define a custom `HealthIndicator`, we will monitor the health status of a REST API to which our Spring Boot application is integrated with. We'll use the https://dog.ceo/dog-api/ as our REST API that returns beautiful dog images.

Source Code

To start with this technique, you can use the Spring Boot project available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-endpoint/course-tracker-custom-endpoint-start.

You can find the completed Spring Boot project used in this technique available at [https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-endpoint/course-tracker-custom-endpoint-final.](https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-endpoint/course-tracker-custom-endpoint-final)

Once you are done with the project set up, you'll provide an implementation of `HealthIndicator` called `DogsApiHealthIndicator`. Note that it is a convention to use the `HealthIndicator` suffix in the custom `HealthIndicator` class. Listing 4.22 shows this implementation:

Listing 4.22 The DogsApiHealthIndicator class

```
package com.manning.sbip.ch04.health.indicator;

// imports

@Component
public class DogsApiHealthIndicator implements HealthIndicator {

       @Override
       public Health health() {
         try {
                  ParameterizedTypeReference<Map<String, String>> reference = new
       ParameterizedTypeReference<Map<String, String>>() {};
               ResponseEntity<Map<String, String>> result = new
       RestTemplate().exchange("https://dog.ceo/api/breeds/image/random", HttpMethod.GET,
       null, reference);
               if (result.getStatusCode().is2xxSuccessful() && result.getBody() != null) {
                  return Health.up().withDetails(result.getBody()).build();
               }
               else {
                  return Health.down().withDetail("status", result.getStatusCode()).build();
               }
         }
         catch(RestClientException ex) {
                   return Health.down().withException(ex).build();
         }
       }
}
```

We are doing the following activities in this class:

- This class implements the `HealthIndicator` interface. It implies that this class provides the health status of some application component
- It is annotated with `@Component` annotation so that it can be discovered by Spring Boot component scanning
- We've used Spring's `RestTemplate` class to call the `https://dog.ceo` API. `RestTemplate` lets you invoke the REST APIs from your application
- We then evaluate the HTTP response status. If the status code is HTTP 2XX series (e.g., 200, 201) and the response body is not null, we define the health status as `UP` and return the REST service response body so that it can be shown in the `/health` endpoint
- If we encounter any exception, we return the actuator health status as down and provide the exception so that it could be shown in the /health endpoint result

That's all. You just need to define the `HealthIndicator` and Spring Boot will ensure to discover it and collect the health status and provide the output in /health endpoint. You can start the application and access the http://localhost:8080/actuator/health/ endpoint. Figure 4.8 shows the output:

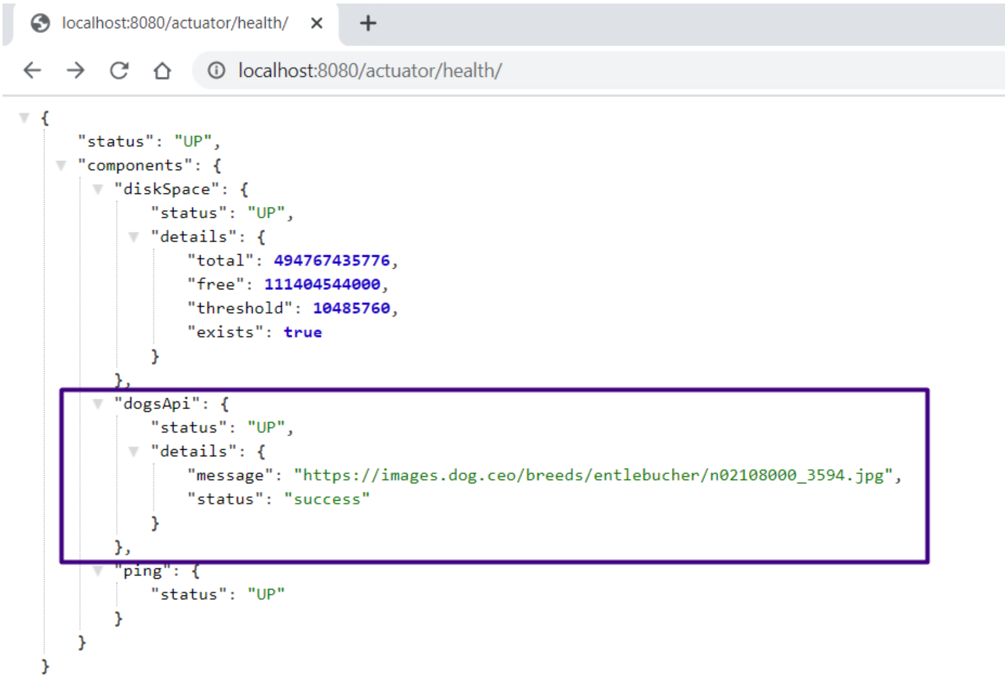


Figure 4.8 Spring Boot Actuator health endpoint with custom HealthContributor

Note that you need to have an active internet connection to get the result as shown above. To see the custom health indicator failing, you can disconnect your computer from the network and access the same URL. Figure 4.9 shows the outcome:

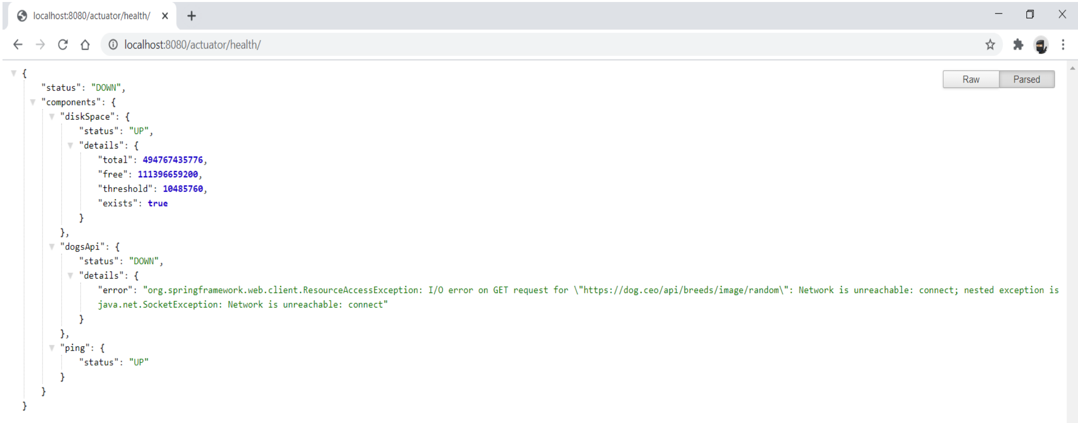


Figure 4.9 Spring Boot Actuator health endpoint with failed health status for custom HealthIndicator

Discussion

In this technique, we've discussed how to define a custom `HealthIndicator` that enquires the health status of a REST API. As you've seen it is straightforward to define a custom health indicator and return the health status. In the next section, let us explore more on the `/info` endpoint and learn how to define a custom `InfoContributor`.

4.4.6 Info Endpoint Deep Dive

In the previous sections, you've explored the `health` actuator endpoint. In this section, you'll dive into the `info` actuator endpoint.

TECHNIQUE CONFIGURING INFO SPRING BOOT ACTUATOR ENDPOINT

Problem

You need to configure the Info Spring Boot Actuator endpoint in your application

Solution

As the name indicates, the `info` endpoint provides information related to the application. By default, the `info` endpoint does not provide any information. However, you can customize this behaviour to return some information related to your application. There are two modes through which you can configure the data for the `info` endpoint.

Source Code

You can find the completed Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator-info-endpoint

First, you can configure the properties in the `application.properties` file by setting the `info.*` properties. For instance, you can configure the following properties in the `application.properties` in your Spring Boot application as shown in the listing 4.23:

Listing 4.23 The Info Properties

```
info.app.name= Spring Boot Actuator Info Application
info.app.description=Spring Boot application that explores the /info endpoint
info.app.version=1.0.0
```

You can configure any number of properties with the `info.*` prefix in the `application.properties` file and these properties will be rendered at `/info`. Restart the application and access the http://localhost:8080/actuator/info endpoint. Figure 4.10 shows the output:

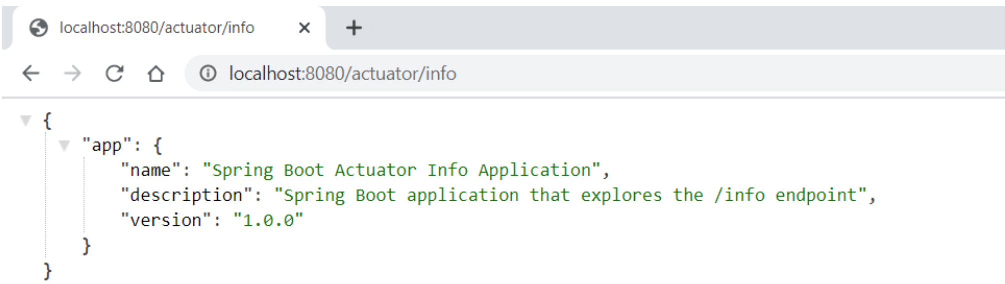


Figure 4.10 Spring Boot Actuator /info endpoint shows the application name, description, and version as configured in the application.properties file

You can also print the project details such as `artifactId`, `groupId`, `version` through the `info` endpoint. For instance, configure the following properties as shown in Listing 4.24:

Listing 4.24 The info properties

```
info.build.artifact=@project.artifactId@
info.build.name=@project.name@
info.build.description=@project.description@
info.build.version=@project.version@
info.build.properties.java.version=@java.version@
```

In the listing, the values are configured as `@..@`. Spring Boot automatically expands the properties from the Maven project. Restart the application and access the http://localhost:8080/actuator/info endpoint again, you will find the following output as shown in figure 4.11:

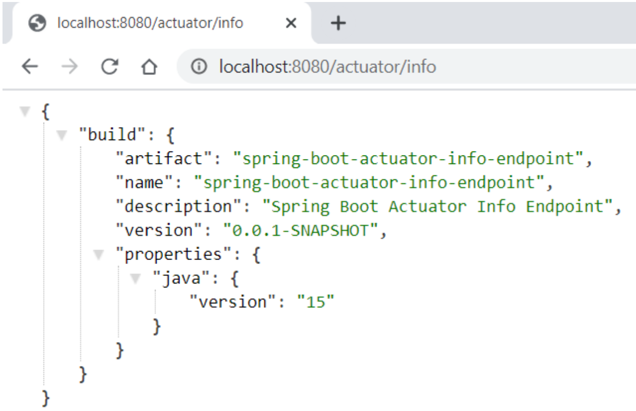


Figure 4.11 Spring Boot Actuator *info* endpoint with the application details. These details are sourced from the pom.xml file of the application

Gradle Users

If you are using Gradle, you can also retrieve the details. Add the following in the build.gradle file of your application:

```
springBoot {
  buildInfo()
}
```

Start the application using the gradlew bootRun command and access the http://localhost:8080/actuator/info endpoint and you will notice the following details as shown in figure 4.12:

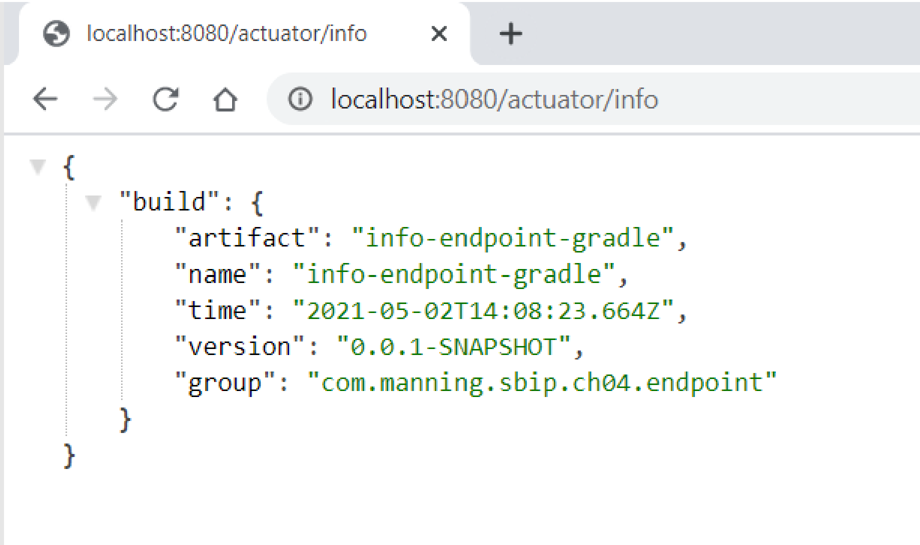


Figure 4.12 Accessing build information in a Spring Boot Gradle application through info endpoint

Second, the `/info` endpoint lets you also fetch your application's git repository, environment, and build details. The git repository details are automatically displayed if a `git.properties` file is available in the classpath. You can refer to https://github.com/spring-boot-in-practice/repo/wiki/How-to-generate-git.properties-file on how to generate a `git.properties` file.

Similarly, the build details are also available if the `build-info.properties` file is available inside the `META-INF` folder in the classpath. The git repository and the build information are managed through the `GitInfoContributor` and `BuildInfoContributor` classes respectively. You'll shortly learn more about the `InfoContributor` interface.

To generate these files, you can perform the following changes in the application's `pom.xml` file as shown in the listing 4.25:

Listing 4.25 The pom.xml changes to generate the build.info and git.properties file

```
<build>
  <plugins>
    <plugin>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-maven-plugin</artifactId>
      <executions>
        <execution>
          <goals>
            <goal>build-info</goal>
          </goals>
        </execution>
      </executions>
```

```
    </plugin>
    <plugin>
      <groupId>pl.project13.maven</groupId>
      <artifactId>git-commit-id-plugin</artifactId>
    </plugin>
  </plugins>
</build>
```

The changes in the listing do the following:

- The `build-info` goal in the `spring-boot-maven-plugin` generates the `build-info.properties` file.
- The `git-commit-id-plugin` generates the `git.properties` file. This file contains git repository information such as git commit, build, and branch details. Note that this is not a Spring Boot plugin, instead of a third party one

Open a command line or terminal window and start the application. If you access the http://localhost:8080/actuator/info, you'll find the details as shown in 4.13:

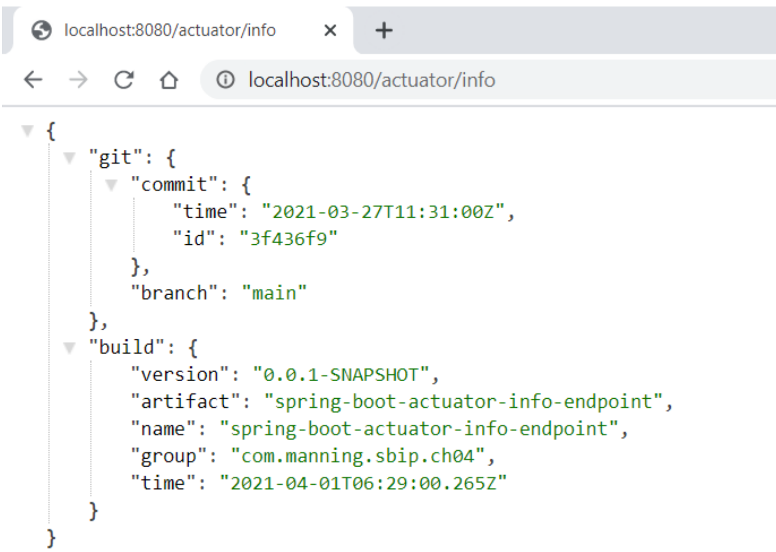


Figure 4.13 Spring Boot Actuator info endpoint with git and build details. The git details are sourced from the git.properties file. The build details are sourced from the build-info.properties file. You can control the git details with the *management.info.git.mode* property in the application.properties file with values full or simple. Setting the property to full displays complete git details. By default, this default value of this property is simple and it only shows git commit time and id.

Lastly, you can provide a custom `InfoContributor` that can provide application details. Previously, we mentioned that the `GitInfoContributor` provide the information regarding your git repository. This class reads the `git.properties` file and presents the related data through the `info` endpoint.

TECHNIQUE CONFIGURING CUSTOM INFO CONTRIBUTOR TO PROVIDE CUSTOM APPLICATION INFO IN THE SPRING BOOT ACTUATOR ENDPOINT

Problem

You need to provide custom application details through the Info Spring Boot Actuator endpoint in your application

Solution

Spring Boot provides the `InfoContributor` interface that lets you expose application information through the Spring Boot Actuator built-in `info` endpoint.

Source Code

You can find the completed Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator-info-endpoint

In this technique, you'll create a custom implementation of `InfoContributor` named `CourseInfoContributor` in the course tracker application. This custom `InfoContributor` provides the course name and the course ratings through the `info` endpoint. Listing 4.26 shows this class:

Listing 4.26 Defining a custom InfoContributor

```
package com.manning.sbip.ch04.info;

import org.springframework.boot.actuate.info.InfoContributor;
// Other Imports

@Component
public class CourseInfoContributor implements InfoContributor {

    @Autowired
    private CourseService courseService;

    @Override
    public void contribute(Info.Builder builder) {
        Map<String, Integer> courseNameRatingMap = new HashMap<>();
        List<CourseNameRating> courseNameRatingList = new ArrayList<>();
        for(Course course : courseService.getAvailableCourses()) {

       courseNameRatingList.add(CourseNameRating.builder().name(course.getName()).rating(co
       urse.getRating()).build());
        }
        builder.withDetail("courses", courseNameRatingList);
    }

    @Builder
    @Data
    private static class CourseNameRating {
```

```
        String name;
        int rating;

    }
}
```

In the listing, you've done the following:

- First, you've implemented the Spring Boot `InfoContributor` interface and defined the `contribute(..)` method
- Second, you've used the course service that returns all available courses in the application
- Lastly, you map the course name and rating information from the course, and the list of course name and ratings are added to the `Info.Builder` instance. As the name indicates, the `Info.Builder` lets you build the info details

Start the application, and you'll notice the following output as shown in figure 4.14:

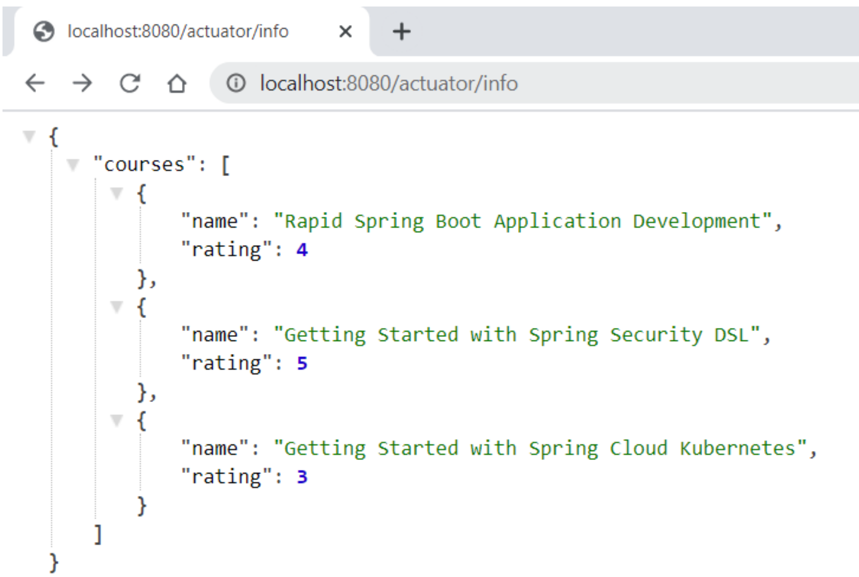


Figure 4.14 Showing application-specific custom details with info endpoint

Note

In this technique, you may notice that we are using the application business domain details in the Spring Boot Actuator endpoint. You'll notice the use of application business domain details in several other techniques as well. Ideally, Spring Boot Actuator endpoints are intended to be used for application monitoring and interaction purposes and not to expose/alter business domain details. A RESTful web service is more appropriate to manage business

domain details. Only for demonstration purposes and to keep the examples simple, we've used the business domain details in the Spring Boot Actuator endpoints.

4.4.7 Creating a Custom Spring Boot Actuator Endpoint

In the previous section, you've seen the built-in Spring Boot actuator endpoints such as /health, and /info. However, sometimes you may need to define custom endpoints specific to your application that can provide your application-specific data. The custom endpoints are an easy and useful way to get some insight into your application. In the next technique, let us explore how to define a custom Spring Boot actuator endpoint.

TECHNIQUE CREATE A CUSTOM SPRING BOOT ACTUATOR ENDPOINT

Problem

Spring Boot built-in actuator endpoints are generic and do not provide application-specific business details. You need to define an actuator endpoint that lets you monitor and interact with application business details.

Solution

To demonstrate how to define and use a custom Spring Boot actuator endpoint, you'll use the course tracker application you've used in the previous techniques. You'll define a `course` endpoint that provides the details of all the available courses in the application. We'll also enable to view a specific course detail through the `courseId`. Besides, you'll also enable update and delete operations through the actuator endpoint. The update operation lets you update the course rating for a specific course through the coursed. The delete operation enables us to either delete all courses or delete a specific course. Let us implement this in the course tracker application.

Source Code

To start with this technique, you can use the Spring Boot project available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-endpoint/course-tracker-custom-endpoint-start.
You can find the completed Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/custom-endpoint/course-tracker-custom-endpoint-final.

To create a new actuator endpoint, you need to create a Java class, annotate with the `@Endpoint` annotation and define the methods that support the `@ReadOperation`, `@WriteOperation`, and `@DeleteOperation`. We'll discuss these annotations in detail in the discussion section.

Let us create a class named `CourseEndpoint` that provides the details of all available courses in the application. Listing 4.27 shows this class:

Listing 4.27 The CourseEndpoint class

```
package com.manning.sbip.ch04.endpoint;
```

```
//imports

import com.manning.sbip.ch04.model.Course;
import com.manning.sbip.ch04.repository.CourseRepository;

@Component
@Endpoint(id = "courses")
public class CourseEndpoint {

        @Autowired
        private CourseRepository courseRepository;

        @ReadOperation
        public Iterable<Course> courses() {
          return courseRepository.findAll();
        }
}
```

We've performed the following actions in this class:

- Annotated the class with `@Component` annotation so that Spring Boot component scanning can detect this class and create the bean
- Annotated the class with `@Endpoint` annotation that indicates this class is an actuator endpoint. We've also provided an id named `courses` to uniquely identify the endpoint
- Autowired the `CourseRepository` in this class so that it can be used to perform the database CRUD operation
- Lastly, we've defined a method with `@ReadOperation` annotation that returns all courses available in the database

To access the `courses` endpoint, you need to configure the `management.endpoints.web.exposure.include` property with the value `courses` or with the value `*`. Listing 4.28 shows this property with `courses` endpoint:

Listing 4.28 Expose the custom endpoint

```
management.endpoints.web.exposure.include=courses
```

If you start the application and access the actuator discovery page http://localhost:8080/actuator/ from your browser, you will notice that the endpoint is listed as shown in figure 4.15.

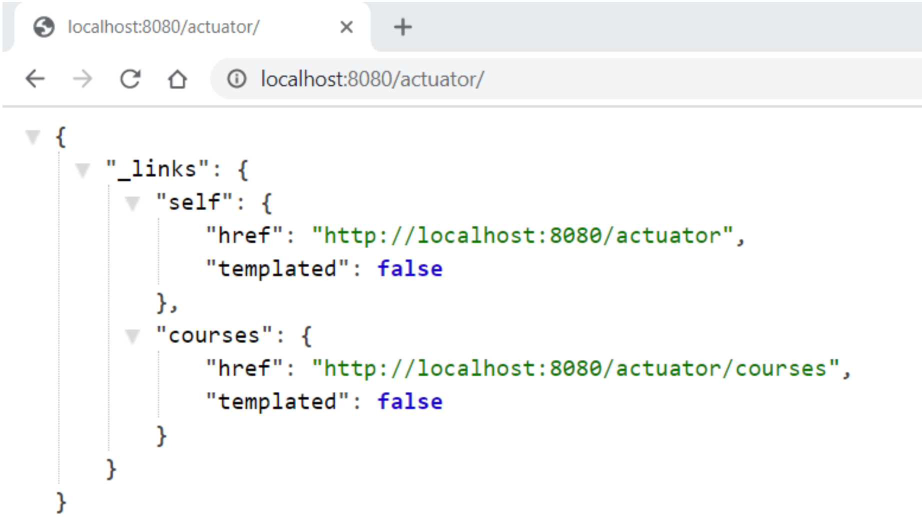


Figure 4.15 Defining custom endpoint /course and exposing it through the Actuator discovery page

If you access the http://localhost:8080/actuator/courses endpoint, you'll notice that it provides the list of courses available in the application as shown in figure 4.16:

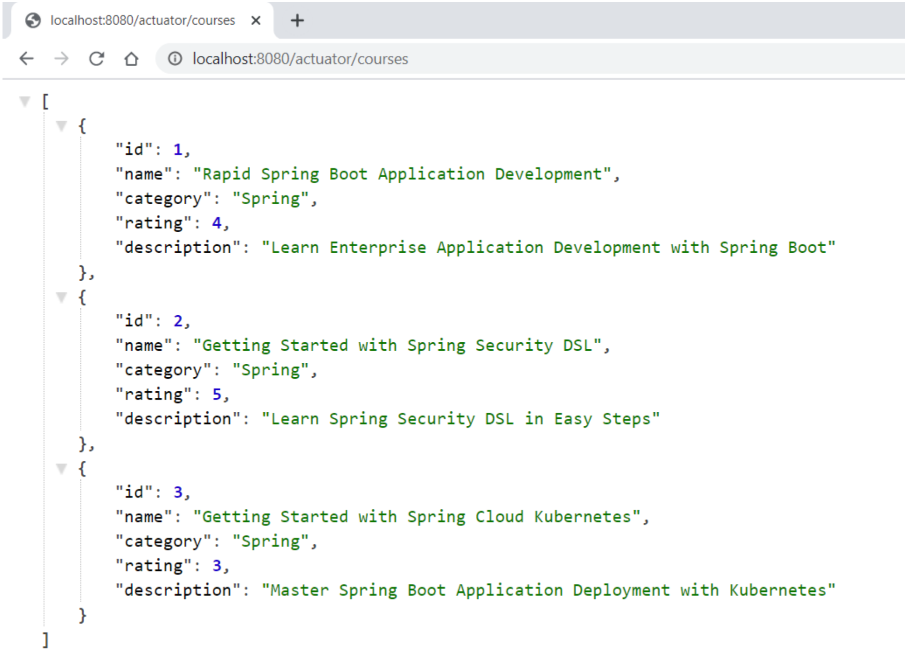


Figure 4.16 The courses endpoint with course details

Let us now implement the endpoint that lets you find a specific course details through the `courseId`. Listing 4.29 shows this in the `CourseEndpoint` class presented in Listing 4.29:

Listing 4.29 Defining the Read operation

```
@ReadOperation
public Object selectCourse(@Selector Long courseId) {
       Iterable<Course> courses = courseRepository.findAll();
       for(Course course : courses) {
         if(course.getId().equals(courseId)) {
                 return course;
         }
       }
       return String.format("No course with course id %d available", courseId);
}
```

In Listing 4.29, we've implemented another `@ReadOperation` that lets you specify a `courseId` as the `@Selector` and return only the course-specific details. If there is an invalid course id, it returns the error message that No course with course id available.

Let us now focus on to the next operation that lets you update the course rating. Spring Boot provides the `@WriteOperation` annotation to implement such operations. Listing 4.30 shows this operation:

Listing 4.30 Defining the Write Operation

```
@WriteOperation
public void updateCourseRating(@Selector Long courseId, int newRating) {
       Optional<Course> optionalCourse = courseRepository.findById(courseId);
       if(!optionalCourse.isEmpty()) {
         Course course = optionalCourse.get();
         course.setRating(newRating);
         courseRepository.save(course);
       }
}
```

The `@WriteOperation` implementation takes a `courseId` and the new course rating to update the course. A write operation is a POST operation; thus, you can't use your browser to test this endpoint. You can either use tools such as Postman or the command-line utility such as cURL to update the course rating. Listing 4.31 shows the `cURL` command to update the course rating to five for `courseId` one:

Listing 4.31 Updating a Couse Rating with cURL

```
curl -i -X POST -H "Content-Type:application/json" -d "{\"newRating\": 5}"
       http://localhost:8080/actuator/courses/1
```

You can access the http://localhost:8080/actuator/courses/1 URL from your browser and notice that the course rating has been updated to five. By invoking this URL, you are invoking the `@ReadOperation` of Listing 4.29.

The next operation you'll implement is to delete course details. Similar to the read operation, you'll implement two variants of the delete operation. The first one lets you delete all courses and the other one lets you specify a `courseId` and deletes the specific course. Listing 4.28 shows these operations:

Listing 4.32 Defining the delete operation

```
@DeleteOperation
public void deleteCourses() {
       courseRepository.deleteAll();
}

@DeleteOperation
public void deleteCoursebyId(@Selector Long courseId) {
       courseRepository.deleteById(courseId);
}
```

In the code snippet in the listing, you've used the `CourseRepository` to delete the course. Let us delete the course with `courseId` one. Listing 4.33 shows the `cURL` command to delete the course:

Listing 4.33 Performing the delete operation for a single course with cURL

```
curl -i -X DELETE http://localhost:8080/actuator/courses/1
```

You can access the http://localhost:8080/actuator/courses URL from your browser and notice that the course with `courseId` one is deleted. Listing 4.34 shows the `cURL` command to delete all courses from the application:

Listing 4.34 Performing the delete operation for all courses with cURL

```
curl -i -X DELETE http://localhost:8080/actuator/courses
```

Discussion

In this technique, you've learned how to define a custom Spring Boot actuator endpoint. It is straightforward to define a custom endpoint with the `@Endpoint`, `@ReadOperation`, `@WriteOperation`, `@DeleteOperation`, and the `@Selector` annotations.

The `@Endpoint` annotation indicates that the annotated class is a Spring Boot actuator endpoint and able to provide or mutate information in the running application. It takes two arguments `– id` and `enablebyDefault`. In this example, you've configured the id as `/courses`. By default, the `enableByDefault` parameter is set to true. However, to expose it over a specific technology (e.g., JMX, or web), you need to configure the associated `management.endpoints.<web/jmx>.exposure.include` parameter in the `application.properties` file.

Spring Boot also provides two technology-specific endpoint annotations – `@JmxEndpoint` and `@WebEndpoint`. The first one lets you define an endpoint that is only exposed over JMX, and the latter one exposes the endpoint over HTTP only. For instance, in the listing, you can change the `@Endpoint` to `@JmxEndpoint` and notice that the /courses endpoint is not available on the discovery page at http://localhost:8080/actuator. You can use the `JConsole` tool (https://docs.oracle.com/javase/8/docs/technotes/guides/management/jconsole.html) to view the JMX endpoints. Figure 4.17 shows this:

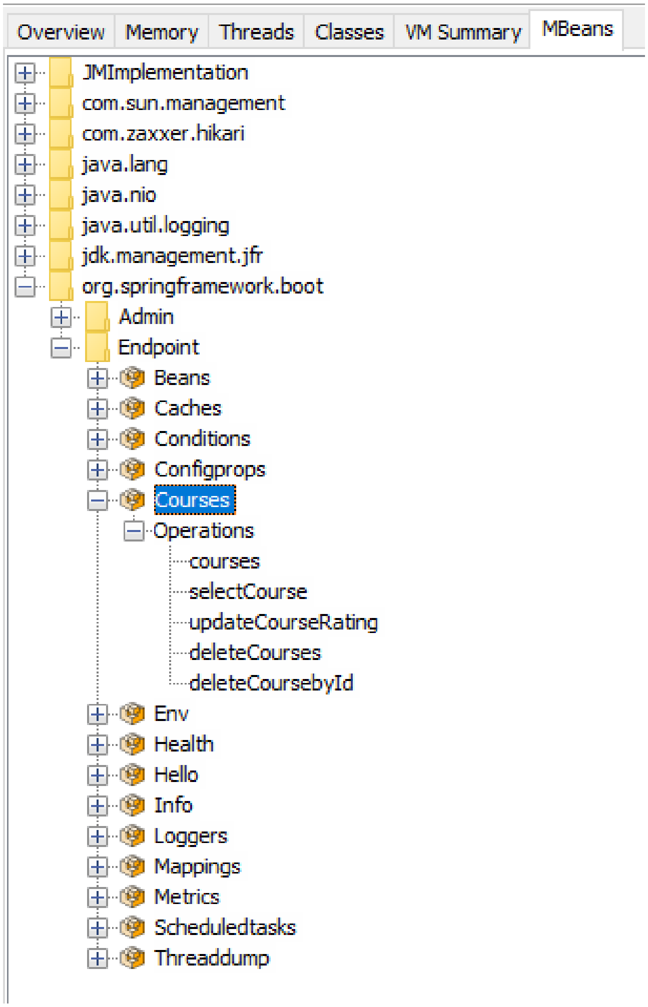


Figure 4.17 The Spring Boot Actuator endpoints exposed through JMX

4.4.8 Spring Boot Actuator Metrics

In addition to other endpoints, Spring Boot provides the `metrics` actuator endpoint that provides various application metrics. For instance, if you access the http://localhost:8080/actuator/metrics endpoint, you'll see the following output as shown in figure 4.18:

Figure 4.18 List of available Spring Boot actuator metrics

Each one of these is an application metric that provides application-related information. For example, if you need to know how much time the application was paused for garbage collection, you can use the `jvm.gc.pause` metric through the http://localhost:8080/actuator/metrics/jvm.gc.pause URL. Figure 4.19 shows this:

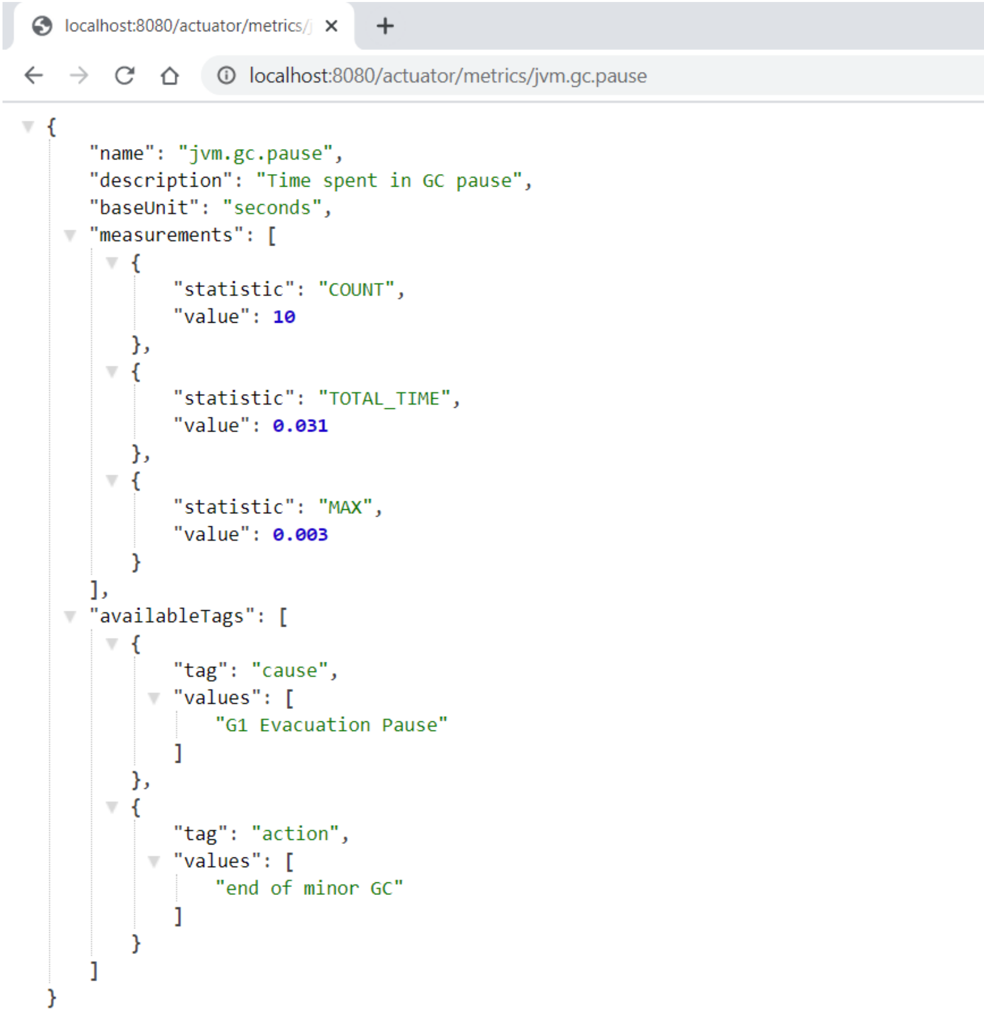


Figure 4.19 Details of the *jvm.gc.pause* metric

In this example, the application was paused 10 times and the total pause duration was 0.031 seconds. Under the hood, the Spring Boot actuator uses Micrometer Framework (https://micrometer.io/) to configure the metrics. Besides, it also lets us define custom metrics, such as counters, timers, gauges, and distribution summaries. Shortly, you'll learn how to create these metrics in a Spring Boot application. Let us now provide a brief overview of the Micrometer framework.

Note

An in-depth discussion on the Micrometer framework or other monitoring systems is beyond the scope of this text. You can refer to Micrometer documentation (https://micrometer.io/docs) or the respective monitoring system documentation for further references. You can also refer to the https://spring.io/blog/2018/03/16/micrometer-spring-boot-2-s-new-application-metrics-collector for more insight on Micrometer with Spring Boot. For a list of supporting monitoring systems, you can refer to the Spring Boot documentation at https://docs.spring.io/spring-boot/docs/current/reference/html/production-ready-features.html#production-ready-metrics.

In this book, we'll show you how to use the monitoring tool Prometheus that collects the metrics and observability platform Grafana lets you visualize these metrics.

The Micrometer is a metrics collection facade intended to collect various types of metrics in a vendor-neutral way. Spring Boot can select various monitoring systems through configuration and classpath to export these metrics data. The Micrometer is a metrics collection facade intended to collect various types of metrics in a vendor-neutral way. It lets you plug in the various concrete implementation of monitor systems (e.g.: Prometheus, Graphite, New Relic, etc.).

Spring Boot can select various monitoring systems through configuration and classpath to export metrics data.

Micrometer provides a vendor-neutral metrics collection API (`io.micrometer.core.instrument.MeterRegistry` and its subclasses) and provide implementations for other monitoring frameworks such as Prometheus (`io.micrometer.prometheus.PrometheusMeterRegistry`). To configure a different monitoring system, you can provide the corresponding dependency `micrometer-registry-{monitoring_system}` and Spring Boot automatically configures the registry for you. For instance, to configure Prometheus, you need to configure the `micrometer-registry-prometheus` dependency in the `pom.xml` file.

Further, Spring Boot also provides several properties to control these features. Listing 4.35 shows some of these properties:

Listing 4.35 Exposing the metrics

```
management.metrics.export.<registry>.enabled=false
management.metrics.export.defaults.enabled=false
```

The first command indicates whether exporting metrics to the registry (e.g., Graphite) is enabled. The second command indicates whether to enable default metrics exporters. For instance, setting `management.metrics.export.defaults.enabled` to false does not expose any metrics. You can validate that by accessing http://localhost:8080/actuator/metrics URL.

Spring Boot auto-configures a composite `MeterRegistry` that lets you add any number of registry implementations. Thus, you can ship your metrics to more than one monitoring system. Besides, you configure the registries with `MeterRegistryCustomizer`. For instance, you can ship your application metrics to both Prometheus and New Relic. You can then configure a common set of tags for both registries. Tags in this context are used as an identifier. For instance, if multiple applications publish metrics data, they can use a tag to identify the application name. Let’s say you need to add a tag in your metrics that add the `application name` in all metrics. Listing 4.36 shows how you can customize the `MeterRegistry` using the `MeterRegistryCustomizer` with a Spring bean definition in a Spring configuration file:

Listing 4.36 Customizing MeterRegistry with MeterRegistryCustomizer

```
@Bean
MeterRegistryCustomizer<MeterRegistry> metricsCommonTags() {
      return registry -> registry.config().commonTags("application", "course-tracker");
}
```

Open a browser window and access any of the metrics, you’ll find the application tag is present in the metrics data. You can then use the custom tag to filter the metric data. You can append the query string `?tag=tagName:tagValue` in the metric URL to achieve this. For instance, figure 4.20 shows this in an example:

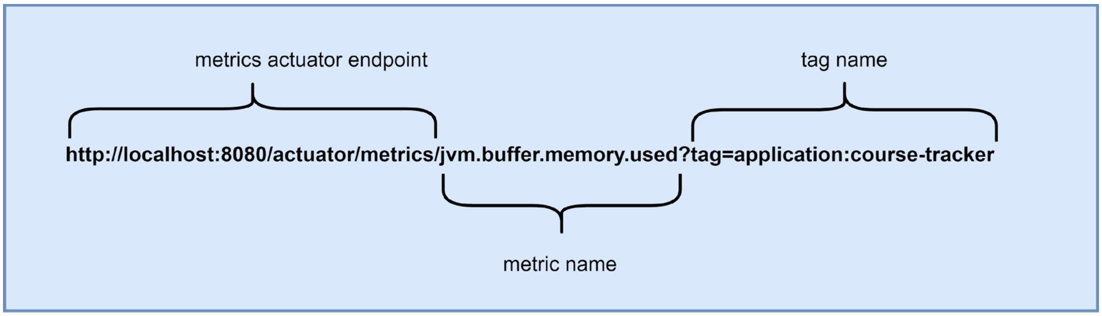


Figure 4.20 Using the tag to filter the metric output

This summarizes the overview of the Spring Boot metrics. In the next section, you’ll learn how to create custom metrics in a Spring Boot application.

4.4.9 Creating Custom Metrics

In the previous section, you’ve explored the /metrics endpoint that exposes critical application and system information worth monitoring for application performance and overall health. The metrics that you’ve seen so far are built-in in the Micrometer and Spring Boot auto-configures those for us. For instance, the Micrometer framework provides `JvmGcMetrics`, `JvmMemoryMetrics`, `JvmThreadMetrics` classes that expose JVM garbage collection, memory, and thread details, respectively. All these metrics are auto-configured by the Spring Boot `JvmMetricsAutoConfiguration` class.

Spring Boot lets you create custom metrics that expose application-specific data that you may need to monitor. Let us explain this in terms of the `CourseTracker` application. In this application, you may be interested to monitor the number of courses created in the application on a real-time basis. Besides, you may also track the time that is being taken to create a new course or time taken is within the service level agreements (SLA).

The micrometer framework provides several types of the meters such as `Counter`, `Gauge`, `Timer`, `DistributionSummary` that you can use to create custom metrics. Let us explore some of these. We'll define the following additional metrics in the `CourseTracker` application:

- Count the number of courses created using the `Counter` metric
- Count the number of courses created using the `Gauge` metric. We'll discuss the difference between `Counter` and `Gauge` metrics
- Capture the time taken to create the course using the `Timer` metric
- Capture the distribution summary of the course ratings using the `DistributionSummary` metric

Source Code

To continue with this exercise, you can download the initial version of the Spring Boot project from GitHub available at https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator-custom-metrics/spring-boot-actuator-custom-metrics-start

The final version of the application can be accessed from the https://github.com/spring-boot-in-practice/repo/tree/main/ch04/spring-boot-actuator-custom-metrics/spring-boot-actuator-custom-metrics-final URL.

Counter

The `Counter` is the first type of metric that we'll explore. A `Counter` represents a single numeric value that can be incremented. For instance, we can use it to count the number of times a method was invoked. Thus, if we need to count the total number of courses created, we can use the `Counter` in the course creation method to keep track. Let us first create a Counter instance and then use it in the `DefaultCourseService` to count the number of courses. Listing 4.37 shows the `createCourseCounter` bean definition in the `CourseTrackerMetricsConfiguration` class:

Listing 4.37 The createCourseCounter bean

```
@Configuration
public class CourseTrackerMetricsConfiguration {

    @Bean
    public Counter createCourseCounter(MeterRegistry meterRegistry) {
        return Counter.builder("api.courses.created.count")
                .description("Total number of courses created")
                .register(meterRegistry);
    }
}
```

In the listing, you've created a Counter instance with the name `api.courses.created.count` and provided a description indicating its purpose. Finally, you've registered it to the `MeterRegistry` so that it can be exposed in the metrics list.

Let us now use this Counter instance in the `createCourse(..)` method of the `DefaultCourseService` class so that each time this service method is invoked, the `Counter` value can be incremented. Listing 4.38 shows this:

Listing 4.38 Count the number of courses created

```
@Autowired
private final Counter createCourseCounter;

public Course createCourse(Course course) {
    createCourseCounter.increment();
    return courseRepository.save(course);
}
```

Start the application and access the http://localhost:8080/actuator/metrics URL. You'll notice that a new metric endpoint is added. Access this http://localhost:8080/actuator/metrics/api.courses.created.count endpoint URL, and you'll notice that it is displaying the total number of courses created so far. However, as we haven't created any courses yet, it shows the count value is 0.

Note

In Listing 4.38, we've used the Counter metric directly inside the Spring Boot service class. Although this approach works, it tightly couples the metric code with the actual business logic. As a better design, you can use Spring's event listener mechanism to decouple the use of the Counter metric.

Open a browser window and access the http://localhost:8080/index URL to create a new course. Post that, access the http://localhost:8080/actuator/metrics/api.courses.created.count endpoint again. This time you'll notice that the course count is increased to one. Figure 4.21 shows the output:

Figure 4.21 Outcome of the api.courses.created.count custom metric

Gauge

The drawback of the `Counter` metric is that it can't persist the counter value once there is an application restart. The counter value is set to zero after the restart. Thus, if you need to keep a track of the total number of courses created in the application irrespective of the application restart, a Counter is not the right metric.

A Gauge is the other metric that is more suitable to keep track of the total number of courses available. For instance, in a production application, you'll use a database that can persist the application data. Thus, you can query the database on the total number of courses available and expose it through a Gauge metric. Let us demonstrate how to implement this with a Gauge.

Let us begin with defining a Gauge metric that retrieves the total number of courses available in the database. Add the following bean definition in the previously created `CourseTrackerMetricsConfiguration` class. Listing 4.39 shows the `createCoursesGauge` bean definition:

Listing 4.39 The createCoursesGauge bean definition

```
@Bean
public Gauge createCoursesGauge(MeterRegistry meterRegistry, CourseService courseService) {
    return Gauge.builder("api.courses.created.gauge", courseService::count)
            .description("Total courses available")
            .register(meterRegistry);
}
```

In the listing, you've created a Gauge metric named `api.courses.created.gauge` with a suitable description and registered it with the `MeterRegistry`. The metric data is fetched from the database using the `count(..)` method defined in the `CourseService`.

As the data required by the Gauge metric is supplied from the database, you need not incorporate it in the `createCourse(..)` service. Besides, as the `api.courses.created.gauge metric` is already registered with the `MeterRegistry`, it is already exposed in the /metrics endpoint.

Start the application, and create a few courses, and access the http://localhost:8080/actuator/metrics/api.courses.created.gauge URL. You'll find the total number of courses available in the application.

Note

In this example, you are using the H2 in-memory database, and it is restarted each time there is an application restart. Thus, you'll notice that the Gauge metric is behaving similarly to the Counter metric. To explore the data persistence across application restart, use a database that persists the data in the disk. For instance, you can use MySQL to explore this.

Timer

The previous two metrics Counter and Gauge let you measure the count of *something* (e.g., courses) in your application. Further, at times you may be interested to measure the time taken to perform an operation in your application. For instance, you may need to measure the time taken to create a course. Besides, in time-critical applications, you can additionally measure whether the operation is completed within the SLA. A Time lets you achieve this. Let us define a timer that lets you measure the time taken to create a course in the `CourseTracker` application.

Let us define a `Timer` metric in the `CourseTrackerMetricsConfiguration` class. Listing 4.40 shows this:

Listing 4.40 The createCoursesTimer bean definition

```
@Bean
public Timer createCoursesTimer(MeterRegistry meterRegistry) {
    return Timer.builder("api.courses.creation.time")
        .description("Course creation time")
        .register(meterRegistry);
 }
```

In the listing, you've defined a metric named `api.courses.creation.time` with a suitable description and registered it with the `MeterRegistry`. Let us now use this metric in the `createCourse(..)` method of `DefaultCourseService` to capture the time taken to create a course. Listing 4.41 shows this:

Listing 4.41 Using the createCoursesTimer

```
@Autowired
private Timer createCoursesTimer;

@SneakyThrows
```

```
public Course createCourse(Course course) {
    return createCoursesTimer.recordCallable(() -> courseRepository.save(course));
}
```

In the listing, you are using the `recordCallable(..)` method of the `Timer` interface. This method accepts a `java.util.concurrent.Callable` instance. In this demonstration, we've represented it with a lambda expression in which we invoke the repository to save the course details. Internally, the Timer uses this Callable instance to capture the total time taken to invoke the repository `save(..)` method. The `recordCallable(..)` method throws Exception. We've used Lombok's `@SneakyThrows` annotation that wraps the checked exception to an unchecked one.

You can restart the application, create a few courses and then access the http://localhost:8080/actuator/metrics/api.courses.creation.time URL. The `api.courses.creation.time` provides the details such as total courses created, total time is taken to create the courses, and the maximum time taken to create a course. Figure 4.22 shows this:

Figure 4.22 Outcome of the api.courses.creation.time custom metric. The *baseUnit* indicates the unit for the metric and provides an option to customize the unit for the metric.

Distribution Summary

A distribution summary lets you measure the distribution of events. It is similar to a Timer structurally but used to record values that do not represent a unit of time. For example, a distribution summary could be used to measure the course ratings in the `CourseTracker` application.

Let us define a `DistributionSummary` metric in the `CourseTrackerMetricsConfiguration` class. Listing 4.42 shows this:

Listing 4.42 Defining a Distribution Summary

```
@Bean
public DistributionSummary createDistributionSummary(MeterRegistry meterRegistry) {
    return DistributionSummary.builder("api.courses.rating.distribution.summary")
           .description("Rating distribution summary")
            .register(meterRegistry);
}
```

Like other metrics, in the listing, you've defined a `DistributionSummary` metric with a name, description, and registered it with the `MeterRegistry`.

Let us now use this metric in the `createCourse(..)` method of `DefaultCourseService` as shown in the listing 4.43:

Listing 4.43 Using DistributionSummary in CreateCourse method

```
@Autowired
private DistributionSummary distributionSummary;
@SneakyThrows
public Course createCourse(Course course) {
    distributionSummary.record(course.getRating());
    return createCoursesTimer.recordCallable(() -> courseRepository.save(course));
}
```

Restart the application and create a few courses with different course ratings. Post that, browse to the http://localhost:8080/actuator/metrics/api.courses.rating.distribution.summary URL to access the newly defined distribution summary endpoint. Figure 4.23 shows the output:

Figure 4.23 Outcome of the api.courses.rating.distribution.summary custom metric. The COUNT property indicates how many courses have been created. The TOTAL provides information regarding the aggregated value of the rating. Lastly, the MAX property shows the maximum value of a course rating. For demonstration, we've used the course rating in this example. We can also use other details such as time in units of second, length to capture distribution summary

This completes the discussion of the major metrics that you may need to use in your application. In the next section, you'll learn how to use Prometheus and Grafana to view these metrics in a graphical dashboard.

4.4.10 Metrics dashboard with Prometheus and Grafana

In this section, you'll learn how to use Prometheus to collect the metrics you've defined so far. Note that Prometheus is a monitoring solution and Spring Boot publishes all metrics (built-in and custom) if Prometheus libraries are present in the application classpath. Prometheus uses a different format to represent metrics. Refer to https://github.com/spring-boot-in-practice/repo/wiki/Sample-Prometheus-Metrics for a list of Prometheus metrics. Further, you'll configure Grafana to visualize the Prometheus metrics.

Note

Prometheus (https://prometheus.io/) is an open-source system monitoring and alerting toolkit originally built at SoundCloud. You can find more information on Prometheus documentation available at https://prometheus.io/docs/introduction/overview/. Grafana (https://grafana.com/) provides a set of the graphical

toolkit that lets you collect and visualize the metrics in dashboards in the form of various graphical representations such as Graph, Time Series, Gauge Table, etc.

You can use Prometheus and Grafana either by installing them in your local machine or running the docker images. Refer to the GitHub wiki available at https://github.com/spring-boot-in-practice/repo/wiki/Configuring-Prometheus-and-Grafana for a quick guide on how to set up these applications. You can refer to the Prometheus and Grafana documentation for more details.

Spring Boot provides an easy integration with Prometheus and publish all the metrics under the /actuator/prometheus endpoint. Add the following dependency in the `pom.xml` of your project as shown in the listing 4.44:

Listing 4.44 Prometheus dependency

```
<dependency>
    <groupId>io.micrometer</groupId>
    <artifactId>micrometer-registry-prometheus</artifactId>
    <scope>runtime</scope>
</dependency>
```

We discussed previously that Spring Boot autoconfiguration can configure one or more systems in a Spring Boot application based on the presence of libraries in the application classpath. Adding this dependency enables `PrometheusMetricsExportAutoConfiguration` class which in turn configures the `PrometheusMeterRegistry` bean. This bean is the Prometheus registry plugged in the Metrics facade.

Restart the application and access the http://localhost:8080/actuator/prometheus endpoint URL to view the available metrics. Notice that the metrics are published in a slightly different format.

To proceed with the remaining part of this section, you need to ensure that you've installed and configured Prometheus and Grafana. Refer to the https://github.com/spring-boot-in-practice/repo/wiki/Configuring-Prometheus-and-Grafana for a quick discussion on how to set up these applications. Once you've installed Prometheus, you should be able to access the server and view the metrics. For instance, in this demonstration, we've installed Prometheus in the local machine and can access it through the http://localhost:9090 URL. Prometheus provides a functional query language named `PromQL` (Prometheus Query Language) that lets you select and aggregate metric data. You can view the result either in tabular or graphical format in Prometheus's expression browser. We'll leave it to the reader to explore how to select and view various metric data through `PromQL` (https://prometheus.io/docs/prometheus/latest/querying/basics/).

Although Prometheus lets you view the data in graphical format through the table and simple graphs, the visualization capability of Prometheus is limited. To present data with better visualization, we'll use Grafana as has a rich set of visualization toolkit. Grafana can pull the metric data from the Prometheus server and present it in the Grafana dashboard. You can use the `PromQL` to select the metric and present the metric data in the dashboard.

To use Grafana, you first need to create a data source. In this demonstration, the data source is the Prometheus server. You can then proceed with creating an empty dashboard and add one or more panels to it. Each panel can represent one metric of data. Grafana lets you choose the type of UI toolkit (e.g., Graph, Table, Heatmap, gauge) you would like to use to present the data in the dashboard. Refer to Grafana documentation at https://grafana.com/docs/grafana/latest/getting-started/getting-started/ on how to create a Grafana dashboard. Figure 4.24 shows a sample dashboard created for the demonstration:

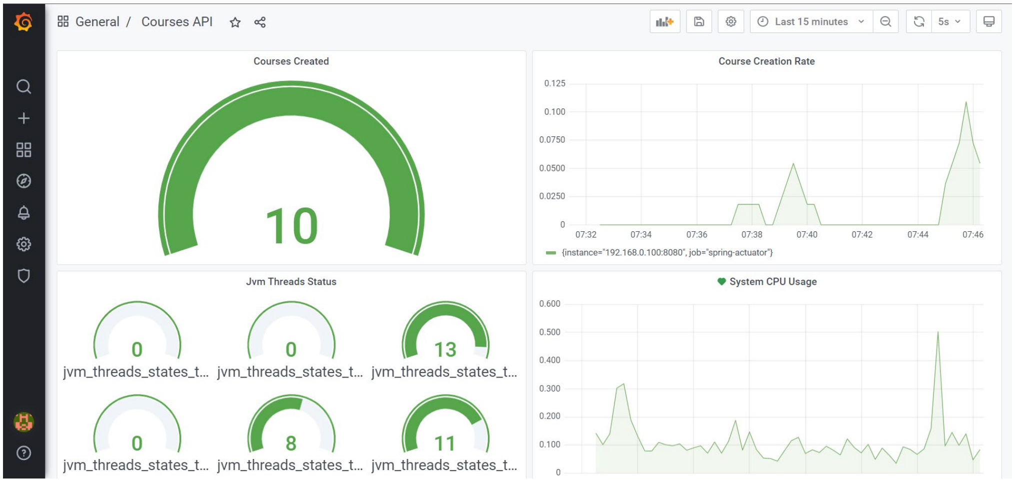


Figure 4.24 Spring Boot Actuator metric in the Grafana dashboard

In figure 4.24, we have shown four panels in the dashboard. The Courses Created panel shows the number of courses created. The second panel Course Creation Rate shows the rate of courses created per minute. The third panel JVM Thread Status shows the threads in the application in various state. The last panel System CPU Usage shows the use of the CPU over a period. The above is a basic dashboard created for demonstration purpose. You can explore the various metrics and present them in a variety of visualization (e.g., Bar, Chart, Table, Heatmap etc.) in Grafana.

4.5 Chapter Summary

We've come along a long way with our Spring Boot Journey. You can now develop and monitor Spring Boot applications with the concepts covered so far. Let's quickly summarize the concepts you've learned in this chapter:

- Provided an in-depth discussion on Spring Boot auto-configuration. We've explored various conditional annotations which play a critical role in implementing auto-configuration. Explored a built-in class `DataSourceAutoConfiguration` to understand how it works in a Spring Boot application
- We discussed Spring Boot DevTools which provided a suite of features for a pleasant

development experience. The automatic application restart, disabling caching and browser refresh are a few notable features

- Explored Spring Boot `FailureAnalyzer` and its role to validate various application start-up issues. Besides, we also discussed how to implement a custom `FailureAnalyzer`
- Provided an in-depth discussion on the Spring Boot actuator and its various endpoints. We then explored the /info and /health endpoint in further detail. Besides, we also learned several techniques on how to define and include custom application information and health status in these endpoints
- Explored the built-in metrics exposed by Spring Boot. We also discussed how to create custom metrics such as Counter, Gauge, Timer, and Distribution Summary. Lastly, we demonstrated how to use Prometheus and Grafana to monitor and view the metrics in a GUI console in real-time

In Chapter 5, you'll learn to secure your Spring Boot applications with Spring Security. You'll explore Spring Security basic concepts, various fundamental security techniques such as basic and JDBC authentication. Let's get started!

5

Securing Spring Boot applications

This chapter covers

- **Overview of Spring Security, Common Security threats**
- **Enabling Spring Security in a Spring Boot application and understanding Spring Security Auto-configuration**
- **Customizing Spring Security with in-memory, JDBC, and LDAP authentication**
- **Implementing HTTP basic authentication in a Spring Boot project**

In the past chapters, you've learned several essential techniques to build Spring Boot applications. You are now well-versed with core Spring Boot concepts, understood several techniques to communicate to the database, can monitor Spring Boot applications with Spring Boot Actuator, and in a position to start building enterprise-grade Spring Boot applications. However, before you are super excited and announce to the world your newly acquired skills, there is another essential technique that you need to master on. *What about the security of our Spring Boot applications*? In this chapter, you'll explore several techniques to secure Spring Boot applications with Spring Security.

5.1 Introducing Spring Security

In the previous chapters, you've seen the use of some of the core Spring modules such as Spring MVC, Spring Data and features such as Spring Boot Actuator, and DevTools. Spring Framework provides a dedicated module called Spring Security that focuses on the security aspects of the Spring applications. Spring Boot provides easy integration with Spring Security with the `spring-boot-starter-security` dependency. In this chapter, we'll demonstrate the use of Spring Security in Spring Boot applications.

However, before we deep-dive into the techniques on how to implement various security features offered by Spring Security, let us explore some of the default security features offered by Spring Security in a Spring Boot application:

- Spring Security enforces the application users to be authenticated before accessing it
- If the application does not have a `login` page, Spring Security generates a default login page for user login and lets the user logs out from the application
- Spring security provides a default user named `user` and generates a default password (printed in the console log) for form-based login
- Provides several Password Encoders to encode the plain-text password and store it in the persistence storage
- Prevents Session Fixation attacks by changing the session id after successful user authentication

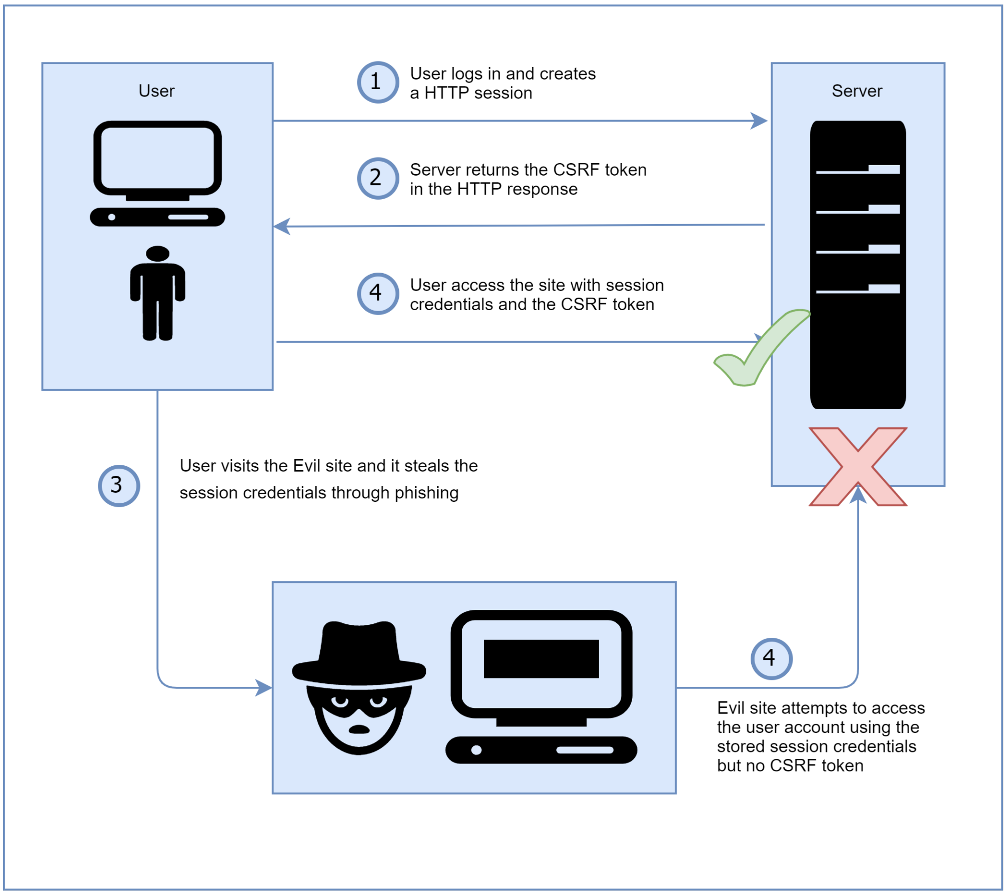


Figure 5.1 CSRF protection in a Spring Security application

- Spring Security provides default protection from Cross-Site Request Forgery (CSRF) attack. It does so by including a randomly generated token in the HTTP response. It expects this token to be available in all subsequent form-based requests that intend to perform a state-changing operation in the application. A malicious user won't have access to the token and thus can't make CSRF attacks. Figure 5.1 demonstrates the CSRF protection with Spring Security.

- By default, Spring security includes several HTTP response headers that prevent many common types of attacks. These headers are shown in Listing 5.1:

Listing 5. 1 Default Spring Security HTTP Response Headers

```
Cache-Control: no-cache, no-store, max-age=0, must-revalidate
Pragma: no-cache
Expires: 0
X-Content-Type-Options: nosniff
Strict-Transport-Security: max-age=31536000 ; includeSubDomains
X-Frame-Options: DENY
X-XSS-Protection: 1; mode=block
```

Let us explore these headers and their role to protect a Spring Boot application:

- The `Cache-Control` header instructs the browser to disable the browser caching completely
- The `X-Content-Type-Options` header prevents the browser from attempting to guess the content type of a request when the `Content-Type` header is missing in the request
- The Strict-Transport-Security header enforces the `HTTP Strict Transport Security (HSTS)`. Refer to Spring Security reference documentation at https://docs.spring.io/spring-security/site/docs/current/reference/html5/#headers-hsts to learn more on `HSTS`
- The `X-Frame-Options` HTTP header with `DENY` configuration indicates the browser not to load application pages in a `frame`, `iframe`, or `embed`. This prevents clickjacking attacks in a web application
- The `X-XSS-Protection` HTTP header with `1; mode=block` prevents reflective `Cross-Site-Scripting` attacks. The value `1` enables the browser's built-in XSS filtering and the option `mode=block` lets the browser prevent loading a page if an XSS attack is detected

You can find a detailed discussion on these and other HTTP response headers in the Spring Security reference document available at https://docs.spring.io/spring-security/site/docs/current/reference/html5/#headers.

5.2 Hello Spring Security with Spring Boot

In this section, we'll introduce Spring Security in the course tracker application that we're building since previous chapters. Let's explore this in the next technique.

TECHNIQUE ENABLE APPLICATION SECURITY WITH SPRING SECURITY IN A SPRING BOOT APPLICATION

Problem

You've developed a web application with Spring Boot. However, there is no application security implemented in the application. You need to implement basic application security in the application.

Solution

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/introducing-spring-security/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/introducing-spring-security/course-tracker-final

The simplest way to provide security in a Spring Boot application is to introduce the spring-boot-starter-security dependency in the application's pom.xml file. This dependency is shown in Listing 5.2:

Listing 5.2 Spring Security Starter Dependency

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-security</artifactId>
</dependency>
```

The `spring-boot-starter-security` dependency brings all the necessary library and enables Spring Security in the Spring Boot application. Spring Boot starter dependency includes core Spring Security libraries such as `spring-security-config`, `spring-security-web` into the application.

You can start the application using the IDE's run configuration option. Once the application successfully starts, let us access the `index` page of the application by accessing the URL http://localhost:8080/index. To your surprise, you'll find a `login` page asking you to sign in instead of presenting the application `index` page. This happens because you've incorporated Spring Security in the application, and it has automatically enabled a form-based login in the application. By default, Spring Security displays the login page as shown in Figure 5.2 to sign in to the application:

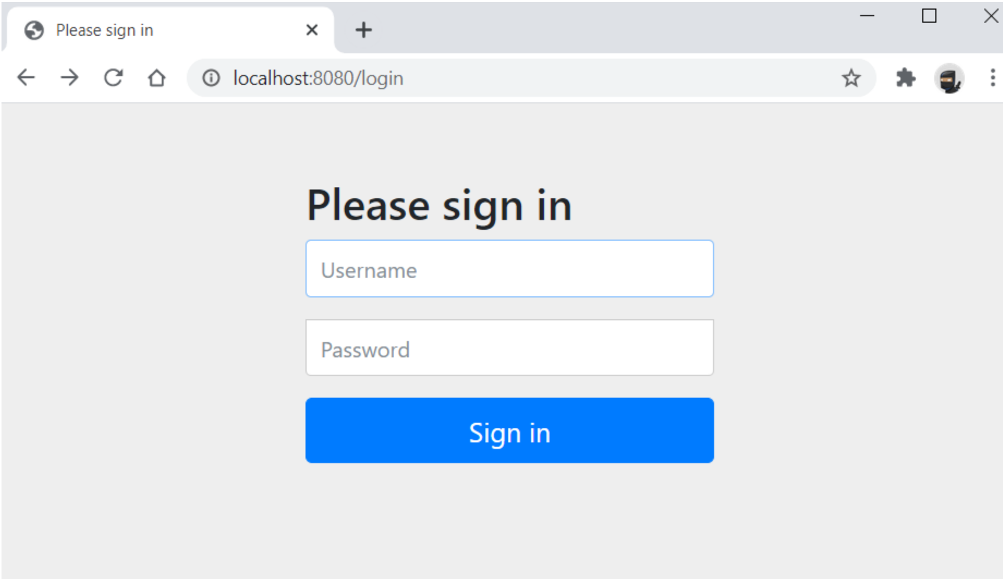


Figure 5.2 Default login page for user sign-in. This login page is generated by Spring Security in the absence of a custom login page in the application. You can customize this login page to configure a custom page

The default username for the application is the `user`. Spring Boot generates and prints a password in the console log. This password changes each time the application is restarted. This default password might not be convenient for a production application where you would need the user to configure their passwords. Later in this chapter, you'll notice Spring Boot is flexible enough and let you achieve the same. However, for now, let us proceed with the default password printed in the console as shown in Figure 5.3:

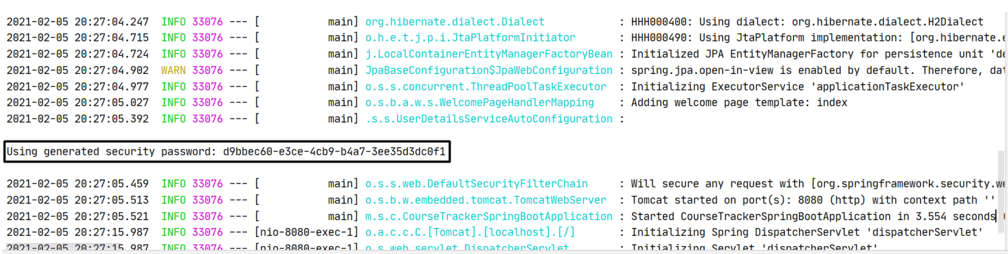


Figure 5.3 Spring Security generated password printed in the console log

Log in to the application with the username as the `user` and the password as printed in the console. For instance, in this example, the password is `d9bbec60-e3ce-4cb9-b4a7-3ee35d3dc0f1`. After successful login, you'll be redirected to the application index page as shown in Figure 5.4:

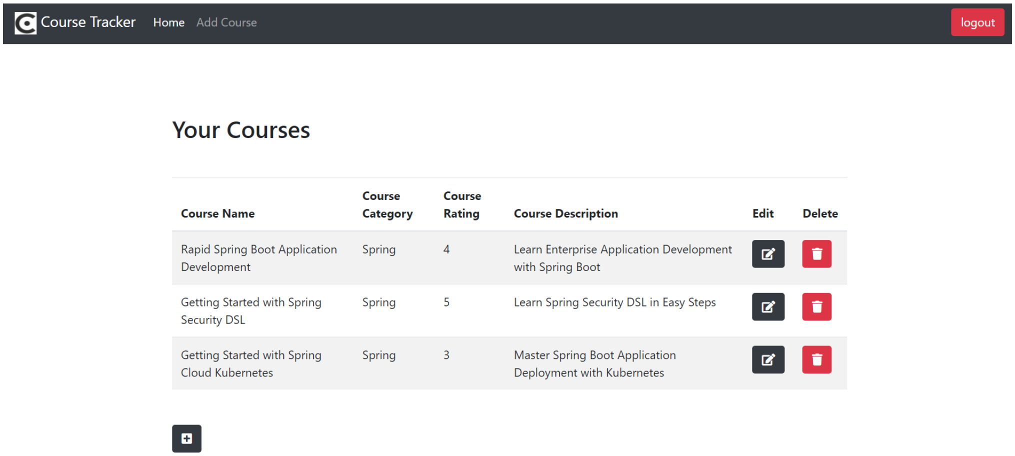


Figure 5.4 Course Tracker application index page. On application start-up, we've initialized the database schema and created three courses. Thus, three courses are shown in the course list

You are now logged in to the application and can access all application features such as adding a new course, edit and delete an existing course. Besides, you can also log out from the application by clicking the `logout` button available at the top right corner of the application. Once logged out, you will be redirected to the login page and can't access any of the application features unless you are logging in again. By default, Spring Security exposes the `/logout` endpoint. In the course tracker example, we've included the logout button in the index page of the application. Once you click on the logout button, the `/logout` endpoint is invoked, and you are logged out from the application.

Discussion

In this technique, you've seen how to enable default application security in a Spring Boot application with Spring Security. You've observed that introducing `spring-boot-starter-security` dependency in the `pom.xml` magically enables some level of application security through a form-based login in the application. Besides, Spring Boot also generates a password to login into the application.

The introduction of `spring-boot-starter-security` dependency integrates the Spring Security ecosystem to the application. You can inspect the `spring-boot-starter-security` dependency in the `pom.xml` file and find that it has transitive dependencies to `spring-security-config` and `spring-security-web` libraries. Together, these two libraries provide the necessary support for Spring Security.

As you've seen before with Spring Boot auto-configuration, the presence of Spring Security libraries in the application classpath enables Spring Boot to configure necessary security components in the application. You'll shortly examine what are these components and how these are configured in the Spring Security auto-configuration section.

Before we make ourselves familiar with the internal workings of Spring Security, let us provide a very high-level overview of the authentication process in a typical web application. The sequence diagram in Figure 5.5 provides the sequence of steps.

1. You attempt to access the home page of an application by accessing a web URL (e.g., http://localhost:8080/ in the course tracker application)
2. The request reaches the server, and it finds that you are trying to access a protected resource
3. As you are not presently authenticated, the server responds indicating that you need to be authenticated. The response could be an HTTP response code or redirect to a web page based on the security implementation at the server

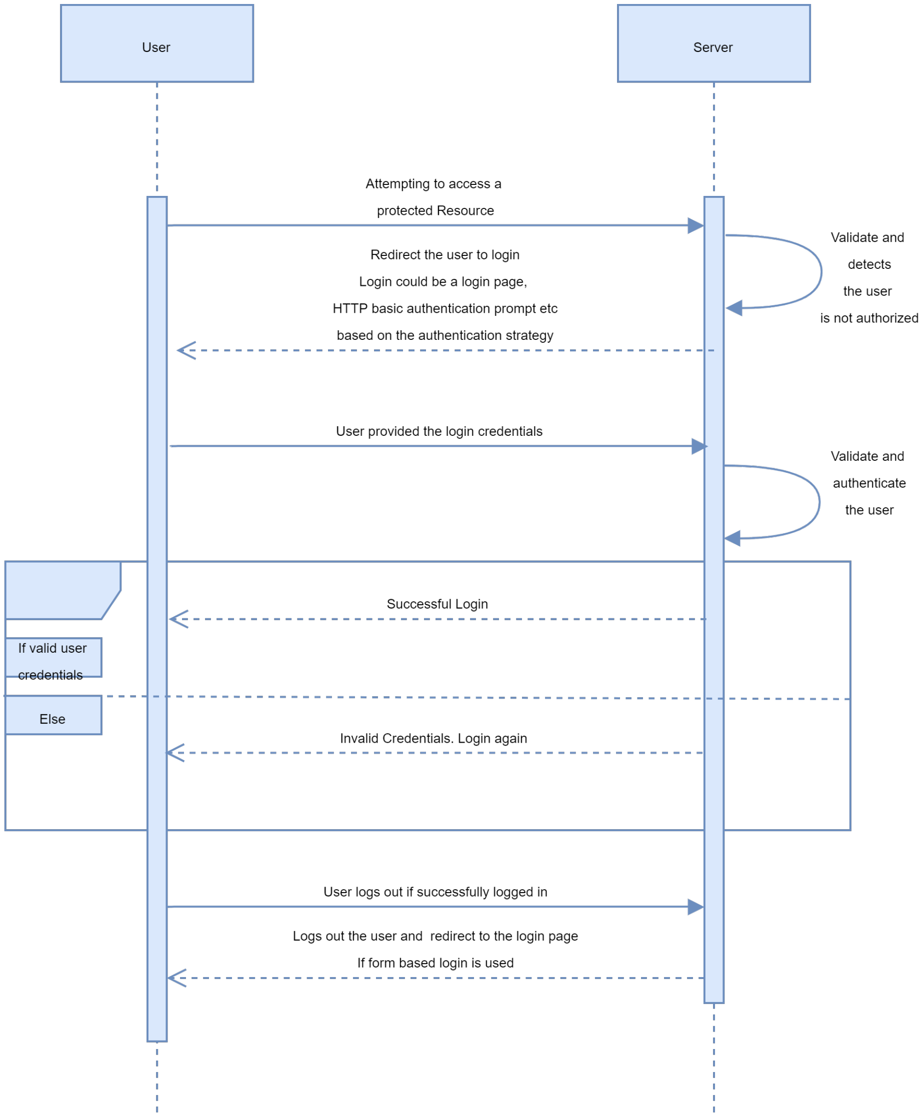


Figure 5.5 Sequence diagram of user authentication in a web application

4. Based on the authentication mechanisms implemented in the server, the browser will either redirect you to a login page or retrieve the credentials through other modes such as the HTTP basic authentication dialogue box or a cookie. You'll learn how to configure the authentication mechanisms in the server in later techniques

5. The credentials are then sent back to the server. Browsers can either use an HTTP POST request (e.g., for a login page) or an HTTP header (e.g., for BASIC authentication) to pass the credentials to the server
6. The server validates the credentials. If the credentials are valid, the login is considered successful, and the server moves to the next step. However, if the credentials are invalid, the browser typically asks to try again. So, you return to step 3
7. If the login is successful and logged in with sufficient authorities, then the request will be successful. Otherwise, the server returns with an HTTP error code 403, which indicates forbidden
8. If the user logs out from the application, the server clears the session and other login credentials from the server and logs out the user. It then redirects the user to the login or the index page of the application based on the security configuration of the server

In the next section, you'll begin with Spring Security architecture, and learn how the above steps are implemented in Spring Security.

Note

Spring Security is a large topic and contains numerous features. It is beyond the scope of this text to provide in-depth coverage on Spring Security concepts, and various features it offers. In this book, we'll cover the bare minimum Spring Security concepts that you need to understand to continue with the subsequent techniques.

In this chapter and the next, you'll learn several techniques that show how to implement various Security features leveraging Spring Security. Besides, as this is a Spring Boot book, we'll keep our focus limited to the use of Spring Security in the context of Spring Boot.

For an in-depth understanding of Spring Security, we recommend referring dedicated Spring Security books or the Spring Security reference available at https://docs.spring.io/spring-security/site/docs/current/reference/html5/. Manning has a dedicated book on Spring Security available at https://www.manning.com/books/spring-security-in-action.

9.

5.2.1 Filter, FilterChain, and Spring Security

In a typical Java web application, a client requests the server to access a resource through HTTP or HTTPS protocol. The client request in the server is handled by a servlet. The servlet processes the HTTP request and provides an HTTP response. This response is sent back to the client. In a Spring web application, this servlet is the `DispatcherServlet` which handles all incoming requests to the application.

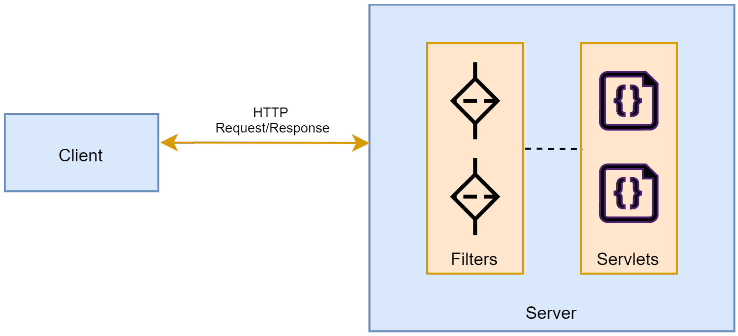


Figure 5.6 High-level overview of request-response processing in a Spring Security application

A major component of Servlet specification that plays a pivotal role in request-response processing is a `Filter`. A Filter sits before a `Servlet` and intercepts the request-response and can make changes to the request-response objects as shown in Figure 5.6. One or more filters can be configured through a `FilterChain` and all Filters part of the chain can intercept and modify the request-response objects. Many of the Spring Security features are based on these filters. Both `Filter` and `FilterChain` are interfaces from `javax.servlet` package.

Similar to how a special servlet named `DispatcherServlet` handles all incoming requests in a Spring web application, a special filter named `DelegatingFilterProxy` is used to enable Spring Security. This filter is registered to the servlet container and it starts intercepting the incoming requests. In a Spring Boot application, this registration is done by Spring Boot's Spring Security auto-configuration. Let us now have a look into the Filter interface as shown in Listing 5.3:

Listing 5.3 The Filter Interface

```
public interface Filter {

    public default void init(FilterConfig filterConfig) throws ServletException {}

    # Contains the logic that the filter needs to perform
    public void doFilter(ServletRequest request, ServletResponse response,
            FilterChain chain) throws IOException, ServletException;

    public default void destroy() {}
}
```

A `Filter` implementation needs implement three methods `(init(), doFilter(),` and `destroy(..)`) as shown in Figure 5.7:

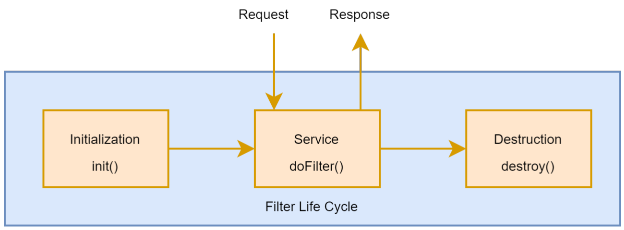


Figure 5.7 Filter life cycle methods. The init(..) method contains a code snippet that is invoked at the time of the filter initialization and destroy(..) method contains code that is invoked when the filter is about to go out of service from the container. The doFilter(..) method performs the request handling and returns a response to the caller.

The three filter methods are discussed below:

- The `init(..)` is invoked by the web container to indicate to a filter that it is being placed into service
- The `doFilter(..)` is the main method where the actual action of the filter is done. It has access to the request, response, and `FilterChain` objects. The `FilterChain` let the current filter invoke the next filter in the chain once its processing is over
- The `destroy(..)` is called when the container takes the filter out of service

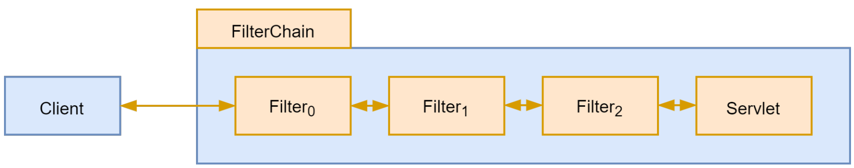


Figure 5.8 Representation of a FilterChain. A Client invokes the first filter in the chain. This filter then invokes the subsequent filter in the chain. Lastly, the request reaches a servlet which is at the end of the FilterChain.

A `FilterChain` is another component provided by the servlet container that provides a view into the invocation chain of a filtered request. Figure 5.8 shows a sample filter chain. Filters use the `FilterChain` to invoke the next filter in the chain or the actual resource (e.g., the Servlet) if the filter is the last in the chain. A `FilterChain` has only one method named `doFilter()`. If you revisit Listing 5.3, you'll notice the `doFilter()` method in the `Filter` interface has access to the `FilterChain` along with the `ServletRequest` and `ServletResponse` instances. Thus, a `Filter` can perform its assigned task and access the `FilterChain` to invoke the next filter in the chain. Listing 5.4 shows the `FilterChain` interface:

Listing 5.4 The FilterChain interface

```
public interface FilterChain {
    public void doFilter(ServletRequest request, ServletResponse response) throws
       IOException, ServletException;
```

```
}
```

Spring Security makes heavy use of the Filters to implement various security features. The core foundation of Spring Security is based on these Filters. For instance, if Spring Security needs to perform a username and password-based authentication, it delegates the request to a filter named `UsernamePasswordAuthenticationFilter` that is responsible for authenticating the user based on the supplied credentials. Similarly, for HTTP basic authentication Spring Security uses `BasicAuthenticationFilter` to do the authentication.

Let us now discuss two major Filter implementations in Spring Security – `DelegatingFilterProxy` and the `FilterChainProxy` that acts as the entry point for an HTTP request into Spring Security infrastructure. Further, you'll also explore the `SecurityFilterChain` interface.

5.2.2 Spring Security Architecture

In the previous section, we've provided a high-level overview of `Filter`, `FilterChain`, and discussed how Spring Security leverages the features provided by these components. In this section, let us discuss the `DelegatingFilterProxy`, the `FilterChainProxy` filter, and the `SecurityFilterChain` class.

A `Filter` is a very useful component in the Servlet specification. Spring Security uses it to implement several of its core functionalities and authentication strategies. Although useful, a `Filter` instance is a servlet container component, and it is managed by the servlet container. The container instantiates, initializes, and destroys it. The servlet specification doesn't require any kind of Spring integration to deal with a Filter.

Spring Security provides a filter called `DelegatingFilterProxy` to bridge this gap. You configure this filter with the servlet container so that its life cycle is managed by the servlet container. We then define a separate Filter implementation and make it a Spring bean managed by Spring. This Spring-managed bean is configured as a delegate in the `DelegatingFilterProxy`. At runtime, `DelegatingFilterProxy` finds out this actual Spring-managed filter and delegates the request for processing.

The `FilterChainProxy` class is the other Filter implementation that the `DelegatingFilterProxy` delegates the HTTP requests. It contains one or more `SecurityFilterChain` that processes the HTTP request. Figure 5.9 shows a high-level overview of these components:

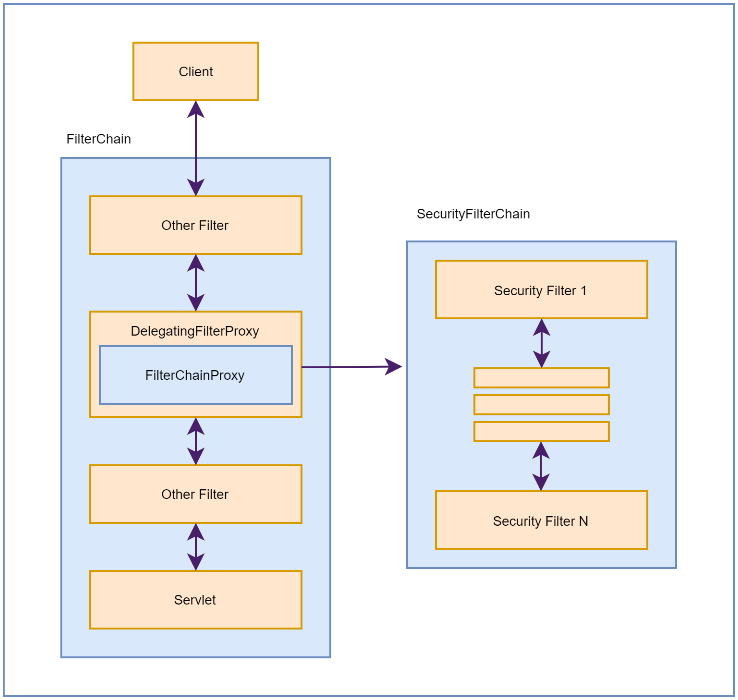


Figure 5.9 Position of DelegatingFilterProxy, FilterChainProxy, and the SecurityFilterChain while accessing a resource in the server. One or more filter sits behind the actual servlet that serves the client request. DelegatingFilterProxy is a special filter that delegates the request processing to FilterChainProxy which in turn leverages the filters in the SecurityFilterChain.

The `SecurityFilterChain` interface has two methods – `matches(..)` and `getFilters(..)`. The first method lets Spring Security evaluate whether the current `SecurityFilterChain` matches the incoming request. Spring Security provides the `RequestMatcher` interface and provides several implementations to perform the match. For instance, to match any request it provides the `AnyRequestMatcher` that matches all HTTP requests. Spring Security also provides ant-style matcher `AntPathRequestMatcher` that matches the URL paths.

If there is a match, the `getFilters(..)` method returns the list of filters that needs to be applied to the incoming request. If you continue with Spring Security default configurations, then it configures a default `SecurityFilterChain` named `DefaultSecurityFilterChain` and configures a list of required filters. Besides, it also ensures that all HTTP request passes through this filter chain.

Based on the application design and other security requirements, you may choose to override the default security configurations and configure one or more `SecurityFilterChains` in an application. For instance, you might configure one `SecurityFilterChain` for a set of application URLs (e.g., `/courses`) that has access to one module of the application. Similarly, you can configure another `SecurityFilterChain` for another set of URLs (e.g., `/users`). Since `SecurityFilterChain` consists of a list of filters that provides security, this approach provides better flexibility in your security implementation. For example, you may choose to implement form-based authentication for the *user* controller of the application. Whereas, for the courses controller, you can use HTTP basic authentication.

Implementing Multiple SecurityFilterChains

In case you are configuring multiple `SecurityFilterChains` in your application, you need to ensure the order of the chains. You can use Spring's @Order annotation to order the SecurityFilterChains. The `SecurityFilterChain` for a more specific application URL should be ordered before the generic ones. Otherwise, the generic `SecurityFilterChain` will always match the incoming requests and the specific `SecurityFilterChain` will never invoke. For instance, if you have two filter chains -for the URLs - /admin and /*, you need to ensure that /admin specific filter chain orders before the /* as the latter one is generic and matches all requests.

5.2.3 Authenticating a User

Before discussing authentication steps in detail, let us first discuss a few of the notable classes and concepts that play an important role in authentication:

SecurityContextHolder: This class associates the `SecurityContext` instance to the current execution thread. A `SecurityContext` contains information about an authenticated principal such as username, user authorities, and other additional user identification details. The `SecurityContextPersistenceFilter` manages the `SecurityContext` instance. This filter tries to retrieve the `SecurityContext` from a `SecurityContextRepository`. In a web application, the `HttpSessionSecurityContextRepository` implementation tries to load the `SecurityContext` from the HTTP Session. In the beginning, as we are not authenticated, an empty security context is added to the `SecurityContextHolder`. Figure 5.10 shows a block diagram of `SecurityContextHolder`:

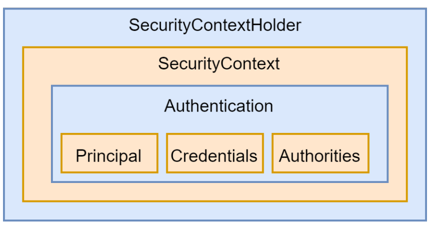


Figure 5.10 A SecurityContextHolder holds a SecurityContext which in turn holds the Authentication details.

AuthenticationFilters: These filters are used to authenticate a principal and Spring Security provides several authentication filters. For instance, the `BasicAuthenticationFilter` performs HTTP basic authentication, the `DigestAuthenticationFilter` performs `Digest` authentication. Once an authentication filter authenticates a principal, it places an authentication token in the `SecurityContext`. This authentication token then can be used by other filters in the filter chain

ExceptionTranslationFilter: The `ExceptionTranslationFilter` plays a key role in the authentication process. Based on whether the user is already authenticated or the user has the necessary access to a resource there are two exception types – `AuthenticationException` and `AccessDeniedException`. The `ExceptionTranslationFilter` addresses both these exception types. For an `AuthenticationException`, this filter redirects to an `AuthenticationEntryPoint` to initiate the authentication process. Based on the configured authentication mechanisms, Spring Security provides several `AuthenticationEntryPoint` implementations. For an `AccessDeniedException`, the request is redirected to an appropriate `AccessDeniedHandler` implementation. One key benefit of the Spring Security architecture is that it is extremely flexible and allows you to define custom implementations if the framework defined ones do not meet your requirement, or you need to further customizations.

UserDetailsService: The `UserDetailsService` provides the necessary abstractions to map user-specific data to Spring Security's `UserDetails` that contains the core user information. You can either choose to use Spring Security's implementations or provide a custom implementation

AuthenticationProvider: The `AuthenticationProvider` process a specific Authentication implementation. It accepts an authentication request object, performs the authentication, and returns a fully authenticated instance. It throws `AuthenticationException` if the authentication fails.

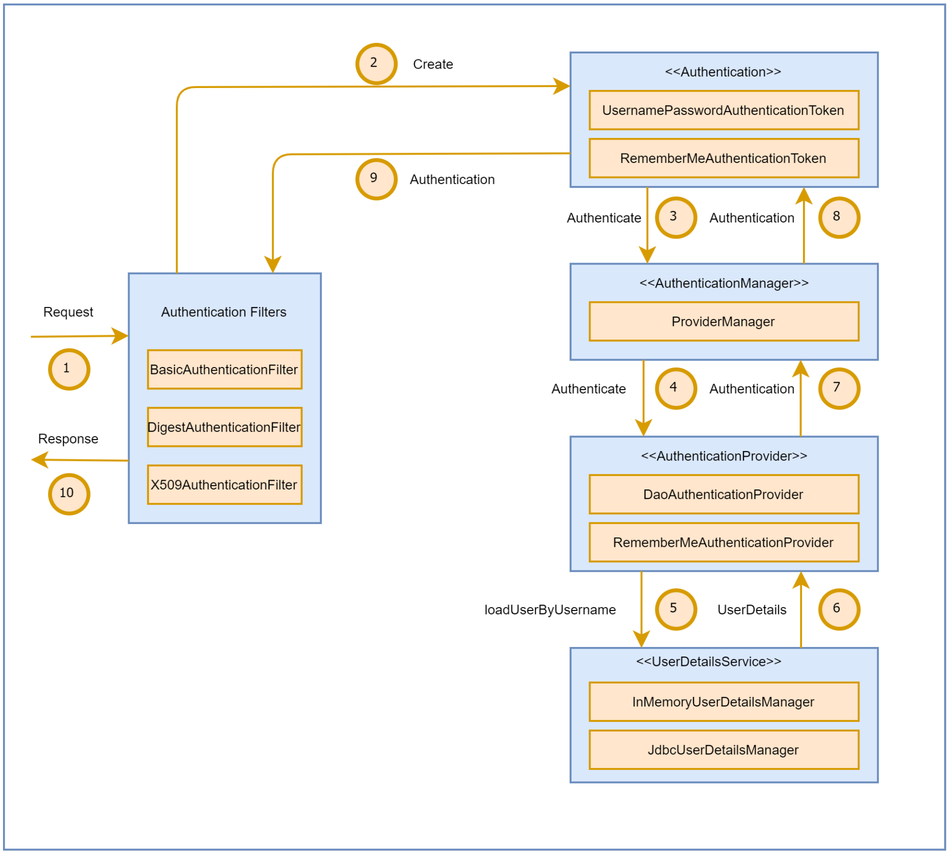


Figure 5.11 High-level overview of the Spring Security authentication steps

Let us now understand how the authentication process is implemented in Spring Security. Figure 5.11 shows this process through a block diagram.

10. The initial request is handled by the authentication filters. Based on the security strategy configured in the server (you'll notice how you can configure this shortly), an appropriate authentication filter handles the request. For instance, the `BasicAuthenticationFilter` processes the request if the HTTP basic authentication is configured
11. The authentication filter creates an authentication request from the incoming request
12. It then invokes an `AuthenticationManager` to authenticate the request.
13. The `AuthenticationManager` contains a list of `AuthenticationProvider` instances. An `AuthenticationProvider` has two methods – `supports(..)` and `authenticate(..)`. The `supports(..)` method decides whether the

AuthenticationProvider supports the authentication type. The authenticate(..) performs the actual authentication

14. The AuthenticationProvider uses the UserDetailsService implementation to perform the authentication. The UserDetailsService loads the UserDetails from an identity store that contains user account details such as user authorities, username, password, and other account-related statistics. The AuthenticationProvider uses the loaded UserDetails instance and performs the actual authentication. The authenticated principal is then returned to the AuthenticationManager and the returned Authentication object is stored in the SecurityContext for later usage by other filters

Role of UserDetailsService

The UserDetailsService interface performs a crucial role by bridging the application-specific user details to Spring's UserDetails implantations. The UserDetails interface represents an application user in a Spring application and contains various user account-related information. The UserDetailsService exposes a loadUserByUsername (String username) method that lets you connect to the application-specific identity store and load the user account details by the supplied username. Spring Security provides several implementations of this interface such as InMemoryUserDetailsManager and JdbcUserDetailsManager. Besides, you can also provide your custom implementations of this interface by defining the loadUserByUsername(..) method. We'll discuss the custom implementation in a later technique.

5.2.4 Spring Security Auto-configuration

By now, you've acquired the foundational knowledge in Spring Security and understand various building blocks such as DelegatingFilterProxy, FilterChainProxy, SecurityFilterChain, list of filters, and several other components. However, the last piece of the puzzle is how these components are configured and work together in a Spring Boot application. As you might have already anticipated, Spring Boot does this with its smart and efficient auto-configuration strategies. Let us explore how Spring Security auto-configuration is implemented in Spring Boot. Figure 5.12 shows the main auto-configuration classes:

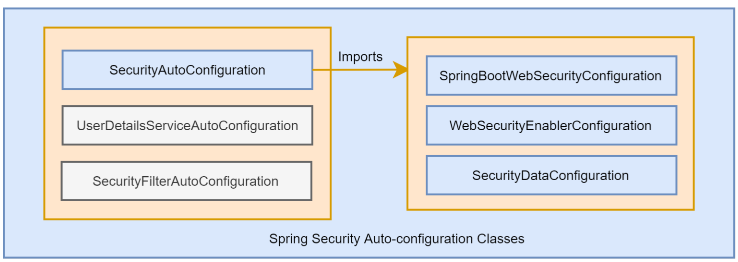


Figure 5.12 Spring Security auto-configuration classes

Spring Boot uses three configuration classes - `SecurityAutoConfiguration`, `UserDetailsServiceAutoConfiguration`, and `SecurityFilterAutoConfiguration` to auto-configure the core Spring Security components in a Spring Boot application.

SecurityAutoConfiguration

The `SecurityAutoConfiguration` is at the heart of Spring Security auto-configuration. It leverages three other classes - `SpringBootWebSecurityConfiguration`, `WebSecurityEnablerConfiguration`, `SecurityDataConfiguration` to perform the auto-configuration. Listing 5.5 shows this class:

Listing 5.5 SecurityAutoConfiguration

```
package org.springframework.boot.autoconfigure.security.servlet;

// Imports ommitted

@Configuration(proxyBeanMethods = false)
@ConditionalOnClass(DefaultAuthenticationEventPublisher.class)
@EnableConfigurationProperties(SecurityProperties.class)
@Import({ SpringBootWebSecurityConfiguration.class, WebSecurityEnablerConfiguration.class,
        SecurityDataConfiguration.class })
public class SecurityAutoConfiguration {

       @Bean
       @ConditionalOnMissingBean(AuthenticationEventPublisher.class)
       public DefaultAuthenticationEventPublisher
       authenticationEventPublisher(ApplicationEventPublisher publisher) {
         return new DefaultAuthenticationEventPublisher(publisher);
       }

}
```

Let us discuss these classes briefly. The `SpringBootWebSecurityConfiguration` class is loaded if security is available and we haven't defined our configuration. Listing 5.6 shows the `WebSecurityEnablerConfiguration` class:

Listing 5.6 WebSecurityEnablerConfiguration

```
package org.springframework.boot.autoconfigure.security.servlet;
// imports omitted

@Configuration(proxyBeanMethods = false)
@ConditionalOnMissingBean(name = BeanIds.SPRING_SECURITY_FILTER_CHAIN)
@ConditionalOnClass(EnableWebSecurity.class)
@ConditionalOnWebApplication(type = ConditionalOnWebApplication.Type.SERVLET)
@EnableWebSecurity
class WebSecurityEnablerConfiguration {

}
```

The `WebSecurityEnablerConfiguration` is a configuration class that adds the `@EnableWebSecurity` annotation in the Spring configuration if Spring Security is present in the classpath. This is to ensure that the `@EnableWebSecurity` annotation is present with default Spring Security auto-configuration. However, if we explicitly add this annotation in our Spring Security configuration file or define a bean with the name `springSecurityFilterChain` this configuration backs off and does nothing.

The `@EnableWebSecurity` annotation performs a pivotal role in Spring Security configuration. It provides three key configurations along with other functionalities. It provides default `WebSecurityConfiguration`, `HttpSecurityConfiguration`, and enables `@EnableGlobalAuthentication`. The `WebSecurityConfiguration` creates the `WebSecurity` instance that performs the web-based security in Spring Security. Web Security lets you manage the security of web components in your application (e.g., images, CSS, JS files). The `HttpSecurityConfiguration` creates the `HttpSecurity` bean that allows us to configure web security for the HTTP requests. The `@EnableGlobalAuthentication` annotation provides the necessary configuration to configure the `AuthenticationManagerBuilder` instance. We use this instance to configure the `AuthenticationManager`.

If you need to customize the default configuration provided in the above configuration classes, you can easily do that by defining a class that extends the `WebSecurityConfigurerAdapter` or implementing the `WebSecurityConfigurer` interface. In the upcoming techniques, you'll notice that we heavily use the `WebSecurityConfigurerAdapter` class to customize `WebSecurity`, `HttpSecurity` implementations, and use the `AuthenticationManagerBuilder` to configure various types of authentications in our Spring Boot application.

The `SecurityDataConfiguration` class provides support for Spring Data integration with Spring Security. It defines a bean named `SecurityEvaluationContextExtension` which allows Spring Security to be exposed as `SpEL` expressions to create Spring Data queries. Refer to the Java Documentation of this class available at https://docs.spring.io/spring-security/site/docs/4.2.20.RELEASE/apidocs/org/springframework/security/data/repository/query/SecurityEvaluationContextExtension.html for a better understanding of how this works.

UserDetailsServiceAutoConfiguration

The `UserDetailsServiceAutoConfiguration` class automatically configures `InMemoryUserDetailsManager` if an instance of `UserDetailsService` is not configured in the application. The default implementation contains a user with the default username as a `user` and a generated password which is a random UUID. In the previous technique, you have seen this generated password printed in the application console. You can customize and provide your implementation of the `UserDetailsService` interface so that Spring Security's default configuration can back off and the custom implementation takes effect. You'll see this in practice in the upcoming techniques.

The last auto-configuration that we'll discuss is the `SecurityFilterAutoConfiguration` class that configures the `DelegatingFilterProxyRegistrationBean`. This is a `ServletContextInitializer` that registers the Spring Security filter `DelegatingFilterProxy`. This auto-configuration class is invoked after the `SecurityAutoConfiguration`.

5.3 Implementing Spring Security

In the previous sections, you've learned several concepts related to Spring Security architecture, its authentication mechanism, and the Spring Security auto-configuration by Spring Boot. In this section, you'll implement several techniques that explain the use of various Spring Security features in a Spring Boot based web application. In the next technique, let us customize the login page of the course tracker application.

TECHNIQUE CUSTOMIZE THE DEFAULT SPRING SECURITY LOGIN PAGE OF A SPRING BOOT APPLICATION

Problem

In the previous technique, you've introduced Spring Security in the course tracker application and noticed that Spring Security has enabled user log-in in the application with a default `login` page. You want to customize the login page with a custom login page.

Solution

The default `login` page generated and provided by Spring Security is a basic one and just does the job. However, there are several reasons you'll be interested to customize this page. For instance, you might want to keep the application login page in line with your application's web page design. Besides, you might implement additional authentication strategies such as the additional security pin along with the regular login, One Time Password (OTP), or a captcha.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/implementing-custom-loginpage/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/implementing-custom-loginpage/course-tracker-final

Let us first add a new login page in the application which is in line with the course tracker application design. Place this page inside the templates folder under `src\main\resources` folder. Listing 5.7 shows the `login.html` page:

Listing 5.7 Course Tracker Application Login Page

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
<meta charset="utf-8">
<meta http-equiv="x-ua-compatible" content="ie=edge">
<title>Login</title>
<meta name="viewport" content="width=device-width, initial-scale=1">
# Custom Stylesheet and the Bootstrap configuration
<link rel="stylesheet" type="text/css"
      href="http://cdn.jsdelivr.net/webjars/bootstrap/4.1.0/css/bootstrap.min.css"
```

```
       th:href="@{/webjars/bootstrap/css/bootstrap.min.css}" />
<script src="http://cdn.jsdelivr.net/webjars/bootstrap/4.1.0/js/bootstrap.min.js"
       th:src="@{/webjars/bootstrap/js/bootstrap.min.js}"></script>
<script src="http://cdn.jsdelivr.net/webjars/jquery/3.3.1/jquery.min.js"
       th:src="@{/webjars/jquery/jquery.min.js}"></script>
</head>

<body>
      # Navigation Bar
       <nav class="navbar navbar-dark bg-dark navbar-expand-sm">
         <a class="navbar-brand brand-text" href="#">
                  <img src="/images/logo.png" width="30" height="30" alt="logo">
                  Course Tracker
         </a>
         <button class="navbar-toggler" type="button" data-toggle="collapse" data-
       target="#navbar-list" aria-controls="navbarNav" aria-expanded="false" aria-
       label="Toggle navigation">
                  <span class="navbar-toggler-icon"></span>
         </button>
         <div class="collapse navbar-collapse justify-content-between" id="navbar-list">
                  <ul class="navbar-nav">
                           <li class="nav-item">
                                    <a class="nav-link" href="#"
       th:href="@{/index}">Home</a>
                           </li>
                           <li class="nav-item">
                                    <a class="nav-link" href="#" th:href="@{/addcourse}">Add
       Course</a>
                           </li>
                  </ul>
         </div>
       </nav>
      # Login header
       <div class="container my-5">
         <div class="row">
                  <div class="col-md-3"></div>
                  <div class="col-md-6">
                           <h2 class="mb-1 text-center">Login</h2>
                  </div>
                  <div class="col-md-3"></div>
         </div>
        # Login Form
         <div class="row">
                  <div class="col-md-3"></div>
                  <div class="col-md-6">
                           <form th:action="@{/login}" method="post">
                                    <div class="form-group">
                                             <label for="username">Username</label>
                                             <input type="text" class="form-control"
       name="username" placeholder="Enter Username" required autofocus>
                                    </div>
                                    <div class="form-group">
                                             <label for="password">Password</label>
                                             <input type="password" class="form-control"
       name="password" placeholder="Enter Password" required autofocus>
                                    </div>
                                    <button type="submit" class="btn btn-
       dark">Submit</button>
                           </form>
```

```
                  </div>
                  <div class="col-md-3"></div>
         </div>
       </div>
</body>
</html>
```

This is a basic HTML page designed with Bootstrap. There is a login form that accepts the username and password of the user and invokes the `login` HTTP endpoint. Let us now define a `LoginController` that exposes this `login` endpoint. Listing 5.8 shows the `LoginController`:

Listing 5.8 The LoginController Class

```
package com.manning.sbip.ch05.controller;

// imports

@Controller
public class LoginController {

    @GetMapping("/login")
    public String login() {
        return "login";
    }
}
```

This endpoint ensures whenever there is an invocation to the `login` URL (e.g., http://localhost:8080/login), the `login.html` page is presented to the user. Let us now customize the Spring Security `HTTPSecurity` configuration to instruct Spring to redirect to the `login` endpoint for user login. If you recall, Spring Security provides the default security configuration in the `WebSecurityConfigurerAdapter` class. Thus, to provide a custom configuration, you need to override this method. Listing 5.9 shows the `SecurityConfiguration` class that provides a custom security configuration:

Listing 5.9 The SecurityConfiguration class

```
package com.manning.sbip.ch05.security;

import org.springframework.context.annotation.Configuration;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
       org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
       erAdapter;

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {


    # Customizing the HTTPSecurity to configure the custom login page. We have excluded the login page from
       authentication and enforced login for all other URLs.
    @Override
    protected void configure(HttpSecurity http) throws Exception {
```

```
        http.authorizeRequests()
                .antMatchers("/login").permitAll()
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login");
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web.ignoring().antMatchers("/webjars/**", "/images/**", "/css/**", "/h2-
       console/**");
    }
}
```

We've done the following configuration changes:

- Defined this class as the Spring configuration so that Spring Boot component scanning find this class
- `SecurityConfiguration` class extends the `WebSecurityConfigurerAdapter` class. It lets you customize the Spring Security configuration
- We've overridden the `configure(HttpSecurity http)` method and provided a custom implementation to include the custom login page
- We've also overridden the `configure(WebSecurity web)` method to allow the static contents such as CSS and images to be excluded from authentication. Otherwise, the web components such as images, CSS, and JavaScript files will not be rendered for the pages that do not require authentication

Let us now start the application and access the index page by accessing the URL http://localhost:8080/index. As you are not yet logged in to the application, you'll be redirected to the login page to the URL http://localhost:8080/login. Figure 5.13 shows the custom login page of our application:

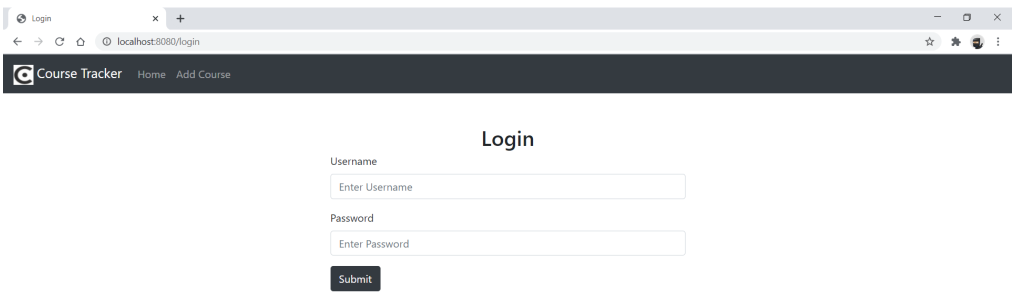


Figure 5.13 Course Tracker custom login page

You can notice that this is not the same login page you have used previously for login. You can use the username as a `user` and the password as printed in the application console. Once successfully logged in, you'll be redirected to the http://localhost:8080/index page which shows the list of available courses.

Discussion

In this technique, you've explored how to customize the login page of a Spring Boot application with Spring Security. As part of this technique, we've added the `login.html` page and add a `LoginController` which contains an HTTP GET endpoint `login`. Once this endpoint is accessed, it returns the logical view name `login` and it is rendered in the browser as `login.html`.

The most notable change is the induction of the `SecurityConfiguration` class in the application. The first thing to notice here is that it extends the `WebSecurityConfigurerAdapter` class. If you recall, the `WebSecurityConfigurerAdapter` class is the base class that provides the default Spring Security configurations in your Spring Boot application. You can extend this class to customize various security settings in Spring Security. As will notice later in this chapter, we'll heavily use this class to customize or configure several features of Spring Security.

The second change to notice is that you've overridden the `configure(HttpSecurity http)` method that allows us to customize the security configuration in the application. Listing 5.10 shows the changes inside the method:

Listing 5.10 Security Configuration

```
http.authorizeRequests()
                .antMatchers("/login").permitAll()
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login");
```

The `antMatchers` allows us to specify an application URL or an URL pattern. In the above code snippet, we are ensuring that the `login` endpoint is permitted to be accessed by all users and does not require to be authenticated. This is obvious as the login page lets us do the login. Next, we are enforcing that all other requests (i.e., `anyRequest()`) to the application need to be authenticated. The authentication type is form-login (i.e., `formLogin()`), and the associated login page is available at the `login` endpoint.

Besides, you've also overridden the `configure(WebSecurity web)` method to ensure the static web resources such as the images, stylesheet files are accessible without any form of authentication. Otherwise, the stylesheets or the images for the login page will not be accessible.

TECHNIQUE CONFIGURING IN-MEMORY AUTHENTICATION WITH CUSTOM USERS IN SPRING SECURITY IN A SPRING BOOT APPLICATION

Problem

Although the application in the previous technique just works fine, there is one major issue with the user login. The password is a random `UUID` that is changed each time the application is restarted. You need to enhance the application login experience by configuring a few custom users.

Solution

In earlier techniques, we relied on the Spring Boot's default `InMemoryUserDetailsManager` configuration to configure the user in our application. This default configuration creates an in-memory user with a username as a `user` and password as a random `UUID`. Let us now change this to provide our custom `InMemoryUserDetailsManager` implementation.

If you recall from earlier chapters, Spring Boot backs off with the default configurations if it finds a user-defined implementation. Thus, Spring Boot provided `InMemoryUserDetailsManager` implementation will no longer be used if we provide our implementation.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/Implementing-inmemory-authentication/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/Implementing-inmemory-authentication/course-tracker-final

Let us enhance the `SecurityConfiguration` class by defining the `InMemoryUserDetailsManager` as shown in Listing 5.11:

Listing 5.11 Updated SecurityConfiguration

```
package com.manning.sbip.ch05.security;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import
       org.springframework.security.config.annotation.authentication.builders.Authenticatio
       nManagerBuilder;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
       org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
       erAdapter;
import org.springframework.security.crypto.bcrypt.BCryptPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;
import org.springframework.security.web.access.AccessDeniedHandler;

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private AccessDeniedHandler customAccessDeniedHandler;

    @Override
    protected void configure(AuthenticationManagerBuilder auth) throws Exception {
```

```
        auth.inMemoryAuthentication().passwordEncoder(passwordEncoder())
                .withUser("user")
                .password(passwordEncoder().encode("p@ssw0rd"))
                .roles("USER")
                .and()
                .withUser("admin")
                .password(passwordEncoder().encode("pa$$w0rd"))
                .roles("ADMIN");
    }

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests()
                .antMatchers("/login").permitAll()
                .antMatchers("/delete/**").hasRole("ADMIN")
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login")
                .and()
                .exceptionHandling().accessDeniedHandler(customAccessDeniedHandler);
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web
                .ignoring()
                .antMatchers("/webjars/**", "/images/**", "/css/**", "/h2-console/**");
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return new BCryptPasswordEncoder();
    }
}
```

In Listing 5.11, we are performing the following activities:

- First, we've overridden the `configure(AuthenticationManagerBuilder auth)` method to define the `InMemoryUserDetailsManager` configuration. In this method, we have created two custom users named `user` and `admin` with their respective passwords and roles `USER` and `ADMIN`. A role is an important aspect in controlling user authorization in the application
- In the `HttpSecurity` configuration, we've done the following:
- The login page does not require any authentication and it is available at the login endpoint
- The `delete` endpoint can only be invoked by a user with the role of `ADMIN`. Note how we are leveraging the user roles to control user actions in the application. Spring Security throws an `AccessDeniedException` if any user without the `ADMIN` role attempts to invoke the delete endpoint
- If there is an access denied exception, we've configured a custom `AccessDeniedHandler` that lets us perform the actions when an `AccessDeniedException` occurs. Note that we've autowired the

`CustomAccessDeniedHandler`

- We've additionally provided an implementation for a `PasswordEncoder`. A password encoder encodes a password from a plain text format to an encoded format. We'll discuss more on `PasswordEncoder` shortly. In this example, we've used the `BCryptPasswordEncoder` to encode the password

Listing 5.12 shows the `CustomAccessDeniedHandler` class:

Listing 5.12 The CustomAccessDeniedHandler Implementation

```
package com.manning.sbip.ch05.security;

//imports
@Component
public class CustomAccessDeniedHandler implements AccessDeniedHandler {

       @Override
       public void handle(HttpServletRequest request, HttpServletResponse response,
                  AccessDeniedException accessDeniedException) throws IOException,
       ServletException {
         // log unauthorized access

      response.sendRedirect(request.getContextPath() + "/accessDenied");

       }
}
```

In the `CustomAccessDeniedHandler` class, we are redirecting the user to the `accessDenied` endpoint which redirects the user to an error page. The `AccessDeniedHandler` provides the flexibility to perform custom actions if there is an `AccessDeniedException`. For instance, you can log the unauthorized access details such as the user who attempts the unauthorized access on which resource in your application for auditing purposes.

The last change you'll perform is to add a `LogoutController` that is invoked when you click on the logout button. Listing 5.13 shows this controller:

Listing 5.13 The Logout Controller

```
package com.manning.sbip.ch05.controller;

//imports

@Controller
public class LogoutController {

       @PostMapping("/doLogout")
       public String logout(HttpServletRequest request, HttpServletResponse response) {
         Authentication authentication =
       SecurityContextHolder.getContext().getAuthentication();
         if(authentication != null) {
                  new SecurityContextLogoutHandler().logout(request, response,
       authentication);
         }
         return "redirect:/login";
       }
```

```
}
```

You’ve done the following operations in listing:

- Created an HTTP POST endpoint that handles the user logout from the application. Notice that it is recommended to use the HTTP POST method instead of the HTTP GET method for logout to avoid a CSRF attack
- Next, you’ve invoked the `SecurityContextLogoutHandler` for the user to log out from the application. This class invalidate the existing `HttpSession`, clears the authentication in the `SecurityContext` and completes the logout

Let us now start the application and access the index page by accessing the URL http://localhost:8080/index. As you are not yet logged in to the application, you’ll be redirected to the login page to the URL http://localhost:8080/login. You’ll be prompted to the custom login page. You can log in to the application by the username `user` and password `p@ssw0rd` or with the username `admin` and password as `pa$$w0rd`. After successful login, you’ll be redirected to the `index` page containing the list of courses.

Besides, if you notice the application console log, you’ll not find the Spring Security generated password anymore. This is since you’ve configured custom `InMemoryUserDetailsManager` implementation, and there is no default `InMemoryUserDetailsManager` configuration provided by Spring Boot.

If you login to the application with the user as a user and attempts to delete a course, you’ll be redirected to the error page as shown in figure 5.14:

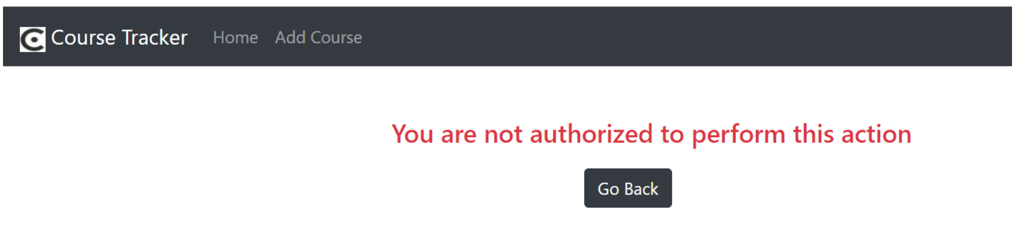


Figure 5.14 Error page for unauthorized access

Discussion

In this technique, you’ve learned to customize a Spring Boot application with custom users through Spring Security’s `AuthenticationManagerBuilder` class. This class provides easy access to configure various types of authentications such as the in-memory, JDBC, LDAP. For instance, you’ve used the `inMemoryAuthentication(..)` method to configure the in-memory authentication. Similarly, you can also use the `jdbcAuthentication(..)` and `ldapAuthentication(..)` methods to configure JDBC and LDAP based authentication, respectively. You’ll learn more about JDBC and LDAP authentication in later techniques.

Let us now focus on to the `PasswordEncoder` bean definition. A `PasswordEncoder` encodes the plain-text password to an encoded string to protect it. Spring Security provides several `PasswordEncoder` implementations such as `NoOpPasswordEncoder`, `BCryptPasswordEncoder`, `Pbkdf2PasswordEncoder` and `SCryptPasswordEncoder` to name a few. In this example, for demonstration, we've used the `BCryptPasswordEncoder`.

Spring Security provides a factory class named `PasswordEncoderFactories` which lets you create an instance of a `DelegatingPasswordEncoder` instance. A `DelegatingPasswordEncoder` instance delegates the password encoding to an actual `PasswordEncoder` such as `BCryptPasswordEncoder` which performs the actual encoding.

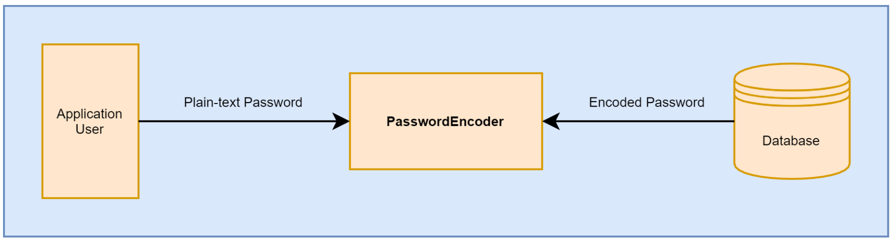


Figure 5.15 PasswordEncoder's password comparison process. A PasswordEncoder takes the plain-text password supplied by the user and the encoded password is retrieved from the database. Based on the type of PasswordEncoder used, it applies an internal algorithm to compare the password. If there is a match, the comparison is successful. If the passwords do not match, the comparison is marked as failed

In general, the password of a user is encoded using the configured `PasswordEncoder` and the encoded password is stored into the persistence store if a persistence store-based identity store is used. Later while the password is supplied for authentication, the supplied password is provided to the encoder and it matches the user-supplied password with the previously encoded password retrieved from the identity store. This is shown in Figure 5.15.

After the authentication, the supplied plain-text password is erased from the application. This prevents the plain-text password to be available in the application.

Let us now provide an alternative approach of creating an `InMemoryUserDetailsManager` that uses the `DelegatingPasswordEncoder` instance to encode the password. Listing 5.14 shows this configuration:

Listing 5.14 The SecurityConfiguration Class

```
package com.manning.sbip.ch05.security;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
      org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
```

```
        erAdapter;
import org.springframework.security.core.userdetails.User;
import org.springframework.security.core.userdetails.UserDetails;
import org.springframework.security.core.userdetails.UserDetailsService;
import org.springframework.security.crypto.factory.PasswordEncoderFactories;
import org.springframework.security.crypto.password.PasswordEncoder;
import org.springframework.security.provisioning.InMemoryUserDetailsManager;
@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private PasswordEncoder passwordEncoder;

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests()
                .antMatchers("/login").permitAll()
                .antMatchers("/delete/**").hasRole("ADMIN")
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login")
                .and()
                .exceptionHandling().accessDeniedHandler(customAccessDeniedHandler);
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web.ignoring().antMatchers("/webjars/**", "/images/*", "/css/*", "/h2-console/**");
    }

    #Defining the UserDetailsService as a Spring Bean definition
    @Bean
    @Override
    public UserDetailsService userDetailsService() {

        UserDetails user = User.withUsername("user")
                .passwordEncoder(passwordEncoder::encode)
                .password("p@ssw0rd").roles("USER").build();

        UserDetails admin = User.withUsername("admin")
                .passwordEncoder(passwordEncoder::encode)
                .password("pa$$w0rd").roles("ADMIN").build();

        InMemoryUserDetailsManager userDetailsManager = new InMemoryUserDetailsManager();

        userDetailsManager.createUser(user);
        userDetailsManager.createUser(admin);

        return userDetailsManager;
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return PasswordEncoderFactories.createDelegatingPasswordEncoder();
    }
}
```

In Listing 5.12, you've defined an instance of `UserDetailsService`. First, you've created the builder methods of the `User` class and build the instance of `UserDetails` instance. Recall that the `UserDetails` represents a user in the Spring Security context. Notice that you've used Java 8's method reference with the password encoder to encode the supplied password.

Also, you've created an instance of `DelegatingPasswordEncoder` that internally uses the `BCryptPasswordEncoder`. A `BCryptPasswordEncoder` is an actual password encoder and considered more secure. With this configuration, if you start the application and notice that it works in the same way it worked previously. The major difference in this approach is the way you have initialized the `InMemoryUserDetailsManager` and used an appropriate password encoder.

Authentication, Authorization, and Roles

In the previous technique, you've noticed that while creating the application users, along with the user details, we've also defined user roles. While dealing with security, you need to understand the concept of authentication and authorization.

Authentication is the process of ensuring that a user is the one who he/she claims to be. This is done through some sort of user identification mechanism such as user's username and password, certificates, biometric information, etc. Authorization defines what an authenticated user is allowed to perform once they are logged in to the application. Let us explain this through an analogy of travelling through an airport. To catch a flight, you reach the airport and present your identity document to get access inside the airport terminal. The identity document authenticates you as the right traveller. Once you are inside the terminal you are only authorized to board the aeroplane as recorded in your boarding pass. The boarding pass defines your travel authority. Even though you are inside the terminal, you can't board random flights of your choice as you are not authorized to board them. A similar concept is applied to the users in an application. They can only perform the activities they are authorized in the application.

In a Spring Security application, you use the notion of roles to control what a logged-in user is authorized to view and perform in the application. You can think of a role as the permission or right of a user. Refer to the https://github.com/spring-boot-in-practice/repo/wiki/Understanding-Roles for more details on how to use roles in a Spring Boot application.

TECHNIQUE CONFIGURING JDBC AUTHENTICATION WITH SPRING SECURITY IN A SPRING BOOT APPLICATION

Problem

Storing user credentials in the source code is a bad idea as it can be retrieved by anyone with access to the source code. Storing user credentials in a database table is a relatively better approach. You need to configure JDBC authentication in a Spring Boot application.

Solution

The application you've developed in the previous technique is slightly better than its previous version as you have an option to configure the custom users in the application. However, this is not enough as you will rarely be interested to keep the user credentials hardcoded in your source code. This defeats the purpose of enabling the security altogether as anyone with access to the source code can easily retrieve the user credentials. Besides, if your application allows the registration of new users it will be a challenge to let them log in to the application with this approach.

A better alternative to store the user credentials in a persistent store such as a database. A database table in most production applications is secure and only authorized persons can access it. Thus, this technique lets us explore how to store the user credentials in a database table and use it for user authentication.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/jdbc-default-authentication/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/jdbc-default-authentication/course-tracker-final

The first change you'll need to perform is to introduce two tables – `USERS` and `AUTHORITIES`. As the names suggest the `USERS` table contains the user details and the `AUTHORITIES` table contains the user authorities. Note that authorities in border term define what a user is authorized to do in the application. Previously, we have defined the user role also in the same manner. Note that the core difference between these two is in the semantics of how we use these features. In the Spring Security context, the differences are minimal and mostly works in the same manner. Providing an in-depth discussion on the differences between roles and authorities are beyond the scope of this book.

`USERS` and `AUTHORITIES` are the default table names used by Spring JDBC and to use the default JDBC authentication provided by Spring Security, we need to use these table names. In the latter technique, you'll learn to customize these table names and the table structure. Listing 5.15 show the modified `schema.sql` located at `src/main/resources` folder:

Listing 5.15 Modified Schema.sql

```
// Users and Authorities DDL

# The USERS table stores the application user details
create table users(
    username varchar(50) not null primary key,
    password varchar(500) not null,
    enabled boolean not null
);

# The AUTHORITIES table stores the user authorities
create table authorities (
    username varchar(50) not null,
    authority varchar(50) not null,
    constraint fk_authorities_users foreign key(username) references users(username)
);

# Unique index to ensure the unique username and authority mappings
create unique index ix_auth_username on authorities (username,authority);
```

Listing 5.16 shows the modified `data.sql` file:

Listing 5.16 The data.sql file

```
// Users insert queries
# Application Users
INSERT into USERS(username, password, enabled) values ('user','p@ssw0rd', true);
INSERT into USERS(username, password, enabled) values ('admin','pa$$w0rd', true);
# Application User Authorities

INSERT into AUTHORITIES(username, authority) values ('user','USER');
INSERT into AUTHORITIES(username, authority) values ('admin','ADMIN');
```

On application startup, Spring Boot will execute the queries provided in the above listings. Recall from chapter 3 that Spring Boot automatically executes these scripts on startup. Let us now move on to the `SecurityConfiguration` changes as shown in Listing 5.17:

Listing 5.17 The Security Configuration

```
package com.manning.sbip.ch05.security;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import
       org.springframework.security.config.annotation.authentication.builders.Authenticatio
       nManagerBuilder;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
       org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
       erAdapter;
import org.springframework.security.crypto.password.NoOpPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;

import javax.sql.DataSource;

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private DataSource dataSource;

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests()
                .antMatchers("/login").permitAll()
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login");
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web.ignoring().antMatchers("/webjars/**", "/images/**", "/css/**", "/h2-
       console/**");
```

```
    }

    # Implementing JDBC authentication. By default Spring Security uses the supplied
       datasource (autowired above) to connect to the database and loads the user details
       and authorities from USERS and AUTHORITIES tables respectively
    @Override
    protected void configure(AuthenticationManagerBuilder auth) throws Exception {
        auth.jdbcAuthentication().dataSource(dataSource);
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return NoOpPasswordEncoder.getInstance();
    }
}
```

The first change you've done is to autowire the `DataSource` into the class. You've updated the authentication strategy to JDBC authentication in the `configure(AuthenticationManagerBuilder auth)` method. You then configured the JDBC authentication with this data source so that Spring Boot can perform the necessary database lookup for user authentication.

Note that you've just specified the data source in JDBC authentication. By default, Spring Security executes the queries listed on Listing 5.18 to load the user details and its authorities. It then uses these details to authenticate the users and validate their authority to access the resource (e.g., if the user is authorized to access the index page)

Listing 5.18 Queries used by Spring Security to load User details and authorities

```
# Queries to fetch the user's details and authorities from the supplied username to perform
       authentication
select username, password, enabled from users where username =?
select username, authority from authorities where username =?
```

Let us now start the application and access the index page by accessing the URL http://localhost:8080/index. You'll be redirected to the login page to the URL http://localhost:8080/login. You can log in to the application by the username `user` and password `p@ssw0rd` or with the username `admin` and password as `pa$$w0rd`. After successful login, you'll be redirected to the index page containing the list of courses.

Discussion

In this technique, you've learned to perform JDBC authentication in the application. This approach is much better than the previous authentication strategies as the user credentials are stored in a database table.

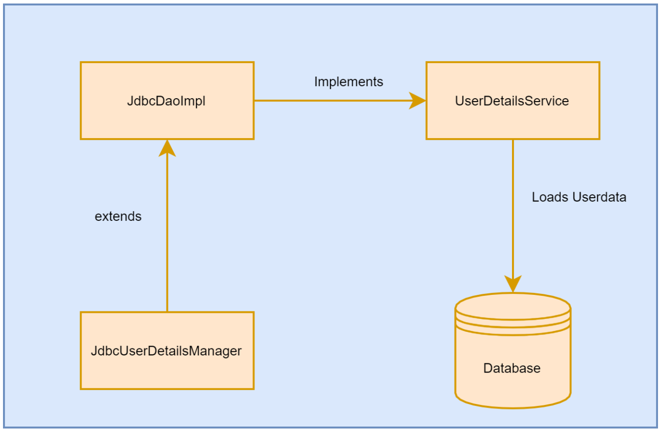


Figure 5.16 Spring Security Class and Interfaces for JDBC authentication

For JDBC authentication, Spring Security provides the `JdbcDaoImpl` class that implements the `UserDetailsService` and defines the `loadUserByUsername(..)` method. This method loads the user details using the database. Besides, the `JdbcUserDetailsManager` class extends the `JdbcDaoImpl` and provides more extensive support for user management services through JDBC. For instance, this class allows performing CRUD operations for a user. Thus, if your application supports user management, you can use this class to create or delete a user in the application.

Although this technique works fine, it has a certain limitation as it enforces you to use the Spring default tables (`USERS` and `AUTHORITIES`) for authentication. But your application might have its database tables to store user details and you would like to use that table for the JDBC authentication. In the next technique, we'll demonstrate how to use custom tables for JDBC authentication.

TECHNIQUE IMPLEMENT JDBC AUTHENTICATION WITH CUSTOM USERDETAILSSERVICE IN A SPRING BOOT APPLICATION

Problem

Implementing JDBC authentication with custom queries does not provide complete control on the user account management. Features such as user account locking, account expiry, user credentials expiry are not available.

Solution

Spring Security provides a `UserDetailsService` interface that acts as a bridge between the application user implementation and the Spring Security `UserDetails`. If you have a custom user management module and user details that do not conform to the Spring Security User implementation, you can provide an implementation of this interface.

The `UserDetailsService` interface is straightforward and provides only one method `loadUserByUsername()` that lets you load the user details from the identity store and return a Spring Security's `UserDetails` implementation.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/jdbc-custom-table-authentication-userdetailsservice/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/jdbc-custom-table-authentication-userdetailsservice/course-tracker-final

In this technique, we are talking about application-specific users. Thus, let us model an application user entity as shown in Listing 5.19:

Listing 5.19 Custom User in Course Tracker Application

```
package com.manning.sbip.ch05.model;

import lombok.Data;

import javax.persistence.*;

@Entity
@Table(name = "CT_USERS")
@Data
public class ApplicationUser {

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    private Long id;
    private String firstName;
    private String lastName;
    private String username;
    private String email;
    private String password;
    private boolean verified;
    private boolean locked;
    @Column(name = "ACC_CRED_EXPIRED")
    private boolean accountCredentialsExpired;
}
```

The details in the Listing 5.19 are straightforward. It contains user details such as first_name, last_name, username, and other user account details. We've named the table that stores user details as `CT_USERS`.

We need a Spring Data repository interface implementation for the `ApplicationUser` so that we can manage the user details in the database. Listing 5.20 shows the `ApplicationUserRepository` interface:

Listing 5.20 The ApplicationUserRepository Interface

```
package com.manning.sbip.ch05.repository;

@Repository
public interface ApplicationUserRepository extends CrudRepository<ApplicationUser, Long> {

    ApplicationUser findByUsername(String username);
}
```

In Listing 5.20, we've added the method `findByUsername()` that finds the `ApplicationUser` from the database with the supplied username. We need this method as we need to load the user details in the `UserDetailsService` implementation. Let us provide the custom `UserDetailsService` implementation as shown in Listing 5.21:

Listing 5.21 Custom UserDetailsService Implementation

```
package com.manning.sbip.ch05.service;

import com.manning.sbip.ch05.model.ApplicationUser;
import com.manning.sbip.ch05.repository.ApplicationUserRepository;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.security.core.userdetails.User;
import org.springframework.security.core.userdetails.UserDetails;
import org.springframework.security.core.userdetails.UserDetailsService;
import org.springframework.security.core.userdetails.UsernameNotFoundException;

@Service
public class CustomUserDetailsService implements UserDetailsService {

    @Autowired
    private ApplicationUserRepository applicationUserRepository;

    # Providing implementation of loadUserByUsername(..) method that maps an application specific user details to
       Spring Security Specific UserDetails. We first load the user from the database and then use the Spring
       Security's builder method to construct the UserDetails instance. If the user is not available, we throw the
       UsernameNotFoundException exception
    @Override
    public UserDetails loadUserByUsername(String username) throws UsernameNotFoundException
       {
        ApplicationUser applicationUser =
       applicationUserRepository.findByUsername(username);
        if(applicationUser == null) {
            throw new UsernameNotFoundException("No user with "+username+" exists in the
       system");
        }
        return User.builder()
                .username(applicationUser.getUsername())
                .password(applicationUser.getPassword())
                .disabled(!applicationUser.isVerified())
                .accountExpired(applicationUser.isAccountCredentialsExpired())
                .accountLocked(applicationUser.isLocked())
                .roles("USER")
                .build();
    }
}
```

Let us explain the changes in Listing 5.21:

- The `CustomUserDetailsService` class provides an implementation of the `UserDetailsService` interface
- It autowire the `ApplicationUserRepository` interface implementation as this is used to load the user details from the database
- Lastly, in the `loadUserByUsername()` method, we are doing the following activities:
- Find the user details from the database
- If there is no user with the supplied username throws the `UsernameNotFoundException`. This is a Spring Security exception to indicate the user is not available
- If the user exists, then we build the Spring Security user with the `ApplicationUser` details

Besides, in this example, we mark a user as disabled if the user account is not verified. Similarly, `accountExpired()` and `accountLocked()` can be used to control the user account status. For instance, you can implement the account as locked after a configurable number of incorrect login attempts. In fact, you can also implement account expiry to enforce the user to change their password after a period. Besides, we've set the user role as `USER` to indicate they have the role as user. Spring Security enforces you to configure either the role or the authorities of the user.

The last change we need to perform is to use this custom `UserDetailsService` in the `SecurityConfiguration` class so that the custom implementation can be used by Spring Security. Listing 5.22 shows the updated `SecurityConfiguration` class:

Listing 5.22 SecurityConfiguration Class

```
package com.manning.sbip.ch05.security;

import com.manning.sbip.ch05.service.CustomUserDetailsService;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
       org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
       erAdapter;
import org.springframework.security.core.userdetails.UserDetailsService;
import org.springframework.security.crypto.password.NoOpPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http
                .authorizeRequests()
                .antMatchers("/login").permitAll()
                .anyRequest().authenticated()
                .and()
```

```
                .formLogin().loginPage("/login");
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web
                .ignoring()
                .antMatchers("/webjars/**", "/images/*", "/css/*", "/h2-console/**");
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return NoOpPasswordEncoder.getInstance();
    }

  # Defining custom UserDetailsService implementation as a Spring Bean
    @Bean
    public UserDetailsService userDetailsService() {
        return new CustomUserDetailsService();
    }
}
```

In Listing 5.22, you've done two additional changes – added the `UserDetailsService` bean definition and removed the `configure(AuthenticationManagerBuilder auth)` method. The last method is no longer necessary as you are providing the `UserDetailsService` implementation.

The last change you'll perform is to create the `CT_USERS` table and add few user details to it. Listing 5.23 shows the `schema.sql` changes:

Listing 5.23 The CT_USERS table definition

```
create table ct_users(
  ID   BIGINT(19) NOT NULL,
  EMAIL  VARCHAR(255)      NOT NULL,
  FIRST_NAME      VARCHAR(255) NOT NULL,
  LAST_NAME       VARCHAR(255) NOT NULL,
  PASSWORD        VARCHAR(255) NOT NULL,
  USERNAME        VARCHAR(255) NOT NULL,
  VERIFIED        BOOLEAN(1) NOT NULL,
  LOCKED BOOLEAN(1) NOT NULL,
  ACC_CRED_EXPIRED BOOLEAN(1) NOT NULL,
  PRIMARY KEY (ID)
);
```

Listing 5.24 shows the `data.sql` changes that contain two user details:

Listing 5.24 CT_USERS INSERT Queries

```
INSERT INTO CT_USERS(ID, FIRST_NAME, LAST_NAME, USERNAME, PASSWORD, EMAIL, VERIFIED,
       LOCKED, ACC_CRED_EXPIRED) VALUES(1, 'John', 'Socket', 'jsocket', 'password',
       'jsocket@example.com', TRUE, FALSE, FALSE);
INSERT INTO CT_USERS(ID, FIRST_NAME, LAST_NAME, USERNAME, PASSWORD, EMAIL, VERIFIED,
       LOCKED, ACC_CRED_EXPIRED) VALUES(2, 'Steve', 'Smith', 'smith', 'password',
       'smith@example.com', FALSE, FALSE, FALSE);
```

In Listing 5.24, we are creating two users with username `jsocket` and `smith` respectively. The first user account is enabled and the last one is disabled. You can start the application and try login in with both the users. You'll notice that you can successfully login with the `jsocket` user but not with the `smith` user.

Discussion

Many applications store their application user details in the database and use them to authenticate the users. Spring Security provides several approaches to use JDBC authentication based on the complexity of the application user set up in the application.

In the last three techniques, we've discussed these approaches to perform JDBC based user authentication. In the first technique, you've seen the default use of basic JDBC authentication where you need to implement the tables as Spring Security requires you to configure. In the next technique, you've used the custom SQL queries which is better than the previous one as it removes the restriction of using Spring Security specific tables. The third approach provides you more control over how you need to manage your users and user account configuration.

Although storing user details in the database works well, many organization stores user details and roles in an LDAP (Lightweight Directory Access Protocol) server for better user management and authentication. Let's discuss this in the next technique.

TECHNIQUE IMPLEMENT LDAP AUTHENTICATION IN A SPRING BOOT APPLICATION

Problem

Many organizations manage Lightweight Directory Access Protocol (LDAP) to store user details and use it for authenticating users. In the course tracker application, you need to enable LDAP authentication.

Solution

Most major organizations use LDAP as the central repository to store user details, their roles, and for authentication purposes. An LDAP server is typically fast for reading and query operations. As user details are changed less frequently and are queried for purposes such as authentication, validation on their roles, LDAP is the suitable protocol to manage user details.

Since LDAP is an important part that is often used by organizations, Spring Security provides built-in support for it to perform user authentication. In this technique, you'll first learn how to use LDAP authentication in a Spring Boot application.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/ldap-authentication/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/ldap-authentication/course-tracker-final

The first change you need to perform is to include the Maven dependencies required to include LDAP support in the course tracker project. Listing 5.25 shows the Maven dependencies to be included in the pom.xml file:

Listing 5.25 LDAP dependencies

```
<dependency>
    <groupId>org.springframework.ldap</groupId>
    <artifactId>spring-ldap-core</artifactId>
</dependency>
<dependency>
    <groupId>org.springframework.security</groupId>
    <artifactId>spring-security-ldap</artifactId>
</dependency>
<dependency>
    <groupId>com.unboundid</groupId>
    <artifactId>unboundid-ldapsdk</artifactId>
</dependency>
```

In Listing 5.25, the spring-ldap-core and spring-security-ldap dependencies provide the necessary support to enable LDAP features in the Spring Boot application. Besides, to use LDAP, you need an LDAP server. For simplicity, in this example, you've used an embedded LDAP server named UnboundID (https://ldap.com/unboundid-ldap-sdk-for-java/).

The next change you'll need to perform is to add the user data that will be accessed by the LDAP server. By default, an LDAP server does not store the data, it is stored in an underlying data storage. In this example, we'll use an LDAP Data Interchange Format (LDIF)[11] file that stores the user records. Listing 5.26 shows the users.ldif file stored inside the src\main\resources folder:

Listing 5.26 The users.ldif file

```
# These acronyms will be explained later in the discussion section
dn: dc=manning,dc=com
objectclass: top
objectclass: domain
objectclass: extensibleObject
dc: manning

dn: ou=people,dc=manning,dc=com
objectclass: top
objectclass: organizationalUnit
ou: people

# Defines user Steve Smith

dn: uid=steve,ou=people,dc=manning,dc=com
objectclass: top
objectclass: person
objectclass: organizationalPerson
objectclass: inetOrgPerson
cn: Steve Smith
```

1 https://en.wikipedia.org/wiki/LDAP_Data_Interchange_Format

```
sn: Smith
uid: steve
userPassword: password

# Defines user John Socket

dn: uid=jsocket,ou=people,dc=manning,dc=com
objectclass: top
objectclass: person
objectclass: organizationalPerson
objectclass: inetOrgPerson
cn: John Socket
sn: Socket
uid: jsocket
userPassword: password
```

We'll provide a brief explanation about the `users.ldif` file in the discussion section. For now, understand that you've two user details with the username `steve` and `jsocket`. The password for both the user is set to password. Let us now include the LDAP server configuration in the `application.properties` file as shown in Listing 5.27:

Listing 5.27 Embedded LDAP Server Configuration

```
# Embedded LDAP server port
spring.ldap.embedded.port=8389
#Embedded LDIF file location
spring.ldap.embedded.ldif=classpath:users.ldif
#Embedded LDAP server Distinguished Name
spring.ldap.embedded.base-dn=dc=manning,dc=com
```

In the Listing, you specify the embedded LDAP server port and the LDIF file location. Besides, you also specify the base Distinguished Name (i.e.: "dn") of the LDAP server which acts as the root entity in the LDAP server.

The next and last change you'll need to make is to configure the `SecurityConfiguration` class to instruct Spring Security to perform an LDAP authentication. Listing 5.28 shows the updated `SecurityConfiguration` class:

Listing 5.28 The SecurityConfiguration Class

```
package com.manning.sbip.ch05.security;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import
       org.springframework.security.config.annotation.authentication.builders.Authenticatio
       nManagerBuilder;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
       org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
       erAdapter;
import org.springframework.security.crypto.password.NoOpPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;
```

```
@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http
                .authorizeRequests()
                .antMatchers("/login").permitAll()
                .anyRequest().authenticated()
                .and()
                .formLogin().loginPage("/login");
    }

    # Defining LDAP configuration through AuthenticationManagerBuilder
    @Override
    protected void configure(AuthenticationManagerBuilder auth) throws Exception {
        auth
                .ldapAuthentication()
                .userDnPatterns("uid={0},ou=people")
                .contextSource()
                .url("ldap://localhost:8389/dc=manning,dc=com")
                .and()
                .passwordCompare()
                .passwordEncoder(NoOpPasswordEncoder.getInstance())
                .passwordAttribute("userPassword");
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web
                .ignoring()
                .antMatchers("/webjars/**", "/images/*", "/css/*", "/h2-console/**");
    }
}
```

Let us discuss the changes done for LDAP authentication:

- You’ve used the `AuthenticationManagerBuilder` to configure the LDAP authentication
- You then set the DN (Distinguished Name) to `uid={0},ou=people`. In the `uid={0}`, the `{0}` is replaced with the user id (e.g., steve) while performing the authentication. Besides, the `ou=people` indicate the user belongs to the people organization unit
- You then perform the `contextSource` to configure Spring Security to point to the LDAP server that should be used to authenticate users
- The next operation you are performing is to do a password comparison. Unlike a database table, LDAP servers do not let to fetch the user password. Thus, while authentication Spring Security takes the password supplied by the user and does an LDAP compare operation by supplying the user password to the LDAP server
- While performing password comparison, you specify the password encoder and the LDAP entity attribute name that represents the password in the LDAP server. In this example, we are supplying a `NoOpsPasswordEncoder` as we are using a plain text password. We also set the password attribute to `userPassword` as in our LDIF file, we’ve used this attribute to represent the user password

You can start the application and access the index page of the application. You'll be redirected to the familiar login page. You can log in with the users configured in the LDAP server. You can use the username steve and password as a password for login.

Discussion

In this technique, you've seen how to implement LDAP authentication through Spring Security in a Spring Boot application. LDAP is an extremely popular directory access protocol and most major organizations manage their users and other organizational details through LDAP servers.

In this example, we've kept the LDAP implementation as minimal as possible to keep the example simple and clear. If you are not familiar with LDAP and its purpose, you can find an in-depth LDAP guide available at http://www.zytrax.com/books/ldap/.

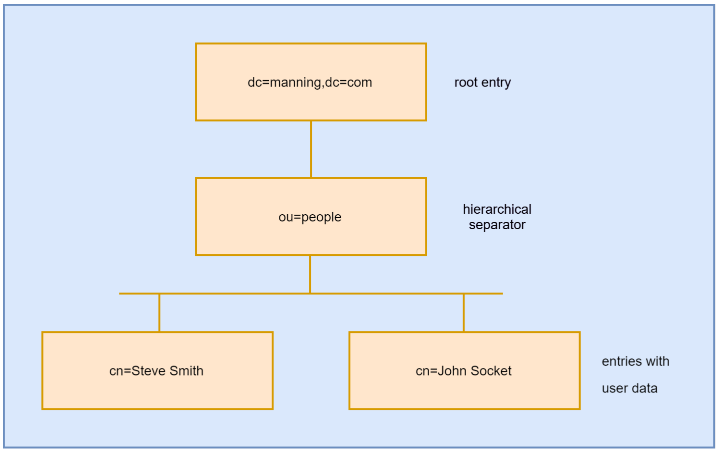


Figure 5.17 The users.ldif file structure. Its shows the root entries, the separator, and the user data

Let us provide a brief explanation of the `users.ldif` file that you've used in this technique to store the user details. Figure 5.17 provides a high-level overview of this file. In Listing 5.26, you've first created a root entry with `dc=manning,dc=com`. You've then created the organizational unit (`ou`) with `ou=people`. Lastly, you've stored two user details – Steve Smith with `uid` smith and John Socket with `uid` jsocket. Figure 5.15 shows these details.

In the previous technique, you've seen the use of `UserDetailsService` that plays a major role in user authentication. In LDAP authentication we can't use the `UserDetailsService` as the LDAP server does not allow to read user password. Spring Security provides a `LdapAuthenticator` interface that is responsible to perform the LDAP authentication.

In Spring Security, you can perform LDAP authentication in two ways- bind authentication and password authentication. In the password authentication, the user-supplied password is *compared* with the one present in the LDAP server. In this example, you've used the password comparison to authenticate the users. In the bind authentication, users are authenticated to establish an authorization identity that is used in subsequent operations to the LDAP server. To authenticate the users provides identity proof such as a password. Refer to https://ldap.com/the-ldap-bind-operation/ to read more on LDAP bind operation.

In all these above techniques, you've seen the use of form-based user authentication. In form-based authentication, a login form is presented to the user to enter the user credentials. Once the user attempts to log in, these credentials are read by the server, and user authentication is done. Another popular form of authentication is HTTP basic authentication that lets the user agent (e.g., the browser) accept the user credentials and do the user authentication. The HTTP basic authentication technique is useful when you don't have an option to perform form-based authentication.

TECHNIQUE IMPLEMENT HTTP BASIC AUTHENTICATION IN A SPRING BOOT APPLICATION

Problem

In the previous techniques, you've explored form-based user authentication for the users to allow access to the application. However, some applications prefer to use HTTP basic authentication instead of form-based login. You need to implement HTTP basic authentication in your application.

Solution

HTTP basic authentication is an alternative authentication approach used in applications to authenticate the users. Similar to form-based login, it also accepts the user credentials and let the server authenticate the user. In this technique, we'll first demonstrate the use of HTTP basic authentication in the course tracker application. In the discussion section, we'll provide more information on the HTTP basic authentication and how it works.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/http-basic-authentication/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch05/http-basic-authentication/course-tracker-final

In this technique, we'll use the default JDBC based HTTP basic authentication. Thus, we'll remove the form-based login as used in the previous techniques and define HTTP basic authentication in the `SecurityConfiguration` class as shown in Listing 5.29:

Listing 5.29 The SecurityConfiguration class for HTTP basic Authentication with JDBC

```
package com.manning.sbip.ch05.security;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import
```

```
        org.springframework.security.config.annotation.authentication.builders.Authenticatio
        nManagerBuilder;
import org.springframework.security.config.annotation.web.builders.HttpSecurity;
import org.springframework.security.config.annotation.web.builders.WebSecurity;
import
        org.springframework.security.config.annotation.web.configuration.WebSecurityConfigur
        erAdapter;
import org.springframework.security.crypto.password.NoOpPasswordEncoder;
import org.springframework.security.crypto.password.PasswordEncoder;

import javax.sql.DataSource;

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private DataSource dataSource;

    # The below method indicates that all requsest to the application needs to be
       authenticated and the authentication needs to be performed by HTTP Basic
       Authentication
    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http
                .authorizeRequests()
                .anyRequest()
                .authenticated()
                .and()
                .httpBasic();
    }

    @Override
    protected void configure(AuthenticationManagerBuilder auth) throws Exception {
        auth.jdbcAuthentication().dataSource(dataSource);
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web
                .ignoring()
                .antMatchers("/webjars/**", "/images/**", "/css/**", "/h2-console/**");
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return NoOpPasswordEncoder.getInstance();
    }
}
```

In Listing 5.29, you've defined that any requests to the application need to be authenticated and the authentication scheme is HTTP basic authentication. These are the only changes you've done to implement HTTP basic authentication in the application.

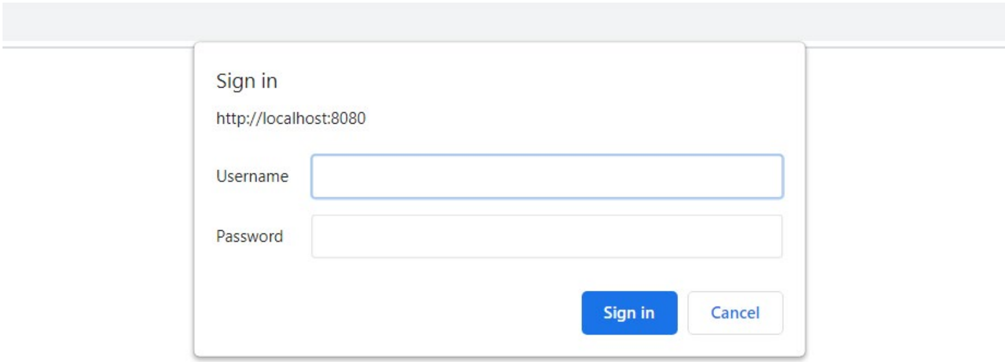


Figure 5.18 HTTP basic authentication dialogue box for user authentication in Google Chrome browser

Let us start the application and access the http://localhost:8080/index from the browser. You'll not find the familiar login page, instead, there will be a dialogue box from the browser prompting you to enter the username and password as shown in Figure 5.16. Provide the same credentials user earlier as there is no change in the users you have created previously. For example, you can use the username user and password p@ssw0rd for login.

Post successful login, you'll be redirected to the index page of the application. You'll notice that there is no Logout button available on any of the pages. This is because there is no logout function in HTTP basic authentication. To log out from the application, you'll need to close all instances of the browser.

Discussion

HTTP basic authentication is one of the simplest and easiest forms of authentication available in HTTP. When you request the index page, the server detects that basic authentication is enabled and does two things:

- It adds an HTTP response header named WWW-Authenticate with the value Basic realm="Realm"
- Send an HTTP status code 401 indicating the Unauthorized request

A realm can be interpreted as an area (e.g., a group of web pages) for which the user credentials are shared. On receipt of the HTTP 401 error, the browser understands that it needs to supply the username and password. Thus, it opens the dialogue box for the user to enter the credentials as shown in Figure 5.16. Once the credentials are provided, the browser concatenates the details in username:password format and perform Base64 encoding on the concatenated data. It then inserts the Authorization HTTP header in the request in the format Authorization: Basic <Base64 encoded data>.

The browser remembers the credentials and on all subsequent requests, it inserts the `Authorization` header with the encoded credentials. You need to close all instances of the browser for it to discard the remember credentials.

5.4 Chapter Summary

Let's summarize the key takeaways of this chapter:

- You've learned Spring Security, its architecture, and Spring Boot auto-configuration for Spring Security
- You've learned how to implement Spring Security in a Spring Boot application and customize the user login page
- How to implement in-memory, JDBC, and LDAP authentication with Spring Security
- How to implement role-based access control in a Spring Boot application
- How to implement HTTP basic authentication to authenticate users in a Spring Boot application

In the next chapter, you'll extend the understanding of Spring Security by implementing a few more advanced application security features.

6 Implementing additional security with Spring Security

This chapter covers

- **Configuring advanced security configurations – Securing passwords with Spring Cloud Vault, Remember Me, and Google reCAPTCHA**
- **Enabling Multi-Factor Authentication – Email Verification, Two Factor Authentication with Google Authenticator**
- **Implementing login with OAuth2 in a Spring Boot application**
- **Securing Spring Boot Actuator endpoints with Spring Security**

In chapter 5, we've introduced you to Spring Security and provided an introduction to the various Spring Security concepts. Further, we've explored several techniques to use Spring Security in a Spring Boot application. In this chapter, you'll use the foundational concepts from the previous chapter and implement several advanced security features in your Spring Boot application using Spring Security. Some of these features include enabling HTTPS, storing passwords in Hashicorp Vault, implementing Remember me, reCAPTCHA, Email verification, Two Factor Authentication etc.

You can use Spring Security to implement several advanced application security features in a Spring Boot application. Some of these features are widely used in production applications and implementing these in your Spring Boot application can certainly enhance the application security. Let us summarizes the features that you'll implement in this chapter:

- **Enabling HTTPS:** The interaction between client and server over the HTTP protocol poses a serious security risk. This is because HTTP protocol transfer data in plain text. Thus, malicious uses can intercept the network traffic and can access the application data. HTTPS protocol encrypts the interaction between client and server and protects the application data

- **Secret Management:** Managing application secrets (password, API keys etc.) is a key concern in any application. In a Spring Boot application, it is a common occurrence to place secrets in the `application.properties` (or application.yml) file. This defeats the purpose of the actual use of the secret. We'll demonstrate how to use Spring Cloud Vault to manage application secrets
- **User Registration:** Most web applications deal with users. Thus, effectively managing users in an application is one of the key tasks. You'll learn this by implementing a user registration module in the Course Tracker application
- **Email Verification:** While registering users in an application, the users must be providing a valid email address. You'll learn how to verify user email by implementing email verification in the user registration in the Course Tracker application
- **Locking User Account:** It is a common practice to lock user accounts in case there are multiple failed login attempts. These features can protect user account from brute-force attacks by malicious users or internet bots
- **Remember Me:** Remembering users in a trusted device can save users time. Spring Security provides built-in support to enable the remember-me feature in a Spring application
- **Enabling reCAPTCHA:** Internet bots can cause severe damage to an application as they can overwhelm the application by creating fictitious users. It can drain the computing resources for the application and provide poor or no service to the real application user. You can prevent this by enabling CAPTCHA. You'll implement Google reCAPTCHA in the Course Tracker application
- **Two Factor Authentication:** The two-factor authentication provides an added security to the applications as requires the user to provide additional authentication. You'll implement two-factor authentication in the Course Tracker application that requires users to submit a One Time Password (OTP) from the Google Authenticator application
- **Login with Google:** Most users these days have their user accounts on websites like Google, Facebook, GitHub etc. The ability for the users to use these existing accounts to access an application such as Course Tracker provides an added convenience as it does not require the user to go through the lengthy user registration and account activation process in third party applications. In the Course Tracker application, you'll let the users log in with their Google account

Note

In this chapter, we intend to show you how to implement several advanced security features that often used in enterprise/production applications. Thus, in this chapter, you'll see a lot of code examples and comparatively fewer theoretical explanations. Further, as some of these techniques are lengthy, at times, we'll refer you to the book's GitHub repository for the relevant code snippets.

6.1 Enable HTTPS in a Spring Boot Application

In modern-day applications, it is a common practice to serve the users through HTTPS instead of the HTTP protocol. HTTPS is the HTTP with TLS encryption. With HTTPS, the HTTP request and response are encrypted and is more safe and secure. It is relatively easy to enable HTTPS in a Spring Boot application. Let us explore this in the next technique.

TECHNIQUE ENABLE HTTPS IN A SPRING BOOT APPLICATION

Problem

HTTPS provides better security to a web application. You need to enable HTTPS in the Course Tracker application

Solution

Enabling HTTPS in a Spring Boot application is a two-step process. First, you need to obtain a TLS certificate and second, configure the certificate in your Spring Boot application. A TLS certificate contains information including the public and private key of the certificate owner. These details serve two purposes – encrypt the data and provide identity assurance of the certificate owner. For the first step, you can obtain a certificate in two ways. Obtain it through a trusted Certificate Authority (CA) such as Verisign, Entrust, Let's Encrypt or generate a self-signed certificate through the utilities such as `keytool` or `openssl`. For a production application, it is always recommended to use a certificate obtained from a trusted CA. For demonstration purposes, we'll generate a self-signed certificate using the JDK's `keytool` utility. You can refer to the https://github.com/spring-boot-in-practice/repo/wiki/Generating-a-Self-Signed-Certificate-Using-Keytool GitHub wiki link for the steps to generate a self-signed certificate.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/implementing-https/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/implementing-https/course-tracker-final

Once you have the certificate, you can proceed with the HTTPS configuration in the Spring Boot application. The first step is to place the keystore file (contains the certificate) inside the Spring Boot application. We'll keep the file inside a folder called `keystore` in the `src\main\resources` folder. The next step is to configure the Spring Boot application to use the provided keystore and then enable HTTPS.

Next, to enable the HTTPS in the Spring Boot application, let's open the application.properties (or application.yml) file and define the properties as shown in the listing 6.1:

Listing 6.1 HTTPS properties

```
# The format used for the Keystore. It could be set to JKS in case it is a JKS file
server.ssl.key-store-type=PKCS12
# The path to the keystore containing the certificate. We have kept the certificate in the
       keystore folder which is in the application class path
server.ssl.key-store=classpath:keystore/sbip.p12
# The password used to generate the certificate
server.ssl.key-store-password=p@ssw0rd
# The alias mapped to the certificate
server.ssl.key-alias=sbip
# HTTPS Port
server.port=8443
```

The next change we'll implement is to enforce HTTPS for every single request. This can be done in the `SecurityConfiguration` class that extends the `WebSecurityConfigurerAdapter` class (We've introduced you to this Spring Security class in chapter 5). Listing 6.2 shows the changes:

Listing 6.2 Updated SecurityConfiguration class

```
@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

       @Override
       protected void configure(HttpSecurity http) throws Exception {
         http.requiresChannel().anyRequest().requiresSecure()
         .and()
         .authorizeRequests().antMatchers("/login").permitAll()
         .anyRequest().authenticated().and().formLogin().loginPage("/login");
       }

       // Additional code

}
```

In the listing, the highlighted (in bold) code snipped indicates that all request needs to be secure (i.e., over HTTPS). You can start the application and access the login page by accessing https://localhost:8443/login URL. Notice that we are using the HTTPS protocol and associated port 8443 instead of the default HTTP port 8080.

Now that we've implemented HTTPS and the application blocks all HTTP requests, we need to redirect all traffic to HTTPS automatically. In the `application.properties` file you've already configured the HTTPS configuration (through the `server.port=8443` property) Thus, you can't configure HTTP anymore as Spring Boot supports only one of the protocol configuration at a time in the `application.properties` file. We'll configure the HTTP connector for the Tomcat server programmatically so that all incoming HTTP requests can be automatically redirected to HTTPS. Listing 6.3 shows the code snippet added in the `CourseTrackerSpringBootApplication` class:

Listing 6.3 Configuration redirect HTTP request to HTTPS

```
@Bean
public ServletWebServerFactory servletContainer() {
    TomcatServletWebServerFactory tomcat = new TomcatServletWebServerFactory() {
        @Override
```

```
        protected void postProcessContext(Context context) {
            SecurityConstraint securityConstraint = new SecurityConstraint();
            securityConstraint.setUserConstraint("CONFIDENTIAL");
            SecurityCollection collection = new SecurityCollection();
            # We have prtovided pattern as /* to include all incoming requests
            collection.addPattern("/*");
            securityConstraint.addCollection(collection);
            context.addConstraint(securityConstraint);
        }
    };
    tomcat.addAdditionalTomcatConnectors(redirectConnector());
    return tomcat;
}

private Connector redirectConnector() {
    Connector connector = new Connector("org.apache.coyote.http11.Http11NioProtocol");
    connector.setScheme("http");
    # Default HTTP port is set to 8080 and the redirect port is configured to HTTPS port
      8443
    connector.setPort(8080);
    connector.setRedirectPort(8443);
    return connector;
}
```

In Listing you've done the following changes:

- Defined the `TomcatServletWebServerFactory` class, created the security constraint and included it in the Context
- Next, you've defined the redirect connector that redirects HTTP requests at 8080 requests to HTTPS port 8443

Restart the application and access the http://localhost:8080/login URL. You'll notice that you are automatically redirected to the https://localhost:8443/login URL.

Discussion

In any production-grade application, it is always recommended to use HTTPS over HTTP. In HTTP the request and response are transferred in plain-text mode and your application is vulnerable to expose sensitive application information. For example, imagine that your social account password or the credit card details are transferred in plain text and can be accessed by malicious users.

HTTPS encrypts the request and response and prevents exposing the application data in transit. Thus, applications using HTTPS are trustworthy to the users. Besides, it provides security to both application users and application owners.

Spring Boot provides built-in support to configure HTTPS, and, in this technique, you've explored how easily you can configure it in a Spring Boot application. Besides, you've also learned how to block the HTTP requests using Spring Security and implemented auto redirection of HTTP requests to HTTPS.

You may notice that the HTTPS URL of the Course Tracker Spring Boot application shows a Not secure message in the browser. This is due to the use of a self-signed certificate that we are using in our example. Self-signed certificates are not trusted by browsers as these can be generated by anyone and does not have any credibility. However, self-signed certificates are useful for development and demonstration purposes. In a production application, you must use certificates issued from a trusted CA.

6.2 Securing Secrets in Spring Cloud Vault

Managing application secrets are one of the key challenges to any application and Spring Boot applications are no exceptions to it. An application can contain verities of secrets such as passwords, API Keys, TLS certificates, encryption keys to name a few. Exposing these secrets to malicious actors can cause catastrophic damage to an application. For instance, imagine the consequences if the database password of a banking application is exposed to malicious users.

Spring Boot lets you manage the application properties (including secrets) through the `application.properties` (or the `application.yml`) file for a smooth application configuration. Although this approach is developer-friendly, it can leave room for developers to accidentally place secrets in plain text and exposed them outside. It is a common occurrence that developers accidentally check-in secrets into public repositories and compromises the overall application security. For instance, in the previous technique, you've stored the keystore password in the `application.properties` file.

In this section, we'll introduce you to HashiCorp's Vault (https://www.vaultproject.io/). It is a popular tool that lets you manage the secrets of an application securely and efficiently. You'll also explore how to integrate Vault into a Spring Boot project and manage the application secrets in the vault. Before we start discussing Vault concepts, let us first use it in the next technique and then provide a discussion on it.

A note on HashiCorp Vault

HashiCorp Vault provides plenty of configurations and options to manage and use the vault. Some of these configurations include configuring the vault persistence storage, cloud integration, dynamic secret generation etc. It is beyond the scope of this text to provide in-depth coverage on this topic. In this section, we aim to show how to configure a basic vault and use it in a Spring Boot application. For further details on various vault features, refer to the documentation at https://www.vaultproject.io/docs.

TECHNIQUE MANAGING APPLICATION SECRETS WITH HASHICORP VAULT IN A SPRING BOOT APPLICATION

Problem

Your application contains sensitive application information such as database password or external API keys. You need to secure those with HashiCorp Vault.

Solution

In this technique, we'll demonstrate to store application secrets in the Hashicorp Vault and use the secrets in a Spring Boot application. Presently, in the CourseTracker application, we are storing the keystore password as plain text in the `application.properties` file. We'll externalize this secret to the vault and made the necessary configuration changes in the application to refer it from the vault.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/implementing-vault/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/implementing-vault/course-tracker-final

Before we proceed with this technique, you'll need to set up the vault server and configure it to store your secrets. You can refer to the https://github.com/spring-boot-in-practice/repo/wiki/Installing-and-Configuring-HashiCorp-Vault to do this set-up in your machine.

Next, let us perform the pom.xml changes to include the Spring Cloud config support in the Course Tracker application. Listing 6.4 shows the updated `pom.xml` changes:

Listing 6.4 Updated pom.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
       <parent>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-parent</artifactId>
         <version>2.4.5</version>
         <relativePath /> <!-- lookup parent from repository -->
       </parent>
       <groupId>com.manning.sbip.ch06</groupId>
       <artifactId>course-tracker-implementing-vault-final</artifactId>
       <version>1.0.0</version>
       <name>course-tracker-implementing-vault-final</name>
       <description>Spring Boot application for Chapter 06</description>

       <properties>
         <java.version>15</java.version>
         <spring-cloud.version>2020.0.1</spring-cloud.version>
       </properties>

       <dependencies>
         // additional configurations
         <dependency>
                 <groupId>org.springframework.cloud</groupId>
                 <artifactId>spring-cloud-starter-vault-config</artifactId>
         </dependency>
       </dependencies>

       <dependencyManagement>
         <dependencies>
                 <dependency>
                         <groupId>org.springframework.cloud</groupId>
                         <artifactId>spring-cloud-dependencies</artifactId>
                         <version>${spring-cloud.version}</version>
                         <type>pom</type>
```

```
                            <scope>import</scope>
                    </dependency>
          </dependencies>
        </dependencyManagement>
        // additional configurations
</project>
```

Next, let us provide the vault configuration in the application.properties file as shown in listing 6.5:

Listing 6.5 Application.properties changes

```
spring.cloud.vault.token=s.YGgzy5qOtEf4d6Xo0i6qqQGL
spring.cloud.vault.authentication=token
spring.cloud.vault.host=localhost
spring.cloud.vault.port=8200
spring.cloud.vault.scheme=http
# Spring configuration to refer to the secret/coursetracker in the vault
spring.config.import=vault://secret/coursetracker
spring.application.name=coursetracker

# Replace the server.ssl.key-store-password=p@ssw0rd property with below configuration
server.ssl.key-store-password=${keystore}
```

Let us discuss the changes done in Listing 6.5:

1. Included the Initial Root Token obtained while initializing the vault. The token value for your configuration will be different. This token is required for the Course Tracker application to authenticate itself to the vault
2. You are using the authentication mode as a token. Vault support several other authentication modes
3. Next, we’ve supplied the vault host, port and scheme. We are using HTTP as we have configured the Vault to run with HTTP. This is solely to keep the example simple and in a production application you should always use the HTTPS scheme
4. Next, we’ve provided the secret configuration. Note that we’ve used the `secret/coursetracker` in the Vault to store the keystore password. We’ve also provided the application name as coursetracker.
5. Finally, we’ve replaced the keystore password with the Vault key which is configured as a `keystore` in the Vault

You can start the application, and access the https://localhost:8443 URL. You’ll find the application is running as usual.

Discussion

In this technique, you’ve explored how to use the Hashicorp Vault to store application secrets and use it in a Spring Boot application. Hashicorp Vault is a powerful and feature-rich vault that is flexible and let you configure the vault as per your requirement.

Figure 6.1 shows the interaction between the user, Spring Boot application, and the Vault:

Figure 6.1 Interaction between User, Spring Boot application and Hashicorp Vault.

In this technique, we've placed the initial root token in the application.properties file. Vault generates this token when you initialize the Vault with the `vault operator init` command. In a production application, you should refer to it from an environment variable or use some other means to supply it to the application. Besides, we are using HTTP to communicate to the vault which can compromise the secrets. It is recommended to configure HTTPS to use the vault in a production application.

6.3 Implementing User Registration

Registering and managing users is one of the key features of a web application. In this section, we'll discuss how we can create new users in the Course Tracker application. Let us implement this in the next technique.

TECHNIQUE IMPLEMENTING USER REGISTRATION WITH SPRING SECURITY IN A SPRING BOOT APPLICATION

Problem

You need to implement a user registration module in the Course Tracker application. The new user details should be persisted in the application and the user should be able to login into the application.

Solution

Before we deep dive into the actual implementation of the user registration, let us provide an outline of the changes you'll perform in the existing Course Tracker application:

- Define a user registration HTML page (`add-user.html`) to capture the new user details
- You'll then create a `UserDto` Data Transfer Object (DTO) class that captures the details submitted through the HTML page
- We'll then define the `ApplicationUser` domain entity class that represents the user in the Course Tracker application. Note that `UserDto` class represents the data captured in the HTML page and might contain additional parameters which might not be required to be part of actual `ApplicationUser` details (e.g. ConfirmPassword field in UserDto class)
- Next, you'll create the associated service implementations and the Spring Data repositories

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/user-registration/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/user-registration/course-tracker-final

To add a new user, let us begin with defining a user registration page. You can find the HTML page at https://github.com/spring-boot-in-practice/repo/blob/main/ch06/user-registration/course-tracker-final/src/main/resources/templates/add-user.html.

This user registration page is similar to the previous HTML pages you've used earlier. It has an HTML form that lets the users enter the basic user details and register themselves in the application. Let us now add a Java POJO class that captures these details. Listing 6.6 shows the `UserDto` class which captures the user data entered by the user on the registration page:

Listing 6.6 The UserDto class

```
package com.manning.sbip.ch06.dto;

import javax.validation.constraints.*;

public class UserDto {

    @NotEmpty(message="Enter your firstname")
    private String firstName;

    @NotEmpty(message="Enter your lastname")
    private String lastName;
    @NotEmpty(message="Enter a username")

    private String username;
    @NotEmpty(message="Enter an email")
    @Email(message="Email is not valid")
    private String email;

    @NotEmpty(message="Enter a password")
    private String password;

    @NotEmpty(message="Confirm your password")
    private String confirmPassword;

    // Getter, Setter, and Constructors omitted
}
```

The `UserDto` is a plain Java class containing the fields same as the registration page with `javax.validation.constraints` annotations that are used to perform the validations. Note that you've named this class as `UserDto`. This is because it is transferring the data from the HTML page to the controller. Typically, you need to have a different user class that represents the actual user in the application. For instance, you might have additional details in the `UserDto` class that might not be useful to store for the actual user. For instance, in the example above, you have the `password` and `confirmPassword` fields which are required to ensure whether the passwords provided are the same. However, for the actual application entity using only the password field is enough. Listing 6.7 shows the `ApplicationUser` class:

Listing 6.7 ApplicationUser Java Class

```
package com.manning.sbip.ch06.model;

import javax.persistence.*;

@Entity
@Table(name = "CT_USERS")
public class ApplicationUser {

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    private Long id;

    private String firstName;
    private String lastName;
    private String username;
    private String email;
    private String password;

       // Getter, Setter, and Constructors omitted
}
```

This class is a JPA entity, and you are using a custom table named `CT_USERS` to store application user details. It is a common practice to append the acronym of the application module (e.g., `CT` for the `CourseTracker` application) in the table name. Listing 6.8 shows the table details located in `src\main\resources\script.ddl` file:

Listing 6.8 The CT_USERS table DDL

```
create table CT_USERS (
    id BIGINT NOT NULL auto_increment,
    first_name varchar(50),
    last_name varchar(50),
    email varchar(50),
    username varchar(50),
    password varchar(100),
    PRIMARY KEY (id)
);
```

Let us define the `UserRepository` interface that lets us manage the `ApplicationUser` details in the application as shown in Listing 6.9:

Listing 6.9 UserRepository Interface

```
package com.manning.sbip.ch06.repository;

//imports

@Repository
public interface UserRepository extends CrudRepository<ApplicationUser, Long> {
```

```
    ApplicationUser findByUsername(String username);
}
```

Listing defines a custom method that lets us find the `ApplicationUser` based on the supplied `username`. In chapter 3, we've defined in details how Spring Data uses these custom methods and retrieve data from the database. Next, let us define a `UserService` interface that provides the operations you can perform to maintain the users in the application. Listing 6.10 shows this:

Listing 6.10 The UserService interface

```
package com.manning.sbip.ch06.service;

//imports

public interface UserService {
    # Create a new user in the application
    ApplicationUser createUser(UserDto userDto);
    # Finds a user from the supplied username
    ApplicationUser findByUsername(String username);
}
```

In the listing, you've defined two operations:

- The `createUser(..)` method lets you create a new user
- The `findByUsername(..)` method finds the user from the supplied username

The listing 6.11 provides an implementation to this interface:

Listing 6.11 The default implementation of the UserService interface

```
package com.manning.sbip.ch06.service.impl;

//imports

@Service
public class DefaultUserService implements UserService {

    @Autowired
    private UserRepository userRepository;

    @Autowired
    private PasswordEncoder passwordEncoder;

    # Maps the UserDto details captured from the HTML page to the actual ApplicationUser
       instance that is persisted into the database. Notice the use of a password encoder
       that encodes the plain-text password into an encoded password

    public ApplicationUser createUser(UserDto userDto) {
       ApplicationUser applicationUser = new ApplicationUser();
       applicationUser.setFirstName(userDto.getFirstName());
       applicationUser.setLastName(userDto.getLastName());
       applicationUser.setEmail(userDto.getEmail());
       applicationUser.setUserName(userDto.getUsername());
       applicationUser.setPassword(passwordEncoder.encode(userDto.getPassword()));
```

```
        return userRepository.save(applicationUser);
    }

    public ApplicationUser findByUsername(String username) {
        return userRepository.findByUsername(username);
    }
}
```

In the listing, you've implemented the `createUser(..)` method. You create an instance of the `applicationUser` and populate the object using the details from the `userDto` object. You then save the application object details in the `CT_USERS` table using the `userRepository`. Notice that, you've used the password encoder to encode the password so that the encoded password is stored in the database table.

Besides, you've also provided an implementation of the `findByUsername(..)` method which finds the `ApplicationUser` using the supplied username. You'll see the use of this method while we implement our custom `UserDetailsService` to load data from the `CT_USERS` table.

If you recall from chapter 5, the `UserDetailsService` interface provides a bridge between the custom identity store and Spring Security user management. The next thing you'll do is to provide an implementation of the `UserDetailsService`. Listing 6.12 shows this:

Listing 6.12 UserDetailsService Implementation

```
package com.manning.sbip.ch06.service.impl;

//import

@Service
public class CustomUserDetailsService implements UserDetailsService {

    @Autowired
    private UserService userService;


    public UserDetails loadUserByUsername(String username) throws UsernameNotFoundException
       {

       ApplicationUser applicationUser = userService.findByUsername(username);
       if(applicationUser == null) {
         throw new UsernameNotFoundException("User with username "+username+" does not
       exists");
       }
       # We are returning a Spring Security UserDetails instance created from the custom
       ApplicationUser class
       UserDetails userDetails  =
       User.withUsername(username).password(applicationUser.getPassword()).roles("USER").di
       sabled(false).build();
       return userDetails;
    }
}
```

In this technique, you áre using a custom table(i.e. CT_USERS) to manage the users. Thus, you need to provide a mapping between your custom user details and the Spring Security user.

In the CustomUserDetailsService class, you use the UserService implementation to find the ApplicationUser instance from the CT_USERS table. If there is no such user exists, you return a UsernameNotFoundException exception. However, if there is a user with the supplied username, you map the ApplicationUser instance to Spring Security UserDetails.

Let us now add a Spring controller that manages the user registration. Listing 6.13 shows this:

Listing 6.13 RegistrationController

```
package com.manning.sbip.ch06.controller;

//imports

@Controller
public class RegistrationController {

    @Autowired
    private UserService userService;

    # The HTTP GET mapping that returns the caller to the add-user.html page. We also add
       an empty instance of the UserDto class that is used to bind the data entered into
       the HTML page
    @GetMapping("/adduser")
    public String register(Model model) {
        model.addAttribute("user", new UserDto());
        return "add-user";
    }

    # The HTTP POST mapping that performs the user registration. In the UserDto class,
       you've used validation (Using the annotations such as @NotEmpty) to ensure that the
       UserDto fields are not empty. Thus, we check if the BindingResult has any error.
    @PostMapping("/adduser")
    public String register(@Valid @ModelAttribute("user") UserDto userDto, BindingResult
       result) {
        if(result.hasErrors()) {
            return "add-user";
        }
        userService.createUser(userDto);
        return "redirect:adduser?success";
    }
}
```

In the listing, you've added two endpoints, the adduser HTTP GET endpoint returns the add-user.html page. The adduser HTTP POST endpoint checks if the UserDto object is valid and all necessary details are provided. This endpoint is the one bound in the submit attribute of the add-user.html page. If it is invalid, you return to the add-user.html page with the list of errors. If valid, the user is created in the CT_USERS table.

Let us now handle the user login failure in the LoginController class. If you recall from chapter 05, this controller displays the login page to the user. Let us add a new HTTP GET endpoint `login-error` which displays a login error message to the user in case of an unsuccessful login. Listing 6.14 shows the updated `LoginController` class:

Listing 6.14 The Login Controller

```
package com.manning.sbip.ch06.controller;

//imports

@Controller
public class LoginController {

    @GetMapping("/login")
    public String login() {
        return "login";
    }

    # For login error, this endpoint is invoked. It set the loginError flag to true and
       based on this the login page displays the login error issue to the user. Notice that
       you are using Spring MVC's model instance to transport the loginError attribute to
       the login.html page
    @GetMapping("/login-error")
    public String loginError(Model model) {
        model.addAttribute("loginError", true);
        return "login";
    }
}
```

The last change you'll perform is to update the `ScurityConfiguration` class. Listing 6.15 shows the updated class:

Listing 6.15 The SecurityConfiguration class

```
package com.manning.sbip.ch06.security;
//imports

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests()
       .antMatchers("/adduser", "/login", "/login-error").permitAll()
       .anyRequest().authenticated()
       .and()
       .formLogin().loginPage("/login").failureUrl("/login-error");
    }

    @Override
    public void configure(WebSecurity web) throws Exception {
        web.ignoring().antMatchers("/webjars/**", "/images/*", "/css/*");
    }

    @Bean
    public PasswordEncoder passwordEncoder() {
        return new BCryptPasswordEncoder();
    }
```

```
}
```

You've done the following changes in this class:

- The `login-error` endpoint added to the list of endpoints accessible without any authentication
- Added the login `failureUrl` to the `login-error` endpoint to redirect the user to re-login for an unsuccessful login. Spring Security internally redirects the users to the `login-error` endpoint in case of a login failure
- Defined the `BCryptPasswordEncoder` to encode the password. Recall that in the `DefaultUserService` class you've used this encoder to encode the passwords before storing them in the database

You can start the application and access the http://localhost:8080 URL and click on the Register menu to add a new user. You'll see the user registration page as shown in figure 6.2:

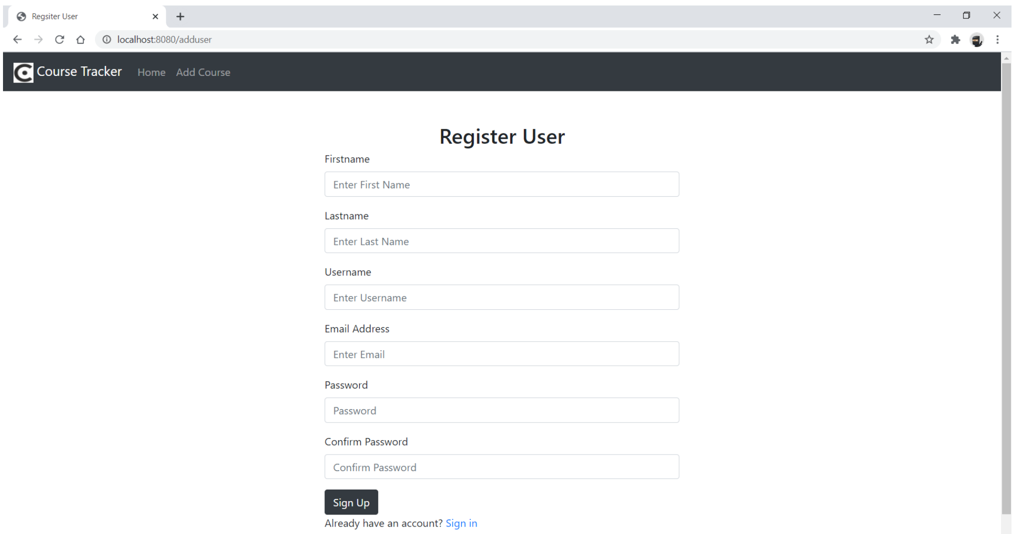


Figure 6.2 User Registration Page. This page contains basic user details which are saved into the CT_USERS table

Once you fill in the details and click on Sign Up, you'll see a successful user registration message and see a link for login. At this stage, If you query to the `CT_USERS` table in the `h2-console`, you'll notice that a new user is created, and the password is stored in an encoded text.

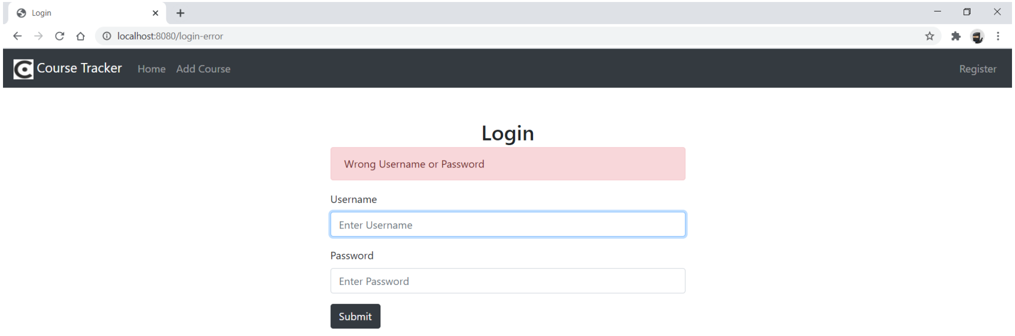


Figure 6.3 User login failed. The user is presented with an error message for invalid credentials

If you click on the Sign In link, you'll be redirected to the login page. You can log in with your username and password. If the login is successful, you'll be redirected to the index page containing the list of available courses. For an unsuccessful login, you'll notice an error message as shown in figure 6.3. Notice that this error page is the one appearing when the `loginError` is set to true.

Discussion

In this technique, you've implemented a user registration module in the Course Tracker application. Course Tracker application is now able to register new users and the newly created users can log in with their credentials.

You've introduced a few components in the application to enable the user registration capability in the application. Notice that in this technique, we've used a handful of already discussed technical concepts to implement this feature. Let us recap the major changes you've done in this technique:

- First, introduced a user registration HTML page, and the associated `RegistrationController`
- Second, inducted the `UserDto` and `ApplicationUser`. The `UserDto` class is transferring data from the HTML page to the controller. The `ApplicationUser` class represents the users in the application
- Third, created a new `UserRepository` service and the corresponding `UserService` class to perform operations on the User class
- Lastly, provided an implementation of the `UserDetailsService` and changed the `SecurityConfiguration` and `LoginController` classes to additionally handle the login failures

Although this user registration module works fine, few additional validations need to be handled. For instance, you need to ensure that the `Password` and `ConfirmPassword` filed data is the same. Besides, the email address and the username values need to be unique across the application. Further, there is no password policy implemented, and most production application should have a defined password policy (e.g., minimum password length, usage of special characters, etc.). We leave these activities as an exercise for the reader. You can refer to Chapter 2, Validate User Data using Bean Validation section on hints how you can implement these features.

6.4 Implementing Email Verification at User Registration

In the previous section, while registering a user, you've collected the user email address. On the registration page, you've enforced email validation that ensures the user is providing a structurally valid email address. However, you've not validated whether the provided email address exists, or it belongs to the user. Validating user email is an important action performed by the most web application. There are several reasons for this:

- You are validating that the user is the same who they are claiming to be and not impersonating anyone else
- The user is not an internet bot https://en.wikipedia.org/wiki/Internet_bot, but a legitimate user wants to register to the application
- A valid email is also useful to inform the user of various marketing, promotions, and product offerings

Let us demonstrate how to validate the user email address by sending a verification link to the provided email address. The next technique discusses this.

TECHNIQUE VALIDATE USER EMAIL ADDRESS IN A SPRING BOOT APPLICATION

Problem

While registering a new user, you need to validate the user email address by sending a verification link to the supplied email address.

Solution

In this technique, you'll learn how to validate a user email address in a Spring Boot application. You'll do this by sending a verification link to the user's email address. Until the user verifies their email address through the verification link, the associated user account will be disabled. Once the user confirms the email address by clicking the verification link, the user account is activated.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/email-verification/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/email-verification/course-tracker-final

Let us begin by providing a high-level outline of the changes you'll be performing in this technique:

A user registers to the course application by creating a new user account. The Course Tracker application successfully records the user details in the `CT_USERS` table. However, it marks the user account as disabled as the user email id is not yet verified. As part of the registration process, the Course Tracker application sends an email to the registered email id with a verification link to activate the account. If the user attempts to access the account before activation, they are redirected to an error page asking the user to activate the account. Post successful verification, the account is activated in the application and the user can log in.

Note

In this example, we've used Gmail as the preferred email server for demonstration purposes. You can use other email service provides as well as your custom email server. If you choose to do so, ensure to provide relevant email server configuration in place of Gmail. You'll see how to configure these details in listing 6.17

Let us now begin with the necessary code changes to implement this feature. The first change you need to make is to add the `spring-boot-starter-mail` dependency in the application's `pom.xml` file. This dependency contains necessary libraries that lets you send an email to the user's email address. Listing 6.16 shows the dependency:

Listing 6.16 The spring-boot-starter-mail dependency

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-mail</artifactId>
</dependency>
```

Let us also update the `application.properties` file to provide the email server details that should be used to send the email. In this demonstration, we'll use Gmail as our email server. You can use any other email server (such as Outlook or your custom email server configuration). If you use an email server other than Gmail, ensure to provide the necessary configurations. Listing 6.17 shows the Gmail email server configuration in the `application.properties` file:

Listing 6.17 Updated application.properties file with Gmail Email server configuration

```
// Other properties
#Email server. We have used Gmail Email Server
spring.mail.host=smtp.gmail.com
#Email server port. We have used Gmail Email Port
spring.mail.port=587
#Email server username. Provide a Gmail email id
spring.mail.username=<Enter Gmail Email ID>
#Email server password. Provide the password of the provided Gmail email id.
spring.mail.password=<Enter Gmail Password>
#Email server additional properties
spring.mail.properties.mail.smtp.auth=true
spring.mail.properties.mail.smtp.starttls.enable=true
spring.mail.protocol=smtp
spring.mail.test-connection=false
```

In the listing, you've provided the Gmail email server configuration. By default, Gmail does not allow to send of email from less secure applications. The Course Tracker is treated as a less secure application by Gmail. Thus, you need to enable the *Less secure app access* option in your Gmail account security settings.

Note

In listing 6.17, you've included the Gmail user name and password in the application.properties file. The application.properties file is part of your application codebase and eventually moved to the source code repository. It is strongly discouraged to configure any type of application secrets in the application.properties (or, application.yml) file as doing so risks exposing the secrets to a wider audience. Imagine you pushed the configurations with the email address and password to a public repository in GitHub and it is forked by other users. Your credentials will sprawl to all these forked repositories and let others gain access to your email account.

A better alternative is to use solutions such as Vault to keep application secrets which we have discussed in one of the previous technique.

Next change you need to make in the `ApplicationUser` class to ensure whether the user account is verified. Add a new `boolean` variable named `verified` and the associated getter/setter methods in the ApplicationUser class.

Since we are changing the entity class, we need to change the `CT_USERS` table as well to add the new column verified. Listing 6.18 shows this:

Listing 6.18 The updated CT_USERS table with verified column

```
create table CT_USERS (
    id BIGINT NOT NULL auto_increment,
    first_name varchar(50),
    last_name varchar(50),
    email varchar(50),
    username varchar(50),
    password varchar(100),
    verified smallint(1),
    PRIMARY KEY (id)
);
```

In this technique, you are attempting to validate the newly registered user by sending an activation link to their email. To keep this implementation simple, we'll use a Base64 encoded UUID as the unique id for a given username. It works as follows:

- Once the user is registered, we generate a UUID and store it along with the user's username in a table named CT_EMAIL_VERIFICATIONS
- This UUID is Base64 encoded and sent to the user as part of their activation email
- Once the user clicks on the link available in the activation email, we retrieve the Base 64 encoded UUID value, decode it, and compare it against the stored value in the table
- If there is a match, we record the user as a verified user in the application by updating the verified flag in the `CT_USERS` table to true

Let us define the `EmailVerification` entity class that contains the `verificationId` and the `username` of the users as shown in the listing 6.19:

Listing 6.19 EmailVerification POJO class

```
package com.manning.sbip.ch04.model;

//imports

@Entity
@Table(name = "CT_EMAIL_VERIFICATIONS")
public class EmailVerification {
    # The UUID-based verification ID
    @Id
    @GeneratedValue(generator = "UUID_GENERATOR")
    @GenericGenerator(name = "UUID_GENERATOR", strategy = "org.hibernate.id.UUIDGenerator")
    private String verificationId;
    # The username of the registered user
    private String username;
}
```

Let us define the `CT_EMAIL_VERIFICATIONS` table that stores the verification id and the username as shown in listing 6.20. You can append this table DDL in the `script.ddl` file located in the `src\main\resources` folder. This table contains the binding between usernames and their validation identifiers:

Listing 6.20 CT_EMAIL_VERIFICATIONS table

```
create table CT_EMAIL_VERIFICATIONS (
    verification_id varchar(50),
    username varchar(50),
    PRIMARY KEY (verification_id)
);
```

Let us now define a Spring service class that manages the `EmailVerfication` entity services. Listing 6.21 shows the `EmailVerificationService` class:

Listing 6.21 The EmailVerificationService Class

```
package com.manning.sbip.ch04.service;

//imports
@Service
public class EmailVerificationService {

    private final EmailVerificationRepository repository;

    @Autowired
    public EmailVerificationService(EmailVerificationRepository repository) {
        this.repository = repository;
    }

    # Generates a verification id for a supplied username
    public String generateVerification(String username) {
        if (!repository.existsByUsername(username)) {
```

```
            EmailVerification verification = new EmailVerification(username);
            verification = repository.save(verification);
            return verification.getVerificationId();
        }
        return getVerificationIdByUsername(username);
    }

    # Provides the verification id for a supplied username
    public String getVerificationIdByUsername(String username) {
        EmailVerification verification = repository.findByUsername(username);
        if(verification != null) {
            return verification.getVerificationId();
        }
        return null;
    }

    # Provides the username for a supplied verification id
    public String getUsernameForVerificationId(String verificationId) {
        Optional<EmailVerification> verification = repository.findById(verificationId);
        if(verification.isPresent()) {
            return verification.get().getUsername();
        }
        return null;
    }
}
```

Let us now focus to generate the verification email once a new user registers in the application. You'll leverage Spring's `ApplicationEvent` and `ApplicationListener` for this purpose. The `ApplicationEvent` class represents an event in the application. The `ApplicationListener` class lets you listen to the published events and perform some action once the events are emitted.

In this technique, you'll generate a `UserRegistrationEvent` whenever a new user is created in the application. Then you'll define an `EmailVerificationListener` that listens to this event and let you compose and send an email with the verification link.

You might ask that we could send the email in the `RegistrationController` class itself while registering the user. The benefit of using Spring's `ApplicationEvent` is that it lets you decouple the email sending activity from the actual user registration process. The usage of this observer pattern is generally a best practice, especially in distributed microservices scenarios. Refer to https://github.com/spring-boot-in-practice/repo/blob/main/ch06/email-verification/course-tracker-final/src/main/java/com/manning/sbip/ch06/event/UserRegistrationEvent.java for the `UserRegistrationEvent` class. Listing 6.22 shows the `EmailVerificationListener` class:

Listing 6.22 EmailVerificationListener class

```
package com.manning.sbip.ch06.listener;

//imports

@Service
public class EmailVerificationListener implements
       ApplicationListener<UserRegistrationEvent> {
```

```
    @Autowired
    private final JavaMailSender mailSender;

    @Autowired
    private final EmailVerificationService verificationService;

    public void onApplicationEvent(UserRegistrationEvent event) {
        ApplicationUser user = event.getUser();
        String username = user.getUsername();
        String verificationId = verificationService.generateVerification(username);
        String email = event.getUser().getEmail();

        SimpleMailMessage message = new SimpleMailMessage();
        message.setSubject("Course Tracker Account Verification");
        message.setText(getText(user, verificationId));
        message.setTo(email);
        mailSender.send(message);
    }

    private String getText(ApplicationUser user, String verificationId) {
       String encodedVerificationId = new
       String(Base64.getEncoder().encode(verificationId.getBytes()));
StringBuffer buffer = new StringBuffer();
buffer.append("Dear ").append(user.getFirstName()).append("
       ").append(user.getLastName()).append(",").append(System.lineSeparator()).append(Syst
       em.lineSeparator());
buffer.append("Your account has been successfully created in the Course Tracker
       application. ");

buffer.append("Activate your account by clicking the following link:
       http://localhost:8080/verify/email?id=").append(encodedVerificationId);
buffer.append(System.lineSeparator()).append(System.lineSeparator());
buffer.append("Regards,").append(System.lineSeparator()).append("Course Tracker Team");
return buffer.toString();
    }
}
```

In the `EmailVerificationListener` class, on receiving a `UserRegistrationEvent` (which is created at the time of user registration in the `RegistrationController`), you retrieve the `username` and use the `EmailVerificationSevice` to generate the verification id. You then create an instance of Spring's `SimpleMailMessage` class and compose the email message. Finally, you send the email with the verification link to the configured email id.

Note

Notice that by default the event publisher and listener is executed by the same thread. Thus, the user registration is not completed unless the event listener sends the email. If you need to handle the email generation and sending as an asynchronous task, you can use Spring's SimpleApplicationEventMulticaster. Listing 6.23 shows the configuration:

Listing 6.23 SimpleApplicationEventMulticaster Bean Definition

```
package com.manning.sbip.ch06.config;

// imports
```

```
@Configuration
public class EventConfiguration {

        @Bean(name = "applicationEventMulticaster")
        public ApplicationEventMulticaster simpleApplicationEventMulticaster() {
                SimpleApplicationEventMulticaster eventMulticaster = new
SimpleApplicationEventMulticaster();

                eventMulticaster.setTaskExecutor(new SimpleAsyncTaskExecutor());
                return eventMulticaster;
        }
}
```

In listing 6.23, you've defined an instance of `SimpleApplicationEventMulticaster` and provided it with an instance of `SimpleAsyncTaskExecutor` that handles the published event asynchronously.

Let us now define the `EmailVerificationController` class that is invoked once the user clicks on the verification link as shown in Listing 6.24:

Listing 6.24 The EmailVerificationController class

```
package com.manning.sbip.ch04.controller;

//imports

@Controller
public class EmailVerificationController {

    @Autowired
    private EmailVerificationService verificationService;
    @Autowired
    private UserService userService;

    @GetMapping("/verify/email")
    public String verifyEmail(@RequestParam String id) {
       byte[] actualId = Base64.getDecoder().decode(id.getBytes());
       String username = verificationService.getUsernameForVerificationId(new
       String(actualId));
       if(username != null) {
            ApplicationUser user = userService.findByUsername(username);
            user.setVerified(true);
            userService.save(user);
            return "redirect:/login-verified";
        }
        return "redirect:/login-error";
    }
}
```

In the listing, you first retrieve the `verificationId` and find the associated username. If there is a user found against the username, you load the user and update the account as verified. Otherwise, the user is redirected to a login error page. Let us explore the changes you need to perform in the `SecurityConfiguration` class as shown in Listing 6.25:

Listing 6.25 The SecurityConfiguration Class

```
package com.manning.sbip.ch06.security;

//import

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private CustomAuthenticationFailureHandler customAuthenticationFailureHandler;

    @Override
    protected void configure(HttpSecurity http) throws Exception {

       http.requiresChannel().anyRequest().requiresSecure()
       .and()
       .antMatchers("/adduser", "/login", "/login-error", "/login-verified", "/login-
       disabled", "/verify/email").permitAll()
       .anyRequest().authenticated()
       .and()
       .formLogin().loginPage("/login").failureHandler(customAuthenticationFailureHandler);
    }

       // Additional code
}
```

In the listing, you've done the following changes:

- Allowed the `"/login-verified"`, `"/login-disabled"`, `"/verify/email"` endpoints to be accessed without any form of authentication. This is obvious as these endpoints deal with actions that either let a user logs in or a new user register to the application
- Used Spring Security's `AuthenticationFailureHandler` interface to provide a custom failure handler implementation that handles login failure. Recall in previous techniques, you had used a `failureUrl` to forward the request to a failure page. The `AuthenticationFailureHandler` implementation provides better control as you can place additional logic on what needs to be done in case of a login failure
- Let us define the `CustomAuthenticationFailureHandler` class as shown in Listing 6.26:

Listing 6.26 CustomAuthenticationFailureHandler Class

```
package com.manning.sbip.ch06.handler;

import org.springframework.security.authentication.DisabledException;
//Other imports

@Service
public class CustomAuthenticationFailureHandler implements AuthenticationFailureHandler {

       private DefaultRedirectStrategy defaultRedirectStrategy = new
       DefaultRedirectStrategy();

    public void onAuthenticationFailure(HttpServletRequest request, HttpServletResponse
       response, AuthenticationException exception) throws IOException, ServletException {
```

```
        if(exception instanceof DisabledException) {
          defaultRedirectStrategy.sendRedirect(request, response, "/login-disabled");
          return;
        }
        defaultRedirectStrategy.sendRedirect(request, response, "/login-error");
    }
}
```

In case of an authentication failure, Spring Security throws the actual exception that indicates the type of authentication failure. In this technique, there could be a situation that a user can attempt to access their account without activating it. However, the user account is disabled in the application unless the account is activated through the activation link. Spring Security automatically throws a `DisabledException` indicating that the user account is disabled. If that happens, we redirect the user to the `/login-disabled` endpoint. You've used Spring's `DefaultRedirectStrategy` class to redirect the response to the appropriate endpoint.

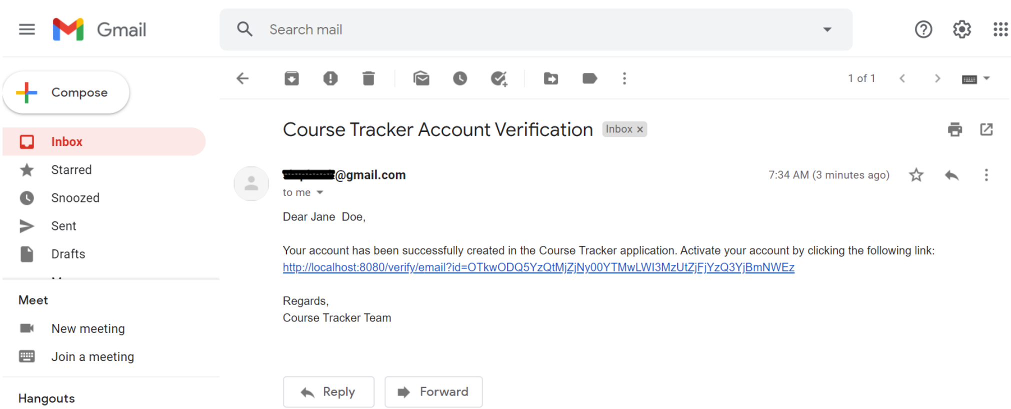


Figure 6.4 Account verification email for a newly registered user in the Course Tracker application

If you start the application and create a new user using the `Register` option, you'll notice that an email is sent out to the configured email as shown in figure 6.4. You need to ensure that you have an active internet connection for the application to send the email. Post successful registration of the user, you'll receive an email similar to the one shown in the figure.

Discussion

In this technique, you've learned how to effectively implement a user registration through a verification email. We've leveraged some of the core Spring features such as Spring event management and used Spring Security features such as `AuthenticationFailureHandler`. We recommend you try out the following scenarios:

- Register a new user in the application. On successful registration, you'll notice there is

an activation link
- At this stage, if you try to login into the application, you'll receive an error message stating the user account is disabled
- Once you click on the activation link, you'll notice a confirmation message that the account is activated, and you can log in
- At this stage, you can try login with valid credentials, and you will be redirected to the index page that shows the available courses

In this technique, you've shared a verification link in the user email and asks the users to click on it to activate the user account. You can further enhance this implementation by imposing an expiry time on the verification link. We leave this task as an exercise to the reader. Following is a hint on how you can proceed with this task. Include an expiry time in the verification link and store this expiry time in the `CT_EMAIL_VERIFICATIONS` table. Once the user clicks on the verification link, along with the verification token, validate whether the expiry time provided in the link is still valid. Further, clear the verification link details from the `CT_EMAIL_VERIFICATIONS` table for any misuse of the verification link.

6.5 Implementing Login Attempt

In many applications, it is a common practice to temporarily suspend user access if there are multiple incorrect login attempts. This is one of the security measures taken by applications to prevent brute-force attacks on an application to gain unauthorized access to the application. In this section, you'll learn how to implement this in the Course Tracker application.

TECHNIQUE CONTROLLING MULTIPLE INCORRECT LOGIN ATTEMPTS IN A SPRING BOOT APPLICATION

Problem

In the current implementation, the Course Tracker application let the users make any numbers of login attempts. You need to temporarily suspend the user access for 24 hours if the user performs three incorrect login attempts.

Solution

Spring Security publishes several Spring events while it performs various security activities in an application. For instance, once a user is successfully authenticated Spring Security publishes `AuthenticationSuccessEvent`. Similarly, Spring publishes `AuthenticationFailureBadCredentialsEvent` if the authentication fails due to invalid credentials. There are many such events published by Spring Security that applications can listen to and perform necessary action.

Let us provide an outline on how we can use the aforementioned Spring Security events to suspend user access if there are multiple incorrect login attempts:

- First, you'll define a cache that maintains the number of failed login attempts
- Second, use the aforementioned events to manage the user status in the cache
- Finally, we'll block the user access if the cache indicates the user has more than three failed login attempts

- The cache automatically expires the user login attempts status after 24 hours

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/login-attempt/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/login-attempt/course-tracker-final

We'll use Google Guava library to implement the cache. Thus, lets add the Guava dependency in the pom.xml file as shown in listing 6.27:

Listing 6.27 Guava depenedncy

```
<dependency>
    <groupId>com.google.guava</groupId>
    <artifactId>guava</artifactId>
    <version 30.1.1-jre </version>
</dependency>
```

Next, let us define the LoginAttemptService class that defines the cache and few useful methods to maintain the cache and user login attempt status. Listing 6.28 shows this in action:

Listing 6.28 LoginAttemptService class

```
package com.manning.sbip.ch06.service;

//imports

@Service
public class LoginAttemptService {

       private static final int MAX_ATTEMPTS_COUNT = 3;

       # In this cache, the String type represents a username and the Integer type
       represents the failed login attempts
       private LoadingCache<String, Integer> loginAttemptCache;

       # Creates the cache and expires the cache contents after one day
       public LoginAttemptService() {
         loginAttemptCache = CacheBuilder.newBuilder().expireAfterWrite(1, TimeUnit.DAYS)
                          .build(new CacheLoader<String, Integer>() {
                                   @Override
                                   public Integer load(final String key) {
                                            return 0;
                                   }
                          });
       }

       # Invalidates the cache contents for the specified username if there is a successful
       login.
       public void loginSuccess(String username) {
```

```
        loginAttemptCache.invalidate(username);
      }

      # Increments the failed login attempt counter for the specified username
      public void loginFailed(String username) {
        int failedAttemptCounter = 0;

        try {
                failedAttemptCounter = loginAttemptCache.get(username);
        }
        catch (ExecutionException e) {
                failedAttemptCounter = 0;
        }
        failedAttemptCounter++;
        loginAttemptCache.put(username, failedAttemptCounter);
      }

      # Indicates whether the user has excedeed the maximum number of allowed login
      attempts
      public boolean isBlocked(String username) {
        try {
                return loginAttemptCache.get(username) >= MAX_ATTEMPTS_COUNT;
        }
        catch (ExecutionException e) {
                return false;
        }
      }
}
```

You'll now define two event listeners. One that listens to the `AuthenticationFailureBadCredentialsEvent` and invokes the `LoginAttemptService` to update the cache with the failed login attempt count. Listing 6.29 shows this:

Listing 6.29 AuthenticationFailureEventListener Class

```
package com.manning.sbip.ch06.listener;

//imports

@Service
public class AuthenticationFailureEventListener implements
       ApplicationListener<AuthenticationFailureBadCredentialsEvent> {

    @Autowired
    private LoginAttemptService loginAttemptService;

    @Override
    public void onApplicationEvent(AuthenticationFailureBadCredentialsEvent
       authenticationFailureBadCredentialsEvent) {
        String username = (String)
       authenticationFailureBadCredentialsEvent.getAuthentication().getPrincipal();
        loginAttemptService.loginFailed(username);
    }
}
```

Next, you'll define the `AuthenticationSuccessEventListener` class that listens to `AuthenticationSuccessEvent` and invalidate the cache for the user. Listing 6.30 shows this:

Listing 6.30 AuthenticationSuccessEventListener class

```
package com.manning.sbip.ch06.listener;

//imports

@Component
public class AuthenticationSuccessEventListener implements
       ApplicationListener<AuthenticationSuccessEvent> {

    @Autowired
    private LoginAttemptService loginAttemptService;

    @Override
    public void onApplicationEvent(AuthenticationSuccessEvent authenticationSuccessEvent) {
        User user = (User) authenticationSuccessEvent.getAuthentication().getPrincipal();
         loginAttemptService.loginSuccess(user.getUsername());
    }
}
```

In the listing, we retrieve the username of the user from the `AuthenticationSuccessEvent` and invalidate the cache for the username. Thus, previous incorrect login attempts are removed from the cache as the user logs in to the application successfully.

Next, we'll update the CustomUserDetailsService class to validate whether the user is blocked. Recall that `isBlocked(..)` method from LoginAttemptService class that checks if the user has exceeded the maximum allowed incorrect login attempts. Listing 6.31 shows this:

Listing 6.31 CustomUserDetailsService Class

```
package com.manning.sbip.ch06.service.impl;

//imports

@Service
public class CustomUserDetailsService implements UserDetailsService {

    @Autowired
    private LoginAttemptService loginAttemptService;


    public UserDetails loadUserByUsername(String username) throws UsernameNotFoundException
       {

       if(loginAttemptService.isBlocked(username)) {
         throw new LockedException("User Account is Locked");
       }

       // other parts are omitted

    }
}
```

In the listing, you are returning Spring Security's `LockedException` if the user account is blocked. This exception indicates that there is an error in the login attempt and the login is failed. Recall that we invoke the `CustomAuthenticationFailureHandler` to identify the login failure type and redirect the user to the appropriate login endpoint. Listing 6.32 shows the updated `CustomAuthenticationFailureHandler` class:

Listing 6.32 CustomAuthenticationFailureHandler Class

```
package com.manning.sbip.ch06.handler;

//imports

@Service
public class CustomAuthenticationFailureHandler implements AuthenticationFailureHandler {

       private DefaultRedirectStrategy defaultRedirectStrategy = new
       DefaultRedirectStrategy();

    public void onAuthenticationFailure(HttpServletRequest request, HttpServletResponse
       response, AuthenticationException exception) throws IOException, ServletException {

       if(exception instanceof DisabledException) {
         defaultRedirectStrategy.sendRedirect(request, response, "/login-disabled");
         return;
       }
       if(exception.getCause() instanceof LockedException) {
         defaultRedirectStrategy.sendRedirect(request, response, "/login-locked");
         return;
       }
       defaultRedirectStrategy.sendRedirect(request, response, "/login-error");
    }
}
```

In listing 6.32, we modify the `CustomAuthenticationFailureHandler` already implemented in the previous technique, with the addition of another redirect for LockedException instances. We redirect the user to the `login-locked` endpoint if there is a `LockedException`. Define the `login-locked` endpoint that redirects the user to the login page with an error message specifying the user account is locked. Listing 6.33 shows this endpoint defined in the `LoginController`:

Listing 6.33 The login-locked endpoint

```
@GetMapping("/login-locked")
    public String loginLocked(Model model) {
        model.addAttribute("loginLocked", true);
        return "login";
    }
```

You need to use the `loginLocked` flag in the `login.html` page to display the error message that the user account is locked. It is available at https://github.com/spring-boot-in-practice/repo/blob/main/ch06/login-attempt/course-tracker-final/src/main/resources/templates/login.html. Lastly, you need to permit this endpoint to be accessed without any authentication. Listing 6.34 shows this:

Listing 6.34 Updated SecurityConfiguration

```
package com.manning.sbip.ch06.security;
```

```
//imports

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Override
    protected void configure(HttpSecurity http) throws Exception {
       http.requiresChannel().anyRequest().requiresSecure().and().authorizeRequests()
                .antMatchers("/adduser", "/login", "/login-error", "/login-verified",
       "/login-disabled", "/verify/email", "/login-locked").permitAll()

       .anyRequest().authenticated().and().formLogin().loginPage("/login").failureHandler(c
       ustomAuthenticationFailureHandler);
    }

       // Other code snippets are omitted
}
```

In listing 6.34, we've included the `login-locked` endpoint in the existing antMatchers list.

You can start the application, register and activate a new user. Then, try to make incorrect login attempts multiple times. After three failed login attempts, you'll find that the user account is suspended, and the following error is displayed as shown in figure 6.5:

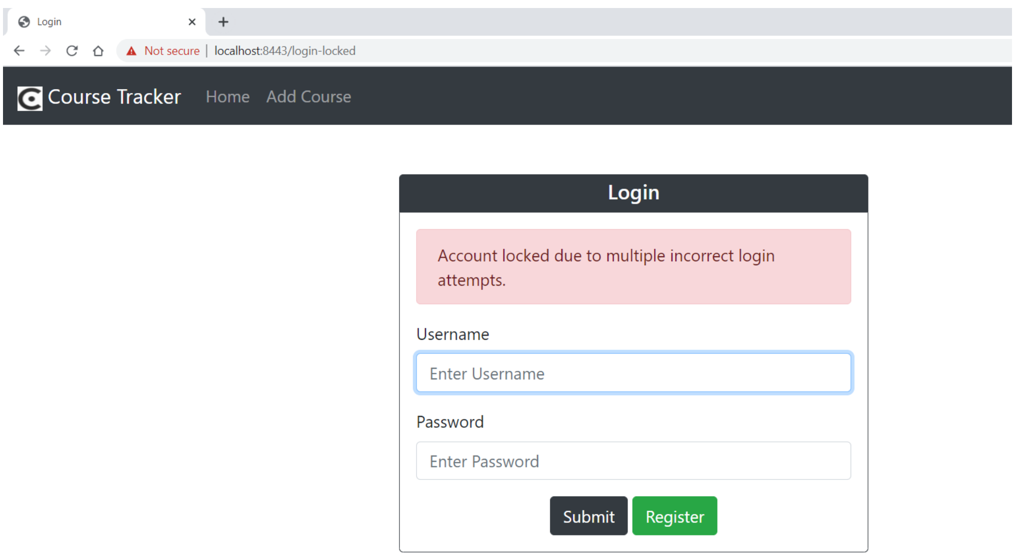


Figure 6.5 User account is locked due to multiple incorrect login attempts. The red tag appearing in the form here is the one showing when the loginLocked flag is set to true

Discussion

In this technique, you've learned how to temporarily suspend a user account if there are multiple incorrect login attempts. The key takeaway from this technique is the use of Spring Security built-in security events to identify the user authentication status. Besides, note the use of the cache to manage the user login attempt statistics. The cache automatically clears the login statistics after 24 hours and makes the user eligible for login.

6.6 Implementing Remember-Me Feature

Although you'll make every effort to secure your application, you also need to be mindful of the user experience. If you make your application too secure that the users need to make a great deal of effort to access the application, it can easily discourage them from accessing the application. Thus, you need to maintain a careful balance between user experience and application security. For instance, many applications provide a `remember-me` feature that lets the application remembers the identity of the user between sessions. Spring Security supports this with an additional cookie to the user's browser which is included in all subsequent requests to the server. In case the session cookie is expired, Spring uses the remember me cookie to authenticate the user.

Spring Security provides two built-in approaches to implement remember-me services – hash-based token approach and persistent token approach. The first one stores user identity in a browser cookie which makes it less secure. The persistent token approach stores the details in a database. Let us first implement the Hash-based token approach in the Course Tracker application.

TECHNIQUE ENABLING REMEMBER-ME FEATURE IN A SPRING BOOT APPLICATION WITH SPRING SECURITY

Problem

For a better user experience, many applications provide a `remember-me` feature. You need to implement this feature in the Course Tracker application.

Solution

Spring Security provides built-in support for the remember-me feature and provides sensible defaults for most of the configurations. To enable remember-me, you'll need to perform two changes in the application:

- Need to add an HTML checkbox in the login page with the name `remember-me`. The checkbox name in the HTML page must be `remember-me` as Spring Security checks the HTTP request to validate whether there is a parameter with this name
- In the `SecurityConfiguration` class, you've to enable the remember-me configuration so that Spring Security can include necessary configurations

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/remember-me/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/remember-me/course-tracker-final

Listing 6.35 shows the changes in the `login.html` page:

Listing 6.35 The Login.html changes

```
<div class="form-group">
       <label for="password">Password</label>
       <input type="password" class="form-control" name="password" placeholder="Enter
       Password" required autofocus>
</div>
<div class="form-check">
       <input type="checkbox" class="form-check-input" name="remember-me">
       <label for="remember-me" class="form-check-label">Remember me</label>
</div>
<div class="text-center mt-1">
       <button type="submit" class="btn btn-dark">Submit</button>
       <a class="btn btn-success" href="#" th:href="@{/adduser}">Register</a>
</div>
```

You've added the checkbox on the login page. The key part here is that the input parameter name must be `remember-me`. Listing 6.36 shows the `SecurityConfiguraton` changes:

Listing 6.36 The SecurityConfiguraton Class Changes

```
 @Override
 protected void configure(HttpSecurity http) throws Exception {

    http.authorizeRequests()
    .antMatchers("/adduser", "/login", "/login-error", "/login-verified", "/login-
       disabled", "/verify/email").permitAll()
    .anyRequest().authenticated()
    .and()
    .formLogin().loginPage("/login").failureHandler(customAuthenticationFailureHandler)
    .and()
    .rememberMe().key("remember-me-key").rememberMeCookieName("course-tracker-remember-me")
    .and()
    .logout().deleteCookies("course-tracker-remember-me");
}

 @Override
 protected UserDetailsService userDetailsService() {
   return this.customUserDetailsService;
 }
```

In the listing, you've made two changes:

- Invoke the `rememberMe()` method in the `HttpSecurity` configuration for Spring Security to enable the remember me services. Further, you've customized the key and the cookie name both of which are optional, and Spring provides default values as remember-me if you don't configure these parameters
- You also need to ensure to override the `userDetailsService()` method and return

the `UserDetailsService` implementation. This is needed as `RememberMeServices` loads the `UserDetails` based on this implementation to load the user details and create the authentication instance

If you start the application and attempts to log in, you'll find a new checkbox option for remember-me. If this is enabled, post successful login, you'll find an additional cookie in your browser with the name `course-tracker-remember-me`.

Discussion

Let us understand how a Hash-based token approach works. When the user ticks the checkbox in the login page while logging in to the application, Spring Security sends an additional cookie to the user browser which is included in all subsequent requests to the server. Thus, even if the session cookie is expired, the `remember-me` cookie is available and not expired. The server can fetch the user details from the remember me cookie and re-authenticate the user automatically.

If you inspect the `remember-me` cookie in your browser, you'll find that it has a large, scrambled text. This is the Base64 encoded details Spring Security stores inside the cookie. The cookie has the below details in the following format as shown in the listing 6.37:

Listing 6.37 The hash-based token format

```
Base64(username:expirationTime:md5Hex(username:tokenExpiryTime:password:key))
```

Following are the details used in the token:

- username: As identifiable to the `UserDetailsService`
- expirationTime: The date and time when the remember-me token expires, expressed in milliseconds. By default, it is set to two weeks
- md5Hex: Calculates the MD5 hash of the username, tokenExpiry, password, and the key and represent in hexadecimal
- password: That matches the one in the retrieved in the `UserDetails`
- key: A private key to prevent modification of the remember-me token. By default, Spring Security generates the key if you haven't configured one. However, the drawback with this generated key is that if the application shuts down, then all remember me cookies will be invalidated as the key will be different after restarting the application. In our example, we've used the `remember-me-key` as the key name

Although the hash-based remember-me token approach makes it a lot easier for a user to access the application, it has several shortcomings:

- If the `remember-me` cookie is stolen or accessed by malicious users, it can be used by them to gain unauthorized access to the application if the expiry time in the cookie is valid
- Even if the cookie is expired, malicious users can use the details present in the cookie to gain access to the `key` and the `password` through brute force attacks. If the key or the password is poorly chosen, malicious users can perform dictionary attacks https://en.wikipedia.org/wiki/Dictionary_attack to retrieve them

Due to these shortcomings, Spring Security provides another alternative with a Persistent token approach that uses a database table to store confidential information. Further, you'll also find that the hash-based token approach is useful if it is used along with other security measures such as two-factor authentications.

6.7 Implementing reCAPTCHA

The CAPTCHA stands for *Completely Automated Public Turing test to tell Computers and Humans Apart*. It is a computer program or application that distinguishes human inputs from machine inputs as a measure to prevent bot spams. CAPTCHAs can be available in many formats. It could be as simple as clicking a checkbox to more complicated such as clicking on certain image types to entering some texts.

Although CAPTCHAs might be annoying to the users, it serves a purpose to protect the application. For instance, these days internet bots are used to spam applications a lot. In the Course Tracker application, internet bots may create fictitious users and exhaust the application resources resulting in a Denial-Of-Service (DoS) attack. CAPTCHAs help application prevent bot spamming to a certain degree.

There are several providers of CAPTCHA – reCAPTCHA (https://www.google.com/recaptcha/about/) from Google is a popular choice for many. Besides, hCaptcha (https://www.hcaptcha.com/) is another alternative.

Let us secure the Course Tracker application registration page with Google's reCAPTCHA in the next technique.

TECHNIQUE ENABLING GOOGLE RECAPTCHA IN A SPRING BOOT APPLICATION WITH SPRING SECURITY

Problem

Internet Bot spamming is a growing concern for web application owners as it creates fictitious users and exhausts the application resources. You need to implement CAPTCHA to prevent bot spamming in the Course Tracker application.

Solution

In this technique, you'll implement Google reCAPTCHA services at the time of user registration. This will ensure that only a human user can register successfully in the Course Tracker application. You find the steps to set up Google reCAPTCHA documented at https://github.com/spring-boot-in-practice/repo/wiki/Setting-up-for-Google-reCAPTCHA.

After this setup is done, you'll have two keys – the Site Key and the Secret key. You'll need these keys in your Spring Boot application. The site key is to be specified on the HTML page and the secret key is to be used to validate the captcha response captured from the user. You'll explore this shortly.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/remember-me/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/remember-me/course-tracker-final

The first change you'll need to make is to include the link for the Captcha in the registration page. Add the following in the `add-user.html` page before the Sign Up form group as shown in listing 6.38:

Listing 6.38 Sitekey in the add-user.html page

```
// Additional Code
<div class="form-group">
 <label for="confirmPassword">Confirm Password</label>
 <input type="password" th:field="*{confirmPassword}" class="form-control"
       id="confirmPassword" placeholder="Confirm Password">
 <span th:if="${#fields.hasErrors('confirmPassword')}" th:errors="*{confirmPassword}"
       class="text-danger"></span>
</div>
<div class="g-recaptcha mb-2" data-sitekey="<Your Site Key>"></div>
<div class="form-group text-center">
    <input type="submit" class="btn btn-dark center" value="Sign Up" />
    <p>Already have an account? <a href="/login">Sign in</a></p>
</div>

// Additional Code
```

In the listing, the highlighted code (in bold) enables the Captcha verification checkbox on the user registration page. Further, add the following script tag inside the head section of the page as shown in the listing 6.39:

Listing 6.39 Recaptcha API Script tag

```
<script src="https://www.google.com/recaptcha/api.js"></script>
```

The code snippet in the previous two listings enables the Google reCAPTCHA option on the registration page. Let us now define a reCAPTCHA verification service that validates the reCAPTCHA response from the user as shown in the listing 6.40:

Listing 6.40 Google Recaptcha Verification Service

```
package com.manning.sbip.ch06.service.impl;

//imports

@Service
public class GoogleRecaptchaService {

       private static final String VERIFY_URL =
       "https://www.google.com/recaptcha/api/siteverify"
                 + "?secret={secret}&remoteip={remoteip}&response={response}";
       private final RestTemplate restTemplate;

       # This is the secret key defined in the application.properties file with the key
       captcha.secret.key. Secrets are placed in the application.properties only for
       demonstration purpose
```

```
        @Value("${captcha.secret.key}")
        private String secretKey;

        public GoogleRecaptchaService(RestTemplate restTemplate) {
          this.restTemplate=restTemplate;
        }

        public RecaptchaDto verify(String ip, String recaptchaResponse) {
          Map<String, String> request = new HashMap<>();
          request.put("remoteip", ip);
          request.put("secret", secretKey);
          request.put("response", recaptchaResponse);
           # We are using the RestTemplate to validate the user response with Google. The
        RecaptchaDto contains the success (and errors, if any). In listing 6.42, you are
        using this RecaptchaDto POJO
          ResponseEntity<Map> response = restTemplate.getForEntity(VERIFY_URL, Map.class,
        request);
          Map<String, Object> body = response.getBody();
          boolean success = (Boolean)body.get("success");
          RecaptchaDto recaptchaDto = new RecaptchaDto();
          recaptchaDto.setSuccess(success);
          if(!success) {
             recaptchaDto.setErrors((List)body.get("error-codes"));
          }
          return recaptchaDto;
        }
}
```

The code in the listing validates the user provided captcha response with the google reCAPTCHA verification service hosted at https://www.google.com/recaptcha/api/siteverify. You've supplied your secret key, the server IP address (localhost in this example), and the captcha response. The secret is added in the `application.properties` with the key name `captcha.secret.key`. If these details are correct, you get a successful response. For failures, you get the list of error code. For instance, for an incorrect response, the error code is `invalid-input-response`.

We've also added a `RestTemplate` configuration to invoke the Google reCAPTCHA service as shown in the listing 6.41:

Listing 6.41 RestTemplate Configuration

```
package com.manning.sbip.ch04.configuration;

//imports

@Configuration
public class CommonConfiguration {

        @Bean
        public RestTemplate restTemplate(RestTemplateBuilder restTemplateBuilder) {
          return restTemplateBuilder.build();
        }
}
```

Listing 6.42 shows the `RecaptchaDto` class that captures the captcha validation response:

Listing 6.42 RecaptchaDto Class

```
package com.manning.sbip.ch04.dto;

import java.util.List;

public class RecaptchaDto {

       private boolean success;
       private List<String> errors;

       // Getter and Setters
}
```

In the listing, the success captures whether the user response is correct. The errors store the errors if there is a failure in validating the user provided captcha response.

In the `RegistrationController` class you need to validate that the user provided Captcha response is valid. For a valid response, you continue and create the user in the application. Otherwise, an error message is shown to the user in the user registration page. Listing shows the updated `adduser` endpoint:

Listing 6.43 Updated adduser endpoint

```
@PostMapping("/adduser")
public String register(@Valid @ModelAttribute("user") UserDto userDto, HttpServletRequest
       httpServletRequest, BindingResult result) {
    if(result.hasErrors()) {
        return "add-user";
    }
    # The following statements validate whether the user has provided any response in the
       Captcha checkbox in the user registration page. If not, we redirect them to the add-
       user.html page again
    String response = httpServletRequest.getParameter("g-recaptcha-response");
    if(response == null) {
        return "add-user";
    }

    # If user has provided a response in the Captcha checkbox, we use the Captcha service
       to validate with Google whether the response is correct. For incorrect response, the
       uesr is redirect to the Captcha error page
    String ip = httpServletRequest.getRemoteAddr();
    RecaptchaDto recaptchaDto = captchaService.verify(ip, response);
    if(!recaptchaDto.isSuccess()) {
        return "redirect:adduser?incorrectCaptcha";
    }

    ApplicationUser applicationUser = userService.createUser(userDto);
    if("Y".equalsIgnoreCase(emailVerification)) {
        eventPublisher.publishEvent(new UserRegistrationEvent(applicationUser));
        return "redirect:adduser?validate";
    }
    return "redirect:adduser?success";
}
```

Let's start the application and browse to the Register option to add a new user. You'll be redirected to the user registration page and notice a Captcha option above the Sign-Up button. Fill in all the details and click on the `I'm not a robot` checkbox. You'll be presented with a graphic challenge that will ask you to select the tiles that belong to a specific category. Figure 6.6 shows the user registration page with a sample Captcha. Note that the Captcha images change each time you perform a user registration.

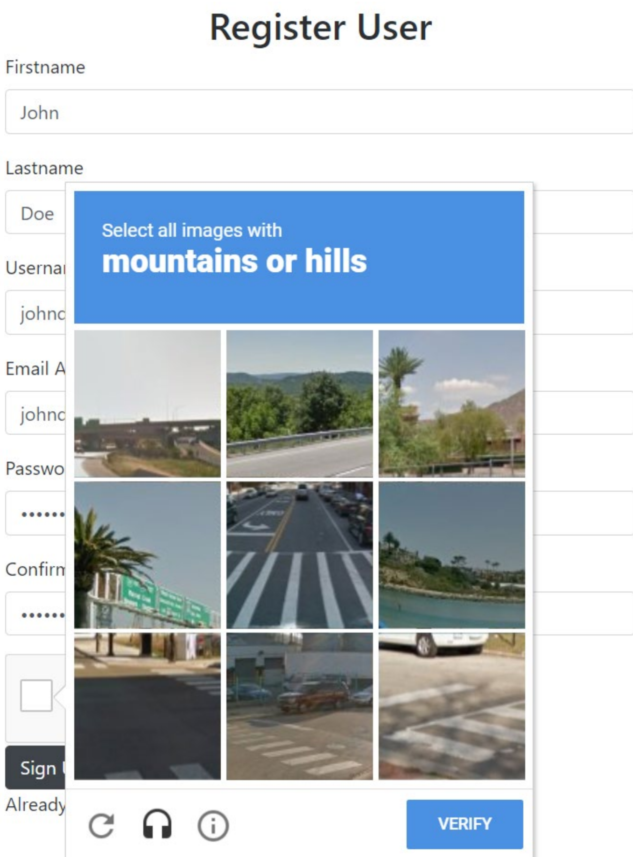


Figure 6.6 Google reCAPTCHA while performing user registration

Discussion

To be precise, this is not a Spring Boot or Spring Security technique as we have not used any specific features from these technologies. However, in the era of machine learning and artificial intelligence, this is a useful feature to protect applications from internet bot spamming.

There are several variations of Captcha implementations these days. As the bots are getting smarter day by day, there is a growing need to improve the Captcha technologies as well. In this technique, we've implemented Google reCAPTCHA v2 which is relatively old and there are newer versions available as well.

Further, in this technique, we've used the Captcha secret in the application.properties file. In a production application, use a safer solution such as Vault.

Before we conclude this technique, a note of caution. As discussed previously, application security needs to be balanced against user experience. This applies to captcha-based application security as well. For instance, many applications only start displaying captcha if it detects multiple login failures. This is a balanced approach as the application becomes suspicious against the repeated failed login attempts and automatically increases the application security by enabling additional security measures such as captcha. We leave this as an exercise to the reader. As a hint, you can use a cache to store the login failure attempts and enable the captcha once there are three or more incorrect failure attempts.

6.8 Enabling Two Factor Authentication with Google Authenticator

Multi-factor authentication (MFA) is an authentication pattern that enforces the users to undergo multiple authentication steps before the user is allowed to access the application. Two-factor authentication (or 2FA) is one variant of MFA that let the user undergo two different levels of authentication steps.

Most web applications use the username and password-based authentication to authenticate the application users. Although this authentication pattern works perfectly well in most circumstances, it may make the users vulnerable if the user's username and password are compromised. An additional level authentication with a different authentication mode ensures greater security to the users. For instance, along with the regular username and password, a random one-time password (OTP) is often used in the majority of the application.

In this section, you'll learn to enable two-factor authentication in the Course Tracker application. You'll use the regular username and password as the first level of authentication. Next, you'll use an OTP as the second level of authentication. We'll use the Google Authenticator App to generate the OTP. Let us explore this in the next technique.

TECHNIQUE ENABLING TWO FACTOR AUTHENTICATION IN A SPRING BOOT APPLICATION

Problem

Course Tracker application currently uses the username and password-based authentication. For better application security, you need to implement two-factor authentication in the application.

Solution

In this technique, you'll use the Google Authenticator app to enable two-factor authentication in the Course Tracker application. You need to download this application on a smartphone from Google play store https://play.google.com/store/apps/details?id=com.google.android.apps.authenticator2 or

Apple store https://apps.apple.com/us/app/google-authenticator/id388497605. This app will generate a Time based One Time Password (TOTP) and we'll use this to perform the second level authentication. We'll provide a brief discussion on how the TOTP algorithm works in the discussion section.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/two-factor-auth/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/two-factor-auth/course-tracker-final

You may notice that two-factor authentication is not a mandatory authentication strategy. Applications provide a choice to the users whether they would like to opt for this feature. In the Course Tracker application, we'll provide the users with the same choice. Following is the outline to implement 2FA in the Course Tracker application:

1. The user registers and the user account is created in the application.
2. On the first login to the application, we'll ask the user whether they would like to enable 2FA. If they are not interested, they can skip and redirect to the application index page
3. If the user opts for 2FA, we'll then generate a Quick Reference (QR) code and let the user scan the code in the Google Authenticator app on their smartphone
4. Once the app configured the Course Tracker application, we'll ask the user to enter the OTP from the smartphone app on the 2FA registration page. This process completed the 2FA registration for the user. For all subsequent logins, the user needs to enter the OTP from the Google Authenticator app to proceed with application access
5. If the user has not enabled 2FA at the time of registration, we'll prompt the user to enable 2FA on each successful login. Note that this is for demonstration purpose only. Most applications provide an option in their application security settings to the users to enable it at their convenience

To start with, let's add the following dependency in the pom.xml file as shown in the listing 6.44:

Listing 6.44 Google Auth dependency

```
<dependency>
	<groupId>com.warrenstrange</groupId>
	<artifactId>googleauth</artifactId>
	<version>1.4.0</version>
</dependency>
```

The Google Auth dependency in the listing provides the necessary support to implement the TOTP based two-factor authentication in the application. You can refer to https://github.com/wstrange/GoogleAuth for further details on this library.

Next, while the user registers for 2FA, we share a QR code with the user. This QR code contains a secret that needs to be stored against the username for further usage. Let us define a Java POJO entity that let us capture these details and persist them into the `CT_TOTP_DETAILS` table. Listing 6.45 shows the `TOTPDetails` class:

Listing 6.45 TOTP Details

```
package com.manning.sbip.ch06.model;

// imports

@Entity
@Data
@NoArgsConstructor
@AllArgsConstructor
@Table(name = "CT_TOTP_DETAILS")
public class TotpDetails {

    @Id
    @GeneratedValue(strategy = GenerationType.IDENTITY)
    private long id;
    private String username;
    private String secret;

    public TotpDetails(String username, String secret) {
       this.username = username;
       this.secret = secret;
    }
}
```

Listing 6.46 shows the CT_TOTP_DETAILS table DDL located in `src/main/resources/script.ddl` file:

Listing 6.46 CT_TOTP_DETAILS Table DDL

```
create table CT_TOTP_DETAILS (
  id BIGINT NOT NULL auto_increment,
  secret varchar(255),
  username       varchar(255),
  PRIMARY KEY (id)
);
```

Recall from the outline post successful login, we need to ask the user whether they would like to opt for 2FA. From the previous techniques, you have seen Spring Security provides an `AuthenticationSuccessHandler` interface that you can implement to define post successful login actions. Let's define the `DefaultAuthenticationSuccessHandler` class that implements the AuthenticationSuccessHandler interface as shown in Listing 6.47:

Listing 6.47 DefaultAuthenticationSuccessHandler Class

```
package com.manning.sbip.ch06.service;

//imports

@Component
```

```
public class DefaultAuthenticationSuccessHandler implements AuthenticationSuccessHandler {

    private RedirectStrategy redirectStrategy = new DefaultRedirectStrategy();

    public void onAuthenticationSuccess(HttpServletRequest request, HttpServletResponse
       response, Authentication authentication) throws IOException, ServletException {
        if(isTotpAuthRequired(authentication)) {
            redirectStrategy.sendRedirect(request, response, "/totp-login");
        }
        else {
            redirectStrategy.sendRedirect(request, response, "/account");
        }
    }

    # We'll explain more on this snippet later. Specifically the TOTP_AUTH_AUTHORITY and
       its use
    private boolean isTotpAuthRequired(Authentication authentication) {
        Set<String> authorities =
       AuthorityUtils.authorityListToSet(authentication.getAuthorities());
        return authorities.contains("TOTP_AUTH_AUTHORITY");
    }
}
```

In the above listing, you are validating whether the user has 2FA configured by checking whether the user has the role `TOTP_AUTH_AUTHORITY`, if the user has 2FA configured, you redirect the user to the `totp-login` endpoint. Otherwise, the user is redirected to the account endpoint. Note that `TOTP_AUTH_AUTHORITY` is a custom authority in the application that is assigned to the users enabled 2FA. You'll explore this shortly. The `totp-login` redirects the user to the 2FA login page that let the user enter the OTP from their Google Authenticator app. The `account` endpoint redirects the user to the 2FA set-up page if the user has not configured 2FA already. Listing 6.48 shows the `AccountController` class:

Listing 6.48 AccountController Class

```
package com.manning.sbip.ch06.controller;

//imports

@Controller
@RequiredArgsConstructor
public class AccountController {


       # This service class provides services to generate and validate TOTP for a user
       private final TotpService totpService;

       # Redirects the user to the 2FA set up page. Sets the totpEnabled and configureTotp
       parameters used in the account.html page. The account.html page lets you enable 2FA
       @GetMapping("/account")
       public String getAccount(Model model, @AuthenticationPrincipal CustomUser
       customUser) {
         if (customUser != null && !customUser.isTotpEnabled()) {
                 model.addAttribute("totpEnabled", false);
                 model.addAttribute("configureTotp", true);
         } else {
                 model.addAttribute("totpEnabled", true);
```

```
        }
        return "account";
      }

      # This endpoint let the user set up 2FA. If the user does not have TOTP configured,
      it invokes the TOTP service and generates the QR code that lets the user configure
      the Course Tracker application in the Google Authenticator app.
      @GetMapping("/setup-totp")
      public String getGoogleAuthenticatorQrUrl(Model model, @AuthenticationPrincipal
      CustomUser customUser) {
        String username = customUser.getUsername();
        boolean isTotp = customUser.isTotpEnabled();
        # This conditional branch happens when the QR code needs to be created. The
      TotpCode is used to capture the verification OTP in the account.html page
        if (!isTotp) {
                model.addAttribute("qrUrl",
      totpService.generateAuthenticationQrUrl(username));
                model.addAttribute("code", new TotpCode());
                return "account";
        }
        model.addAttribute("totpEnabled", true);
        return "account";
      }

      # This endpoint enables the TOTP for the user.
      @PostMapping("/confirm-totp")
      public String confirmGoogleAuthenticatorSetup(Model model, @AuthenticationPrincipal
      CustomUser customUser,
                TotpCode totpCode) {
        boolean isTotp = customUser.isTotpEnabled();
        if (!isTotp) {
                try {
                        totpService.enableTotpForUser(customUser.getUsername(),
      Integer.valueOf(totpCode.getCode()));
                } catch (InvalidVerificationCode ex) {
                        model.addAttribute("totpEnabled", customUser.isTotpEnabled());
                        model.addAttribute("confirmError", true);
                        model.addAttribute("configureTotp", false);
                        model.addAttribute("code", new TotpCode());
                        return "account";
                }

                model.addAttribute("totpEnabled", true);
        }
        customUser.setTotpEnabled(true);
        return "redirect:/logout";
      }
}
```

Next, let us define the TOTPService class as shown in Listing 6.49:

Listing 6.49 TOTPService

```
package com.manning.sbip.ch06.service;

//imports

@Service
public class TotpService {
```

```
    private final GoogleAuthenticator googleAuth = new GoogleAuthenticator();
    private final TotpRepository totpRepository;
    private final UserRepository userRepository;
    private static final String ISSUER = "CourseTracker";

    public TotpService(TotpRepository totpRepository, UserRepository userRepository) {
        this.totpRepository = totpRepository;
        this.userRepository = userRepository;
    }

    # Generates the QR URL for the supplied username
    @Transactional
    public String generateAuthenticationQrUrl(String username){
        GoogleAuthenticatorKey authenticationKey = googleAuth.createCredentials();
        String secret = authenticationKey.getKey();
        totpRepository.deleteByUsername(username);
        totpRepository.save(new TotpDetails(username, secret));
        return GoogleAuthenticatorQRGenerator.getOtpAuthURL(ISSUER, username,
       authenticationKey);
    }

    public boolean isTotpEnabled(String userName) {
        return userRepository.findByUsername(userName).isTotpEnabled();
    }

    # Validates whether the supplied OTP is correct and valid and configures that the user
       has configured 2FA
    public void enableTotpForUser(String username, int code){
        if(!verifyCode(username, code)) {
            throw new InvalidVerificationCode("Invalid verification code");
        }

        User user = userRepository.findByUsername(username);
        user.setTotpEnabled(true);
        userRepository.save(user);
    }

    public boolean verifyCode(String userName, int verificationCode) {
        TotpDetails totpDetails = totpRepository.findByUsername(userName);
        return googleAuth.authorize(totpDetails.getSecret(), verificationCode);
    }
}
```

The TotpService class contains several useful methods related to 2FA. For instance, it contains the method to generate the QR code, enable TOTP for users or verify the supplied verification code.

Next, let us perform the necessary changes to the `CustomUserDetailsService` class that assigns the `TOTP_AUTH_AUTHORITY` authority to the uses based on whether they have enabled 2FA. Listing 6.50 shows this:

Listing 6.50 The CustomUserDetailsService

```
package com.manning.sbip.ch06.service;

//imports
```

```
@Service
public class CustomUserDetailsService implements UserDetailsService {

       private UserRepository userRepository;

       @Autowired
       public CustomUserDetailsService(UserRepository userRepository) {
         this.userRepository = userRepository;
       }

       public UserDetails loadUserByUsername(String username) throws
       UsernameNotFoundException {
         User user = userRepository.findByUsername(username);
         if(user == null) {
                  throw new UsernameNotFoundException(username);
         }
         SimpleGrantedAuthority simpleGrantedAuthority = null;
         if(user.isTotpEnabled()) {
                  simpleGrantedAuthority = new
       SimpleGrantedAuthority("TOTP_AUTH_AUTHORITY");
         }
         else {
                  simpleGrantedAuthority = new SimpleGrantedAuthority("ROLE_USER");
         }
         CustomUser customUser = new CustomUser(user.getUsername(), user.getPassword(),
       true, true, true, true, Arrays.asList(simpleGrantedAuthority));
         customUser.setTotpEnabled(user.isTotpEnabled());
         return customUser;
       }

}
```

In the listing, if the user has configured TOTP, we assign the `TOTP_AUTH_AUTHORITY` authority to the user. Otherwise, we assign the `ROLE_USER` authority to the user.

Once the user has enabled the TOTP, for all subsequent login, they need to enter the OTP which the application verifies. You can do this verification in several ways. For instance, you can include the OTP verification logic in the associated Spring controller and based on the verification, redirect the user to the appropriate page.

However, we'll use a different technique. We'll define a custom Filter that performs this validation. We'll include this filter in the Spring Security filter chain in an appropriate position so that it gets invoked automatically by Spring Security. Listing 6.51 shows the TotpAuthFilter class:

Listing 6.51 TotpAuthFilter Class

```
package com.manning.sbip.ch06.filter;

 //imports

@Component
public class TotpAuthFilter extends GenericFilterBean {

    private TotpService totpService;
    private static final String ON_SUCCESS_URL = "/index";
    private static final String ON_FAILURE_URL = "/totp-login-error";
    private final RedirectStrategy redirectStrategy = new DefaultRedirectStrategy();
```

```
    @Autowired
    public TotpAuthFilter(TotpService totpService) {
        this.totpService = totpService;
    }

    # Implementation of the filter. If the user does not require 2FA, this filter is
       skipped and the next filter on the filter chain is invoked. However, if 2FA is
       enabled, then the verification code supplied from the user is validated and the user
       is assigned with the USER role.
    public void doFilter(ServletRequest request, ServletResponse response, FilterChain
       chain) throws IOException, ServletException {

        Authentication authentication =
       SecurityContextHolder.getContext().getAuthentication();
        String code = request.getParameter("totp_code");
        if(!requiresTotpAuthentication(authentication) || code == null) {
            chain.doFilter(request, response);
            return;
        }
        if(code != null && totpService.verifyCode(authentication.getName(),
       Integer.valueOf(code))) {
            Set<String> authorities =
       AuthorityUtils.authorityListToSet(authentication.getAuthorities());
            authorities.remove("TOTP_AUTH_AUTHORITY");
            authorities.add("ROLE_USER");
            authentication = new
       UsernamePasswordAuthenticationToken(authentication.getPrincipal(),
       authentication.getCredentials(), buildAuthorities(authorities));
            SecurityContextHolder.getContext().setAuthentication(authentication);
            redirectStrategy.sendRedirect((HttpServletRequest) request,
       (HttpServletResponse) response, ON_SUCCESS_URL);
        }
        else {
            redirectStrategy.sendRedirect((HttpServletRequest) request,
       (HttpServletResponse) response, ON_FAILURE_URL);
        }
    }

    private boolean requiresTotpAuthentication(Authentication authentication) {
        if (authentication == null) {
            return false;
        }
        Set<String> authorities =
       AuthorityUtils.authorityListToSet(authentication.getAuthorities());
        boolean hasTotpAutheority = authorities.contains("TOTP_AUTH_AUTHORITY");
        return hasTotpAutheority && authentication.isAuthenticated();
    }

    private List<GrantedAuthority> buildAuthorities(Collection<String> authorities) {
        List<GrantedAuthority> authList = new ArrayList<GrantedAuthority>(1);
        for(String authority : authorities) {
            authList.add(new SimpleGrantedAuthority(authority));
        }
        return authList;
    }
}
```

Let us discuss the changes done in the listing:

1. We retrieve the Authentication object from the `SecurityContextHolder` class and check if the user is authenticated and has `TOTP_AUTH_AUTHORITY` authority
2. We then validate the user-supplied OTP. If the OTP is not valid, we redirect the user to an error page
3. If the OTP is valid, we revoke the `TOTP_AUTH_AUTHORITY` authority from the user and assign the `ROLE_USER`. We remove the `TOTP_AUTH_AUTHORITY` authority as we only need it to enable TOTP. Once the user has enabled TOTP, we remove this and provide an ordinary role such as `USER`.
4. Next, we create a new `UsernamePasswordAuthenticationToken` token with the new role. As we are changing the user role, we build this token and updated it in the `SecurityContextHolder`.
5. Finally, the user is redirected to the index page

Next, let us make the necessary changes in the HTTP configuration in the `SecurityConfiguration` class to configure the `TotpAuthFilter`. Listing 6.52 shows this:

Listing 6.52 SecurityConfiguration

```
package com.manning.sbip.ch06.security;

//imports

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

    @Autowired
    private TotpAuthFilter totpAuthFilter;


    @Override
    protected void configure(HttpSecurity http) throws Exception {

       http.addFilterBefore(totpAuthFilter, UsernamePasswordAuthenticationFilter.class);

       http.authorizeRequests()
       .antMatchers("/adduser", "/login", "/login-error",  "/setup-totp", "/confirm-
       totp").permitAll()
         .antMatchers("/totp-login", "/totp-login-
       error").hasAuthority("TOTP_AUTH_AUTHORITY")
       .anyRequest().hasRole("USER").and()
       .formLogin().loginPage("/login")
         .successHandler(new DefaultAuthenticationSuccessHandler()).failureUrl("/login-
       error");
    }

    // Other code snippets
}
```

In the listing, we are adding the `TotpAuthFilter` before the `UsernamePasswordAuthenticationFilter`. This ensures that the `TotpAuthFilter` is part of the Spring Security filter chain and is invoked. Besides, we are also ensuring that the TOTP related endpoints are only accessed by the users with `TOTP_AUTH_AUTHORITY` authority.

Note

As you may notice this technique involves a few code snippets and we could not accommodate all the code examples as it will take more pages. We suggest you refer to the completed version of the Spring Boot project in the GitHub repository for all code snippets. Only the important and relevant code snippets are provided in the technique

You can start the application and register a new user. Post login you'll notice the following page for 2FA activation as shown in figure 6.7:

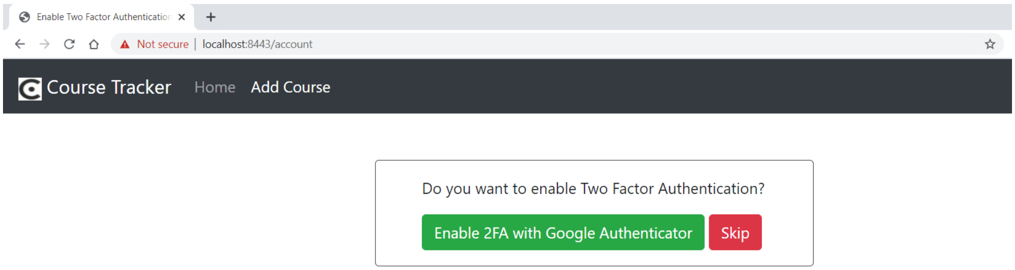


Figure 6.7 Option to enable 2FA with Google Authenticator

You can either opt for the 2FA or skip to the index page. Let us enable 2FA by clicking on the Enable 2FA with the Google Authenticator button. Figure 6.8 shows the next page with the QR code:

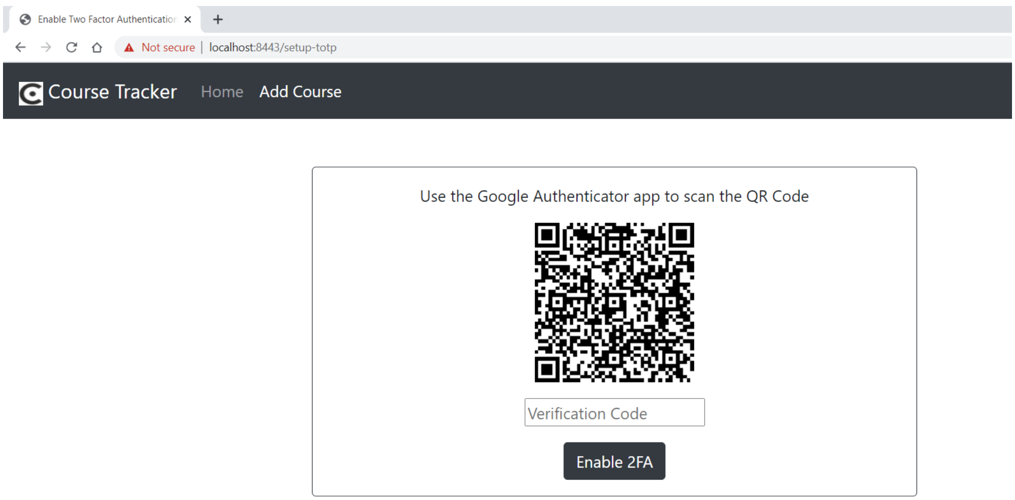


Figure 6.8 QR Code to register for 2FA in the Google Authenticator application. Once the user scans the QR code, they can see the verification code in the smartphone application

Scan the QR code as shown in the Google Authenticator code for your application and enter the verification code displayed in the app. Don't scan the QR code shown in the figure as it won't work for you. You need to scan the QR code shown in the Course Tracker application to the smartphone application. You'll notice an entry in the smartphone application with a verification code. Enter this verification code in the text box as shown in figure 6.8 and click Enable 2FA. For a successful verification code, the Course Tracker application redirects you to the login page. Login again and you'll be redirected to the following page to provide the OTP as shown in figure 6.9:

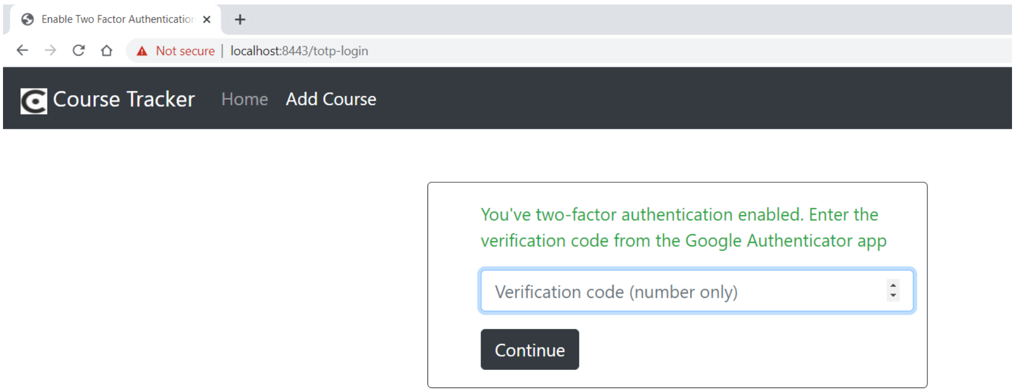


Figure 6.9 For regular logins, the user is prompted to enter the verification code from the Google Authenticator application

Enter the OTP from the Google Authenticator app and you'll be redirected to the application index page showing the list of courses. For every login, you need to provide the OTP to access the application.

Discussion

Google Authenticator supports two types of OTP algorithms – Time-Based OTP algorithm (TOTP) and HMAC based OTP algorithm (HOTP). In this technique, we've shown how to implement TOTP based 2FA with Spring Security in a Spring Boot application.

The way the TOTP algorithm works is relatively simple. In this algorithm, both server (the Course Tracker application) and the client (the Google Authenticator app) uses a common secret and the time to generate the OTP. Recall that once you enable the 2FA, the application provided a QR code that you've scanned in your Google Authenticator application. The QR code transfers the secret key that is used by the Google Authenticator application to calculate the OTP. Both parties use the secret and the time (that's why it's called Time-Based OTP) to generate the OTP.

In this technique, you've also learned to implement custom filters and inserted them into the Spring Security filter chain. For instance, another use case is suspending the user access for incorrect login attempts. The logic presented in listing 6.31 to validate whether the user account is blocked can be implemented through custom filters. You can define any number of custom filters to implement various business features. Besides, you've also seen how to define custom authorities and leverage in the application.

6.9 Authentication With OAuth2

Previously you've learned several techniques on how to let users log in to the Course Tracker application. We've implemented a user registration module that captures user details, performs email verification to let users activate their account and finally log in to the application. There is an alternative way to let users access your application without requiring them to register in the application.

These days many people have a user account on websites like Google, Facebook, GitHub etc. They have already provided their details to these websites at the time of registration. You can leverage these websites to let users access your application. The interesting part is that both your custom user management module and the login through Google, Facebook, GitHub can co-exist in the application. For instance, https://stackoverflow.com lets you log in to the application through both modes.

As you proceed with this technique, you'll learn that this feature is implemented through an open standard for access delegation. Spring Security provides a separate module that deals with this integration. You'll learn more about this in the upcoming technique.

Let us implement user login with Google in the next technique.

TECHNIQUE ENABLING SIGN IN WITH GOOGLE IN A SPRING BOOT APPLICATION

Problem

To access the Course Tracker application, users need to register and activate their account before they can access the application. However, some users already have a Google account and they need to log in using their Google account. You need to enable users to log in through their Google account in the Course Tracker application.

Solution

To let the users log in through their Google account, your application first needs to be a client of Google. This can be done by registering your application with Google. Once your application has registered with Google, you'll have a Google Client ID and a Secret key. We'll discuss the role of these keys later in the technique. You can refer to https://github.com/spring-boot-in-practice/repo/wiki/Registering-Your-Application-for-Google-OAuth2 to register the Course Tracker application with Google.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/login-with-google/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/login-with-google/course-tracker-final

Note

In this technique, you'll use OAuth 2.0 to provide login access to the users through Google.

The OAuth2.0 is an authorization framework that enables third-party applications (e.g. the Course Tracker) to obtain limited access to a resource (e.g. an HTTP service) either on behalf of a Resource Owner (e.g. Google) by orchestrating an approval interaction between the resource owner and the HTTP service or by allowing the third-party application to obtain access on its behalf.

Providing a detailed discussion on OAuth 2.0 is beyond the scope of this text. You can refer to the OAuth 2.0 RFC available at https://datatracker.ietf.org/doc/html/rfc6749 for more details on OAuth 2.0 Authorization Framework. Refer to the Spring Security specific texts to learn more about the use of OAuth 2.0 with the Spring framework. You can refer to the Manning Publication's API Security in Action or Spring Security in Action books for further details

To begin with, lets add the `spring-boot-starter-oauth2-client` dependency in the pom.xml file. This provides necessary support to configure OAuth2 in the application. Listing 6.53 shows this:

Listing 6.53 Spring Boot Started Oauth2 Client

```
<dependency>
       <groupId>org.springframework.boot</groupId>
       <artifactId>spring-boot-starter-oauth2-client</artifactId>
</dependency>
```

Next add the following properties in the `application.properties` file as shown in listing 6.54:

Listing 6.54 Google OAuth2 properties

```
spring.security.oauth2.client.registration.google.client-id=<Your client ID>
spring.security.oauth2.client.registration.google.client-secret=<Your Secret>
spring.security.oauth2.client.registration.google.scope=email, profile
```

In the listing 6.54, we've configured the client-secret (ontained from Google) in the `application.properties` file only for demonstration purpose. In a production application, you should not place it in the code or property file. A better alternative is to use environment variables or use Vault to keep the secret.

Next, let us update the HTTP security configuration in the SecurityConfiguration file as shown in Listing 6.55:

Listing 6.55 The Updated HTTP Configuration

```
@Override
protected void configure(HttpSecurity http) throws Exception {

      http.authorizeRequests()
      .antMatchers("/adduser", "/login", "/login-error", "/login-verified", "/login-
       disabled", "/verify/email").permitAll()
      .anyRequest().authenticated()
```

```
        .and()
    .formLogin().loginPage("/login").failureHandler(customAuthenticationFailureHandler)
        .and()
        .oauth2Login().loginPage("/login").successHandler(new
         Oauth2AuthenticationSuccessHandler());
}
```

To enable OAuth2 support, you've enabled the `oauth2Login()` in the configuration. This configuration invokes the `OAuth2LoginConfigurer` class and lets you customize the OAuth2 related features. For instance, we've used a custom login page by configuring the `loginPage("/login")`. This ensures to redirect the user to a customized login page instead of the Spring default login page. You've also provided an `AuthenticationSuccessHandler` implementation which is invoked once the user is authenticated. Listing 6.56 shows the `Oauth2AuthenticationSuccessHandler` implementation:

Listing 6.56 Oauth2AuthenticationSuccessHandler

```
package com.manning.sbip.ch06.service.impl;

//imports

@Component
public class Oauth2AuthenticationSuccessHandler implements AuthenticationSuccessHandler {

    private RedirectStrategy redirectStrategy = new DefaultRedirectStrategy();

    public void onAuthenticationSuccess(HttpServletRequest request, HttpServletResponse
       response, Authentication authentication) throws IOException, ServletException {
       redirectStrategy.sendRedirect(request, response, "/index");
    }
}
```

In listing 6.56, you are redirecting the user to the `/index` endpoint which shows the logged-in user the application index page. Note that the `authentication` parameter is an instance of `OAuth2AuthenticationToken` and you can access various user information (e.g. Name, Email etc) from it. To keep the implementation simple, we've not demonstrated this.

Lastly, let us update the login page to enable a `Login with Google` button on the login page. You can access the updated login page at https://github.com/spring-boot-in-practice/repo/blob/main/ch06/social-sigin/course-tracker-final/src/main/resources/templates/login.html.

Start the application and you'll find the following page as shown in figure 6.10:

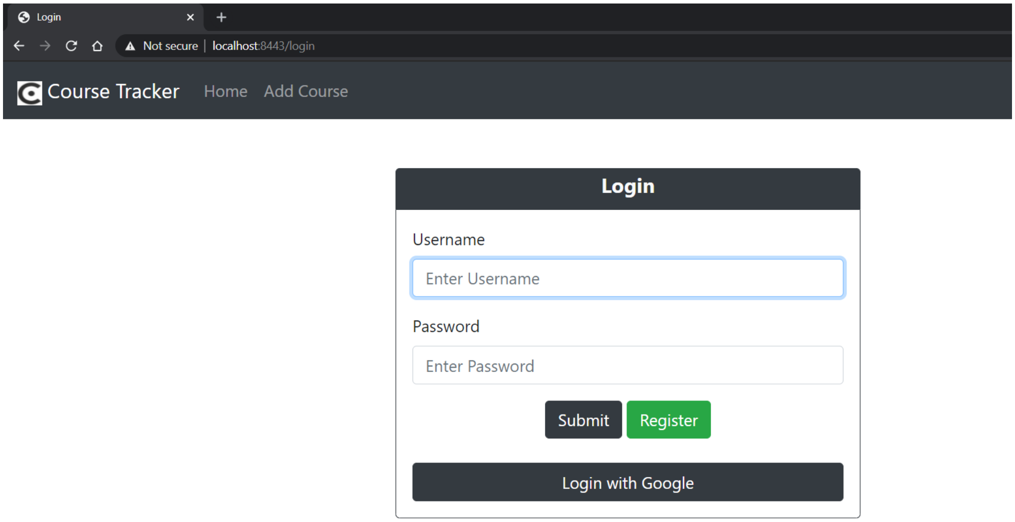


Figure 6.10 User login page with the Login with Google option

Click on the **Login with Google** button and you'll be redirected to the Google sign-in page. If you pay attention to the URL, you'll notice it has the application client_id, scope and the redirect URL. Listing 6.57 shows this:

Listing 6.57 Google Redirect URL

```
https://accounts.google.com/o/oauth2/v2/auth/identifier?response_type=code&client_id=816847
        64817-
        lb9qc6bgsb4o73smdkhfkdj72q7pa6ns.apps.googleusercontent.com&scope=email%20profile&st
        ate=judvx4EoF8AnPBLSGbqCdpqZCR6xdkX0hbC8D4ub-
        Co%3D&redirect_uri=https%3A%2F%2Flocalhost%3A8443%2Flogin%2Foauth2%2Fcode%2Fgoogle&f
        lowName=GeneralOAuthFlow
```

Figure 6.11 shows the Google Sign In page with a message to continue accessing the Course Tracker:

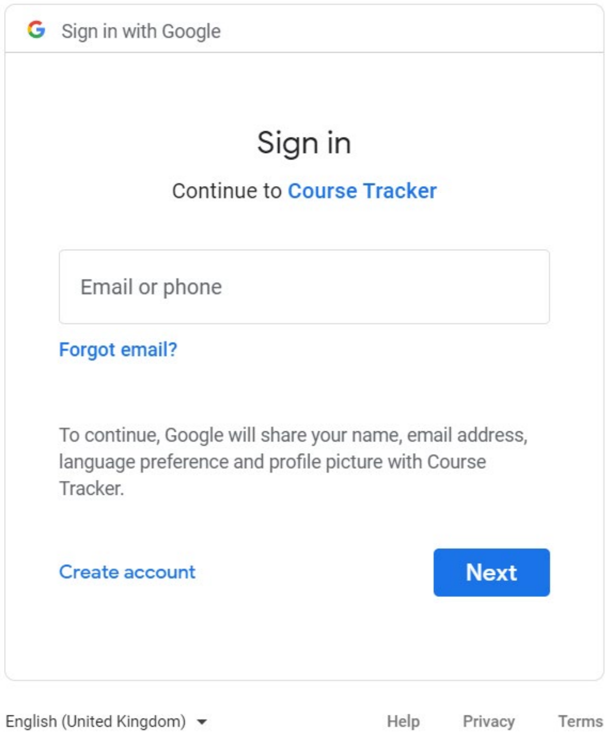


Figure 6.11 Google login page to login to the Course Tracker application with Oauth2

Provide your Google credentials and you'll be redirected to the application index page.

Discussion

To enable OAuth2 support in the Spring Boot application, you've added the `spring-boot-starter-oauth2-client` in the `pom.xml` file. Spring Boot provides an auto-configuration class named `OAuth2ClientAutoConfiguration` that performs several configurations automatically to set up OAuth2 in the Spring application. The presence of `spring-boot-starter-oauth2-client` triggers this autoconfiguration. The authentication for OAuth2 is performed by the `OAuth2LoginAuthenticationFilter` filter. This filter is configured by `OAuth2LoginConfigurer` class.

Let us now provide a brief overview of how we've used OAuth2 while letting the user sign in with Google. In the beginning, you've registered your application with Google and you've received a client_id and a secret. The client_id is a unique ID for the Course Tracker application. The secret is a confidential piece of information that is internally used by Google and the Course Tracker application. Figure 6.12 shows the authorization flow in detail:

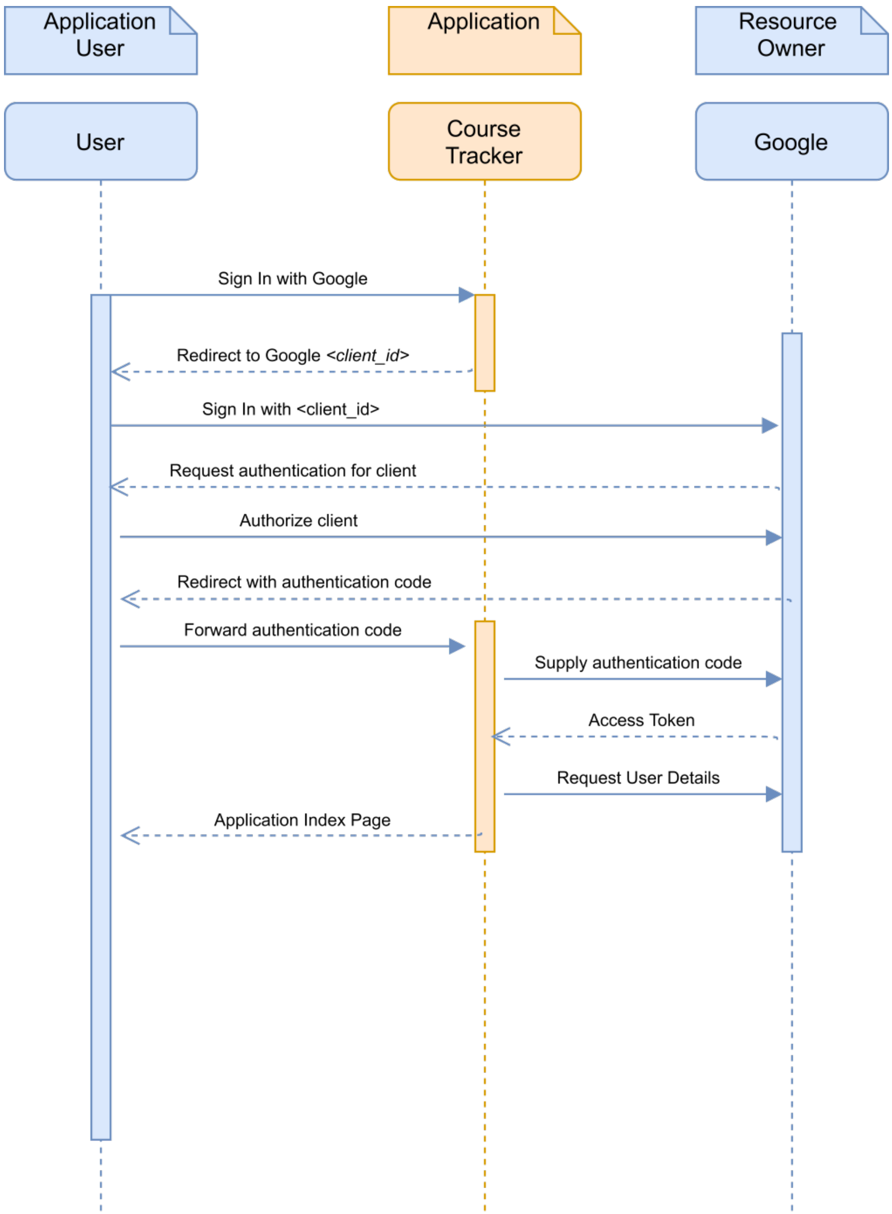


Figure 6.12 OAuth2 authorization flow between the user, Google and Course Tracker application

Let us discuss the steps in detail:

1. The user attempts to log in to the application with Google
2. The application redirects the user to the Google Sign In page and embedded the client_id in the redirect URL
3. The user signs in to Google with the Google login credentials
4. Google then displays a confirmation page whether the user authorizes the Course Tracker application to access the following details. Notice that while you register your application with Google, you provide certain scopes (such as user name, email) to Google that you will need from the user. On this confirmation page, Google shows the user the same details that the Course Tracker application will access
5. The user confirms to Google to grant access for the details to the Course Tracker application
6. Google then sends an authentication code to the user (i.e. to the user browser). Google uses the secret key to encrypt the authentication code.
7. The browser then forwards it to the Course Tracker application. The application uses its secret key to decrypt the authentication code
8. The application then sends the authentication code to Google and it is validated by Google
9. Next, Google shares an access token to the application
10. The application then uses this access token to retrieve the authenticated user details
11. Finally, the application redirects the user to the application index page

In this technique, you've learned to log in with Google. You can also implement Login with Facebook or GitHub in the same manner. You first need to register your application with these websites and obtain the client_key and secrets. You can then use these details in the Spring Boot application to implement these login options. We leave it an exercise to the reader to implement this in the Course Tracker application.

6.10 Securing Actuator Endpoints

In chapter 04, we have discussed Spring Boot application observability and explored the built-in Spring Boot actuator that exposes various application metrics. Spring Boot Actuator endpoints contain sensitive application details and should be protected from unauthorized access. You need to ensure two things:

- The actuator endpoints are protected and should not be exposed without authentication
- You should be able to authorize access to endpoints to privileged users such as application admins or the monitoring team

Let us explore how to implement these in the next technique:

TECHNIQUE SECURE SPRING BOOT ACTUATOR ENDPOINTS

Problem

In the Course Tracker application, the actuator endpoint is accessible by ordinary users. However, as actuator endpoints contain sensitive application information, it needs to be protected from unauthorized access.

Solution

In the previous chapter and this one, you've learned several Spring Security concepts. You'll leverage the same concepts to enable appropriate authentication and authorization to safeguard the actuator endpoints from unauthorized access.

Source Code

To start with this technique, you can use the base version of the Spring Boot project used in this technique available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/spring-boot-actuator-security/course-tracker-start

The final version of this Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch06/spring-boot-actuator-security/course-tracker-final

In this technique, we'll enable all actuator web endpoints and provide access to health endpoint to both the user groups with role `USER` and `ENDPOINT_ADMIN`. We are providing health endpoint access to both groups as it lets users find out the health status of the application and will be useful to find out if the application has any infrastructure issue. All other endpoints are accessible only by the users with the role `ENDPOINT_ADMIN`.

Let us add the security configuration to implement the above feature. Listing 6.58 shows the Spring Security configurations:

Listing 6.58 Security Configuration to Safeguard Actuator Endpoints

```
package com.manning.sbip.ch06.security;

//imports

@Configuration
public class SecurityConfiguration extends WebSecurityConfigurerAdapter {

       @Override
       protected void configure(AuthenticationManagerBuilder auth) throws Exception {
         auth.inMemoryAuthentication().passwordEncoder(passwordEncoder())
.withUser(User.builder().username("user").password(passwordEncoder().encode("password")).ro
       les("USER").build())
.withUser(User.builder().username("admin").password(passwordEncoder().encode("admin")).role
       s("ENDPOINT_ADMIN").build());
       }

      # The health endpoint is accessible to users with either of the USER or
       ENDPOINT_ADMIN role. All other endpoints require ENDPOINT_ADMIN role. Also, we've
       used a form based login for authentication
       @Override
       protected void configure(HttpSecurity http) throws Exception {

         http.authorizeRequests().requestMatchers(EndpointRequest.to("health")).hasAnyRole(
```

```
        "USER", "ENDPOINT_ADMIN")

          .requestMatchers(EndpointRequest.toAnyEndpoint()).hasRole("ENDPOINT_ADMIN").and().
        formLogin();
        }

        @Bean
        public PasswordEncoder passwordEncoder() {
          return new BCryptPasswordEncoder();
        }
}
```

In the listing, we've done the following changes:

1. Programatically defined two users - user and admin. The user is assigned with role USER and the admin is assigned with role `ENDPOINT_ADMIN`
2. We allowed access to the actuator `health` endpoint to both the user and admin. Rest all endpoints are accessible only by the users with role `ENDPOINT_ADMIN`
3. You've used form-based authentication for both user types

Start the application and log in with the user as the `user`. You can only access the http://localhost:8080/actuator/health endpoint. For all other endpoints, you'll receive a 403 Forbidden error message.

Next, you can log in with the admin user and you'll notice that you have access to all endpoints.

6.11 Chapter Summary

Let's summarize the key takeaways of this chapter:

- Enabled HTTPS in a Spring Boot application with a self-signed certificate and implemented redirection of all HTTP request to HTTPS
- Implemented Hashicorp Vault to externalize application secrets in the vault and connected the Spring Boot application to the vault for secret access
- Implemented a user registration module and enables user account verification through email
- Enabled an application feature that temporarily suspends user account for multiple incorrect login attempts
- Enabled Remember Me feature for quick login in the trusted devices
- Implemented Google reCAPTCHA to prevent internet bot and spam attacks
- Enabled two-factor authentication with Google Authenticator for additional application security
- Implemented OAuth2 login in a Spring Boot application with Google
- Learn how to protect Spring Boot Actuator endpoints from unauthorized access with Spring Security

7

Developing RESTful Web Services with Spring Boot

This chapter covers

- **Design and building RESTful web services with Spring Boot**
- **Exception handling in RESTful web services**
- **Developing unit test cases to test RESTful web services**
- **Documenting the RESTful web services through OpenAPI**
- **Implementing different versioning strategies for RESTful web services**
- **Techniques to secure RESTful web services**

In the microservice-based architecture, it is a common practice to expose application functionality in terms of RESTful APIs. These APIs can then be accessed through a range of application devices such as desktop applications, mobile devices as well as other APIs.

In this chapter, we'll introduce you to design and build RESTful APIs with Spring Boot. You'll also learn to document the API so that the API consumers can find required details about the API such as the request, response structures, HTTP return codes etc. Finally, you'll learn to develop unit test cases to test the API. Lastly, we'll show you to secure your RESTful API. Let's get started.

7.1 Developing a RESTful API with Spring Boot

A RESTful API (also known as REST API) is an application programming interface that follows the constraints of REST architectural style. REST is an acronym for Representational State Transfer and created by Roy Fielding https://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm. In a REST API, when a client requests a resource from the server, the server provides a representation of the state of the requested resource to the client. This representation can be delivered through various formats such as JSON, plain text, HTML etc. However, JSON is the most widely used format in the REST API parlance.

Spring Boot provides built-in support in the framework to design and build REST APIs. Spring Boot is one of the most popular frameworks in the Java space to develop REST APIs. In this section, we'll explore developing a RESTful API with Spring Boot.

TECHNIQUE DEVELOPING A RESFUL API USING SPRING BOOT

Problem

Previously, you've used the Course Tracker Spring Boot application with Thymeleaf as the frontend. You now need to expose the Course Tracker application as a RESTful API. Exposing application as RESTful API you could allow the implementation of different frontends, e.g. Angular, React, etc

Solution

Designing RESTful APIs with Spring Boot is relatively easy as the framework provides built-in support for it. These days Spring Boot is the de-facto choice for Java developers to build RESTful APIs. If you are following the previous chapters, then you are already aware of most of the contents to build a RESTful API with Spring Boot.

In chapter 3, we've discussed the use of Spring Data and talked about the approaches to configure and use a database in a Spring Boot application. In chapter 5, we've demonstrated to build Spring Boot applications by using Spring controllers in conjunction with the Spring Data repositories.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/developing-an-api/course-tracker-api

In this technique, you'll build a RESTful API for the Course tracker application. It will expose the following REST endpoints as shown in table 7.1:

Endpoint	Operation Type	Purpose
/courses/	GET	Returns all available courses from the application
/courses/{id}	GET	Returns a course with the supplied course ID
/courses/category/{name}	GET	Returns the list of courses with the supplied course category name
/courses/	POST	Create a new course
/courses/{id}	PUT	Update the course for the supplied course ID
/courses/{id}	DELETE	Deletes a course with the supplied course ID

/courses/	**DELETE**	**Deletes all courses from the application**

Table 7.1 List of REST endpoints exposed by the Course Tracker API

Table 7.1 contains the REST endpoints that let you perform the CRUD operations in the Course Tracker application. To keep the example simple, we've only introduced a limited number of endpoints. In a production application, you may define more REST endpoints. For instance, you can have few more GET endpoints that let you filter application data to meet application requirements. However, to demonstrate the concepts, we'll use these REST endpoints throughout this chapter as this endpoint covers the fundamental operations (CRUD) that most APIs support.

In the Course Tracker application, we are managing `Course` details. Thus, let us define the course business entity. You can find this class available at https://github.com/spring-boot-in-practice/repo/blob/main/ch07/developing-an-api/course-tracker-api/src/main/java/com/manning/sbip/ch07/model/Course.java

The `Course` is a Java POJO that models the course details in the application with fields such as course id, name, category, rating and description. Next, let us define the `CourseRepository` interface which lets us manage the courses in the database. You can find this interface definition available at https://github.com/spring-boot-in-practice/repo/blob/main/ch07/developing-an-api/course-tracker-api/src/main/java/com/manning/sbip/ch07/repository/CourseRepository.java

The `CourseRepository` interface extends the `CrudRepository` interface and defines a custom method `findAllByCategory(..)` that finds all courses belongs to a specific category.

Let us now define the service layer of the application. We define the service layer with an interface that provides the operations supported in the application. Listing 7.1 shows the `CourseService` interface:

Listing 7.1 The CourseService interface

```
package com.manning.sbip.ch07.service;

//imports

public interface CourseService {

	Course createCourse(Course course);

	Optional<Course> getCourseById(long courseId);

	Iterable<Course> getCoursesByCategory(String category);

	Iterable<Course> getCourses();

	void updateCourse(long courseId, Course course);

	void deleteCourseById(long courseId);

	void deleteCourses();
```

```
}
```

The methods defined in listing 7.1 are self-explanatory. It contains the method declarations that let us perform the CRUD operations in the application. Let us now provide a default implementation that provides implementations of these methods.

Generally, it is a best practice to define an interface consists of the operations supported in the API. This interface provides a contract to the controller with the operations supported in the service layer. You can then provide a concrete class that implements these operations. Further, in the controller class, you use the interface name instead of specifying the actual implementation class. This lets you decouple the controller with the actual implementation. In future, if you need to provide a different implementation of the service layer, your controller class is not impacted as it uses the interface and not tied to a specific implementation. Listing 7.2 shows the `CourseServiceImpl` class:

Listing 7.2 The CourseServiceImpl Class

```
package com.manning.sbip.ch07.service;

//imports

# Annotated with @Service to indicate it’s a service
@Service
public class CourseServiceImpl implements CourseService {

       # Autowires the CourseRepository to perform the database operations
       @Autowired
       private CourseRepository courseRepository;


       @Override
       public Course createCourse(Course course) {
         return courseRepository.save(course);
       }

       @Override
       public Optional<Course> getCourseById(long courseId) {
         return courseRepository.findById(courseId);
       }

       @Override
       public Iterable<Course> getCoursesByCategory(String category) {
         return courseRepository.findAllByCategory(category);
       }

       @Override
       public Iterable<Course> getCourses() {
         return courseRepository.findAll();
       }

       @Override
       public void updateCourse(Long courseId, Course course) {

         courseRepository.findById(courseId).ifPresent(dbCourse -> {
                 dbCourse.setName(course.getName());
```

```
                dbCourse.setCategory(course.getCategory());
                dbCourse.setDescription(course.getDescription());
                dbCourse.setRating(course.getRating());

                courseRepository.save(dbCourse);
        });
    }

    @Override
    public void deleteCourses() {
      courseRepository.deleteAll();
    }

    @Override
    public void deleteCourseById(long courseId) {
      courseRepository.deleteById(courseId);
    }

}
```

The `CourseServiceImpl` class is annotated with `@Service` annotation to indicate it's a service. Recall that `@Service` is a Spring stereotype annotation that indicates the annotated class is a service class and contains a business login. Further, it uses the `CourseRepository` to perform the necessary database operations.

We are now left with defining the `CourseController` that defines the REST endpoints. A Spring controller contains one of more endpoints and accepts the client requests. It then optionally uses the services offered by the service layer and generates a response. It wraps the response in a model and shares it with the view layer. A RestContoller also performs a similar activity. However, instead of wrapping the response in the model and share to the view layer, it binds the response to the HTTP response body which is directly shared with the endpoint requester. Listing 7.3 shows the `CourseController` class:

Listing 7.3 The CourseController class

```
package com.manning.sbip.ch07.controller;

import java.util.Optional;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.web.bind.annotation.DeleteMapping;
import org.springframework.web.bind.annotation.GetMapping;
import org.springframework.web.bind.annotation.PathVariable;
import org.springframework.web.bind.annotation.PostMapping;
import org.springframework.web.bind.annotation.PutMapping;
import org.springframework.web.bind.annotation.RequestBody;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RestController;

import com.manning.sbip.ch07.model.Course;
import com.manning.sbip.ch07.service.CourseService;

# The RequestMapping annotation specified the route or the path to the API. In this
       example, we have defined the path /courses/ so that all HTTP requests to the
       /courses/ path is redirected to this controller.
```

```
@RestController
@RequestMapping("/courses/")
public class CourseController {

       @Autowired
       private CourseService courseService;


       # A GetMapping is a special type of RequestMapping that handles only the HTTP GET
       request. As no path is specified in this endpoint, it is the default endpoint for
       the HTTP GET /courses/ endpoint
       @GetMapping
       public Iterable<Course> getAllCourses() {
         return courseService.getCourses();
       }

       # Handles HTTP GET requests for the path /courses/{id}. The {id} is a path variable
       and replaced with an appropriate value e.g. /courses/1 where 1 is the value of the
       path variable id
       @GetMapping("{id}")
       public Optional<Course> getCourseById(@PathVariable("id") long courseId) {
         return courseService.getCourseById(courseId);
       }

       # Handles HTTP GET requests for the path /courses/category/{name}. The {name} is a
       path variable and replaced with an appropriate value e.g. /courses/ category/Spring
       where Spring is the value of the path variable name

       @GetMapping("category/{name}")
       public Iterable<Course> getCourseByCategory(@PathVariable("name") String category) {
         return courseService.getCoursesByCategory(category);
       }

       # Handles HTTP POST requests for the path /courses/. An HTTP POST request accepts a
       request payload. You use the @RequestBody annotation to specify the request body.
       Note that, the requester typically sends a JSON payload and in the endpoint, you
       expect a Java POJO class that represents the JSON payload. Spring Boot internally
       performs this deserialization to convert the JSON to the Java type.
       @PostMapping
       public Course createCourse(@RequestBody Course course) {
         return courseService.createCourse(course);
       }

       # Handles the HTTP PUT operations for the path /courses/{id}. The HTTP PUT operation
       is used to perform the update operations. In this endpoint, we expect the id of the
       resource that needs to be updated and the updated representation of the resource in
       the HTTP request payload. We use the @RequestBody to accept the request payload
       @PutMapping("{id}")
       public void updateCourse(@PathVariable("id") long courseId, @RequestBody Course
       course) {
         courseService.updateCourse(courseId, course);
       }

       # Represents the HTTP DELETE operation for the /courses/{id} path. In this endpoint,
       we delete the course for the supplied course id
       @DeleteMapping("{id}")
       void deleteCourseById(@PathVariable("id") long courseId) {
         courseService.deleteCourseById(courseId);
       }
```

```
        # Represents the HTTP DELETE operation for the /courses/ path. In this endpoint, we
        delete all available courses
        @DeleteMapping
        void deleteCourses() {
          courseService.deleteCourses();
        }

}
```

Listing 7.3 defines all the endpoints listed in table 7.1. We'll explore more on this class in the discussion section of this technique. However, one thing that you should take note of is the use of `@RestController` annotation instead of previously used `@Controller` annotation.

HTTPie

HTTPie is a command-line HTTP client that lets you access HTTP URLs. We'll use this as an alternative to cURL to test our APIs. You can find more information on HTTPie at https://httpie.io/. Besides, you can also refer to https://medium.com/swlh/introduction-to-httpie-a-lightweight-http-client-502e6e08ca6c for a quick introduction to how to install and use HTTPie.

Let us start the application and access the endpoints. First, let us create a course using the `POST /courses/` endpoint. Listing 7.4 shows the HTTPie command to create a course:

Listing 7.4 The cURL command to create a new course

```
C:\sbip\repo>http POST :8080/courses/ name="Mastering Spring Boot" rating=4 category=Spring
        description="Mastering Spring Boot intends to teach Spring Boot with practical
        examples"
HTTP/1.1 200
// Other HTTP Response Headers
{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
        examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "rating": 4
}
```

In Listing 7.4, although we've supplied the request body data in key=value pair, the HTTPie tool internally converts it to a JSON payload. Once this command is executed in the terminal, a new course is created in the Course Tracker application. Let us view the course details using the `GET /courses/{id}` endpoint to retrieve course details with a courseId obtained in POST operation of Listing 7.4. This is shown in Listing 7.5:

Listing 7.5 The cURL command to view a course

```
C:\sbip\repo>http GET :8080/courses/1
HTTP/1.1 200
// Other HTTP Response Headers
{
```

```
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "rating": 4
}
```

You can try accessing other endpoints in the same manner and monitor the output.

Discussion

In this technique, you've learned to create a complete RESTful API. We have kept the application extremely simple to demonstrate the concepts. Let us now discuss a few best practices that we've followed while designing the REST API.

If you notice, we've used JSON to accept the requests and similarly responded with JSON in the response. It is a best practice that the REST APIs accept request payloads in JSON and provide a response in JSON.

JSON is widely used to store and transfer data. Spring Boot provides built-in support to perform the mapping between JSON and Java POJOs and vice-versa. For instance, if you notice in Listing 7.4, you've sent a JSON request as the payload to create a new course in the application. However, the POST endpoints accept a `Course` instance. Spring Boot performs this deserialization internally for us. By default, it uses the Jackson library (https://github.com/FasterXML/jackson) to perform this mapping.

The next thing to notice is the use of nouns while defining the endpoint paths. It is a best practice to use the plural form of the noun(e.g. Course, Person, Vehicle etc.) to define the routes. We should not use verbs in the route paths as the HTTP request method already has a verb (e.g., GET, POST, etc.) that defines the actions. Letting the developers using the verbs in paths make the paths lengthy and inconsistent. For instance, to get the course details, one developer may use `/getCourses` whereas another can use `/retrieveCourses`. However, the get or retrieve is already defined through the HTTP GET method. Thus, specifying it in the route path makes it redundant. Hence, `GET /courses/` is the preferred endpoint path to get all courses. Similarly, the `POST /courses/` is the appropriate endpoint to create a new course.

Let us now provide a high-level flow diagram that shows the request and response processing in a REST API in a Spring Boot application. Figure 7.1 shows this diagram:

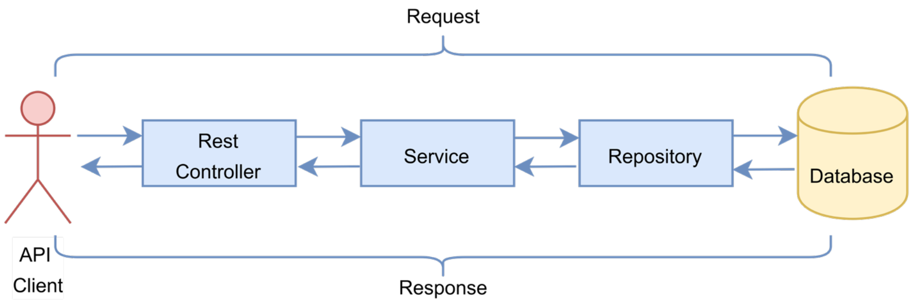


Figure 7.1 The communication flow diagram in a REST API. A user invokes a REST endpoint which is handled by the REST Controller. The controller then uses the service layer to process the request. The service layer relies on the repository to communicate to the database. Once there is a response from the repository, it is processed by the service layer and forwarded to the controller. The controller may perform additional processing and the final response is provided to the API client.

In listing 7.3, we've used the `@RestController` annotation in place of the previously used `@Controller` annotation. The `@RestController` annotation is a convenience annotation that is meta-annotated with the `@Controller` and `@ResponseBody` annotations. The `@ResponseBody` annotation indicates that a method's return value should be bound to the HTTP response body.

Although the above API works well and serves the purpose, currently there is no exception handling. For instance, let us try to delete a course that does not exist in the application. You'll notice that you have presented with an error and an ugly looking large stack trace. Let us fix this in the next technique.

7.2 Managing Exceptions in a Spring Boot RESTful API

Exceptions are inevitable in software code. Numerous reasons could cause an exceptional scenario in your code. For instance, in the RESTful API that we've designed, a user could attempt to access/delete a course with a non-existing course id. Besides, they could submit a malformed JSON request payload to create a new course through the POST endpoint. All these scenarios cause exceptions in the API.

In this section, we'll discuss how to handle these exceptions and provide a meaningful response to the user specifying the exception details.

TECHNIQUE HANDLING EXCEPTIONS IN A RESTFUL API

Problem

The previously defined RESTful API is unable to handle errors as there is no exception handling in place. It presents the user with a large stack trace that is not intuitive and exposes application internal details. You need to handle exceptions and ensure to provide meaningful error responses.

Solution

Exception handling is an important aspect of a RESTful API. Typically, your APIs will be consumed by a variety of consumers and able to provide a meaningful error response in the event of an exception scenario makes your API robust and user friendly.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/exception-handling/course-tracker-api

In the API designed in section 7.1, we've not handled the exceptions and the default Spring Boot exception handling mechanism is in place. For instance, while deleting a course that does not exist in the application presents the error message as shown in Listing 7.6:

Listing 7.6 Default Exception Handling

```
C:\sbip\repo>http DELETE :8080/courses/10
HTTP/1.1 500
{
    "error": "Internal Server Error",
    "message": "No class com.manning.sbip.ch07.model.Course entity with id 10 exists!",
    "path": "/courses/10",
    "status": 500,
    "timestamp": "2021-06-23T16:38:20.105+00:00",
    "trace": "org.springframework.dao.EmptyResultDataAccessException: No class
       com.manning.sbip.ch07.model.Course entity with id 10 exists!\r\n\tat
       org.springframework.data.jpa.repository.support.SimpleJpaRepository.lambda$deleteByI
       d$0(SimpleJpaRepository.java:166)\r\n\tat
       java.base/java.util.Optional.orElseThrow(Optional.java:401)\r\n\tat
       org.springframework.data.jpa.repository.support.SimpleJpaRepository.deleteById(Simpl
       eJpaRepository.java:165)\r\n\tat
       java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native
       Method)\r\n\tat
       java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorI
       mpl.java:64)\r\n\tat

// Remaining section of the exception is omitted
```

As you may notice, the above error message is not desired one and contains details that are not of much use to the API users. Besides, it exposes to the caller information about the tech stack used for the implementation of the API, which generally is considered a security flaw. Further, the HTTP response code is also generic (500 Internal Server Error) which indicates that a server-side error has occurred. In this technique, we'll improve the Course Tracker RESTful API by implementing exception handling in the API.

To begin with, let us first discuss the type of exceptions that we may encounter in the application. For this API, we can have only a handful of exception scenarios. For instance, it may possible that a user attempts to get, update or delete a course that does not exist in the application. This should result in an HTTP 404 Not Found error as the requested resource does not exist in the application. Besides, it is also possible that the user is submitting an incomplete/incorrect JSON payload while creating or updating a course. Let us handle these exception scenarios. This results in an HTTP 400 Bad Request status code as the user request could not be processed as the server is unable to parse the request as it is malformed.

To handle the first scenario, let us create a custom exception called `CourseNotFoundException` as shown in Listing 7.7:

Listing 7.7 CourseNotFoundException

```
package com.manning.sbip.ch07.exception;

public class CourseNotFoundException extends RuntimeException {

       private static final long serialVersionUID = 5071646428281007896L;

       public CourseNotFoundException(String message) {
         super(message);
       }
}
```

This `CourseNotFoundException` is thrown whenever API users attempt to access a course that does not exist in the application. Let us now re-define the `CourseServiceImpl` class as shown in Listing 7.8:

Listing 7.8 CourseServiceImpl class

```
package com.manning.sbip.ch07.service;

//imports

@Service
public class CourseServiceImpl implements CourseService {

       // Additional Code

       @Override
       public Course updateCourse(long courseId, Course course) {

        Course existingCourse = courseRepository.findById(courseId)
         .orElseThrow(() -> new CourseNotFoundException("No course with id %s is available"
       + courseId));
        existingCourse.setName(course.getName());
        existingCourse.setCategory(course.getCategory());
        existingCourse.setDescription(course.getDescription());
        existingCourse.setRating(course.getRating());
        return courseRepository.save(existingCourse);
       }


       @Override
       public void deleteCourseById(long courseId) {
       courseRepository.findById(courseId).orElseThrow(() -> new
       CourseNotFoundException("No course with id %s is available" + courseId));
         courseRepository.deleteById(courseId);      }
```

```
}
```

Listing 7.8 shows the modified methods of `CourseServiceImpl` class. For an update or a delete operation, if a course with the supplied courseId does not exist in the application, we throw the CourseNotFoundException.

Now that we've thrown the exception, what's next? We need to define an exception handler that intercepts the thrown exception and executes custom exception handling logic. For instance, for an unhandled exception, the HTTP response code is 500 Internal Server Error is returned. However, if a course with the supplied `courseid` does not exist in the application, the appropriate HTTP error code should be 404 Not Found. The latter HTTP response code tells the API consumer that the course they are accessing does not exist.

Let us define the `GlobalExceptionHandler` class that defines the ExceptionHandlers of our application. Listing 7.9 shows this class:

Listing 7.9 GlobalExceptionHandler class

```
package com.manning.sbip.ch07.exception.handler;

//imports

@ControllerAdvice
public class CourseTrackerGlobalExceptionHandler extends ResponseEntityExceptionHandler {

       @ExceptionHandler(value = {CourseNotFoundException.class})
       public ResponseEntity<?> handleCourseNotFound(CourseNotFoundException
       courseNotFoundException, WebRequest request) {
         return super.handleExceptionInternal(courseNotFoundException,
                            courseNotFoundException.getMessage(), new HttpHeaders(),
       HttpStatus.NOT_FOUND, request);
       }
}
```

In the class in Listing 7.9, you've defined a few `ExceptionHandler` implementations that handle the exceptions that can be thrown while processing the requests. Let us explore this class in detail:

- This class is annotated with the `@ControllerAdvice` annotation. This annotation is a specialized `@Component` that lets you declare the `@ExceptionHandler`. The `@ControllerAdvice` annotation allows writing global code that applies to a range of controllers (and RestControllers). Thus, the `ExceptionHandler` defined in listing 7.9 applies to all controllers in the application
- This class extends the `ResponseEntityExceptionHandler` class which is a base class for `@ControllerAdvice` annotated classes that provide a centralized exception handling across all `@RequestMapping` annotated methods through `@ExceptionHandler` methods. This class provides exception handling logic for a variety of exceptions that can occur in the application. We can extend this class and override the exception handling logic at our convenience
- We've defined a new `ExceptionHandler` for our custom exception

`CourseNotFoundException`. In this implementation, we are setting the HTTP response code to `404 Not Found` and the error message retrieved from the custom exception. Finally, we are invoking the superclass method `handleExceptionInternal(..)` with these details

Let us now start the application and try out a replicating a few exceptions scenario and observe the response. Let us try deleting a course with a course id that is not present in the application. The HTTPie command and the associated response is shown in Listing 7.10:

Listing 7.10 Delete a Course

```
C:\sbip\repo>http DELETE :8080/courses/1
HTTP/1.1 404
// HTTP Response Headers

No course with id 1 is available
```

Notice that we have an appropriate HTTP status code 404 as well as a relevant error message that specifies the error. Moreover, the user does not see any reference to the technology used for the API implementation (i.e.: no Spring Boot stack trace appearing anymore).

Discussion

The ability of a RESTful API to handle various user errors and able to respond with appropriate HTTP status codes and error messages makes it robust and user-friendly. Besides, this makes the application more compliant with the RESTful paradigm itself.

While designing APIs, it is a common practice to first identify the possible error scenarios in the application. You can then define custom exception classes that define the identified error scenario. One advantage of designing a custom exception is that it lets you model the exception in a better manner and provides flexibility to capture various details about the exception. You can then define `ExceptionHandler` that intercepts these exception classes and let you define custom error response. For instance, try defining an exception handler that handles the wrong request payloads and responds with the HTTP 400 Bad Request. We leave this as an exercise for the readers.

7.3 Testing a RESTful API

In the previous techniques, you've learned to design and build a RESTful API. Once you are done with the development, the next task is to test the endpoints of the API to ensure that the API is working as expected. There are multiple ways we can test a REST API as shown in figure 7.2:

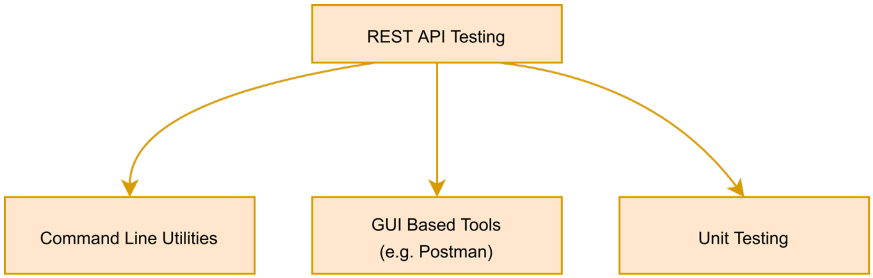


Figure 7.2 Options to test a RESTful API. Command Line Utilities includes cURL, HTTPie. The GUI based tools include Postman, SoapUI. Unit Testing can be done with Spring Boot MockMVC in conjunction with JUnit

So far, we've shown you to use the command-line tool HTTPie that can be used to access the endpoints. Besides you can also use the cURL utility to test the endpoints. If you are not comfortable with CLI utilities, GUI based tools are another great alternatives. In the REST API testing, Postman (https://www.postman.com/) is extensively used by API developers to test the APIs. Besides, if you are familiar with the Microsoft VS Code editor (https://code.visualstudio.com/), it also provides several extensions to enable testing support for the REST APIs. We'll not cover these utilities as there are enough tutorials and how-to guides available on the internet explaining using these tools.

In this section, we'll discuss how to test a REST API through integration testing. It is always a best practice to write test cases for the endpoints that are executed while you build the API. Let us explore it in the next technique.

TECHNIQUE TESTING A RESTFUL API IN A SPRING BOOT APPLICATION

Problem

We haven't defined any test cases to test the REST API endpoints. To ensure the API endpoints are working correctly and are not broken while introducing new changes in future, we need to define integration test cases.

Solution

In a typical application, to test your application classes, you either instantiate those and invoke the methods defined in it or use mocking frameworks such as Mockito to mock the class and other components. In a Spring MVC application as well, we can similarly define test cases. However, that does not verify few important MVC framework features such as to request mapping, validation, data binding, @ExceptionHandler etc.

Spring MVC provides a testing framework that provides comprehensive testing capabilities for Spring MVC based applications without the need for an actual server. This framework also known as MockMvc performs the MVC request handling via mock request and response objects.

In this technique, we'll show you how to use the Spring MockMVC framework in a Spring Boot application to test a REST API. We'll define integration test cases for the API endpoints we've defined in the previous techniques.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/testing-an-api/course-tracker-api

Let us begin with defining the first test case that creates a course in the course tracker application. Listing shows the class:

Listing 7.11 Integration Test Case for Course Tracker REST API Create Course endpoint

```
package com.manning.sbip.ch07;

import static org.hamcrest.Matchers.greaterThan;
import static org.hamcrest.Matchers.hasSize;
import static org.junit.jupiter.api.Assertions.assertNotNull;
import static org.springframework.test.web.servlet.request.MockMvcRequestBuilders.delete;
import static org.springframework.test.web.servlet.request.MockMvcRequestBuilders.get;
import static org.springframework.test.web.servlet.request.MockMvcRequestBuilders.post;
import static org.springframework.test.web.servlet.request.MockMvcRequestBuilders.put;
import static org.springframework.test.web.servlet.result.MockMvcResultHandlers.print;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.jsonPath;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.status;

import org.junit.jupiter.api.Test;
import org.junit.jupiter.api.extension.ExtendWith;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.test.autoconfigure.web.servlet.AutoConfigureMockMvc;
import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.mock.web.MockHttpServletResponse;
import org.springframework.test.context.junit.jupiter.SpringExtension;
import org.springframework.test.web.servlet.MockMvc;

import com.fasterxml.jackson.databind.ObjectMapper;
import com.jayway.jsonpath.JsonPath;
import com.manning.sbip.ch07.model.Course;
import com.manning.sbip.ch07.service.CourseService;

@SpringBootTest
@AutoConfigureMockMvc
@ExtendWith(SpringExtension.class)
class CourseTrackerApiApplicationTests {

       @Autowired
       private CourseService courseService;

       @Autowired
       private MockMvc mockMvc;

       @Test
       public void testPostCourse() throws Exception {
        Course course = Course.builder()
```

```
                 .name("Rapid Spring Boot Application Development")
                 .category("Spring")
                 .rating(5)
                 .description("Rapid Spring Boot Application Development").build();
        ObjectMapper objectMapper = new ObjectMapper();

        MockHttpServletResponse response = mockMvc.perform(post("/courses/")
                .contentType("application/json")
                .content(objectMapper.writeValueAsString(course)))
                .andDo(print())
                .andExpect(jsonPath("$.*", hasSize(5)))
                .andExpect(jsonPath("$.id", greaterThan(0)))
                .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application
       Development"))
                .andExpect(jsonPath("$.category").value("Spring"))
                .andExpect(jsonPath("$.rating").value(5))
                .andExpect(status().isCreated()).andReturn().getResponse();

        Integer id = JsonPath.parse(response.getContentAsString()).read("$.id");
        assertNotNull(courseService.getCourseById(id));

    }
}
```

Let us define various components we've used in the class defined in listing 7.11:

- The `@SpringBootTest` annotation indicates the annotated class runs Spring Boot based tests and provides necessary environmental support to run the test cases
- The `@AutoConfigureMockMvc` annotation enables and auto-configures the MockMVC framework. This annotation performs the heavy-lifting to provide the necessary support so that we can simply autowire an instance of MockMvc and use it in the test
- The `@ExtendWith(SpringExtension.class)` annotation integrates the Spring TestContext Framework with JUnit 5's Jupiter programming model. `@ExtendWith` is a JUnit 5 annotation that lets you specify the extension to be used to run the test case
- Next, we've autowired the CourseService and the MockMvc instanced in the class
- Lastly, we've used the `mockMvc` instance to perform an HTTP POST operation with a sample course

Once the request is fired, we use the andExpect to assert various attributes. We've used the `jsonpath` to extract the values from the JSON response. Lastly, we validate the HTTP response status code.

Let us now provide the test case to get the course by id. Listing 7.12 shows this test case:

Listing 7.12 Test case to get a course by a course id

```
@Test
public void testRetrieveCourse() throws Exception {
        Course course = Course.builder()
                 .name("Rapid Spring Boot Application Development")
                 .category("Spring")
                 .rating(5)
                 .description("Rapid Spring Boot Application Development").build();
    ObjectMapper objectMapper = new ObjectMapper();
```

```
    MockHttpServletResponse response = mockMvc.perform(post("/courses/")
            .contentType("application/json")
            .content(objectMapper.writeValueAsString(course)))
            .andDo(print())
            .andExpect(jsonPath("$.*", hasSize(5)))
            .andExpect(jsonPath("$.id", greaterThan(0)))
            .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application
       Development"))
            .andExpect(jsonPath("$.category").value("Spring"))
            .andExpect(jsonPath("$.rating").value(5))
            .andExpect(status().isCreated()).andReturn().getResponse();
    Integer id = JsonPath.parse(response.getContentAsString()).read("$.id");

    mockMvc.perform(get("/courses/{id}",id))
            .andDo(print())
            .andExpect(jsonPath("$.*", hasSize(5)))
            .andExpect(jsonPath("$.id", greaterThan(0)))
            .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application
       Development"))
            .andExpect(jsonPath("$.category").value("Spring"))
            .andExpect(jsonPath("$.rating").value(5))
            .andExpect(status().isOk());

}
```

In the listing, we've first created a course through the post() method and then used the get(..) method to retrieve the course details. Similar to the previous test case, we've asserted the various response parameters along with the HTTP response status code.

Let us now include the remaining test cases as shown in listing 7.13:

Listing 7.13 Test cases for the Invalid Couse Id, Update and Delete Course endpoints

```
@Test
public void testInvalidCouseId() throws Exception {
       mockMvc.perform(get("/courses/{id}",100))
    .andDo(print())
    .andExpect(status().isNotFound());
}

@Test
public void testUpdateCourse() throws Exception {
        Course course = Course.builder()
                  .name("Rapid Spring Boot Application Development")
                  .category("Spring")
                  .rating(3)
                  .description("Rapid Spring Boot Application Development").build();
    ObjectMapper objectMapper = new ObjectMapper();

    MockHttpServletResponse response = mockMvc.perform(post("/courses/")
            .contentType("application/json")
            .content(objectMapper.writeValueAsString(course)))
            .andDo(print())
            .andExpect(jsonPath("$.*", hasSize(5)))
            .andExpect(jsonPath("$.id", greaterThan(0)))
            .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application
       Development"))
```

```
            .andExpect(jsonPath("$.category").value("Spring"))
            .andExpect(jsonPath("$.rating").value(3))
            .andExpect(status().isCreated()).andReturn().getResponse();
    Integer id = JsonPath.parse(response.getContentAsString()).read("$.id");

    Course updatedCourse = Course.builder()
         .name("Rapid Spring Boot Application Development")
         .category("Spring")
         .rating(5)
         .description("Rapid Spring Boot Application Development").build();

    mockMvc.perform(put("/courses/{id}", id)
         .contentType("application/json")
         .content(objectMapper.writeValueAsString(updatedCourse)))
            .andDo(print())
            .andExpect(jsonPath("$.*", hasSize(5)))
            .andExpect(jsonPath("$.id").value(id))
            .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application 
       Development"))
            .andExpect(jsonPath("$.category").value("Spring"))
            .andExpect(jsonPath("$.rating").value(5))
            .andExpect(status().isOk());

}

@Test
public void testDeleteCourse() throws Exception {
        Course course = Course.builder()
                  .name("Rapid Spring Boot Application Development")
                  .category("Spring")
                  .rating(5)
                  .description("Rapid Spring Boot Application Development").build();
   ObjectMapper objectMapper = new ObjectMapper();

   MockHttpServletResponse response = mockMvc.perform(post("/courses/")
           .contentType("application/json")
           .content(objectMapper.writeValueAsString(course)))
           .andDo(print())
           .andExpect(jsonPath("$.*", hasSize(5)))
           .andExpect(jsonPath("$.id", greaterThan(0)))
           .andExpect(jsonPath("$.name").value("Rapid Spring Boot Application 
       Development"))
           .andExpect(jsonPath("$.category").value("Spring"))
           .andExpect(jsonPath("$.rating").value(5))
           .andExpect(status().isCreated()).andReturn().getResponse();
   Integer id = JsonPath.parse(response.getContentAsString()).read("$.id");

   mockMvc.perform(delete("/courses/{id}", id))
           .andDo(print())
           .andExpect(status().isOk());

}
```

In listing 7.13, we've defined three test cases:

- The first test case attempts to get the course details for a course Id that is not available. The application returns an HTTP 404 status code and we expect the same in the test case

- The second test case performs an HTTP PUT operation to test the update course endpoint
- The last test case performs the HTTP DELETE operation to delete a course with a courseId

Discussion

Spring MockMvc framework provides an excellent way to test Spring MVC based applications. Moreover, Spring Boot auto-configuration of MockMvc has simplified defining the test cases even further. In this technique, we've demonstrated how to define test cases for the REST API endpoints with Spring's MockMvc framework. The MockMvc framework provides a fluent API that lets you perform the assertion of various response parameters. You can find further details regarding MockMvc available at https://docs.spring.io/spring-framework/docs/current/reference/html/testing.html#spring-mvc-test-framework.

Spring also provides an alternate test client named WebTestClient that lets you verify the response in a much better manner. We'll demonstrate the use of WebTestClient in the next chapter.

7.4 Documenting a RESTful API

As part of modern-day application development, APIs play a critical role in the success of an application. As application features are consumed by a variety of devices, it is important that APIs are documented. Further, an API represents a contract between an API provider and consumers. Thus, a good API should ensure that the API details are available to its consumers so that consumers can develop their code accordingly. These details include HTTP request and response structure, HTTP status code that an endpoint returns, security configurations and various other details. You can refer to https://petstore.swagger.io/ for a quick glimpse of the documentation of the Spring Petclinic application (https://github.com/spring-projects/spring-petclinic).

In this section, we'll discuss document the RESTful APIs through OpenAPI (https://swagger.io/specification/) which is the most popular and de facto standard of RESTful API documentation.

TECHNIQUE DOCUMENTING A RESTFUL API WITH OPENAPI

Problem

The Course Tracker API is currently undocumented and there are no means other than exploring the application source code to find out the details regarding the API. We need to document this API with OpenAPI so that the API consumers can find the required details about the API

Solution

The OpenAPI Specification provides a standard approach to document RESTful APIs so that the API consumers can find out the details and the capabilities of the API in a consistent manner.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/documenting-with-openapi/course-tracker-api

The OpenAPI specification is language-agnostic which means that it is not only limited to Spring Boot, but it is available for other languages and frameworks as well. For instance, we can use OpenAPI to document the RESTful API developed through a Spring Boot application and the same is possible for a RESTful API developed through Express JS (https://expressjs.com/).

In this section, we'll demonstrate how to document the Course Tracker API with OpenAPI. To proceed with that lets us first add the following Maven dependency in the `pom.xml` file as shown in listing 7.14:

Listing 7.14 OpenAPI Maven dependency

```
<dependency>
       <groupId>org.springdoc</groupId>
       <artifactId>springdoc-openapi-ui</artifactId>
       <version>1.5.9</version>
</dependency>
```

The `springdoc-openapi` (https://springdoc.org/) library automates the generation of API documentation in a Spring Boot project. It does so by inspecting a Spring Boot application at runtime to infer the API semantics based on Spring configurations, class structure, and other annotations. The `springdoc-openapi-ui` dependency provides integration between Spring Boot and Swagger UI. It automatically deploys the swagger-ui to a Spring Boot application and make it available at http://{server}:{port}/{context-path}/swagger-ui.html.

Notice that we've introduced Swagger in our discussion. Let us clarify the difference between Swagger and OpenAPI. The OpenAPI is the specification that dictates the guidelines for the API documentation. The Swagger is the tool that implements this specification. Swagger consists of various components such as Swagger Editor, Swagger UI, Swagger Codegen and few other modules. Please refer to https://swagger.io/blog/api-strategy/difference-between-swagger-and-openapi/ for a detailed discussion on Swagger vs OpenAPI.

Let us now proceed with documenting the Course Tracker API. To document the API, we annotate the endpoints with various annotations. These annotations contain custom details about the endpoint such as the purpose of the endpoint, the HTTP status code it returns etc. Listing 7.15 shows the updated `CourseController` annotated with the OpenAPI annotations:

Listing 7.15 The CourseController Class

```
package com.manning.sbip.ch07.controller;

// imports

import io.swagger.v3.oas.annotations.Operation;
import io.swagger.v3.oas.annotations.tags.Tag;
```

```
@RestController
@RequestMapping("/courses/")
@Tag(name = "Course Controller", description = "This REST controller provide services to
       manage courses in the Course Tracker application")
public class CourseController {

       private CourseService courseService;

       @Autowired
       public CourseController(CourseService courseService) {
         this.courseService = courseService;
       }

       @GetMapping
       @ResponseStatus(code = HttpStatus.OK)
       @Operation(summary = "Provides all courses available in the Course Tracker
       application")
       public Iterable<Course> getAllCourses() {
         return courseService.getCourses();
       }

       @GetMapping("{id}")
       @ResponseStatus(code = HttpStatus.OK)
       @Operation(summary = "Provides course details for the supplied course id from the
       Course Tracker application")
       public Optional<Course> getCourseById(@PathVariable("id") long courseId) {
         return courseService.getCourseById(courseId);
       }

       @GetMapping("category/{name}")
       @ResponseStatus(code = HttpStatus.OK)
       @Operation(summary = "Provides course details for the supplied course category from
       the Course Tracker application")
       public Iterable<Course> getCourseByCategory(@PathVariable("name") String category) {
         return courseService.getCoursesByCategory(category);
       }

       @PostMapping
       @ResponseStatus(code = HttpStatus.CREATED)
       @Operation(summary = "Creates a new course in the Course Tracker application")
       public Course createCourse(@Valid @RequestBody Course course) {
         return courseService.createCourse(course);
       }

       @PutMapping("{id}")
       @ResponseStatus(code = HttpStatus.NO_CONTENT)
       @Operation(summary = "Updates the course details in the Course Tracker application
       for the supplied course id")
       public void updateCourse(@PathVariable("id") long courseId, @Valid @RequestBody
       Course course) {
         courseService.updateCourse(courseId, course);
       }

       @DeleteMapping("{id}")
       @ResponseStatus(code = HttpStatus.NO_CONTENT)
       @Operation(summary = "Deletes the course details for the supplied course id from the
       Course Tracker application")
       public void deleteCourseById(@PathVariable("id") long courseId) {
```

```
        courseService.deleteCourseById(courseId);
      }

      @DeleteMapping
      @ResponseStatus(code = HttpStatus.NO_CONTENT)
      @Operation(summary = "Deletes all courses from the Course Tracker application")
      public void deleteCourses() {
        courseService.deleteCourses();
      }

}
```

In listing 7.15, we've annotated the class with `@Tag` and the endpoints with `@ResponseStatus` and `@Operation` annotations. The `@Tag` provides information about the controller. The `@ResponseStatus` indicates the HTTP status code the endpoint returns. Notice that the HTTP status code is critical for the API consumer to code their application logic as it defines the status of the API call. Thus, we must take care while determining the HTTP Status code for the endpoints. Lastly, the `@Operation` annotation captures details regarding the purpose of the endpoint.

Let us now capture a few custom details about the API such as API version, title, description, license details etc. You can do this by defining a Spring bean of type OpenAPI. Listing shows this bean definition in the Course. For simplicity, we've defined this bean in the Spring Boot main class as shown in Listing 7.16. In a typical application, you should define a separate Spring configuration class that should contain this `@Bean` definition.

Listing 7.16 the OpenAPI Bean definition

```
package com.manning.sbip.ch07;

//imports

import io.swagger.v3.oas.models.OpenAPI;
import io.swagger.v3.oas.models.info.Info;
import io.swagger.v3.oas.models.info.License;

@SpringBootApplication
public class CourseTrackerApiApplication {

      public static void main(String[] args) {
        SpringApplication.run(CourseTrackerApiApplication.class, args);
      }

      @Bean
      public OpenAPI customOpenAPI(@Value("${app.description}") String appDescription,
                 @Value("${app.version}") String appVersion) {

        return new OpenAPI().info(new Info().title("Course Tracker
      API").version(appVersion)

        .description(appDescription).termsOfService("http://swagger.io/terms/")
                          .license(new License().name("Apache
      2.0").url("http://springdoc.org")));

      }
```

```
}
```

In listing 7.17, we've defined the OpenAPI bean which contains custom API details. We've defined the `app.description` and `app.version` properties in the `application.properties` file as shown in Listing 7.17:

Listing 7.17 The application.properties file

```
app.description=Spring Boot Course Tracker API
app.version=v1
```

That's all. Let us start the application and access the swagger-ui to view the API documentation. You can access swagger-ui for this application at http://localhost:8080/swagger-ui.html. Figure 7.3 shows the swagger-ui for the Course Tracker API:

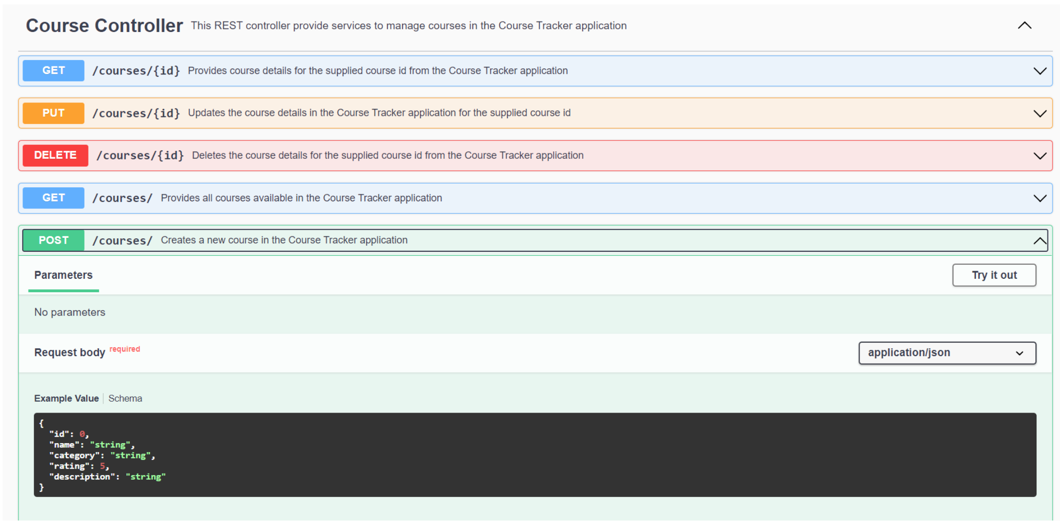


Figure 7.3 The Course Tracker Swagger documentation. It contains the API description, controller details, and endpoint details

Discussion

OpenAPI is the de-facto choice to document RESTful APIs. As you've seen in the previous example, by adding a few dependencies you have a nice HTML based API document that captures the details about the API. However, one issue with the HTML is that it is difficult to share with the API consumers. To handle this, Swagger also lets you extract the API documentation in JSON format. You can retrieve this JSON by accessing the http://localhost:8080/v3/api-docs URL. This is shown in Listing 7.17:

Listing 7.17 The API documentation in JSON format

```
{
   "openapi":"3.0.1",
   "info":{
      "title":"Course Tracker API",
      "description":"Spring Boot Course Tracker API",
      "termsOfService":"http://swagger.io/terms/",
      "license":{
         "name":"Apache 2.0",
         "url":"http://springdoc.org"
      },
      "version":"v1"
   },
   "servers":[
      {
         "url":"http://localhost:8080",
         "description":"Generated server url"
      }
   ],
   "tags":[
      {
         "name":"Course Controller",
         "description":"This REST controller provides services to manage courses in the
       Course Tracker application"
      }
   ],
   "paths":{
      "/courses/{id}":{
         "get":{
            "tags":[
               "Course Controller"
            ],

// Remaining part of the JSON is omitted
```

Swagger provides the Swagger Editor (https://editor.swagger.io/) which lets you import this JSON and renders the same HTML layout as shown in figure 7.4:

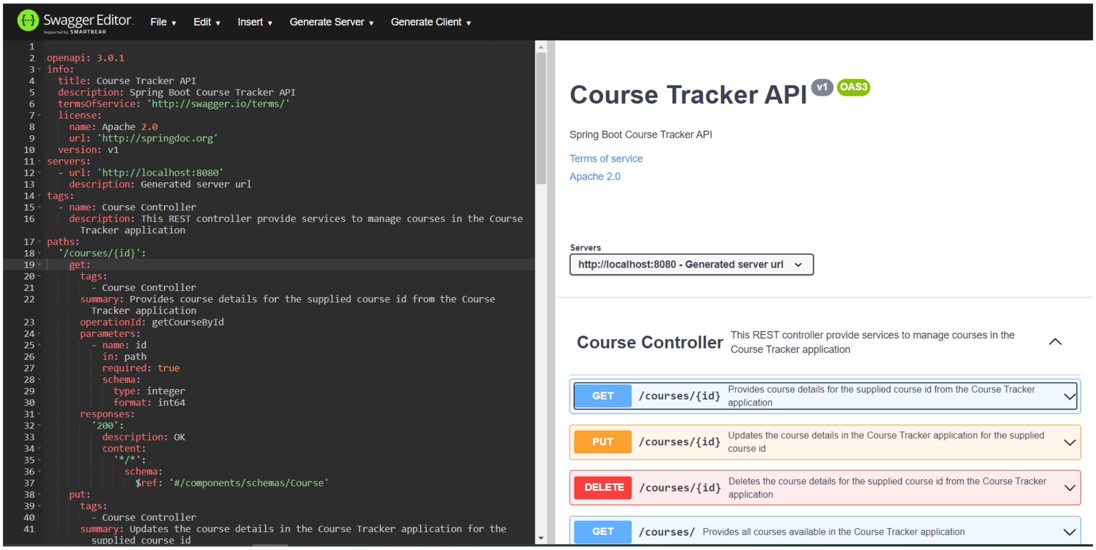


Figure 7.4 Rendering the REST API documentation in the Swagger Editor. The Swagger Editor prefers the YAML version of the JSON data and automatically converts a JSON to YAML while you paste the JSON in the editor.

You can ship this JSON shown in listing 7.17 with API consumers to let them render it through Swagger Editor. To make life further simpler, Swagger also provides a `Codegen` utility that lets you generate client applications from this JSON. For instance, let's assume that the API client uses Node JS as their preferred language. You can generate this Node JS client stub with Swagger Codegen. Besides, Swagger Codegen also lets you generate the client stub for a lot of different languages. Refer to https://swagger.io/tools/swagger-codegen/ for more details on Swagger Codegen. For further details on Spring Doc and OpenAPI integration, refer to Spring Doc reference documentation available at https://springdoc.org/.

7.5 Implementing RESTful API Versioning

In this section, we'll discuss the various approaches to versioning a RESTful API. However, before proceeding with the discussion of various versioning techniques, let us understand REST API versioning and its need.

In simple words, versioning a REST API means the ability for the API to support multiple versions. It is a common occurrence to enhance or upgrade the application features over time. Various reasons could drive these changes. For instance, it could be the implementation of new business features or adoption of new technology stack or it could be due to refinement of the existing APIs.

However, the issue with a breaking API change is that it directly impacts the API consumers and breaks their application. Besides, it causes a cascading impact on the API invocation chain. One way to resolve this issue is to implement versioning while designing your APIs. This way, you may have a version that is stable and available for your API consumers. For any breaking changes, you can introduce a newer version of the API that can be progressively adopted by various consumers.

In this section, we'll discuss the available techniques to implement API versioning. Following is the list of techniques that we'll discuss in this chapter:

- URI versioning: Uses a version number in the URI
- Request Parameter Versioning: Uses an HTTP request parameter to identify the version
- Custom HTTP Header Versioning: Uses an HTTP request header to distinguish the version
- Media Type Versioning: Uses the Accept Header request header in the request to identify the version

We'll demonstrate the different versioning techniques in the next technique. Later we'll provide an analysis on the merits and demerits of the approaches. To better explain the versioning techniques, we'll simplify the `CourseController` class and only use the `GET/courses/` and `POST /courses/` endpoint for versioning. Let us discuss this in the Next technique.

TECHNIQUE IMPLEMENT VERSIONING IN A RESTFUL API

Problem

The Course Tracker API has not implemented any versioning strategy. We need to implement a versioning technique to ensure that the API can handle any breaking changes.

Solution

In this section, we'll first discuss the URI versioning technique. This is a straightforward approach as includes a version identifier in the REST URI. For instance, `/courses/v1` represents version 1 of the API `and /courses/v2` represents version 2 of the API.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/versioning-an-api/course-tracker-api

Let us assume that we now need to enhance Course Tracker API and it needs to also support an additional attribute of course price along with the previous course details. Introduction of course price could also mean that we can have additional REST endpoints such as finding courses between a price range or retrieve courses based on the price order etc.

To demonstrate this change, we'll make changes to the `CourseController` class in the Course Tracker application. We'll rename the existing `CourseController` class to

`LegacyCourseController` and keep only `GET /courses/` and `POST /courses/` endpoints in it. Listing 7.18 shows the modified class:

Listing 7.18 The LegacyCourseController class

```
package com.manning.sbip.ch07.controller;

// imports

# The request mapping URL contains the version number. We've appended version number v1 to
       indicate the first version of the API.
@RestController
@RequestMapping("/courses/v1")
public class LegacyCourseController {

       private CourseService courseService;

       @Autowired
       public LegacyCourseController(CourseService courseService) {
         this.courseService = courseService;
       }

       @GetMapping
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<Course> getAllCourses() {
         return courseService.getCourses();
       }

       @PostMapping
       @ResponseStatus(code = HttpStatus.CREATED)
       public Course createCourse(@Valid @RequestBody Course course) {
         return courseService.createCourse(course);
       }
}
```

The most notable change in listing 7.18 is that we've updated the @RequestMapping URI to /courses/v1. This is now the v1 version of the API. We'll also introduce a new RestController named ModernCourseController. This controller class contains the changes related to the course price. Listing 7.19 shows the ModernCourseController class:

Listing 7.19 The ModernCourseController class

```
package com.manning.sbip.ch07.controller;

//imports

@RestController
@RequestMapping("/courses/v2")
public class ModernCourseController {

       private ModernCourseRepository modernCourseRepository;

       @Autowired
       public ModernCourseController(ModernCourseRepository modernCourseRepository) {
         this.modernCourseRepository = modernCourseRepository;
       }
```

```
        @GetMapping
        @ResponseStatus(code = HttpStatus.OK)
        public Iterable<ModernCourse> getAllCourses() {
          return modernCourseRepository.findAll();
        }

        @PostMapping
        @ResponseStatus(code = HttpStatus.CREATED)
        public ModernCourse createCourse(@Valid @RequestBody ModernCourse modernCourse) {
          return modernCourseRepository.save(modernCourse);
        }
}
```

The listing 7.19 represents the v2 version of the API and we have done this by defining the `@RequestMapping` to `/courses/v2` URI. Also, we've defined a new JPA entity class named `ModernCourse` that contains the new course attribute price along with other parameters. We've also defined a new Spring Data repository interface named `ModernCourseRepository` available at https://github.com/spring-boot-in-practice/repo/blob/main/ch07/versioning-an-api/course-tracker-api/src/main/java/com/manning/sbip/ch07/repository/ModernCourseRepository.java. For simplicity, we have skipped the service layer in the new version of the API.

That's it. Let us now start the application and access both versions of the API. Listing 7.20 shows the output of creating and accessing a course with the `v1` version of the API:

Listing 7.20 Creating and retrieving courses with v1 version of Courses Tracker API

```
C:\Users\musib>http POST :8080/courses/v1 name="Mastering Spring Boot" rating=4
        category=Spring description="Mastering Spring Boot intends to teach Spring Boot with
        practical examples"
HTTP/1.1 201
// Other HTTP Response Headers

{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "rating": 4
}


C:\Users\musib>http GET :8080/courses/v1
HTTP/1.1 200
// Other HTTP Response Headers

[
    {
        "category": "Spring",
        "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
        "id": 1,
        "name": "Mastering Spring Boot",
        "rating": 4
    }
```

```
]
```

Let us now create and retrieve courses with the v2 version of the API. Listing 7.21 shows the output:

Listing 7.21 Creating and retrieving courses with v2 version of Courses Tracker API

```
# Creating a new course with the new version (/courses/v2) of the course API. Notice that
       we’ve included a new field named price in this endpoint
C:\Users\musib>http POST :8080/courses/v2 name="Mastering Spring Boot" rating=4
       category=Spring description="Mastering Spring Boot intends to teach Spring Boot with
       practical examples" price=42.34
HTTP/1.1 201
// Other HTTP Response Headers

{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "price": 42.34,
    "rating": 4
}


C:\Users\musib>http GET :8080/courses/v2
HTTP/1.1 200
// Other HTTP Response Headers
[
    {
        "category": "Spring",
        "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
        "id": 1,
        "name": "Mastering Spring Boot",
        "price": 42.34,
        "rating": 4
    }
]
```

As you can notice, both versions of the APIs are working fine. Let us now discuss the second versioning technique of using an HTTP request parameter to determine the version. We’ll continue in the same application to implement this versioning type. Remove the previous controllers or comment out the `@RestController` and `@RequestMapping` annotations from the previous controller classes.

For the HTTP request parameter based versioning technique, you’ll provide a request parameter in the REST endpoint URI that dictates which version of the API should be invoked. Let us define a new `RestController` class named `RequestParameterVersioningCourseController`. Listing 7.22 shows the `RequestParameterVersioningCourseController` class:

Listing 7.22 Implementing the versioning with HTTP Request Parameter

```
package com.manning.sbip.ch07.controller;

//imports

@RestController
@RequestMapping("/courses/")
public class RequestParameterVersioningCourseController {

      @Autowired
       private CourseService courseService;

      @Autowired
       private ModernCourseRepository modernCourseRepository;

       @GetMapping(params = "version=v1")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<Course> getAllLegacyCourses() {
         return courseService.getCourses();
       }

       @PostMapping(params = "version=v1")
       @ResponseStatus(code = HttpStatus.CREATED)
       public Course createCourse(@Valid @RequestBody Course course) {
         return courseService.createCourse(course);
       }

       @GetMapping(params = "version=v2")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<ModernCourse> getAllModernCourses() {
         return modernCourseRepository.findAll();
       }

       @PostMapping(params = "version=v2")
       @ResponseStatus(code = HttpStatus.CREATED)
       public ModernCourse createCourse(@Valid @RequestBody ModernCourse modernCourse) {
         return modernCourseRepository.save(modernCourse);
       }
}
```

In listing 7.22, notice the use of `version=v1` and `version=v2` request parameters that determines the endpoint to be invoked. Besides, notice that we've used the `CourseService` class for the existing `/v1` API endpoint and `ModernCourseRepository` for the `/v2` API endpoint. Ideally, we should define a service class to wrap the functionalities of the `ModernCourseRepository` interface for /v2 endpoint as well. For simplicity, we have skipped this step. In a real production application, you should define a service class for the controller. You can start the application and access the new endpoints with the `version=v2` parameter. Listing 7.23 shows the output:

Listing 7.23 Invoking the v2 version of POST /courses/ endpoint with Request Parameter

```
C:\Users\musib>http POST :8080/courses/?version=v2 name="Mastering Spring Boot" rating=4
       category=Spring description="Mastering Spring Boot intends to teach Spring Boot with
       practical examples" price=42.34
HTTP/1.1 201
```

```
// Other HTTP Response Headers
{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "price": 42.34,
    "rating": 4
}
```

Let us now discuss the third API versioning technique that uses a custom HTTP header to identify the endpoint that needs to be invoked. This is quite similar to the second technique of using the HTTP request parameter. In this case, instead of an HTTP request parameter in the URI, we use a custom HTTP header in the HTTP request. Let us define a new class that implements this versioning strategy. Before processing with technique, ensure to comment out the `@RequestMapping` and `@RestController` annotation from other controllers to prevent a mapping conflict. Listing 7.24 shows the `CustomHeaderVersioningCourseController` class:

Listing 7.24 Implementing the versioning with custom HTTP Header

```
package com.manning.sbip.ch07.controller;
// imports

@RestController
@RequestMapping("/courses/")
public class CustomHeaderVersioningCourseController {

       private CourseService courseService;
       private ModernCourseRepository modernCourseRepository;

       @Autowired
       public CustomHeaderVersioningCourseController(CourseService courseService,
       ModernCourseRepository modernCourseRepository) {
         this.courseService = courseService;
         this.modernCourseRepository = modernCourseRepository;
       }

       @GetMapping(headers = "X-API-VERSION=v1")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<Course> getAllLegacyCourses() {
         return courseService.getCourses();
       }

       @PostMapping(headers = "X-API-VERSION=v1")
       @ResponseStatus(code = HttpStatus.CREATED)
       public Course createCourse(@Valid @RequestBody Course course) {
         return courseService.createCourse(course);
       }

       @GetMapping(headers = "X-API-VERSION=v2")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<ModernCourse> getAllModernCourses() {
         return modernCourseRepository.findAll();
```

```
        }

        @PostMapping(headers = "X-API-VERSION=v2")
        @ResponseStatus(code = HttpStatus.CREATED)
        public ModernCourse createCourse(@Valid @RequestBody ModernCourse modernCourse) {
          return modernCourseRepository.save(modernCourse);
        }
}
```

In listing 7.24, we've used a custom HTTP header X-API-VERSION to determine the endpoint that needs to be invoked. To invoke a REST endpoint, you need to supply the X-API-VERSION header in your HTTP request. Listing 7.25 shows the use of this custom HTTP header:

Listing 7.25 Invoking the v2 version of POST /courses/ endpoint with Custom HTTP header

```
C:\Users\musib>http POST :8080/courses/ X-API-VERSION:v2 name="Mastering Spring Boot"
        rating=4 category=Spring description="Mastering Spring Boot intends to teach Spring
        Boot with practical examples" price=42.34
HTTP/1.1 201
// Other HTTP Response Headers

{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
       examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "price": 42.34,
    "rating": 4
}
```

The last versioning technique that we'll discuss in this section is Media type versioning. This is also known as Content Negotiation or Accept Header versioning strategy. This is due to the use of `Accept` HTTP request header. In this technique, instead of using a custom HTTP header, we try to leverage the built-in `Accept` HTTP header. With the `Accept` HTTP header, a client indicates a server the content types (through MIME types) that client understands. In the HTTP request, the client provides the `Accept` header. In the content negotiation (https://developer.mozilla.org/en-US/docs/Web/HTTP/Content_negotiation) phase, the server uses its internal algorithm to determine one of the Accept header values and inform the choice with the `Content-Type` response header.

Let us define the `AcceptHeaderVersioningCourseController` class that implements the versioning technique with Accept HTTP header. This implementation is shown in Listing 7.26:

Listing 7.26 Implementing the versioning with Accept HTTP Header

```
package com.manning.sbip.ch07.controller;

//imports


@RestController
@RequestMapping("/courses/")
```

```
public class AcceptHeaderVersioningCourseController {

       private CourseService courseService;
       private ModernCourseRepository modernCourseRepository;

       @Autowired
       public AcceptHeaderVersioningCourseController(CourseService courseService,
       ModernCourseRepository modernCourseRepository) {
         this.courseService = courseService;
         this.modernCourseRepository = modernCourseRepository;
       }

       @GetMapping(produces = "application/vnd.sbip.app-v1+json")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<Course> getAllLegacyCourses() {
         return courseService.getCourses();
       }

       @PostMapping(produces = "application/vnd.sbip.app-v1+json")
       @ResponseStatus(code = HttpStatus.CREATED)
       public Course createCourse(@Valid @RequestBody Course course) {
         return courseService.createCourse(course);
       }

       @GetMapping(produces = "application/vnd.sbip.app-v2+json")
       @ResponseStatus(code = HttpStatus.OK)
       public Iterable<ModernCourse> getAllModernCourses() {
         return modernCourseRepository.findAll();
       }

       @PostMapping(produces = "application/vnd.sbip.app-v2+json")
       @ResponseStatus(code = HttpStatus.CREATED)
       public ModernCourse createCourse(@Valid @RequestBody ModernCourse modernCourse) {
         return modernCourseRepository.save(modernCourse);
       }
}
```

In listing 7.26, we've used the produces attribute of the Mapping annotation that declares the content the endpoint produces. The `application/vnd.sbip.app-v1+json` is a custom MIME type that indicates the v1 version of the API and `application/vnd.sbip.app-v2+json` specifies the v2 version of the API. Listing 7.27 shows the use of the Accept HTTP header:

Listing 7.27 Invoking the v2 version of POST /courses/ endpoint with Accept HTTP header

```
C:\Users\musib>http POST :8080/courses/ Accept:application/vnd.sbip.app-v2+json
       name="Mastering Spring Boot" rating=4 category=Spring description="Mastering Spring
       Boot intends to teach Spring Boot with practical examples" price=42.34
HTTP/1.1 201
Connection: keep-alive
Content-Type: application/vnd.sbip.app-v2+json
Date: Fri, 25 Jun 2021 18:42:15 GMT
Keep-Alive: timeout=60
Transfer-Encoding: chunked

{
    "category": "Spring",
    "description": "Mastering Spring Boot intends to teach Spring Boot with practical
```

```
      examples",
    "id": 1,
    "name": "Mastering Spring Boot",
    "price": 42.34,
    "rating": 4
}
```

Discussion

In this technique, we've seen the various techniques to implement versioning in a REST API. Now that you've several choices to implement versioning, the immediate next question that comes to mind is which approach is better and preferable. This is a hard question and there is no straightforward answer to it. This is because none of the solutions we've discussed is perfect.

For instance, many developers reject the idea of assigning a version number in the endpoint URI as it creates URI pollution. Since the version is not part of the actual URI, many argue the presence of the version identifier is a bad practice. Besides, versioning in the URI exposes to the API consumers that there are multiple versions of the API that exists. Many organizations do not expose this fact to the API consumers.

Similarly, many developers reject the idea of using Accept header for versioning purposes as the Accept HTTP header is not designed for this purpose. Using Accept header for versioning is just a workaround and is not considered as a preferred solution to implement versioning. A similar type of counter-arguments is available for the other two versioning techniques.

Besides, if there are multiple versions of the same endpoint is available, it causes issues while documenting the API. For instance, the API consumers may get confused if they find two different approaches to invoke the same service.

As you can notice, there are both merits and demerits of the discussed approaches. Thus, selecting a versioning strategy is a design choice of API designers or the organizations after analyzing the pros and cons of the approach before adopting it to practice. The following list shows the API versioning approaches adopted by several major API providers:

- Amazon - Request Parameter versioning
- GitHub - Media type versioning
- Microsoft - Custom Header versioning
- Twitter - URI Versioning

7.6 Securing a RESTful API

In the previous sections, you've seen various aspects of developing a RESTful API that includes developing an API, its documentation, testing and versioning. We are still left with another core aspect of API development. And it's the security of the API. Presently, this API is not secure, and anyone who knows the API endpoints can access the API.

There are several ways an API can be secured. The most straightforward approach would be to use HTTP Basic authentication to secure the API. This is the simplest one to implement as it uses username and password to authenticate the users. If you are following this book, you may notice that in chapter 5, we've already demonstrated how to implement HTTP basic authentication to secure a Spring Boot application. You can refer to the technique *Implement HTTP Basic authentication in a Spring Boot Application* in chapter 5 to implement HTTP basic authentication in the Course Tracker API.

However, you should limit the use of HTTP basic authentication to the extent possible due to its various shortcomings. Consider it to use only for your internal testing or development purposes. An attentive reader may ask why we are discussing it here if it is not recommended to use. The use of basic authentication is still widespread https://docs.apigee.com/api-platform/system-administration/basic-auth due to its simplicity and ease of use. Only recently, some organizations are deprecating the use of this authentication strategy. https://developer.github.com/changes/2020-02-14-deprecating-password-auth/

Let us discuss the reasons why we should not use it in a production application in the first place. First, HTTP basic authentication uses the username and password in plain-text format with Base64 encoding to authenticate the users. The Base64 encoding is not an encryption technique, and it is extremely easy to retrieve the credentials from a Based64 encoded string. Thus, without HTTPS, there are high chances that credentials could be exposed. Second, with HTTP basic authentication technique, both the client application and the server application act as the password keeper and manages the user credentials for authentication and authorization purposes. This is again problematic as there are chances that credentials could be compromised by either party.

A preferred approach would be to manage the user credentials in a centralized authorization server instead of letting either the server or the client application dealing with the user password. The authorization server can issue a token that could be used for authentication and authorization purposes. Let us discuss this approach in the next technique.

TECHNIQUE USING JWT TO AUTHORIZE RESTFUL API REQUESTS

Problem

The Course Tracker RESTful API has not implemented any security measures that can secure the REST endpoints. Without security configurations, anyone can access the application endpoints.

Solution

In this technique, we'll demonstrate how to secure the endpoint access with Bearer token approach. As mentioned previously, we'll use an authorization server that lets is used for authorizing the access. However, before proceeding with the implementation, let us provide a high-level overview of the REST request and response flow between the client, REST API server, and the authorization server. The figure shows a block diagram of this flow:

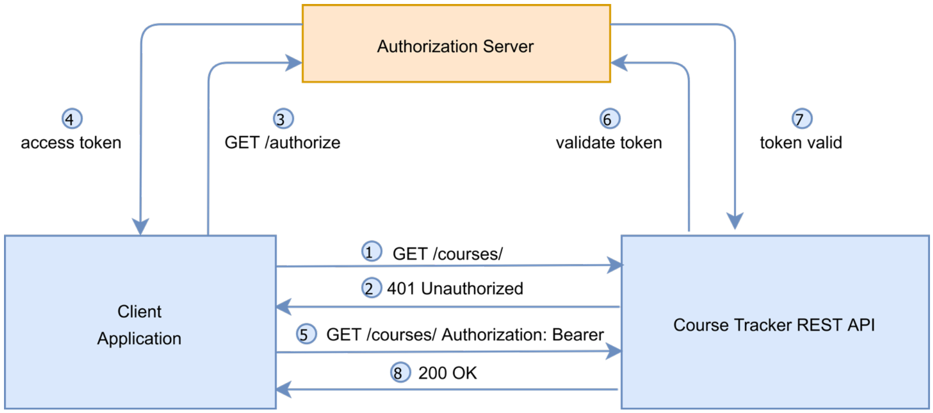


Figure 7.5 The communication between client application, REST API server and the authorization server to access a REST endpoint by a client. We are using the OAuth2 framework for authentication and authorization

Let us understand the flow as discussed in figure 7.5:

- A client requests to get course details from the Course Tracker REST API by invoking the GET `/courses` endpoint
- As the client is not authenticated, the API responds with 401 Unauthorized and indicates in the HTTP response header that it needs to authenticate itself with a bearer token
- The client then requests the authorization server to get a bearer token. While making this request, the client supplied the required details such as client_id, username, password, scope etc. Note that the user for which the bearer token is requested needs to be configured before a token is requested
- For a valid token request, the authorization server returns an access_token in JSON Web Token (JWT) format
- The client application makes a new request to the Course Tracker REST API and supplies the bearer token in the request
- The Course Tracker REST API validates the token with the authorization server and receives a response
- For a valid response, the Course Tracker REST API returns the requested course details. For an invalid response from the authorization server, it returns an error response to the client

Note that the above flow is for a new request if the API client attempts to access the endpoint without supplying the JWT token. In case the client is supplying the token, the communication starts at step 5 of figure 7.6.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch07/securing-an-api/course-tracker-api-jwt

Let us now begin with the implementation. The first things that need to be done are that configuring the authorization server. We'll use Keycloak (https://www.keycloak.org/) as the authorization server. We'll configure two users namely john and steve in the authorization server. You can refer to the following GitHub wiki https://github.com/spring-boot-in-practice/repo/wiki/Setting-up--and-Configuring-Keycloak-as-the-Authorization-Server to set up the authorization server. It is strongly recommended that you set up the authorization server first before continuing with the next steps.

To keep the example simple, we've simplified the Course Tracker application a bit. The Course domain entity now contains only three fields – a course id, a name, and an author. Listing 7.28 shows the updated Course class:

Listing 7.28 The updated Course Entity

```
package com.manning.sbip.ch07.model;

// imports

@Entity
@Data
@NoArgsConstructor
@AllArgsConstructor
public class Course {

	@Id
	@GeneratedValue(strategy = GenerationType.IDENTITY)
	@Column(name = "ID")
	private Long id;

	@NotEmpty
	@Column(name = "NAME")
	private String name;

	@NotEmpty
	@Column(name = "AUTHOR")
	private String author;
}
```

We've also simplified the `CourseController` class, and it has the following endpoints:

- Get courses by an author
- Get course by an id
- Create a new course
- Update an existing course

To enable JSON Web Token (JWT) support, we need to update the pom.xml with the following dependencies as show in listing 7.29:

Listing 7.29 The Maven depencies for OAuth2 and JWT support

```
<dependency>
	<groupId>org.springframework.boot</groupId>
	<artifactId>spring-boot-starter-oauth2-resource-server</artifactId>
</dependency>
<dependency>
	<groupId>org.springframework.security</groupId>
	<artifactId>spring-security-oauth2-jose</artifactId>
</dependency>
```

The first dependency makes the Course Tracker application an OAuth2 resource server. The second dependency provides support for JWT (https://jwt.io/introduction). Let us now include the following property in the `application.properties` file as shown in Listing 7.30:

Listing 7.30 The JSON Web Token Issues URL

```
spring.security.oauth2.resourceserver.jwt.issuer-
	uri=http://localhost:9999/auth/realms/master
```

The listing 7.30 configures the Keycloak JWT issuer URL. Let us now explore the updated `CourseController` class as shown in Listing 7.31:

Listing 7.31 The updated CourseController class

```
package com.manning.sbip.ch07.controller;

//imports

@RestController
@RequestMapping("/courses/")
public class CourseController {

	private CourseRepository courseRepository;

	@Autowired
	public CourseController(CourseRepository courseRepository) {
	  this.courseRepository = courseRepository;
	}

	# The user_name is a custom claim defined in the Authorization Server. In this
	context, we use it to get the author name to look up the courses authored by a user.
	@GetMapping
	public Iterable<Course> getAllCourses(@AuthenticationPrincipal Jwt jwt) {
	  String author = jwt.getClaim("user_name");
	  return courseRepository.findByAuthor(author);
	}

	@GetMapping("{id}")
	public Optional<Course> getCourseById(@PathVariable("id") long courseId) {
	  return courseRepository.findById(courseId);
	}

	@PostMapping
	public Course createCourse(@RequestBody String name, @AuthenticationPrincipal Jwt
	jwt) {
	  Course course = new Course(null, name, jwt.getClaim("user_name"));
```

```
        return courseRepository.save(course);
       }
}
```

In listing 7.31, we've used the `@AuthenticationPrincipal` annotation to get access to the Jwt token. This jwt instance contains the various details about the user request. From the jwt, we retrieve the `user_name` claim which is the course author name in this context.

Let us now create two courses, one for the author `john` and another for author `steve` as shown in Listing 7.32:

Listing 7.32 Create courses in the application

```
@Bean
CommandLineRunner createCourse(CourseRepository courseRepository) {
       return (args) -> {
         Course spring = new Course(null, "Spring", "john");
         Course python = new Course(null, "Python", "steve");
         courseRepository.save(spring);
         courseRepository.save(python);
       };
}
```

That's all. Let now start the application and try accessing the endpoints. Listing 7.33 shows the outcome while we try to access the `GET /courses/` endpoint without supplying a JWT token:

Listing 7.33 Accessing GET /courses/ endpoint without a JWT token

```
C:\Users\musib>http GET :8080/courses
HTTP/1.1 401
WWW-Authenticate: Bearer
// HTTP Response Headers
```

The request is denied with an HTTP 401 unauthorized error response. Besides, the API has also responded with the `WWW-Authenticate:Bearer` response header indicating the client needs to provide a Bearer token in the HTTP request. This is automatically done by Spring Security. As we are using the Bearer token based authentication, Spring Security uses the `BearerTokenAuthenticationFilter` to process the incoming request. It attempts to parse the request and generates a JwtAuthenticationToken which contains the JWT token details. In the discussion section, we'll provide more details on the classes used to process the request. For now, remember that the `BearerTokenAuthenticationFilter` is the Spring Security filter that performs the authentication.

Let us now try to obtain a bearer token for the user `john` so that the same can be included in the HTTP request. Listing 7.34 shows the command to obtain a token:

Listing 7.34 Obtaining a JWT from the Keycloak authorization server

```
C:\Users\musib>http --form POST http://localhost:9999/auth/realms/master/protocol/openid-
       connect/token grant_type=password client_id=course-tracker scope=course:read
       username=john password=password Content-Type:application/x-www-form-urlencoded
```

```
HTTP/1.1 200 OK
// HTTP Response Headers

{
    "access_token":
       "eyJhbGciOiJSUzI1NiIsInR5cCIgOiAiSldUIiwia2lkIiA6ICJxY2lKalIxSWNocTk4QkVMcEo5cDJiWDB
       RaF80MzZ1S0ktbkx4UlF3Zk53In0.eyJleHAiOjE2MjQ3NzczOTgsImlhdCI6MTYyNDc3Mzc5OCwianRpIjo
       iYTY4OWM0Y2ItYTVhZC00YTM5LWE1YjQtNjFjNGNhNGZkMjMzIiwiaXNzIjoiaHR0cDovL2xvY2FsaG9zdDo
       5OTk5L2F1dGgvcmVhbG1zL21hc3RlciIsImF1ZCI6ImNvdXJzZS10cmFja2VyIiwic3ViIjoiNmQxMTE4MTk
       tZmFlZC00NzQzLWFiNTEtMzk0YmVmNGQ0ZjBlIiwidHlwIjoiQmVhcmVyIiwiYXpwIjoiY291cnNlLXRyYWN
       rZXIiLCJzZXNzaW9uX3N0YXRlIjoiOWIyMTdiOTUtOWM1MS00ZGY0LWI3NTYtYTI3NzdmNmI0MDk2IiwiYWN
       yIjoiMSIsInNjb3BlIjoiY291cnNlOndyaXRlIGNvdXJzZTpyZWFkIiwidXNlcl9uYW1lIjoiam9obiIsImF
       1dGhvcml0aWVzIjpbInVzZXIiXX0.NgBcrpPvDB36sd2ytaeMUkqM_1_psUDMsHHkB9zZlT_9sIwF3kdPOhS
       LSmoMqhFtGpOOJI5CmB92WEBu4rVcNa2lnuh16lkksnC-0ASn23z8TIRtucrQ-
       Px2bOgFyducmRH7ec93gOsLKeZSUnjup0YA9FT_0o7eroKFdWrrqoyOiAxOua9nGg307Lkv_VKXtCB5wSrPF
       fPQrp6muw-gcREJaBgcYSx-
       5QKC5UK30cFSsWlKXC9i2ov2O3aPA4DlHIqWx06a_M7AKmvgG3fVpyJSztbi0XHDnU9Y_mJVug-
       WH5MOIpgRUmYYnSL1Ki3PV24tZ11LolyA13XsA859vg",
    "expires_in": 3600,
    "not-before-policy": 0,
    "refresh_expires_in": 1800,
    "refresh_token":
       "eyJhbGciOiJIUzI1NiIsInR5cCIgOiAiSldUIiwia2lkIiA6ICIyYzI4MTNiNy05NmIzLTRkMzctYmUwOS1
       lMTE0ZTkzZjJlNTcifQ.eyJleHAiOjE2MjQ3NzU1OTgsImlhdCI6MTYyNDc3Mzc5OCwianRpIjoiMTU4Y2E1
       ZGQtMDMyNy00NTE4LTk4NWItZGQ5ZTliNzcwNjg5IiwiaXNzIjoiaHR0cDovL2xvY2FsaG9zdDo5OTk5L2F1
       dGgvcmVhbG1zL21hc3RlciIsImF1ZCI6Imh0dHA6Ly9sb2NhbGhvc3Q6OTk5OS9hdXRoL3JlYWxtcy9tYXN0
       ZXIiLCJzdWIiOiI2ZDExMTgxOS1mYWVkLTQ3NDMtYWI1MS0zOTRiZWY0ZDRmMGUiLCJ0eXAiOiJSZWZyZXNo
       IiwiYXpwIjoiY291cnNlLXRyYWNrZXIiLCJzZXNzaW9uX3N0YXRlIjoiOWIyMTdiOTUtOWM1MS00ZGY0LWI3
       NTYtYTI3NzdmNmI0MDk2Iiwic2NvcGUiOiJjb3Vyc2U6d3JpdGUgY291cnNlOnJlYWQifQ.a1O4SuspoN5u_
       RvYdXZsb6WLC3INx1smroEIVdYWG_E",
    "scope": "course:write course:read",
    "session_state": "9b217b95-9c51-4df4-b756-a2777f6b4096",
    "token_type": "Bearer"
}
```

In listing 7.34, we've used the Keycloak authorization server's token endpoint with the required parameters. If you recall, we've configured all the attributes in the command while setting up and configuring the client application and the users in the Keycloak server. Revisit the GitHub wiki link to understand the purpose of these parameters. Let us explain the various request parameters that we've used to access the token details:

- We have used `x-www-form-urlencoded` as the content type as the Keycloak server understands this request
- The grant_type=password The grant_type refers to how an application gets an access token. The grant_type=password tells the token endpoint that the application is using the Password grant type
- client_id: The application's client id. A client id is generated in the authorization server once an application is registered in the server
- scope: One or more space-separated strings indicating which permission the application is requesting. In this case, the scope value we are requesting is **course:read**
- The username and password fields supply the username and password of the user

In the HTTP response, the Keycloak server returns the access_token, the client scopes configured for the user, token_type etc. For now, we'll use the access_token from this response to include this token in the HTTP GET request to the Course Tracker API. Note that we've configured the access token to be valid for one hour. Typically, in a production application, tokens are configured to be short-lived for security reasons. For simplicity and testing purposes, we've configured the token to be valid for one hour. In your testing, you should generate a new token and should not use the token provided in the previous listing.

Listing 7.35 shows the HTTP `GET /courses/` request with the token:

Listing 7.35 Accessing GET /courses/ endpoint with a JWT token

```
# For brevity and readability purposes, we've elided the complete token details.
C:\Users\musib>http GET :8080/courses/ "Authorization:Bearer
       eyJhbGciOiJSUzI1NiIsInR5cCIgOiAi…"
HTTP/1.1 200
// HTTP Response Headers
[
    {
        "author": "john",
        "id": 1,
        "name": "Spring"
    }
]
```

This time the HTTP status code is `200 OK`, and we can retrieve the courses authored by user john.

Although this approach works well, there is a flaw in the implementation. With the current security implementation, we can use the token of one user to get details of the other users. For instance, in this case, we can use the token of john to access the courses authored by steve. Listing 7.36 shows this:

Listing 7.36 Accessing author steve course details with author john's token

```
C:\Users\musib>http GET :8080/courses/2 "Authorization:Bearer
       eyJhbGciOiJSUzI1NiIsInR5cCIgOiAi…"
HTTP/1.1 200
// HTTP Response Headers

{
    "author": "steve",
    "id": 2,
    "name": "Python"
}
```

Ouch! We can access author steve course details (which is course id 2) with the token of author john. This is an access control issue in the application and is knows as the Insecure Direct Object Reference (IDOR) problem https://cheatsheetseries.owasp.org/cheatsheets/Insecure_Direct_Object_Reference_Prevention_Cheat_Sheet.html.

This problem occurred as the token for john is a valid token and the endpoint `GET /courses/{id}` is not performing any access control check. To avoid this issue, we'll implement method level security with Spring Security. Simply put, the method level security lets you secure the methods. We'll leverage the Spring Security `@PreAuthorize` or `@PostAuthorize` annotations to implement this. These annotations take Spring Expression Language (SpEL) expression which is evaluated to make the access control decisions.

Let us demonstrate the use of the `@PostAuthorize` annotation to prevent the Insecure Direct Object Reference problem. The access problem happened as there were no checks performed at the endpoint whether the supplied token belongs to the author requesting access to the course details (with the supplied course id). We can retrieve the author name (using the user_name claim) from the token and compare it with the returned course author name. If there is a mismatch, then we'll forbid this access.

To use the method level security, you need to include the `@EnableGlobalMethodSecurity(prePostEnabled = true)` in the Spring Boot main class. This annotation enabled the method level security in the application. Listing 7.37 shows this:

Listing 7.37 Configuring the EnableGlobalMethodSecurity annotation

```
package com.manning.sbip.ch07;

import
       org.springframework.security.config.annotation.method.configuration.EnableGlobalMeth
       odSecurity;

//Other imports

@SpringBootApplication
@EnableGlobalMethodSecurity(prePostEnabled = true)
public class CourseTrackerApiApplication {

       public static void main(String[] args) {
         SpringApplication.run(CourseTrackerApiApplication.class, args);
       }
}
```

Next, you need to include the `@PostAuthorize` annotation to the offending endpoint. Listing 7.38 shows the updated endpoint:

Listing 7.38 Implementing @PostAuthorize to secure access control

```
@GetMapping("{id}")
@PostAuthorize("@getAuthor.apply(returnObject, principal.claims['user_name'])")
public Optional<Course> getCourseById(@PathVariable("id") long courseId) {
       return courseRepository.findById(courseId);
}
```

We've supplied two attributes to a `BiFunction` implementation that performs the comparison of the token supplied author name and the method returned author name and returns a Boolean value. We've supplied the SpEL expression `@getAuthor.apply(returnObject, principal.claims['user_name'])` to perform the access control. The returnObject is the method return object which is `Optional<Course>` and the `principal.claims['user_name'])` provides the author name.. Listing 7.39 shows this `BiFunction` implementation as a bean definition in the Spring Boot main class. For simplicity, we've included this @Bean definition in the Spring Boot main class. In a real application, define a Spring configuration class to define this bean.

Listing 7.39 The BiFunction Implementation

```
@Bean
BiFunction<Optional<Course>, String, Boolean> getAuthor() {
       return (course, userId) -> course.filter(c ->
       c.getAuthor().equals(userId)).isPresent();
}
```

Let us again try accessing course id 2 with the access token of author john. Listing 7.40 shows the outcome:

Listing 7.40 Accessing author steve course details with author john's token

```
C:\Users\musib>http GET :8080/courses/2 "Authorization:Bearer
       eyJhbGciOiJSUzI1NiIsInR5cCIgOiAi.."
HTTP/1.1 403
// HTTP Response Headers
```

We ended up with the 403 Forbidden HTTP status code. The 403 HTTP return code indicates that the requested user is successfully authenticated to the application but failed in the authorization while accessing the endpoint.

The next thing that we'll discuss in this technique is the use of a scope to perform access control in the application. For instance, we can use a scope named `course:read` to ensure that tokens with this scope can access an endpoint.

A scope defines the access level provided in the token to a client application by a user. Imagine, you've (as the user) granted access to a third-party client application to read all the courses authored by you. But you want to restrict that the client application should not be able to perform any write operation. Thus, you can grant (through grant_type=password) the third-party client application to obtain a token (by accessing the Keycloak server) only with the `course:read` scope. For any reason, if the application attempts to perform a write operation, it will receive a 403 Forbidden error as the write operation requires a different scope (e.g. `course:write`) which is not provided while granting the token.

We'll use the `@PreAuthorize` annotation to implement this. Let us add the following annotation in the `getCourseById(..)` method in the `CourseController` class as shown in listing 7.41:

Listing 7.41 Implementing the Scope based access control

```
@GetMapping("{id}")
@PreAuthorize("hasAuthority('SCOPE_course:read')")
@PostAuthorize("@getAuthor.apply(returnObject, principal.claims['user_name'])")
public Optional<Course> getCourseById(@PathVariable("id") long courseId) {
```

```
        return courseRepository.findById(courseId);
}
```

Spring Security appends the `SCOPE_` prefix in the scope. Thus, we've configured the `course:read` scope as `SCOPE_course:read`. The `@PreAuthorize` annotation checks whether the requester (the client application) has the defined scope and based on that decides the access. We leave it as an exercise to the reader to play around with the Keycloak server to configure various scopes and explore the access control outcomes.

Discussion

In this technique, you've explored using JWT with an authorization server to secure REST endpoints. Explaining the OAuth2 and the authorization server in depth is beyond the scope of this text. You can refer to the books dedicated to OAuth2 https://www.manning.com/books/oauth-2-in-action and Spring Security https://www.manning.com/books/spring-security-in-action for a better understanding of these subjects.

In chapter 5, we've demonstrated the use of Spring Security to secure Spring Boot applications. We've also discussed that Spring Security uses a `FilterChain` and a list of filters that enforces security in the application. For bearer token-based authentication, Spring Security provides `BearerTokenAuthenticationFilter`. Figure 7.6 shows the flow of how the JWT processed and a final `JwtAuthenticationToken` is generated:

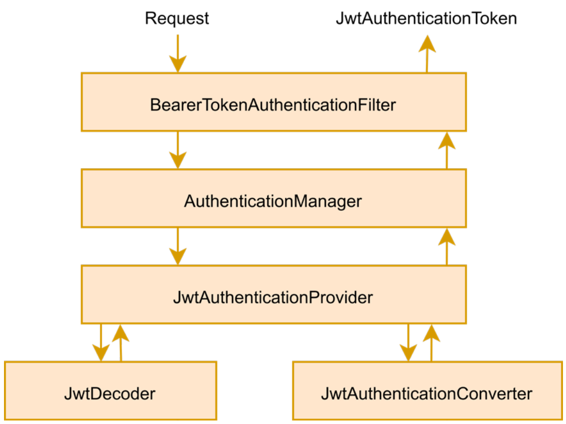


Figure 7.6 The list of classes and the flow to process a JWT and generating a JwtAuthenticationToken

The `BearerTokenAuthenticationFilter` delegates the JWT processing to an `AuthenticationManager` to perform the authentication. The `AuthenticationManager` uses `JwtAuthenticationProvider` to perform the actual authentication task. It uses a `JwtDecoder` and `JwtAuthenticationConverter` that process the request and generates the `JwtAuthenticationToken`. The MappedJwtClaimSetConverter c

7.7 Chapter Summary

Let's summarize the key takeaways of this chapter:

- Developed a RESTful API with Spring Boot application. Discussed a few best practices while developing an API
- Explored how to perform exception handling and provide appropriate HTTP response codes
- Explored the use of OpenAPI to document a REST API
- Explored various techniques to implement versioning in a REST API. The techniques that we discussed are URI versioning, Request Parameter, Custom Header and Accept Header based versioning
- Implemented to Bearer token based authentication and authorization techniques to secure the REST API

8 Reactive Spring Boot Application Development

This chapter covers

- **Introducing Reactive Programming with Spring Webflux**
- **Developing Reactive RESTful APIs with annotated controller and Functional endpoints**
- **Accessing Reactive RESTful APIs with WebClient**
- **Developing Spring Boot applications with RSocket**
- **Using WebSocket and Spring Boot to develop applications**

In the previous chapter, we explored how to design and develop RESTful API with Spring Boot. Spring Framework offers an alternative technology stack with Spring WebFlux to develop reactive applications. Spring WebFlux which is based on Project Reactor offers utilities that lets you design reactive applications with controls such as non-blocking, backpressure and write code in a declarative manner. Besides, it provides the `WebClient` utility with a fluent API to consume the APIs.

In this chapter, we'll look at RSocket and WebSocket protocols, which offers support for bi-directional communication between the communicating parties. Lastly, we'll demonstrate how to use these protocols in a Spring Boot application. Let's get started.

8.1 Introduction to Reactive Programming

Reactive programming is programming with asynchronous data streams. Let us understand the *asynchronous data stream* with a discussion of the terms *asynchronous* and *data streams*.

A *data stream* refers here is a stream of data where data is emitted, one after another, with an interval of time. The data stream can be created from a variety of sources – user inputs, properties, caches, database etc. Let us understand this with a comparison between traditional data processing and stream data processing. Figure 8.1 shows this:

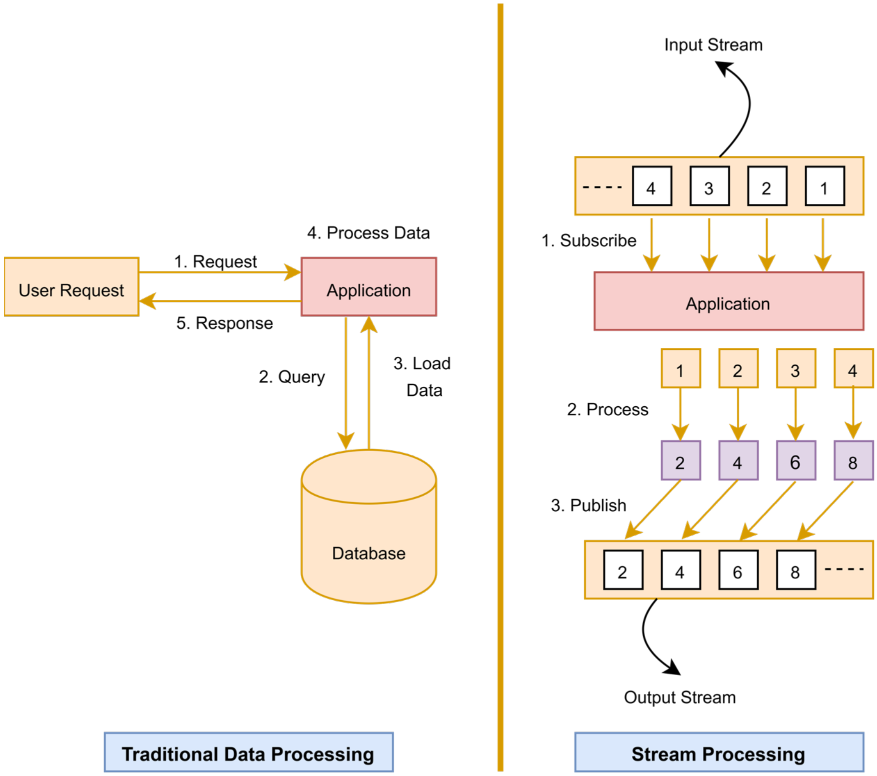


Figure 8.1 Traditional data processing vs Stream data processing

In figure 8.1, on the left side, we've shown the traditional data processing. A user request is received by the application and the requested data is retrieved from the database by the application. The retrieved data is then processed and returned to the user.

On the right side of figure 8.1, we've demonstrated stream processing. In stream processing, an application subscribes to a data stream and receives data when the data is available. The application processes the data and publishes the processed data into another stream. In figure 8.1, we have a data stream of numbers to which the application has subscribed. As the application receives the data stream, it processes the data elements by multiples with two and the resultant data is published into another stream.

Let us now discuss the concept of *asynchronous* processing. The term *asynchronous* means that for a request, the associated response appears once it is ready without the calling thread waits for the response. Figure 8.2 shows a comparison between synchronous and asynchronous processing:

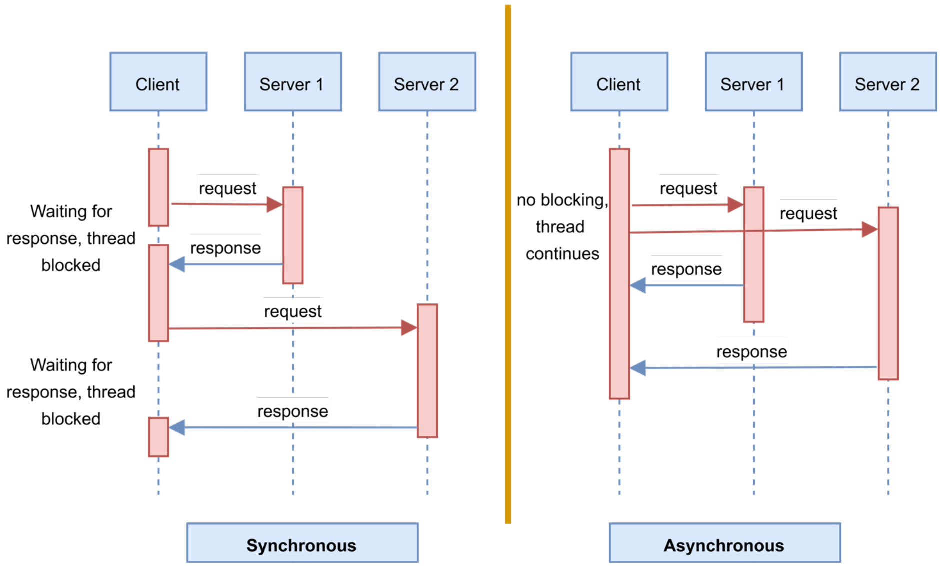


Figure 8.2 synchronous and asynchronous processing. In synchronous, the calling thread waits for a response from the server before proceeding with the next request. Thus, the thread *blocks.* In asynchronous, the thread makes the request and continues with other activities (e.g. making another request). It does not wait for a response. The server sends the response *asynchronously* once the data is ready

Before we proceed further, let us discuss a real-world example of asynchronous data streams. The typical mouse click events are an example of it. Application users can click on a button and generate an event which you can observe and react to the event by performing some activity in your application. You can imagine these events as a stream of asynchronous events. Let us demonstrates this with a diagram as shown in figure 8.3:

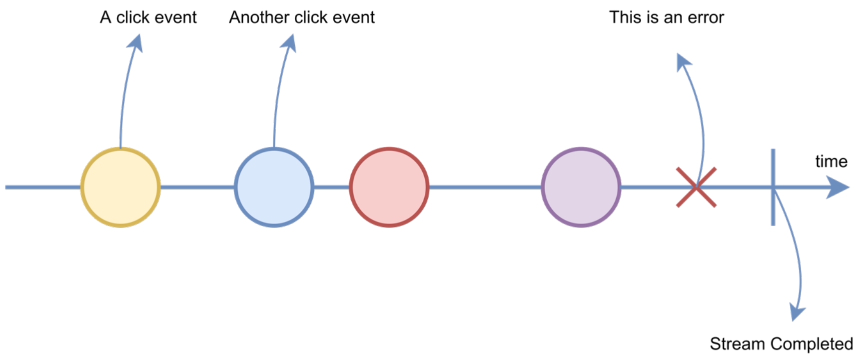


Figure 8.3 An example of asynchronous data stream for the mouse click event. We have a total of four events in the above diagram. After the fourth mouse click event, there is an error and the stream terminates

Thus, as you can notice a stream is an ongoing event ordered in time. A stream can emit three things – a value, an error, or a complete signal. The *value* indicates that the stream has emitted a value on which you can apply a function to take some action. The *error* means the stream has produced an error and you can invoke some error handling mechanism. Lastly, the *complete* signal marks the end of the stream.

Events are emitted asynchronously and we listen to those by defining functions. These functions react when the events have been emitted. For instance, one for the emitted data, one for the error and another for the completion of the stream. In reactive programming, this listening is known as *subscribing*. The functions are the *observers* and the stream is the *observable* which is being observed. This is the Observer design pattern https://en.wikipedia.org/wiki/Observer_pattern.

Note

Spring WebFlux and reactive programming, in general, is a large topic and it is beyond the scope of this text to provide an in-depth discussion on this subject. In this chapter, we aim to introduce you to reactive programming and demonstrate how to develop reactive applications with Spring Boot. In this section, we'll briefly introduce you to reactive programming and then discuss Reactive Streams upon which Project Reactor is based. We'll then talk about Spring WebFlux which primarily use Project Reactor for its reactive support.

You can refer to the following references for a detailed discussion on this topic:

Reactive Streams: https://github.com/reactive-streams/reactive-streams-jvm/blob/master/README.md
Project Reactor: https://projectreactor.io/docs/core/release/reference/
Spring WebFlux: https://docs.spring.io/spring-framework/docs/current/reference/html/web-reactive.html

8.1.1 Backpressure

Let us understand another important concept in reactive programming – backpressure. However, before discussing it, let us discuss the notion of *push* and *pull* methods in a producer and consumer set-up. A consumer subscribes data from a producer and the producer pushes the data to the consumer. This is shown in figure 8.4:

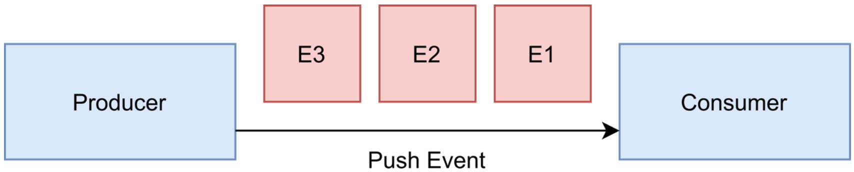


Figure 8.4 A producer pushes events to a consumer using the *push* method

In figure 8.4, a producer pushes the events to the subscribed consumer. This setup is fine if the consumer's consumption rate is the same as the producer's push rate. However, what if the consumer process the events at a slower rate than the producer pushes the events. The consumer can queue the events in some buffer. This is shown in figure 8.5:

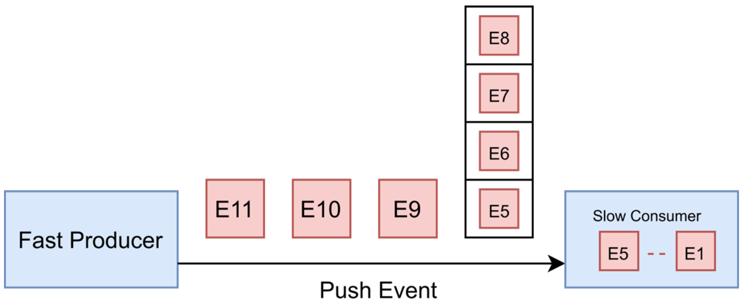


Figure 8.5 A fast producer pushes more events than a slow consumer can consume. The consumer parks the additional events into a buffer

The consumer can either choose a *bounded* or an *unbounded* buffer to park the additional events. With a bounded buffer, some events will be dropped as the buffer has limited space. The producer may need to re-send the dropped events. Resending events require additional network and CPU processing overhead and a complex event processing setup. The unbounded buffer may lead to an out of memory in the application if the buffer fills up rapidly with events. This could result in the unavailability of the application.

To avoid this problem, we can opt for the *pull* method instead of the push. In the pull method, the consumer requests events from the producer based on its processing capacity. This is shown in the figure:

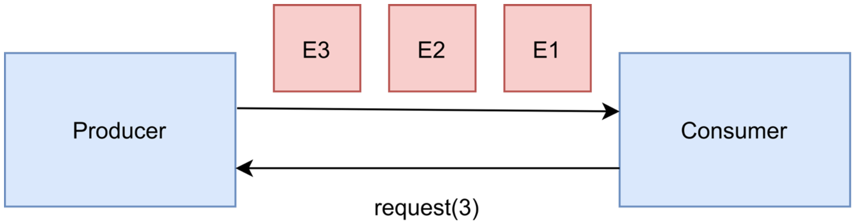


Figure 8.6 A consumer pulls events from a producer using the *pull* method. This approach gives the consumer flexibility to pull events based on their processing capacity

In figure 8.6, the consumer requests three events from the producer and it returns three events. This process allows the consumer to dynamically decide how many events to pull from the producer based on its capacity and is known as backpressure.

8.1.2 Benefits of Reactive Programming

Now that we have some understanding of reactive programming concepts, let us discuss a few of its benefits:

No Blocking: Usually with the traditional programming model, developers write blocking codes. For instance, the calling thread waits for the data while accessing a remote API or makes a database call. Although programs with blocking code work well, it has scalability and performance issues. Besides, it wastes the system resources by simply waiting for the data. The reactive programming model removes these bottlenecks

Better Asynchronous Programming Model in JVM: Java provides two approaches to perform asynchronous programming – through *Callback* and *Future*. With Callback, an asynchronous method takes an extra callback parameter that is invoked when the result is available. With Future, asynchronous methods immediately return a Future<T>. The asynchronous method computes a value T and this value is wrapped inside the Future. The result inside the Future is available only when it is ready. Both these approaches have drawbacks. For instance, composing callbacks are difficult to manage. Nesting of callbacks can quickly go out of hand and is infamously known as *Callback Hell*. Futures are a bit better than the callbacks but they also don’t do well in terms of the composition of the asynchronous operations

Additional Features: Reactive programming approach provides few additional benefits:

- In the reactive model of programming, the code is declarative. You specify *what* needs to be done than *how* something is to be done. This leads to better code composition and makes the code more readable
- A rich set of operators that you can apply to the data stream
- Everything starts when you invoke the subscribe on the stream
- Concept of backpressure that let the consumes to signal producer that the rate of emission is too high

You’ll explore a few of these benefits in practice in the next sections.

8.2 Understanding Project Reactor

The Reactor is a fully non-blocking reactive programming model for the JVM. It is based on the Reactive Streams https://www.reactive-streams.org/. The Reactive Streams is a *standard* and *specification* for Stream-oriented libraries. It processes a potentially unbounded number of elements in a sequence. It also lets asynchronously pass elements between operators with non-blocking backpressure.

The Reactive Streams API is relatively simple and provides four major interfaces as shown in Listing 8.1:

Listing 8.1 Reactive Streams API

```
public interface Publisher<T> {
   public void subscribe(Subscriber<? super T> s);
}

public interface Subscriber<T> {
   public void onSubscribe(Subscription s);
   public void onNext(T t);
   public void onError(Throwable t);
   public void onComplete();
}

public interface Subscription {
   public void request(long n);
   public void cancel();
}

public interface Processor<T, R> extends Subscriber<T>, Publisher<R> {
}
```

Let us provide a brief overview of these interfaces.

Publisher: A *Publisher* is a provider of a potentially unbounded number of sequenced elements and publishing them according to the demand from its subscribers. The `subscribe()` method of the `Publisher` interface lets subscribers subscribe to the producer

Subscriber: A Subscriber decides when and how many elements it is able and willing to receive. The `onNext()` method lets the subscriber process received data, the `onError()` process the error, the `onComplete()` on complete tasks, and `onSubscribe()` to subscribe with parameters

Subscription: A Subscription represents the relationship between a Subscriber and the Producer. The Subscriber is in control over when elements are requested and when more elements are no longer required. The `request()` method is used to request the data and `cancel()` method is used to cancel subscriptions.

Processor: A Processor represents a processing stage and is bound by both Publisher and Subscriber specifications

Figure 8.7 shows the communication between the `Subscriber`, `Publisher` and the `Subscription` interfaces.

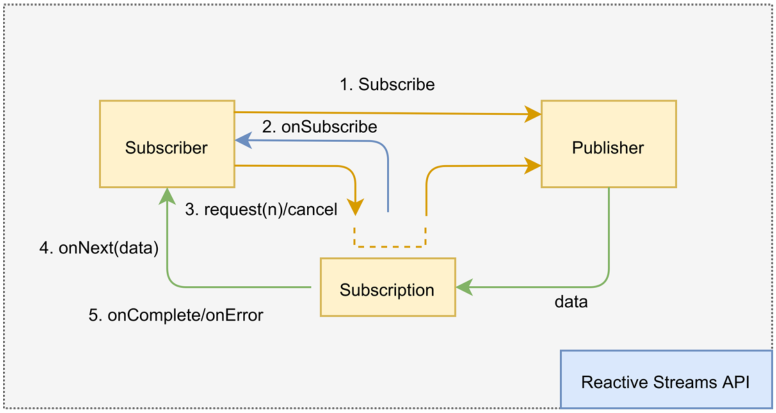


Figure 8.7 Communication between Publisher, Subscriber and Subscription interfaces in Reactive Streams API.

Let us explain how these APIs communicate with each other:

1. A subscriber uses the `subscribe()` method of the `Publisher` interface to add a subscription to a publisher
2. A publisher uses the `onSubscribe()` method of `Subscribe` interface to send the `Subscription` to the subscriber
3. A subscriber uses the `request()` or `cancel()` method of the `Subscription` interface to request or cancel data from the publisher
4. The publisher uses the `onNext()`, `onComplete()`, and `onError()` methods of the `Subscriber` interface to send data/error to a subscriber through the subscription

The main component of the Reactor library is the reactor-core module which is built on top of Reactive Streams specification and targets Java 8. Reactor provides composable reactive types such as `Flux` and `Mono` that implement the `Publisher` interface.

A `Flux` is a standard publisher that represents an asynchronous sequence of `0` to `N` emitted items, optionally terminated by an error or a completion signal. A `Mono` is a specialized Publisher that emits at most one item through the `onNext` signal which is then terminated by an `onComplete` (successful `Mono`) or only emits a single onError signal (failed Mono). Figure 8.8 shows the diagrammatic representation of how `Flux` produces items:

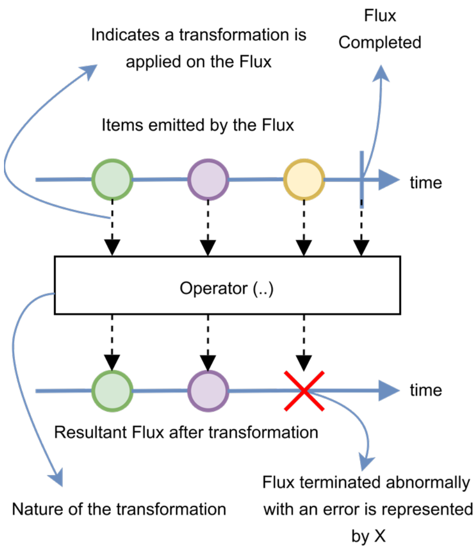


Figure 8.8 The items emitted by the Flux undergoes a user-defined transformation. Once the transformation is applied, the items are converted to another Flux. Once the Flux terminates i.e. it stops producing items, it is represented by a vertical line. An error processing an item is represented with the X symbol

Figure 8.9 shows the diagrammatic representation of how Mono transform items:

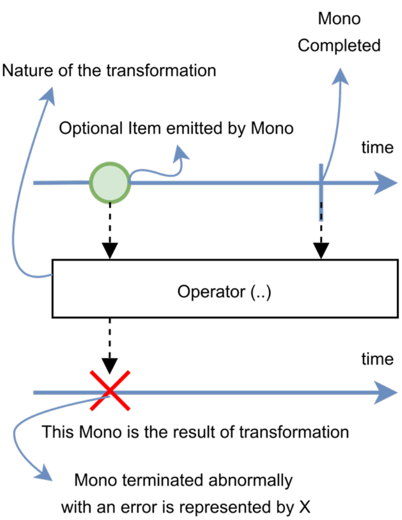


Figure 8.9 A Mono can emit 0..1 element. In case the Mono emits an item, a user-defined transformation can be applied to it and a new Mono is created. The end of the Mono is represented by a vertical line. Any error processing the Mono is represented by an X symbol

Note

If you would like to try out the code snippets shown in listing 8.2, create a Spring Boot project with the following maven depenency and paste the contents of listing 8.2 inside the application's main method.

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-webflux</artifactId>
</dependency>
```

We'll discuss more on webflux in the next section

Now that, we've discussed what `Flux` and `Mono` are, let us explore how to create those. There are several ways, a `Flux` or a `Mono` could be created. Listing 8.2 shows several ways to create a `Flux`:

Listing 8.2 Creating Flux and Mono

```
# Creating Flux
Flux<Integer> intFlux =  Flux.just(1,2,3);
Flux<Integer> intFluxRange =  Flux.range(1,10);
Flux<String> stringFlux =  Flux.fromIterable(List.of("foo", "bar"));
Flux<String> anotherStringFlux =  Flux.fromArray(new String[] {"foo", "bar"});

# Creating Mono
Mono<Integer> emptyMono =  Mono.empty();
Mono<Integer> intMono =  Mono.just(1);

# Using Flux. The intFlux consists of number 1,2,3. We map each number to a new number by
       multiplying by 2 and then print each number in the console
intFlux.map(i -> i * 2).subscribe(System.out::println);
```

Listing 8.2 demonstrates several ways to create a `Flux` and a `Mono`. We've also shown a very simple way how you can use `Flux`. We'll explore more on these in the subsequent sections.

8.3 Introducing Spring WebFlux

Spring Framework 5.0 introduced a new framework that supports reactive web application development in Spring. This is done through the Spring WebFlux https://docs.spring.io/spring-framework/docs/current/reference/html/web-reactive.html. It is a fully non-blocking library and based on the project Reactor. It targets web servers such as Netty, Undertow and Servlet 3.1+ containers.

Spring WebFlux provides two programming models - Annotated Controllers and Functional Endpoints. The *Annotated Controller* model is consistent with the Spring MVC framework and you can use the same set of annotations available in Spring MVC.

The *Functional Endpoints* model provides a lightweight, lambda-based functional programming model. This model provides a small set of libraries that an application can use to route and handle HTTP requests.

Let us now discuss how to use the above mentioned reactive programming model to design a RESTful API. We'll use the previously used Course Tracker example to design the APIs. In the next technique, let us demonstrate how to develop a reactive restful API with annotated controller approach.

TECHNIQUE DEVELOPING A REACTIVE RESTFUL API WITH ANNOTATED CONTROLLERS

Problem

The Course Tracker REST API developed previously is a blocking API and use Spring MVC. You need to use reactive-stack to build a non-blocking, scalable API with Spring WebFlux.

Solution

To develop a reactive non-blocking RESTful API, in this technique, we'll use Spring WebFlux annotated controller model. As we've discussed previously, this approach uses the same Spring MVC annotations to build the API. Thus, you can use the familiar `@GetMapping`, `@PostMapping` and other annotations to design the API.

Using MongoDB database

In this chapter, we'll use a reactive MongoDB database. You need not install and configure MongoDB to continue with this technique as we'll use an embedded MongoDB database. We only require the Spring Data Reactive MongoDB and Embedded MongoDB dependencies for MongoDB support. Note that you can also continue to use the H2 database along with the Spring Data R2DBC dependency if you don't want to use MongoDB. You need to make necessary changes in the POJO class and the repository interface if you want to stick to the H2 database.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch08/reactive-annotated-controller/course-tracker-api

In this technique, we'll use previously used Course Tracker application. However, as we are using MongoDB database, there are a few changes in the application. Thus, let us create a new Spring Boot project with the following dependencies as shown in listing 8.3:

Listing 8.3 The pom.xml file to create the

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
       <parent>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-parent</artifactId>
         <version>2.5.2</version>
         <relativePath /> <!-- lookup parent from repository -->
       </parent>
       <groupId>com.manning.sbip.ch08</groupId>
       <artifactId>course-tracker-api-annotated-controller</artifactId>
       <version>0.0.1-SNAPSHOT</version>
       <name>course-tracker-api-annotated-controller</name>
       <description>Course Tracker REST API</description>
       <properties>
         <java.version>15</java.version>
       </properties>
       <dependencies>
         <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-starter-data-mongodb-reactive</artifactId>
    </dependency>

    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-starter-webflux</artifactId>
    </dependency>

    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-devtools</artifactId>
      <scope>runtime</scope>
      <optional>true</optional>
    </dependency>
    <dependency>
      <groupId>org.projectlombok</groupId>
      <artifactId>lombok</artifactId>
      <optional>true</optional>
    </dependency>
    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-starter-test</artifactId>
      <scope>test</scope>
    </dependency>
    <dependency>
      <groupId>de.flapdoodle.embed</groupId>
      <artifactId>de.flapdoodle.embed.mongo</artifactId>
    </dependency>
    <dependency>
      <groupId>io.projectreactor</groupId>
      <artifactId>reactor-test</artifactId>
      <scope>test</scope>
    </dependency>
       </dependencies>
```

```
       <build>
         <plugins>
                  <plugin>
                           <groupId>org.springframework.boot</groupId>
                           <artifactId>spring-boot-maven-plugin</artifactId>
                  </plugin>
         </plugins>
       </build>
</project>
```

In the listing 8.3, you've included `spring-boot-starter-webflux`, `spring-boot-starter-data-mongodb-reactive`, `de.flapdoodle.embed.mongo` among other dependencies.

The `spring-boot-starter-webflux` dependency provides necessary support for Spring Webflux framework. The `mongodb-reactive` dependency provides reactive Spring Data support for MongoDB database. Lastly, the `de.flapdoodle.embed.mongo` dependency lets us use the embedded instance of a MongoDB database in the application. This ensures that you don't need to install and configure MongoDB in your machine. Lastly, the **`reactor-test`** dependency provides necessary support (classes and methods) to test reactive applications.

Next, let us define the `CourseRepository` interface as shown in Listing 8.4:

Listing 8.4 The CourseRepository Interface

```
package com.manning.sbip.ch08.repository;

import org.springframework.data.mongodb.repository.ReactiveMongoRepository;
import org.springframework.stereotype.Repository;

import com.manning.sbip.ch08.model.Course;

import reactor.core.publisher.Flux;

@Repository
public interface CourseRepository extends ReactiveMongoRepository<Course, String> {

       Flux<Course> findAllByCategory(String category);
}
```

Notice in Listing 8.4, we've used the `ReactiveMongoRepository` interface. This is the MongoDB specific Spring Data repository with reactive support. Besides, we've also defined a custom method `findAllByCategory(String category)` that returns a `Flux` of courses that matches the supplied category. Note that the interface in listing 8.3 is quite similar to the previous repository interfaces except the method return types are of type `Flux`. If you explore the **`ReactiveMongoRepository`** interface or its parent interfaces, you'll find that other method return types are either `Flux` or `Mono` and the input to the repository methods in some cases is an instance of a `Publisher`.

Let us now define the Course domain model as shown in Listing 8.5:

Listing 8.5 The Course domain model

```
package com.manning.sbip.ch08.model;

import org.springframework.data.mongodb.core.mapping.Document;
// Other Imports

@Data
@Builder
@Document
@NoArgsConstructor
@AllArgsConstructor
public class Course {

       @Id
       private String id;
       private String name;
       private String category;
       private int rating;
       private String description;
}
```

This is the same POJO class we've used previously except this time we are using the `@Document` annotation in place of the `@Entity` annotation as we are using MongoDB database instead of the H2 database. MongoDB stores data records in a document. Thus, a course detail in MongoDB is a document.

Let us now define the REST controller class as shown in Listing 8.6:

Listing 8.6 The CourseController Class

```
package com.manning.sbip.ch08.controller;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.http.ResponseEntity;
import org.springframework.web.bind.annotation.DeleteMapping;
import org.springframework.web.bind.annotation.GetMapping;
import org.springframework.web.bind.annotation.PathVariable;
import org.springframework.web.bind.annotation.PostMapping;
import org.springframework.web.bind.annotation.PutMapping;
import org.springframework.web.bind.annotation.RequestBody;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RestController;

import com.manning.sbip.ch08.model.Course;
import com.manning.sbip.ch08.repository.CourseRepository;

import lombok.extern.slf4j.Slf4j;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

@Slf4j
@RestController
@RequestMapping("/courses/")
public class CourseController {

       private CourseRepository courseRepository;
```

```
    @Autowired
    public CourseController(CourseRepository courseRepository) {
      this.courseRepository = courseRepository;
    }

    # This endpoint returns a Flux of courses. Recall that Flux can emit 0..N elements.
    Also, notice the use of @GetMapping annotation to define the endpoint route which is
    similar to what you've used in Spring MVC

    @GetMapping
    public Flux<Course> getAllCourses() {
      return courseRepository.findAll();
    }

    # This endpoint returns a Mono<ResponseEntity<Course>>. As we are getting a course
    by ID, we may or may not find a course with the supplied course ID. Thus, we are
    returning a Mono. Recall that a Mono can emit 0..1 element. We are using
    ResponseEntity to wrap the response with HTTP status 200 OK for a successful
    response or HTTP status 404 Not Found if the course is not found.

    @GetMapping("{id}")
    public Mono<ResponseEntity<Course>> getCourseById(@PathVariable("id") String
    courseId) {
      return courseRepository.findById(courseId)
   # Note the use of map and defaultIfEmpty operators. If the findById(..) returns a
    result, then we map the result to a success response. The defaultIfEmpty operator is
    invoked if the findById returns no course
                    .map(course -> ResponseEntity.ok(course))
                    .defaultIfEmpty(ResponseEntity.notFound().build());
    }

    # Finds all courses for the supplied category and returns a Flux of courses.
    @GetMapping("category/{name}")
    public Flux<Course> getCourseByCategory(@PathVariable("name") String category) {
      return courseRepository.findAllByCategory(category)
   # For any error, the doOnError is invoked and it logs the error message in the
    console log
                    .doOnError(e -> log.error("Failed to create course",
    e.getMessage()));
    }

    # Creates a new course in the application. If the course is successfully created,
    the doOnSuccess is invoked and the success message is logged and a Mono<Course> is
    returned. For any error, the doOnError is triggered and the error message is logged.
    @PostMapping
    public Mono<Course> createCourse(@RequestBody Course course) {
      return courseRepository.save(course)
                    .doOnSuccess(updatedCourse -> log.info("Successfully created
    course", updatedCourse))
                    .doOnError(e -> log.error("Failed to create course",
    e.getMessage()));
    }

    # Updates an existing course, if exist and returns a 200 OK. If not, returns a 404
    Response. The response is wrapped in a Mono instance

    @PutMapping("{id}")
    public Mono<ResponseEntity<Course>> updateCourse(@PathVariable("id") String
    courseId, @RequestBody Course course) {
```

```
        return this.courseRepository.findById(courseId).flatMap(existingCourse -> {
                 existingCourse.setName(course.getName());
                 existingCourse.setRating(course.getRating());
                 existingCourse.setCategory(course.getCategory());
                 existingCourse.setDescription(course.getDescription());
                 return this.courseRepository.save(existingCourse);
        }).map(updatedCourse ->
       ResponseEntity.ok(updatedCourse)).defaultIfEmpty(ResponseEntity.notFound().build())
                           .doOnError(e -> log.error("Failed to update course",
       e.getMessage()));

       }

       # Deletes a course with the supplied course id. If a course with the supplied id is
       found, then it is deleted and a HTTP 200 OK response is created. If a course is not
       found, then a HPP 404 Not Found response is created. This response is then returned
       as Mono<ResponseEntity<Course>>
       @DeleteMapping("{id}")
       public Mono<ResponseEntity<Course>> deleteCourseById(@PathVariable("id") String
       courseId) {
         return this.courseRepository.findById(courseId).flatMap(
                           course ->
       this.courseRepository.deleteById(course.getId()).then(Mono.just(ResponseEntity.ok(co
       urse))))
                           .defaultIfEmpty(ResponseEntity.notFound().build());
       }

       # Delete all courses from the application and retuns a Mono<Void>
       @DeleteMapping
       public Mono<Void> deleteCourses() {
         return courseRepository.deleteAll();
       }

}
```

Listing 8.6 contains the endpoints to perform the CRUD operations in the Course Tracker application. The endpoints are the same as what we had defined previously while we created a REST api with Spring MVC. Notice the declarative style of coding in the endpoints and how various operators are composed. For instance, how the *map* is used or the `doOnSuccess` and `doOnError` are composed.

Lastly, let us define a new Spring `@Configuration` file and define a `CommandLineRunner` bean definition to create a few courses as shown in Listing 8.7:

Listing 8.7 CommandLineRunner bean definition to create few courses

```
package com.manning.sbip.ch08.config;

import org.springframework.boot.CommandLineRunner;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

import com.manning.sbip.ch08.model.Course;
import com.manning.sbip.ch08.repository.CourseRepository;

import reactor.core.publisher.Flux;

@Configuration
public class CourseConfig {

       @Bean
       public CommandLineRunner init(CourseRepository courseRepository) {
         return args -> {

                  Course course1 = Course.builder().name("Mastering Spring
       Boot").category("Spring").rating(4)
                                    .description("Mastering Spring Boot").build();
                  Course course2 = Course.builder().name("Mastering
       Python").category("Python").rating(5)
                                    .description("Mastering Python").build();
                  Course course3 = Course.builder().name("Mastering
       Go").category("Go").rating(3).description("Mastering Go")
                                    .build();

# we are invoking Flux API to declaratively save and then print the output of three courses
                  Flux
                .just(course1, course2, course3)
                .flatMap(courseRepository::save)
                .thenMany(courseRepository.findAll())
                 .subscribe(System.out::println);
         };
       }
}
```

In listing 8.7, we have created three sample courses. We then used the static method `just(..)` from the `Flux` class to create a flux with the sample courses. Next, we've used the `flatMap(..)` operator to save the courses and then used `thenMany(..)` to find all the courses. Lastly, we subscribe to `Flux` to start the processing and print each course in the console. Note that reactive programming is lazy and nothing happens until you invoke the `subscribe()` method.

Let us start the application and test the endpoints. We've already created a few courses in listing 8.7, let us use the `/courses/` endpoint to get those courses. Listing 8.8 shows the `HTTPie` command https://httpie.io/ to get all the courses:

Listing 8.8 Getting all Courses

```
C:\Users\musib>http :8080/courses/
HTTP/1.1 200 OK
Content-Type: application/json
transfer-encoding: chunked

[
    {
        "category": "Spring",
        "description": "Mastering Spring Boot",
        "id": "60fa36d47c237777890dca33",
        "name": "Mastering Spring Boot",
        "rating": 4
    },
    {
        "category": "Python",
        "description": "Mastering Python",
        "id": "60fa36d47c237777890dca34",
        "name": "Mastering Python",
        "rating": 5
    },
    {
        "category": "Go",
        "description": "Mastering Go",
        "id": "60fa36d47c237777890dca35",
        "name": "Mastering Go",
        "rating": 3
    }
]
```

Similarly, let us test the delete endpoint by deleting the course with course id `60fa36d47c237777890dca35`. Listing 8.9 shows the `HTTPie` command to delete a course with a course id:

Listing 8.9 Delete a Course with a course id

```
C:\Users\musib>http DELETE :8080/courses/60fa36d47c237777890dca35
HTTP/1.1 200 OK
Content-Length: 111
Content-Type: application/json

{
    "category": "Go",
    "description": "Mastering Go",
    "id": "60fa36d47c237777890dca35",
    "name": "Mastering Go",
    "rating": 3
}
```

Similarly, you can test other endpoints and find that those are also working as expected.

Discussion

In this technique, you've seen how to create a REST API with Spring WebFlux. If you recall, Spring MVC uses a special servlet named `DispatcherServlet` as a front controller servlet that handles the request and delegates other specialized components to process the request and generates a response.

In Spring WebFlux, the `DispatcherHandler` is the central dispatcher for HTTP request handlers. It dispatches the requests to registered mappers and handlers to process the request. The `HandlerMapping` instances are used to map the request to the handler object. The `HandlerAdapter` is used to handle the request with the supported handler object and it returns a HandlerResult. Lastly, a `HandlerResultHandler` is used to handle the `HandlerResult`.

In the `CourseController` class, you've used the same annotations as available in Spring MVC. The `@GetMapping` to get the course details, `@PostMapping` to create a new course and so on. Similarly, you have also used the `@PathVariable` and `@RequestBody` annotations in Spring MVC.

If you explore the `CourseRepository` interface or any of its parent interfaces, you'll notice that most method names are consistent with what you have seen in the non-reactive Spring Data interfaces. However, the method arguments and the return types of these methods are of reactive types. For instance, the `findAll(..)` method returns a `Flux` instead of an `Iterable`. In the next technique, we'll explore how to define functional endpoints with Spring WebFlux.

TECHNIQUE DEVELOPING A REACTIVE RESTFUL API WITH FUNCTIONAL ENDPOINTS

Problem

Another technique for transforming your blocking REST API in a reactive fashion is the adoption of functional endpoints. You need to build to reactive REST API based on functional endpoints.

Solution

In the previous technique, we've explored building a reactive REST API with Spring WebFlux using the annotated controller approach. Spring WebFlux provides a lambda based, lightweight and functional programming model. This is a different model than what we've used previously with Spring MVC and WebFlux annotated controller-based approach. The functional model provides you with a set of utilities (Java methods) so that you can define the routes to handle requests.

To explore the use of the functional endpoints further, let us build a REST API with functional endpoints. In this technique, we'll continue with our Course Tracker application to build a REST api with the functional endpoint.

> **Source Code**
>
> **The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch08/reactive-functional-endpoints/course-tracker-api**

For the Spring Boot project in this technique, you can continue with the Spring Boot project used in the previous technique. Besides, you can also create a new project with the same set of dependencies as specified in listing 8.3 and continue with the technique. Create the `CourseRepository` interface and `Course` domain class as shown in listing 8.4 and 8.5 respectively.

We'll begin with defining the routes. The routes are the URLs to perform the CRUD operations. Listing 8.10 shows the `RouterContext` class:

Listing 8.10 The RouterContext class to define the routes

```
package com.manning.sbip.ch08.configuration;

import static org.springframework.http.MediaType.APPLICATION_JSON;
import static org.springframework.web.reactive.function.server.RequestPredicates.DELETE;
import static org.springframework.web.reactive.function.server.RequestPredicates.GET;
import static org.springframework.web.reactive.function.server.RequestPredicates.POST;
import static org.springframework.web.reactive.function.server.RequestPredicates.PUT;
import static org.springframework.web.reactive.function.server.RequestPredicates.accept;
import static org.springframework.web.reactive.function.server.RouterFunctions.route;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.web.reactive.function.server.RouterFunction;
import org.springframework.web.reactive.function.server.ServerResponse;

import com.manning.sbip.ch08.component.CourseHandler;

@Configuration
public class RouterContext {

       @Bean
       RouterFunction<ServerResponse> routes(CourseHandler courseHandler) {
         return route(GET("/courses").and(accept(APPLICATION_JSON)),
       courseHandler::findAllCourses)
                          .andRoute(GET("/courses/{id}").and(accept(APPLICATION_JSON)),
       courseHandler::findCourseById)
                          .andRoute(POST("/courses").and(accept(APPLICATION_JSON)),
       courseHandler::createCourse)
                          .andRoute(PUT("/courses").and(accept(APPLICATION_JSON)),
       courseHandler::updateCourse)
                          .andRoute(DELETE("/courses/{id}").and(accept(APPLICATION_JSON)),
       courseHandler::deleteCourse)
                          .andRoute(DELETE("/courses").and(accept(APPLICATION_JSON)),
       courseHandler::deleteAllCourses);
       }

}
```

The listing 8.10 is a Spring `@Configuration` class with one `RouterFunction` bean definition. The `RouteFunction` define the routes to perform the CRUD operation in the Course Tracker reactive REST API. This bean definition requires the `CourseHandler` instance so that once there is a request to any of the routes, it can be forwarded to the handler to handle the request. We have defined two routes with HTTP `GET` requests, one for each of the `POST`, `PUT` requests and two for `DELETE` requests. For each of the routes, we've delegated the request processing to the appropriate methods of the `CourseHandler` class.

Next, let us define the `CourseHandler` class as shown in listing 8.11. This class contains the logic to perform the CRUD operations.

Listing 8.11 The CourseHandler class

```
package com.manning.sbip.ch08.component;

import static org.springframework.http.MediaType.APPLICATION_JSON;
import static org.springframework.web.reactive.function.BodyInserters.fromValue;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.http.HttpStatus;
import org.springframework.stereotype.Component;
import org.springframework.web.reactive.function.server.ServerRequest;
import org.springframework.web.reactive.function.server.ServerResponse;

import com.manning.sbip.ch08.model.Course;
import com.manning.sbip.ch08.repository.CourseRepository;

import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

@Component
public class CourseHandler {

       private CourseRepository courseRepository;

      @Autowired
      public CourseHandler(CourseRepository courseRepository) {
          this.courseRepository = courseRepository;
      }

      # An handler that finds all courses. The ServerRequest represents a server-side HTTP
       request. We find all courses and prepare a ServerResponse with the content type as
       application/json and list of courses as the response body. The ServerResponse
       represents a server side response
       public Mono<ServerResponse> findAllCourses(ServerRequest serverRequest) {
         Flux<Course> courses = this.courseRepository.findAll();
         return ServerResponse.ok().contentType(APPLICATION_JSON).body(courses,
       Course.class);
       }

       # An handler that finds a course by the supplied course id. We retrieve the course
       from the ServerRequest instance through the pathVariable method of it as the course
       id was supplied as a path variable. If there is a course found, we return a HTTP 200
       OK ServerResponse, 404 Not Found otherwise
       public Mono<ServerResponse> findCourseById(ServerRequest serverRequest) {
         String courseId = serverRequest.pathVariable("id");
         Mono<Course> courseMono = this.courseRepository.findById(courseId);
         return courseMono.flatMap(course ->
       ServerResponse.ok().contentType(APPLICATION_JSON).body(fromValue(course)))
                           .switchIfEmpty(notFound());
       }

      # Creates a new course. We use the bodyToMono method of ServerRequest to extract the
```

```
    HTTP request body and convert it to a Mono. This Mono is then used to create the
    course.
    public Mono<ServerResponse> createCourse(ServerRequest serverRequest) {
      Mono<Course> courseMono = serverRequest.bodyToMono(Course.class);

      return courseMono.flatMap(course ->
    ServerResponse.status(HttpStatus.CREATED).contentType(APPLICATION_JSON)
                        .body(this.courseRepository.save(course), Course.class));
    }

   # Updates an existing course with the supplied new course details. We first fetch the
    course to be updated and the extract the existing course and the updated course. We
    then prepare the update the course and return a ServerResponse. For successful
    update an HTTP 200 OK respose is provided, 404 Not Found otherwise.
    public Mono<ServerResponse> updateCourse(ServerRequest serverRequest) {
      String courseId = serverRequest.pathVariable("id");
      Mono<Course> existingCourseMono = this.courseRepository.findById(courseId);
      Mono<Course> newCourseMono = serverRequest.bodyToMono(Course.class);
      return newCourseMono
               .zipWith(existingCourseMono,
      (newCourse, existingCourse) -> Course.builder().id(existingCourse.getId())

      .name(newCourse.getName()).category(newCourse.getCategory())

      .rating(newCourse.getRating()).description(newCourse.getDescription()).build())
      .flatMap(course -> ServerResponse
                      .ok().contentType(APPLICATION_JSON)
                        .body(this.courseRepository.save(course), Course.class))
                        .switchIfEmpty(notFound());
    }

    # Deletes a course with the supplied course id
    public Mono<ServerResponse> deleteCourse(ServerRequest serverRequest) {
      String courseId = serverRequest.pathVariable("id");
      return this.courseRepository.findById(courseId)
                        .flatMap(existingCourse ->
    ServerResponse.ok().build(this.courseRepository.deleteById(courseId)))
                        .switchIfEmpty(notFound());
    }

    # Deletes all courses
    public Mono<ServerResponse> deleteAllCourses(ServerRequest serverRequest) {
      return ServerResponse.ok().build(this.courseRepository.deleteAll());
    }

    private Mono<ServerResponse> notFound() {
      return ServerResponse.notFound().build();
    }

}
```

Next, create a few courses and save them in the database. You can follow the same steps as defined in listing 8.7. Let us now start the application and test the endpoints. Listing 8.12 shows the HTTPie command to access the `/courses/` endpoint with the result:

Listing 8.12 The /courses/ endpoint result

```
C:\Users\musib>http :8080/courses/
HTTP/1.1 200 OK
Content-Type: application/json
transfer-encoding: chunked

[
    {
        "category": "Go",
        "description": "Mastering Go",
        "id": "60fa68a55359e82fcc4c3de9",
        "name": "Mastering Go",
        "rating": 3
    },
    {
        "category": "Spring",
        "description": "Mastering Spring Boot",
        "id": "60fa68a55359e82fcc4c3de7",
        "name": "Mastering Spring Boot",
        "rating": 4
    },
    {
        "category": "Python",
        "description": "Mastering Python",
        "id": "60fa68a55359e82fcc4c3de8",
        "name": "Mastering Python",
        "rating": 5
    }
]
```

If you try accessing the other endpoints, you'll notice that those are also working as expected.

Discussion

In this technique, you've seen how to create a REST API with functional endpoints which are an alternative approach to define endpoints. Spring WebFlux included this functional programming model which lets you define functions to route and handle the request. Other than the programming model, both models run on the same reactive core foundation.

In the functional model, an HTTP request is handled with a `HandlerFunction` which takes a `ServerRequest` and returns a `Mono<ServerResponse>`. The `HandlerFunction` is equivalent to the body of a `@RequestMapping` method in the annotation-based programming model. We've defined all our handler functions in the `CourseHandler` class. The `ServerRequest` provides access to the HTTP method, URI, HTTP headers, and query parameters. The request body is accessed through the various `body` methods. The `ServerResponse` provides access to the HTTP response.

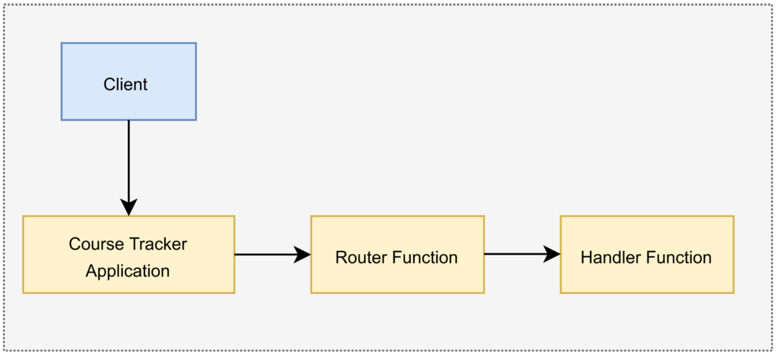


Figure 8.10 Incoming request processing in a Spring WebFlux functional endpoint. A Client request access to the server application with an HTTP endpoint.

As shown in figure 8.10, incoming requests are routed to a `HandlerFunction` through a `RouterFunction` which takes a `ServerRequest` and returns a `HandlerFunction`. If the router function matches, a handler function is returned, otherwise an empty `Mono` is returned. To define router functions, you can use the methods from the `RouterFunctions` utility class to create the routes. Spring WebFlux recommends using the `route()` builder method to create a router function.

In listing 8.11, we've defined several routes. Spring WebFlux evaluates these routes in order. If the first route does not match, the second route is evaluated and so on. Thus, you should define the most specific routes before the generic ones.

8.4 Testing Reactive Applications

In the previous section, you've learned two different approaches to design REST APIs with Spring WebFlux. In this section, you'll learn how to test the APIs. Previously, to test these API endpoints, we've used the HTTPie command-line utility. In this section, you'll learn the use of the `WebClient` to build an API client to access a REST API.

TECHNIQUE USING WEBCLIENT TO BUILD AN API CLIENT

Problem

You have an external REST API and you need to define an API client to test this API.

Solution

It is a common occurrence to access external REST API. Spring provides a client named `WebClient` to perform HTTP requests. In this technique, you'll learn to use WebClient to build an API client. Previously, we've designed a REST API for the Course Tracker application. We'll build an API client with WebClient that will access the Course Tracker REST API.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch08/course-tracker-client-api

To begin with, create a Spring Boot project and include the dependencies as shown in listing 8.13:

Listing 8.13 The Course Tracker Client API pom xml

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
       <parent>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-parent</artifactId>
         <version>2.5.2</version>
         <relativePath /> <!-- lookup parent from repository -->
       </parent>
       <groupId>com.manning.sbip.ch08</groupId>
       <artifactId>course-tracker-client-api</artifactId>
       <version>0.0.1-SNAPSHOT</version>
       <name>course-tracker-client-api</name>
       <description>Course Tracker REST API</description>
       <properties>
         <java.version>15</java.version>
       </properties>
       <dependencies>
         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-webflux</artifactId>
         </dependency>
         <dependency>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
                <optional>true</optional>
         </dependency>
       </dependencies>

       <build>
         <plugins>
                <plugin>
                       <groupId>org.springframework.boot</groupId>
                       <artifactId>spring-boot-maven-plugin</artifactId>
                </plugin>
         </plugins>
       </build>

</project>
```

You'll also need to define the `Course` domain model as we'll be dealing with the courses in the client API. Define the Course Java class as specified in listing 8.5. Let us start building the WebClientApi class that contains the client methods to invoke the various REST endpoints. Listing 8.14 shows this class:

Listing 8.14 The Course Tracker Client API

```
package com.manning.sbip.ch08.api;

import org.springframework.http.ResponseEntity;
import org.springframework.stereotype.Component;
import org.springframework.web.reactive.function.client.ExchangeFilterFunction;
import org.springframework.web.reactive.function.client.ExchangeStrategies;
import org.springframework.web.reactive.function.client.WebClient;

import com.manning.sbip.ch08.model.Course;

import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

@Component
public class WebClientApi {

       private static final String BASE_URL = "http://localhost:8080/courses/";

       private WebClient webClient;

      # Creating the WebClient instance. We are setting the BASE_URL while building the
       WebClient so that we can use the relative URLs while invoking an endpoint
       public WebClientApi() {
         this.webClient = WebClient.builder().baseUrl(BASE_URL).build();
       }

      # Creating a new course. We use the webClient’s post() method to invoke the HTTP POST
       endpoint of the Course Tracker API.
       public Mono<ResponseEntity<Course>> postNewCourse(Course course) {
         return this.webClient
                           .post()
                           .body(Mono.just(course), Course.class)
                           .retrieve()
                           .toEntity(Course.class)
                           .doOnSuccess(result -> System.out.println("POST "+ result));
       }

      # Updating a course. We’ve used the WebClient’s put() method to invoke the HTTP PUT
       endpoint of the course tracker API. We’ve also used the uri() method to set the
       relative URL
       public Mono<Course> updateCourse(String id, String name, String category, int
       rating, String description) {
         return this.webClient
                           .put()
                           .uri("{id}", id)
                           .body(Mono.just(Course
                                          .builder()
                                          .id(id)
                                          .name(name)
                                          .category(category)
                                          .rating(rating)
                                          .description(description)
                                          .build()), Course.class)
```

```
                        .retrieve()
                        .bodyToMono(Course.class)
                        .doOnSuccess(result -> System.out.println("Update Course:
       "+result));
       }

       # Get a course by the supplied course id. Notice that we've used the get() method to
       invoke the HTTP GET endpoint with relative URI {id}.
       public Mono<Course> getCourseById(String id) {
         return this.webClient
                        .get()
                        .uri("{id}", id)
                        .retrieve()
                        .bodyToMono(Course.class)
                        .doOnSuccess(c -> System.out.println(c))
                        .doOnError((e) -> System.err.println(e.getMessage()));
       }

      # Get all courses. We've used the get() method to invoke the HTTP GET method
       public Flux<Course> getAllCourses() {
         return this.webClient
                        .get()
                        .retrieve()
                        .bodyToFlux(Course.class)
                        .doOnNext(c -> System.out.println(c))
                        .doOnError((e) -> System.err.println(e.getMessage()));
       }

      # Delete the course for the supplied course id. We've used the delete() method to
       invoke the HTTP DELETE endpoint with relative URI {id}
       public Mono<Void> deleteCourse(String id) {
         return this.webClient
                        .delete()
                        .uri("{id}", id)
                        .retrieve()
                        .bodyToMono(Void.class)
                        .doOnSuccess(result -> System.out.println("DELETE "+result))
                        .doOnError((e) -> System.err.println(e.getMessage()));
       }
}
```

Listing 8.14 is a Spring component that defines the API client methods to invoke the Course Tracker REST API. Notice the HTTP methods of the `WebClient` class. For instance, you use the `get()` method to perform HTTP GET request, `post()` for a HTTP POST request.

Let us now use some of these client methods to invoke the Course Tracker REST API endpoints. Listing 8.15 shows a `CommandLineRunner` bean definition that creates a new course and then retrieves all courses:

Listing 8.15 Testing Course Tracker API with API Client

```
package com.manning.sbip.ch08.client;

import org.springframework.boot.CommandLineRunner;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

import com.manning.sbip.ch08.api.WebClientApi;
import com.manning.sbip.ch08.model.Course;

@Configuration
public class ApiClient {

       @Bean
       public CommandLineRunner invokeCourseTrackerApi(WebClientApi webClientApi) {
         return args -> {
                  Course course = Course
                                    .builder()
                                    .name("Angular Basics")
                                    .category("JavaScript")
                                    .rating(3)
                                       .description("Learn Angular Fundamentals")
                                    .build();

                  webClientApi.postNewCourse(course)
                  .thenMany(webClientApi.getAllCourses())
                  .subscribe();
         };
       }
}
```

In listing 8.15, we've created a new course instance and used the `WebClientApi` to post the course in Course Tracker API. Finally, we are getting all courses from the API. Notice that the `postNewCourse()` and `getAllCourses()` methods are chained together through the `thenMany` operator.

Before we use the client API, we need to ensure the Course Tracker REST API is running and accessible. Let us not start the client API Spring Boot project. Once the application started successfully, you'll notice the following output in the application console as shown in Listing 8.16:

Listing 8.16 Client API execution output

```
POST <201,Course(id=60faacfb400a9a1c3adb1bf7, name=Angular Basics, category=JavaScript,
       rating=3, description=Learn Angular Fundamentals),[Content-Type:"application/json",
       content-length:"135"]>

Course(id=60faaced400a9a1c3adb1bf5, name=Mastering Python, category=Python, rating=5,
       description=Mastering Python)
Course(id=60faaced400a9a1c3adb1bf6, name=Mastering Go, category=Go, rating=3,
       description=Mastering Go)
Course(id=60faaced400a9a1c3adb1bf4, name=Mastering Spring Boot, category=Spring, rating=4,
       description=Mastering Spring Boot)
Course(id=60faacfb400a9a1c3adb1bf7, name=Angular Basics, category=JavaScript, rating=3,
       description=Learn Angular Fundamentals)
```

In listing 8.16, the first block is the out of successful POST request. The next block shows the list of courses.

Discussion

Spring WebFlux includes the `WebClient` to perform an HTTP request. As shown in listing 8.14, WebClient has a functional, fluent API based on Reactor that lets you compose asynchronous logic without the need for threads and concurrency. It needs an HTTP client library to perform the HTTP requests. By default, it has support for Reactor Netty, Jetty Reactive HttpClient, and Apache HttpComponents.

The easiest way to create an instance of `WebClient` is to use the `create()` static factory method. If you need to use advanced configuration such as configuring HTTP headers, codecs, cookies, Specialized `HttpClient`, you can use the `builder()` method. Listing 8.17 shows a more complex example of building a `WebClient` instance using the `builder()` method:

Listing 8.17 Building a WebClient using the builder method

```
private static final String USER_AGENT = "Mozilla/5.0 (Macintosh; Intel Mac OS X 10_15_7)
       AppleWebKit/537.36 (KHTML, like Gecko) Chrome/89.0.4389.114 Safari/537.36";

# Building a WebClient instance. We've used a custom HTTP client with additional
       configuration. We are also setting a default HTTP header to set the USER_AGENT.
       Besides, we are configuring the codecs with a custom maximum memory size. A codec is
       a component that takes care of the encoding and decoding of the data. Lastly, we are
       using filters to log the HTTP request and response.
public WebClientApi() {
       this.webClient = WebClient.builder()
                  .baseUrl(BASE_URL)
                  .clientConnector(getClientConnector())
                  .defaultHeader(HttpHeaders.USER_AGENT, USER_AGENT)
                  .exchangeStrategies(ExchangeStrategies.builder().codecs(configurer ->
       configurer.defaultCodecs().maxInMemorySize(30 * 1024 * 1024)).build())
                  .filter(logRequest()).filter(logResponse()).build();
}

# Creating a custom HTTP Connector. For requirements such as timeouts, proxy configuration,
       SSL set up you may need to customize the HTTP Connector.
public ReactorClientHttpConnector getClientConnector() {
         return new
       ReactorClientHttpConnector(HttpClient.create().followRedirect(true).compress(true).s
       ecure()
                          .option(ChannelOption.CONNECT_TIMEOUT_MILLIS, 3000));
       }

# Logging the HTTP request. It prints the HTTP request method, URL, and all HTTP headers
private static ExchangeFilterFunction logRequest() {
       return ExchangeFilterFunction.ofRequestProcessor(clientRequest -> {
         System.out.println("Request: " + clientRequest.method() + " " +
       clientRequest.url());
         clientRequest.headers()
                          .forEach((name, values) -> values.forEach(value ->
       System.out.println(name + " " + value)));
         return Mono.just(clientRequest);
```

```
        });
}

# Logging the HTTP response. It prints the HTTP response status code and all HTTP response
        headers

private static ExchangeFilterFunction logResponse() {
        return ExchangeFilterFunction.ofResponseProcessor(clientResponse -> {
          System.out.println("Response: " + clientResponse.statusCode());
          clientResponse.headers().asHttpHeaders()
                        .forEach((name, values) -> values.forEach(value ->
        System.out.println(name + " " + value)));
          return Mono.just(clientResponse);
        });
}
```

You can refer to Section 2 of Spring WebFlux documentation available at https://docs.spring.io/spring-framework/docs/current/reference/html/web-reactive.html for an in-depth discussion on various supported configurations.

8.5 Introduction to RSocket

In the previous section, we've discussed the WebClient and demonstrated its use with Spring Boot. In this section, we'll explore the RSocket protocol and its use with Spring Boot.

RSocket https://rsocket.io/ is an application protocol for **multiplexed**, duplex communication over TCP, WebSocket, and other byte stream transports such as Aeron https://github.com/real-logic/aeron. RSocket allows the following four communication models as shown in figure 8.11:

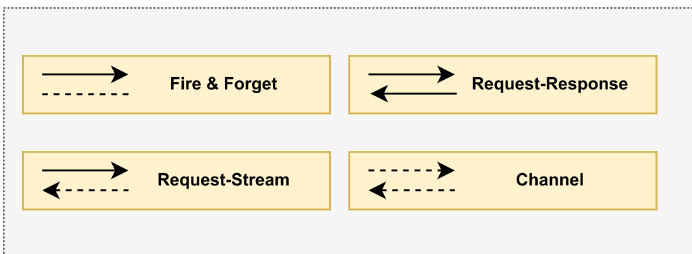


Figure 8.11 Communication models in RSocket protocol. In the Fire-and-Forget pattern, a client sends one message and expect no response from the server. In the Request-Response pattern, the client sends one message and receive one back from the server. In the Request-Stream pattern, a client sends one message and expect a stream of messages in response from the server. In the Channel pattern, the client and server send streams of messages to each other

In RSocket once the initial handshake between the **client** and server is done, the "client" vs "server" distinction is lost as both sides can independently initiate one of the interactions as specified in figure 8.11.

The RSocket protocol has few key features and offers several benefits:

- Reactive Streams semantics for streaming requests interactions Request-Stream and Channel. Support for backpressure signal between requester and responder. This allows a requester to slow down a responder at the source. Thus, reduces reliance on network layer congestion control and network-level buffering
- Support for Request throttling to reduce the number of possible messages. This can be done after sending a `LEASE` frame to limit the total number of requests allowed by other ends for a given time
- Fragmentation and re-assembly of large messages
- Keepalive through heartbeat messages

Next, let us demonstrate how to use the RSocket protocol in a Spring Boot application. We'll implement all four interaction patterns as shown in figure 8.11.

TECHNIQUE DEVELOPING APPLICATIONS USING RSOCKET AND SPRING BOOT

Problem

You learned about RSocket protocol and need to use it in a Spring Boot application

Solution

Spring Framework provides support for RSocket protocol in the `spring-messaging` module. Spring Boot provides the `spring-boot-starter-rsocket` starter dependency that includes the relevant dependencies to use RSocket in a Spring Boot application.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch08/spring-boot-rsocket

To begin with let us create a new Spring Boot project with the dependencies as shown in listing 8.18:

Listing 8.18 The pom.xml file

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
       <parent>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-parent</artifactId>
         <version>2.5.3</version>
         <relativePath/> <!-- lookup parent from repository -->
       </parent>
       <groupId>com.manning.sbip.ch08</groupId>
       <artifactId>spring-boot-rsocket</artifactId>
       <version>0.0.1-SNAPSHOT</version>
       <name>spring-boot-rsocket</name>
       <description>Spring Boot RSocket</description>
       <properties>
         <java.version>16</java.version>
       </properties>
       <dependencies>
         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-rsocket</artifactId>
         </dependency>

         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-devtools</artifactId>
                <scope>runtime</scope>
                <optional>true</optional>
         </dependency>
         <dependency>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
                <optional>true</optional>
         </dependency>
         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-test</artifactId>
                <scope>test</scope>
         </dependency>
         <dependency>
                <groupId>io.projectreactor</groupId>
                <artifactId>reactor-test</artifactId>
                <scope>test</scope>
         </dependency>
       </dependencies>

       <build>
         <plugins>
                <plugin>
                       <groupId>org.springframework.boot</groupId>
                       <artifactId>spring-boot-maven-plugin</artifactId>
                       <configuration>
                              <excludes>
                                     <exclude>
```

```
                                                        <groupId>org.projectlombok</groupId>
                                                        <artifactId>lombok</artifactId>
                                               </exclude>
                                      </excludes>
                             </configuration>
                    </plugin>
           </plugins>
       </build>

</project>
```

The notable dependency in listing 8.18 is the spring-boot-starter-rsocket one. This transitively includes the other required dependencies such as `spring-messaging`, `rsocket-core` etc.

In the application.properties file, let us include the following properties as shown listing 8.19:

Listing 8.19 application.properties configuration

```
spring.rsocket.server.port=7000
spring.main.lazy-initialization=true
```

The first property sets the TCP port for the RSocket server to 7000 and the second property enables the Spring Boot's lazy initialization.

In this Spring Boot application, we'll continue with the `Course` domain object. The updated Course model is shown in Listing 8.20:

Listing 8.20 The Course Domain Class

```
package com.manning.sbip.ch08.model;

import java.time.Instant;
import java.util.UUID;

import lombok.Data;
import lombok.NoArgsConstructor;

@Data
@NoArgsConstructor
public class Course {

       private UUID courseId = UUID.randomUUID();
       private long created = Instant.now().getEpochSecond();
       private String courseName;

       public Course(String courseName) {
         this.courseName = courseName;
       }
}
```

The `Course` class has a `courseId` field which is a random UUID, a `created` field that captures the course creation time and a `courseName` field that is supplied by the user.

Next, let us define the `CourseController` class that contains the routes for all four interaction models as specified in figure 8.11. Listing 8.21 shows the `CourseController` class:

Listing 8.21 The Course Controller

```
package com.manning.sbip.ch08.controller;

import java.time.Duration;

import org.springframework.messaging.handler.annotation.MessageMapping;
import org.springframework.stereotype.Controller;

import com.manning.sbip.ch08.model.Course;

import lombok.extern.slf4j.Slf4j;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

@Slf4j
@Controller
public class CourseController {

       # Implements the request-response interaction pattern. The user is expected to
       supply a course and this endpoint echos it back to the caller
       @MessageMapping("request-response")
       public Mono<Course> requestResponse(final Course course) {
         log.info("Received request-response course details {} ", course);
         return Mono.just(new Course("Your course name: " + course.getCourseName()));
       }

       # Implements the fire-forget interaction pattern. The user is expected to supply a
       course and expects nothing. Thus, we are returning an empty Mono.
       @MessageMapping("fire-and-forget")
       public Mono<Void> fireAndForget(final Course course) {
         log.info("Received fire-and-forget course details {} ", course);
         return Mono.empty();
       }

       # Implements the request-stream interaction pattern. The user is expected to supply
       a course and this endpoint returns a stream of course with modified course name in
       an interval of one second
       @MessageMapping("request-stream")
       public Flux<Course> requestStream(final Course course) {
         log.info("Received request-stream course details {} ", course);
         return Flux
                         .interval(Duration.ofSeconds(1))
                           .map(index -> new Course("Your course name: " +
       course.getCourseName() + ". Response #" + index))
                           .log();
       }

      # Implements the channel interaction pattern. The user is expected to supply a stream
       and this endpoint returns a stream of course with a modified course name in an
       interval configured by the user. The user can specify the interval by invoking the
       delayElements() method in the source Flux.  Recall that in channel interaction
       patterns, both sides can send a stream of data.
       @MessageMapping("stream-stream")
```

```
    public Flux<Course> channel(final Flux<Integer> settings) {
      log.info("Received stream-stream (channel) request... ");

      return settings
   .doOnNext(setting -> log.info("Requested interval is {} seconds", setting))
   .doOnCancel(() -> log.warn("Client cancelled the channel"))
   .switchMap(setting -> Flux.interval(Duration.ofSeconds(setting)).map(index -> new
      Course("Spring. Response #"+index)))
                         .log();
    }
}
```

You can start the application, and find that it is running on configured TCP port 7000. We'll demonstrate two approaches to test the application. First, we can use RSocket Client CLI (RSC) to test the routes. It's a command-line utility that lets you access the endpoints. You can go through https://github.com/making/rsc for the steps to install this in your machine. Once you've installed it, access the `request-response` route using the command as shown in Listing 8.22:

Listing 8.22 Invoking RSocket endpoint with rsc CLI

```
C:\Users\musib>rsc --debug --request --data "{\"courseName\":\"Spring\"}" --route request-
       response --stacktrace tcp://localhost:7000
2021-07-29 10:27:54.597 DEBUG 17700 --- [actor-tcp-nio-2] io.rsocket.FrameLogger
       : sending ->
Frame => Stream ID: 0 Type: SETUP Flags: 0b0 Length: 75
Data:

2021-07-29 10:27:54.607 DEBUG 17700 --- [actor-tcp-nio-2] io.rsocket.FrameLogger
       : sending ->
Frame => Stream ID: 1 Type: REQUEST_RESPONSE Flags: 0b100000000 Length: 53
Metadata:
         +-------------------------------------------------+
         |  0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f |
+--------+-------------------------------------------------+----------------+
|00000000| fe 00 00 11 10 72 65 71 75 65 73 74 2d 72 65 73 |.....request-res|
|00000010| 70 6f 6e 73 65                                  |ponse           |
+--------+-------------------------------------------------+----------------+
Data:
         +-------------------------------------------------+
         |  0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f |
+--------+-------------------------------------------------+----------------+
|00000000| 7b 22 63 6f 75 72 73 65 4e 61 6d 65 22 3a 22 53 |{"courseName":"S|
|00000010| 70 72 69 6e 67 22 7d                            |pring"}         |
+--------+-------------------------------------------------+----------------+
2021-07-29 10:27:54.768 DEBUG 17700 --- [actor-tcp-nio-2] io.rsocket.FrameLogger
       : receiving ->
Frame => Stream ID: 1 Type: NEXT_COMPLETE Flags: 0b1100000 Length: 118
Data:
         +-------------------------------------------------+
         |  0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f |
+--------+-------------------------------------------------+----------------+
|00000000| 7b 22 63 6f 75 72 73 65 49 64 22 3a 22 32 33 39 |{"courseId":"239|
|00000010| 66 37 65 64 61 2d 65 31 61 64 2d 34 66 30 36 2d |f7eda-e1ad-4f06-|
|00000020| 62 66 30 64 2d 63 38 31 32 61 66 36 66 65 37 61 |bf0d-c812af6fe7a|
|00000030| 63 22 2c 22 63 72 65 61 74 65 64 22 3a 31 36 32 |c","created":162|
|00000040| 37 35 33 34 36 37 34 2c 22 63 6f 75 72 73 65 4e |7534674,"courseN|
```

```
|00000050| 61 6d 65 22 3a 22 59 6f 75 72 20 63 6f 75 72 73 |ame":"Your cours|
|00000060| 65 20 6e 61 6d 65 3a 20 53 70 72 69 6e 67 22 7d |e name: Spring"}|
+--------+-------------------------------------------------+----------------+
{"courseId":"239f7eda-e1ad-4f06-bf0d-c812af6fe7ac","created":1627534674,"courseName":"Your
       course name: Spring"}
```

We have enabled the debug in the command to print the frame details. As you can notice the first frame send is `SETUP`, and then `REQUEST_RESPONSE` with some metadata and the payload. Lastly, it receives the response from the endpoint. In listing 8.22, we've shown how to test request-response with the RSC client. Similarly, you can test other patterns also with RSC. Refer to https://rsocket.io/about/protocol for a detailed understanding of the frame and the protocol in detail.

Next, we can also write the integration test cases to test the endpoint. Listing 8.23 shows the test case:

Listing 8.23 Integration test to verify the request-response route

```
package com.manning.sbip.ch08;

import static org.assertj.core.api.Assertions.assertThat;

import java.time.Duration;

import org.junit.jupiter.api.BeforeAll;
import org.junit.jupiter.api.Test;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.rsocket.context.LocalRSocketServerPort;
import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.messaging.rsocket.RSocketRequester;
import org.springframework.messaging.rsocket.RSocketStrategies;

import com.manning.sbip.ch08.model.Course;

import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;
import reactor.test.StepVerifier;

@SpringBootTest
class SpringBootRsocketApplicationTests {

       private static RSocketRequester requester;

       # Set up the RsocketRequester instance. The RSocketRequester.Builder interface lets
       us create a requester by connecting to the server
       @BeforeAll
       public static void setUpOnce(@Autowired RSocketRequester.Builder builder,
       @LocalRSocketServerPort Integer port,
       @Autowired RSocketStrategies rSocketStrategies) {

         requester = builder.tcp("localhost", port);
       }

       @Test
       public void testRequestResponse() {
         # Send a request
```

```
        Mono<Course> courseMono = requester
                    .route("request-response")
                    .data(new Course("Spring"))
                     .retrieveMono(Course.class);

        # Verify the response
        StepVerifier.create(courseMono)
                .consumeNextWith(course ->
      assertThat(course.getCourseName()).isEqualTo("Your course name: Spring"))
                        .verifyComplete();
      }
}
```

In the `testRequestResponse()` we send a request to the route and validate the expected response. In the requester instance, we set the route path, the data and then retrieve the response. Since this `request-response` pattern, we expect a single response and it is captured in a `Mono`. We then use the `StepVerifier` to consume the response and assert the expected value from the response. Once the verification is done, we complete it with `verifyComplete()`.

Let us now define the remaining test cases in the `SpringBootRsocketApplicationTests` class. Listing 8.24 shows the fire and forget endpoint:

Listing 8.24 Testing Fire and Forget Endpoint

```
@Test
public void testFireAndForget() {
      # Send a request
      Mono<Void> courseMono = requester
              .route("fire-and-forget")
              .data(new Course("Spring"))
               .retrieveMono(Void.class);

      # Verify the response
      StepVerifier
     .create(courseMono)
     .verifyComplete();
}
```

Listing 8.25 shows the test case to test the Request Stream endpoint:

Listing 8.25 Testing the Request Stream Endpoint

```
@Test
public void testRequestStream() {
       # Send a request and expect a stream of courses as Flux<Course>
       Flux<Course> courseFlux = requester
                .route("request-stream")
                .data(new Course("Spring"))
                 .retrieveFlux(Course.class);

      # Use StepVerifier to verify the response. We retrieve two courses from the stream
       and then cancel them to indicate we are not interested in further data from the
       stream.
       StepVerifier.create(courseFlux)
                 .consumeNextWith(course ->
       assertThat(course.getCourseName()).isEqualTo("Your course name: Spring. Response
       #0"))
                 .expectNextCount(0)
                 .consumeNextWith(course ->
       assertThat(course.getCourseName()).isEqualTo("Your course name: Spring. Response
       #1"))
                 .thenCancel()
                .verify();
}
```

Listing 8.26 shows the test case to test the channel endpoint:

Listing 8.26 Testing the Channel Endpoint

```
@Test
public void testChannel() {
       # Create first setting after 0 seconds. Server starts sending after 2 # seconds.
       Mono<Integer> setting1 =
       Mono.just(Integer.valueOf(2)).delayElement(Duration.ofSeconds(0));
       # Create next setting after 3 seconds. Server starts sending in after 1
       # second.
       Mono<Integer> setting2 =
       Mono.just(Integer.valueOf(1)).delayElement(Duration.ofSeconds(3));

       # Bundle settings into a Flux
       Flux<Integer> settings = Flux.concat(setting1, setting2);

       # Send a stream of request messages
       Flux<Course> stream = requester.route("stream-
       stream").data(settings).retrieveFlux(Course.class);

       # Verify that the response messages contain the expected data
       StepVerifier
       .create(stream)
       .consumeNextWith(course -> assertThat(course.getCourseName()).isEqualTo("Spring.
       Response #0"))
       .consumeNextWith(course -> assertThat(course.getCourseName()).isEqualTo("Spring.
       Response #0"))
       .thenCancel()
       .verify();
}
```

Discussion

In this technique, we've demonstrated the use of `RSocket` protocol in a Spring Boot application. We've seen the use of the `spring-boot-starter-rsocket` dependency that brings the necessary dependencies in the application.

The Spring Boot also provides several auto-configuration classes that configure the RSocket in a Spring Boot application. Figure 8.12 shows these classes:

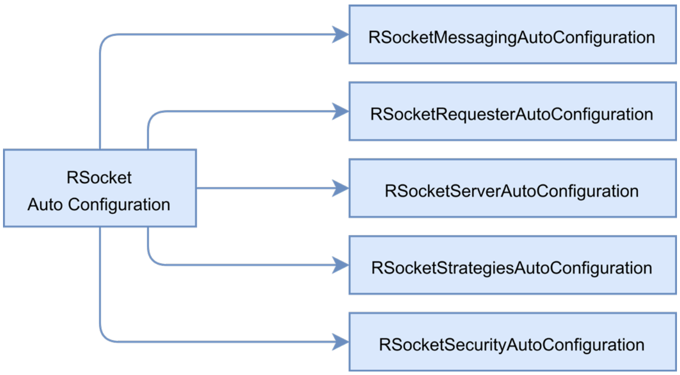


Figure 8.12 Spring Boot RSocket auto-configuration classes

The `RsocketMessagingAutoConfiguration` auto-configures the `RsocketMessageHandler`. This class handles RSocket requests for the methods defined with `@ConnectMapping` and `@MessageMapping` annotations.

The `RsocketRequesterAutoConfiguration` auto-configures the `RsocketRequester`. This class provides a fluent API that can be used to accept and return input and output. It also provides methods to prepare routing and other metadata. We've used this class in our test case in listing 8.23.

The `RsocketServerAutoConfiguration` auto-configures the RSocket server. We've configured the `spring.rsocket.server.port` property to start the standalone RSocket server at port 7000.

The `RsocketStrategiesAutoConfiguration` auto-configures the `RsocketStrategies`. This class defines the strategies for use by `RSocket` requester and responder components. Some of the strategies, for instance, are the decoder and encoder for the messages.

Lastly, the `RsocketSecurityAutoConfiguration` auto-configures Spring Security for an RSocket server. Securing the RSocket server with Spring Security is beyond the scope of this text. You can refer to the internet on this subject.

8.6 Introduction to WebSocket

So far in the book, you've seen the use of HTTP through which you can access contents from the server. For instance, in the Course Tracker REST API, you initiated an HTTP request from the browser/HTTPie CLI to the server to get the available courses. Although HTTP works perfectly well in most scenarios and it is the dominant protocol of the web, it has a major drawback. The communication between client and server can only be initiated by the client. It works in a request-response style – the client should ask the server what it needs by accessing the URLs. The server can't initiate a connection to the client and send data to it. There are workarounds such as HTTP streaming, long polling that attempts to reduce this problem to a certain degree. However, these are not permanent solutions. For instance, in the case of an HTTP long polling, the client sends a request to the server and the server holds the request until there is something to return to the client. Thus, the client polls the server for new data and the server responds when it has something to return to the client.

In this section, we'll introduce you to the WebSocket protocol https://datatracker.ietf.org/doc/html/rfc6455 that intends to remove the above-mentioned drawbacks of HTTP. This protocol provides a *standardized* way to establish a full-duplex, two-way communication channel between client and server over a single TCP connection. Note the emphasis on the standardized part of the definition as this protocol is designed for two-way communication and you need not rely on any workarounds. WebSocket is a different protocol from HTTP but it is designed to work over HTTP and HTTPS, using ports 80 and 443. The client-server communication model in HTTP and WebSocket is shown in figure 8.13.

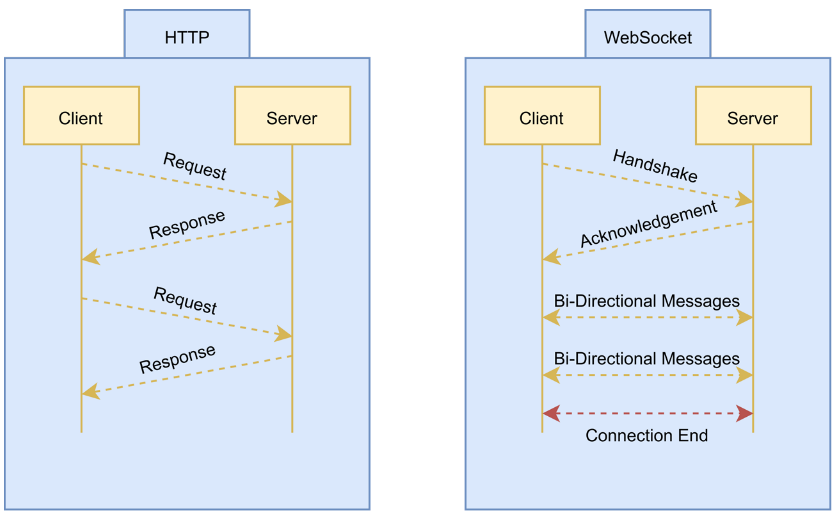


Figure 8.13 The Client-Server communication in HTTP and WebSocket protocol

In this section, we've introduced you to the WebSocket protocol that facilitates two-way communication between client and server. With WebSocket, once the initial handshake is completed, both client and server can send data to each other. It is important to know that the HTTP is used for the initial handshake, and once that is done, the HTTP connection is upgraded to a newly established TCP/IP connection which is used by WebSocket.

Further, the WebSocket protocol is a low-level one and it defines how a stream of bytes is transformed to frames. A frame can contain a binary or text message. However, the message does not carry any additional information related to routing and processing. Thus, it becomes difficult to use raw WebSocket protocol without any additional coding. However, the WebSocket protocol specification allows using higher-level sub-protocols that operates on the application level. One such sub-protocol supported by Spring is *Simple (or Streaming) Text Orientated Messaging Protocol* (STOMP).

The Spring Framework provides a WebSocket API that we can use to write client and server-side application that handles WebSocket messages. We'll provide more details on how the WebSocket protocol works in the discussion section. For now, let us explore how to build a Spring Boot application with WebSocket in the next technique.

TECHNIQUE DEVELOPING APPLICATION USING WEBSOCKET AND SPRING BOOT

Problem

So far you've built applications that use HTTP. You need to explore the use of WebSocket protocol with Spring Boot for more real-time communication between client and server.

Solution

Let us begin with building a Spring Boot application with WebSocket and STOMP.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch08/spring-boot-websocket

In this demonstration, we'll build a really simple chat application that echos the text provided by the users. Let us create a new Spring Boot application with the dependencies as shown in listing 8.27:

Listing 8.27 The pom.xml file

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
       <parent>
         <groupId>org.springframework.boot</groupId>
         <artifactId>spring-boot-starter-parent</artifactId>
         <version>2.5.3</version>
         <relativePath/> <!-- lookup parent from repository -->
       </parent>
       <groupId>io.musibs.dev.labs</groupId>
       <artifactId>spring-boot-websocket</artifactId>
       <version>0.0.1-SNAPSHOT</version>
       <name>spring-boot-websocket</name>
       <description>Demo project for Spring Boot</description>
       <properties>
         <java.version>16</java.version>
       </properties>
       <dependencies>
         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-websocket</artifactId>
         </dependency>
         <dependency>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
                <optional>true</optional>
         </dependency>
         <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-test</artifactId>
                <scope>test</scope>
         </dependency>
       </dependencies>

       <build>
         <plugins>
                <plugin>
                       <groupId>org.springframework.boot</groupId>
                       <artifactId>spring-boot-maven-plugin</artifactId>
                       <configuration>
                              <excludes>
                                     <exclude>
                                            <groupId>org.projectlombok</groupId>
                                            <artifactId>lombok</artifactId>
                                     </exclude>
                              </excludes>
                       </configuration>
                </plugin>
         </plugins>
       </build>

</project>
```

In listing 8.27, we've included the `spring-boot-starter-websocket` dependency. The `spring-boot-starter-websocket` dependency provides the necessary support for WebSocket protocol in Spring. Next, let us configure Spring to enable WebSocket and STOMP messaging as shown in Listing 8.28:

Listing 8.28 Enabling WebSocket and STOMP support

```
package com.manning.sbip.ch08.config;

import org.springframework.context.annotation.Configuration;
import org.springframework.messaging.simp.config.MessageBrokerRegistry;
import org.springframework.web.socket.config.annotation.EnableWebSocketMessageBroker;
import org.springframework.web.socket.config.annotation.StompEndpointRegistry;
import org.springframework.web.socket.config.annotation.WebSocketMessageBrokerConfigurer;

@Configuration
@EnableWebSocketMessageBroker
public class WebSocketConfiguration implements WebSocketMessageBrokerConfigurer {

       # The StompEndpointRegistry interface lets us register STOMP over websocket
       endpoints
       @Override
       public void registerStompEndpoints(StompEndpointRegistry registry) {
         registry.addEndpoint("/ws").withSockJS();
       }

       # The MessageBrokerRegistry lets us configure message broker options
       @Override
       public void configureMessageBroker(MessageBrokerRegistry registry) {
         registry.enableSimpleBroker("/topic");
         registry.setApplicationDestinationPrefixes("/app");
       }
}
```

In Listing 8.28, the `registerStompEndpoints`() method lets us register a STOMP endpoint over a WebSocket endpoint at /ws endpoint. Further, the `withSockJS`() enables SockJS fallback options. SockJS https://github.com/sockjs/sockjs-client lets our WebSockets work even if the browser does not support WebSocket protocol.

The `configureMessageBroker` method creates an in-memory message broker with one or more destinations for sending and receiving messages. In listing 8.18, we've created one destination with prefix as `/topic`. We've also defined the application destination prefix as `/app`. This is used to filter destinations by methods annotated with `@MessageMapping`. You'll define these methods in a separate controller class. Post-processing the message, the controller sends the message to the broker. In this example, you've used an in-memory message broker. In a production application, you may choose to use better alternatives such as RabbitMQ [https://www.rabbitmq.com/.](https://www.rabbitmq.com/)

Next, let us define the controller as shown in Listing 8.29:

Listing 8.29 The MessageController Class

```
package com.manning.sbip.ch08.controller;

import java.time.Clock;
import java.time.Instant;

import org.springframework.messaging.handler.annotation.MessageMapping;
import org.springframework.messaging.handler.annotation.SendTo;
import org.springframework.stereotype.Controller;

import com.manning.sbip.ch08.model.InputMessage;
import com.manning.sbip.ch08.model.OutputMessage;

import lombok.extern.slf4j.Slf4j;

@Slf4j
@Controller
public class MessageController {

       @MessageMapping("/chat")
       @SendTo("/topic/messages")
       public OutputMessage message(InputMessage message) {
         log.info("Input Message "+message);
         return OutputMessage
            .builder()
            .time(Instant.now(Clock.systemDefaultZone()))
            .content(message.getContent())
            .build();
       }
}
```

In listing 8.29, you've defined in the Spring controller, you've defined an endpoint `/chat` with `@MessageMapping` annotation. The `@SendTo` annotation broadcasts the message to all clients subscribed to the `/topic/messages` endpoint. The InputMessage and OutputMessage are two Java POJO classes that represent the input message the output message respectively. Refer to the GitHub repository for the Java files.

Let us now define the client-side HTML page that we will use to send and receive the messages. The index.html file located in the `src/main/resources` folder is shown in Listing 8.30:

Listing 8.30 The index.html page

```
<!DOCTYPE html>
<html lang="en">

<head>
       <meta charset="UTF-8">
       <meta http-equiv="X-UA-Compatible" content="IE=edge">
       <meta name="viewport" content="width=device-width, initial-scale=1.0">
       <title>Spring Boot WebSocket</title>
</head>

<body
         <label for="message-input">Enter your message</label>
         <input type="text" class="form-control" id="message-input">
         <button type="submit" onclick="sendMessage()">Send</button>
         <ul id="message-list"></ul>

      # We are downloading sockjs and stomp.js from the a CDN
       <script src="https://cdnjs.cloudflare.com/ajax/libs/sockjs-
       client/1.5.1/sockjs.js"></script>
       <script
       src="https://cdnjs.cloudflare.com/ajax/libs/stomp.js/2.3.3/stomp.min.js"></script>
       <script src="js/main.js"></script>
</body>

</html>
```

In listing 8.30, we've done the following:

- We've defined a text box and a button so that the user can enter a text message and send it to the server. Clicking the button invokes the `sendMessage()` function
- We've also defined an empty unordered list with an id `message-list` which is used to print the messages broadcasted by the server
- Included the SockJS and STOMP JS in the HTML page. You'll notice the use of these JS files in the custom JS file named `main.js`. The main.js file is used to initiate the WebSocket connection and subscribe to the `/topic/messages` endpoint.

Let us now define the main.js file which is available at `src\main\resources\js` folder. Listing 8.31 shows this file:

Listing 8.31 The main.js file

```
# Create a WebSocket connection at http://localhost:8080/ws
let sock = new SockJS('http://localhost:8080/ws');

# Create a new StompClient object (from stomp.min.js library) with the WebSocket endpoint
let client = Stomp.over(sock);

# Function to send message. This function is invoked while you click on the
# Send in the HTML page. It takes the value in the 'message-input' text field
# and send it to the server with empty headers ({}).
function sendMessage() {
       console.log("Sending message");
       let input = document.getElementById('message-input');
       client.send('/app/chat', {}, JSON.stringify({ content: input.value }));
}


# Start the STOMP communications, provide a callback for when the CONNECTED (part of
       WebSocket protocol) frame arrives.
client.connect({}, (frame) => {
       # Subscribe to "/topic/messages". Whenever there is a new message, add the text in a
       list-item element in the unordered list.
       client.subscribe('/topic/messages', (payload) => {
         let message_list = document.getElementById('message-list');
         let message = document.createElement('li');
         let output = JSON.parse(payload.body);
         message.appendChild(document.createTextNode(output.content +" at " +output.time));
         message_list.appendChild(message);
       });
});
```

Let us now start the application and access http://localhost:8080. You can enter a text and notice that it is broadcasted back with a timestamp. You can open another tab in your browser and access the same URL http://localhost:8080. Enter a text and you'll notice that the same text message is broadcasted to the first window as well.

Discussion

In this technique, you've explored the use of WebSocket protocol in a Spring Boot application with a simple messaging application.

Let us now understand how a handshake between the client and server works in a WebSocket application as shown in figure 8.14:

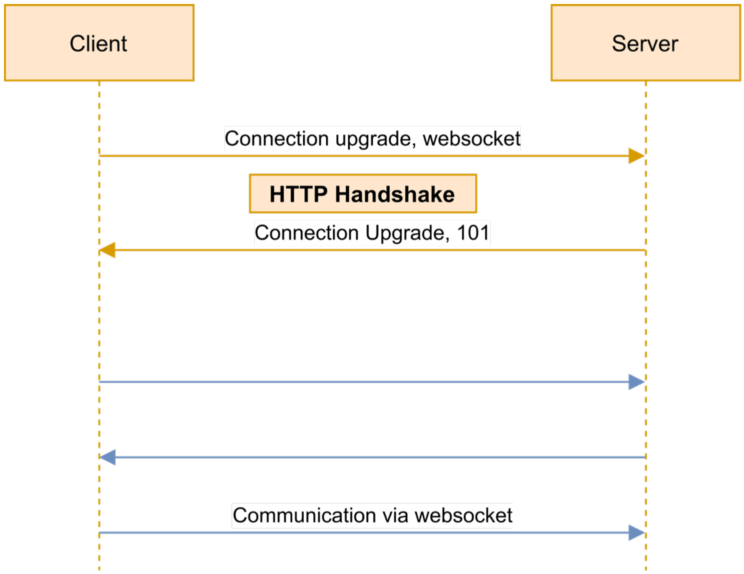


Figure 8.14 Client and server communication through WebSocket protocol

In the initial phase of a connection set up the client sends a few special HTTP headers asking for a WebSocket connection. The HTTP headers are shown in Listing 8.32:

Listing 8.32 HTTP Request Headers

```
GET ws://localhost:8080/ws/257/vktswatd/websocket HTTP/1.1
Host: localhost:8080
Connection: Upgrade
Upgrade: websocket
Origin: http://localhost:8080
Sec-WebSocket-Version: 13
Accept-Encoding: gzip, deflate, br
Accept-Language: en-US,en;q=0.9
Sec-WebSocket-Key: kVE6ElOMjfIi4bPZzojWzA==
Sec-WebSocket-Extensions: permessage-deflate; client_max_window_bits
```

The initial request needs to be an `HTTP GET` request. Besides, the client begins the interaction with the server with an `HTTP Upgrade` header to upgrade or to switch to WebSocket protocol. The client also sends additional `Sec-*` headers for other purposes. For instance, the `Sec-WebSocket-Key` is used for security purposes. Refer to the https://datatracker.ietf.org/doc/html/rfc6455 for more details on these additional headers.

If the server supports WebSocket protocol, it automatically responds with the `HTTP 101 Switching Protocols` response instead of the usual `HTTP 200 Ok` status code. The response headers are shown in Listing 8.33:

Listing 8.33 The HTTP Response Headers

```
HTTP/1.1 101
Vary: Origin
Vary: Access-Control-Request-Method
Vary: Access-Control-Request-Headers
Upgrade: websocket
Connection: upgrade
Sec-WebSocket-Accept: vNLDQJwTllhnlFr6XKRZdjCX2Vk=
Sec-WebSocket-Extensions: permessage-deflate;client_max_window_bits=15
Date: Wed, 28 Jul 2021 10:30:46 GMT
```

After a successful handshake, the TCP socket underlying the HTTP upgrade request remains open for both the client and the server to continue to send and receive messages.

8.7 Chapter Summary

- Introduction to the Reactive programming with a focus on asynchronous data streams and benefits of reactive programming
- Introduction to Reactive Streams, Project Reactor, and Spring WebFlux
- Designing a reactive restful API with Spring WebFlux annotated controllers and functional endpoints
- Techniques to access a reactive application with WebClient
- Introduction to WebSocket protocol and using it in a Spring Boot application
- Introduction to RSocket protocol, its different interaction patterns, and how to use RSocket in a Spring Boot application

9

Deploying Spring Boot applications

This chapter covers:

- **Running Spring Boot applications as JAR or deploy as a WAR file**
- **Deploying Spring Boot applications to Cloud Foundry and Heroku**
- **Running Spring Boot applications as Docker container**
- **Developing Spring Boot application to Kubernetes Cluster and RedHat OpenShift platform**

Once you are done with your application development and testing, you need to deploy the applications into your production server to serve the application users. Spring Boot applications can be deployed through an array of deployment strategies. Based on the application's scalability, availability, and resilience requirements, you can decide on your application deployment strategy.

In this chapter, we'll introduce you to various approaches to deploy the Spring Boot application. You'll learn traditional deployment techniques such as running the application as an executable JAR or deploy into an application server as a WAR. We'll then explore deploying into Pivotal Cloud Foundry and Heroku. Later, we'll also learn how to run Spring Boot applications as a Docker container and deploy them into a Kubernetes cluster. Finally, we'll show how to deploy the application into RedHat OpenShift. Let's get started.

Developing various types of applications with the Spring Boot framework is a popular choice among developers and organizations. Due to the framework's flexibility, ease of use, and popularity, it is often used to develop a diverse category of applications – such as web applications, REST APIs, microservices etc. Some of these applications are small and targeted only a limited user, whereas some are complex and available across multiple geographies and a broad range of users. The deployment strategies for first category applications are straightforward. However, the latter category is complex and requires a sophisticated and thoughtful deployment model.

To meet the need for all categories, Spring Boot supports a wide range of deployment techniques. You can package your Spring Boot application as an executable JAR and run it without the need for any application server. Spring Boot provides built-in support for several embedded web servers. Similarly, if you need to package your application as a WAR file and deploy it to an application server, Spring Boot has built-in support to prepare the WAR file. As you'll explore shortly, it is straightforward to package your Spring Boot application as a WAR file without defining a `web.xml` and other configurations.

Deploying the applications through the JAR or WAR files approach has a pre-requisite that you need to build a package for your application. The Pivotal Cloud Foundry (PCF) https://www.cloudfoundry.org/ offers an alternative approach where you can use your source code directly to deploy the application and PCF will perform the required steps. Similarly, if you don't have your on-premises infrastructure, you can leverage cloud providers such as AWS, Azure, Google Cloud Platform (GCP), Heroku to deploy your packaged application. In this chapter, we'll demonstrate how to deploy your application on Heroku.

Further, if you need to run your application as a container image, Spring Boot provides built-in support to generate a container image for your application. You can then use the image to run your application locally or deploy it to cloud environments. If you need scalable, high available and fault-tolerant applications, you can deploy your application to Kubernetes. In this chapter, we'll demonstrate how to deploy a Spring Boot application to Kubernetes and RedHat OpenShift.

Note

How to deploy an application and serve end-users is a business requirement and is done based on multiple factors such as application performance, availability, scalability, resilience, compliance needs and so on. Thus, there are plenty of deployment techniques and strategies available. There are a lot of technical toolkits and platforms out there to facilitate the diverse need of the deployments. In this book, we aim to focus on the Spring Boot application deployment on popular and commonly used platforms. Due to the vastness of this subject, it is beyond the scope of this text to provide an in-depth discussion on the technologies and platforms. However, we'll provide the additional references for the specific technology or platform wherever possible and cover the set-up steps (if any) in the book's companion GitHub wiki.

9.1 Running Spring Boot Applications as an executable JAR file

Previously, you've seen that you can package a Spring Boot application as an executable JAR file and execute it in local machines or servers. In this section, let us explore this step in detail.

TECHNIQUE PACKAGING AND EXECUTING A SPRING BOOT APPLICATION AS AN EXECUTABLE JAR FILE

Problem

You have developed a Spring Boot application and need to execute it as an executable JAR file

Solution

Once you are done with the application development, you need to execute it to see it in action. Spring Boot provides several options to deploy the application and run it. In this technique, we'll explore Spring Boot's built-in approach to package the application as an executable JAR file and run it. This is one of the popular approaches to package and run a Spring Boot application.

To demonstrate how to package the application components and run the application as an executable JAR file, we'll use the Course Tracker Spring Boot application that we've developed in the earlier chapters.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-jar

To ensure the application is packaged as an executable JAR file, you need to ensure the following two things:

1. The `packaging` type in the `pom.xml` file needs to be set as a `jar`. This ensures that the application components will be packaged as a JAR
2. Configure the `spring-boot-maven-plugin` in the `plugins` section of the `pom.xml` file as shown in listing 9.1:

Listing 9.1 The Spring Boot Maven Plugin

```
<plugin>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-maven-plugin</artifactId>
</plugin>
```

The `spring-boot-maven-plugin` prepares the executable JAR file when the Maven `package` goal is executed. We'll discuss more on this in the discussion section.

Open a terminal window and browse to the location of the `pom.xml` file. Next, execute the `mvn package` command to build and package the application components. This ensures the application is compiled, built and packaged as a jar file. Listing 9.2 shows the output:

Listing 9.2 The mvn package command

```
$course-tracker-app\target>mvn package
[INFO] Scanning for projects...
[INFO]
[INFO] ------------< com.manning.sbip.ch09:course-tracker-app-jar >------------
[INFO] Building course-tracker-app-jar 1.0.0
[INFO] --------------------------------[ jar ]---------------------------------
[INFO]
[INFO] --- maven-resources-plugin:3.2.0:resources (default-resources) @ course-tracker-app-
       jar ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Using 'UTF-8' encoding to copy filtered properties files.
[INFO] Copying 1 resource
[INFO] Copying 7 resources
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:compile (default-compile) @ course-tracker-app-jar -
       --
[INFO] Changes detected - recompiling the module!
[INFO] Compiling 6 source files to C:\sbip\repo\ch09\course-tracker-app-jar\target\classes
[INFO]
[INFO] --- maven-resources-plugin:3.2.0:testResources (default-testResources) @ course-
       tracker-app-jar ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Using 'UTF-8' encoding to copy filtered properties files.
[INFO] skip non existing resourceDirectory C:\sbip\repo\ch09\course-tracker-app-
       jar\src\test\resources
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:testCompile (default-testCompile) @ course-tracker-
       app-jar ---
[INFO] Changes detected - recompiling the module!
[INFO]
[INFO] --- maven-surefire-plugin:2.22.2:test (default-test) @ course-tracker-app-jar ---
[INFO]
[INFO] --- maven-jar-plugin:3.2.0:jar (default-jar) @ course-tracker-app-jar ---
[INFO] Building jar: C:\sbip\repo\ch09\course-tracker-app-jar\target\course-tracker-app-
       jar-1.0.0.jar
[INFO]
[INFO] --- spring-boot-maven-plugin:2.5.3:repackage (repackage) @ course-tracker-app-jar --
       -
[INFO] Replacing main artifact with repackaged archive
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
```

Post successful package, you'll find that there is a `target` directory created in the same location as the `pom.xml` file. This target directory contains an executable jar file. By default, the name of the jar file is `<artifactId>-<version>.jar`. In our example, the jar file name is `course-tracker-app-jar.1.0.0.jar`. You can execute this jar fille using the `java -jar <jarName>` command from your terminal from the target directory. This is shown in Listing 9.3:

Listing 9.3 Executing the Spring Boot executable jar file

```
$course-tracker-app\target>java -jar course-tracker-app-jar.1.0.0.jar
```

You'll notice that the application starts up and is successfully initialized. In this example, the application starts on default HTTP port 8080. Open a web browser and access http://localhost:8080 and you'll see the Course Tracker application index page.

Discussion

In this section, we've discussed how to create and run an executable jar file from your Spring Boot application. In chapter 1 sections 1.3.3 and 1.3.4, we've briefly discussed how the JAR file is created and explored the structure of the jar file. We've discussed that the repackage goal of `spring-boot-maven-plugin` hooks in at the maven `package` phase and prepares the executable JAR file. Previously you've seen that Spring Boot projects have a parent pom named `spring-boot-starter-parent`. This pom file includes the necessary configuration to define the repackage goal. Further, in the same `target` directory, you'll notice that there is another jar file with naming format `<artifactId>-<version>.jar.original`. In our example, this jar name is `course-tracker-app-jar-1.0.0.jar.original`. This is the original JAR file prepared by Maven. Note that this is not an executable jar. The contents of this jar file are subsequently packaged by the `spring-boot-maven-plugin` to create the executable jar file. Listing 9.4 shows the structure of the Spring Boot packaged jar file:

Listing 9.4 Spring Boot repackaged jar file structure

```
course-tracker-app-jar-1.0.0.jar
  |
  +-META-INF
  |  +-MANIFEST.MF
  +-org
  |  +-springframework
  |    +-boot
  |      +-loader
           # These loader classes are used to launch a Spring Boot application
  |        +-<spring boot loader classes>
  +-BOOT-INF
    +-classes
    |  +-com
    |    +-manning
    |      +-sbip
    |        +-ch09
    |          +-CourseTrackerSpringBootApplication.class
    +-lib
      # Third party libraries required for the Spring Boot application to run (e.g. Spring
       Jars, logging jars etc)
    | +-dependency1.jar
    | +-dependency2.jar
    +-classpath.idx
    +-layers.idx
```

The `META-INF` folder contains the `MANIFEST.MF` manifest file. A manifest is a special file that contains several meta-information about the files packaged in the jar file. Listing 9.5 shows the sample contents of a manifest file:

Listing 9.5 The MANIFEST.MF file for Course Tracker JAR file

```
Manifest-Version: 1.0
Created-By: Maven Jar Plugin 3.2.0
Build-Jdk-Spec: 11
Implementation-Title: course-tracker-app-jar
Implementation-Version: 1.0.0
Main-Class: org.springframework.boot.loader.JarLauncher
Start-Class: com.manning.sbip.ch09.CourseTrackerSpringBootApplication
Spring-Boot-Version: 2.5.3
Spring-Boot-Classes: BOOT-INF/classes/
Spring-Boot-Lib: BOOT-INF/lib/
Spring-Boot-Classpath-Index: BOOT-INF/classpath.idx
Spring-Boot-Layers-Index: BOOT-INF/layers.idx
```

Listing 9.5 contains various meta-information about the jar file. The `Main-Class` property contains the `org.springframework.boot.loader.JarLauncher` class is the entry point of the execution of the Jar. The `Start-Class` property contains the actual Spring Boot application class that begins the initialization of the Spring Boot application. The `JarLauncher` class launches this class specified in `Start-Class` property.

The application-specific class files are packaged inside the `BOOT-INF\classes` and the dependencies are packaged inside the `BOOT-INF\lib` folder. These are the third-party libraries required by the Spring Boot application to function.

In addition, the jar also includes two index files – `classpath.idx` and `layers.idx`. The `classpath.idx` file contains a list of jar names (including the directories) in the order that they should be added to the classpath.

The `layers.idx` files contain a list of layers and parts of the jar that should be contained within them. The layers play a crucial role if you need to build a Docker image from the contents of the jar file. While creating the Docker file these layers are written into different layers in the docker image. We'll explore more on this while discussing the creation of a docker image of a Spring Boot application.

By default, Spring Boot defines the following layers:

- **dependencies**: Contains all dependencies whose version does not contain SNAPSHOT
- **spring-boot-loader**: Spring Boot loader classes. For instance, the JarLauncher class is part of this layer
- **snapshot-dependencies**: Contains all dependencies whose version contains SNAPSHOT
- **application**: Contains application classes, and resources

The last thing we will discuss in this section is to view and extract the above-mentioned layers through `layertools` jar mode. Previously, you've noticed that you can execute the executable jar through `java -jar <jarName>` command. You can specify the `-Djarmode=layertools` to view the `layertools` options. Listing 9.6 shows the use of `layertools`:

Listing 9.6 Using layertools jar mode

```
$course-tracker-app\target>java -Djarmode=layertools -jar course-tracker-app-jar-1.0.0.jar
Usage:
  java -Djarmode=layertools -jar course-tracker-app-jar-1.0.0.jar

Available commands:
  list     List layers from the jar that can be extracted
  extract  Extracts layers from the jar for image creation
  help     Help about any command
```

The layertools provides three options – `list` the layers, `extract` the layers, and the `help` command where `help` is the default option. When you execute the command, the `JarLauncher` class is invoked as it is the entry point of the JAR execution. However, as the `jarmode` flag is configured, instead of starting the application, it executes any of the available commands of layertools. These commands are provided by another launcher, named `JarModeLauncher`. It is used whenever we invoke `java -jar` with `-Djarmode=layertools`.

Further, by default, Spring Boot packages the `layers.idx` file. When an executable jar with this file is created, Spring Boot automatically provides and packages the `spring-boot-jarmode-layertools` jar. The `spring-boot-jarmode-layertools` jar includes the `LayerToolsJarMode` class which provides the necessary support for the `layertools` jarmode feature. Let us now see the use of list and extract commands along with `layertools` jarmode. Listing 9.7 shows the use of the list command:

Listing 9.7 Use of list command in jarmode layertools to view the layers

```
$course-tracker-app\target> java -Djarmode=layertools -jar course-tracker-app-jar-1.0.0.jar
       list
dependencies
spring-boot-loader
snapshot-dependencies
application
```

Listing 9.7 shows the layers present inside the `course-tracker-app-jar-1.0.0.jar` file. You can extract these layers into the file system using the extract command. Listing 9.8 shows this:

Listing 9.8 Use of extract command in jarmode layertools to extract the layers in the file system

```
$course-tracker-app\target>java -Djarmode=layertools -jar course-tracker-app-jar-1.0.0.jar
      extract --destination layers

C:\sbip\repo\ch09\course-tracker-app-jar\target>dir layers
 Volume in drive C is OS
 Volume Serial Number is 8EF3-F5B9

 Directory of C:\sbip\repo\ch09\course-tracker-app-jar\target\layers

22/08/2021  01:20 PM    <DIR>          .
22/08/2021  01:20 PM    <DIR>          ..
22/08/2021  01:20 PM    <DIR>          application
22/08/2021  01:20 PM    <DIR>          dependencies
22/08/2021  01:20 PM    <DIR>          snapshot-dependencies
22/08/2021  01:20 PM    <DIR>          spring-boot-loader
```

In listing 9.8, we've first used the extract command and specified a destination folder named `layers` to extract the layers. We then use the dir command to show the created directories. If you browse these directories, you'll notice the contents of the `course-tracker-app-jar-1.0.0.jar` JAR is extracted inside these folders.

If you are wondering what the need for these layers is and why we are discussing these in this section, wait until we demonstrate creating docker images for Spring Boot applications. You'll notice that these layers help us to build an optimized docker image. As we have discussed the executable JAR creation and structure in this section, for continuity purposes, we have provided the layers discussion in the same section.

9.2 Deploying Spring Boot applications as WAR in WildFly application server

In the previous section, we've explored how to package Spring Boot application components in an executable jar and run it. Although it works fine, at times, you need to package your application components into a WAR file and deploy them into a web server or application servers.

Before containerization and Kubernetes, deploying applications into a web server or application servers were the de-facto standards. Application servers offer a lot of enterprise features that help developers and application architects to leverage those features and plan application deployment strategies. For instance, most applications sever provides features such as support for database connection, session replication, sticky sessions, clustering etc. For application server-based deployments, it is a common scenario to deploy the same instance of the application into multiple servers and use a load balancer to balance the incoming requests amongst the application instances.

Figure 9.1 shows a high-level diagram with the use of application server clustering to deploy Spring Boot applications. This cluster deployment provides capabilities such as load balancing and high availability. Note that we've provided this design for a high-level understanding and let you visualize how the typical application server-based production deployments work.

In this section, you'll learn how to package your application as a WAR file and deploy it into a standalone WildFly server https://www.wildfly.org/. WildFly is the community edition of the popular RedHat JBoss Enterprise Application Platform server and is available free of cost.

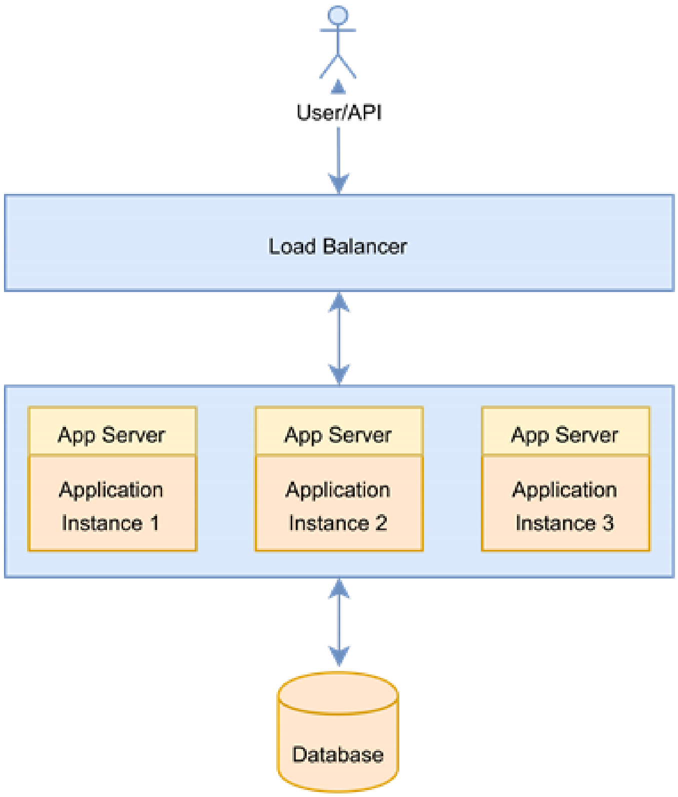


Figure 9.1 Deploying Spring Boot application in an application server cluster. The user request is received by a load balancer that front ends the application servers. Based on the load balancer configuration, the request is routed to one of the application server instances and a response is provided back to the user.

TECHNIQUE PACKAGING AND DEPLOYING A SPRING BOOT APPLICATION AS WAR IN WILDFLY APPLICATION SERVER

Problem

You have developed a Spring Boot application and need to package it as a WAR file and deploy it in the WildFly application server.

Solution

In this section, we'll demonstrate how to package a Spring Boot application and deploy it in the WildFly server (https://www.wildfly.org/). You can refer to the version-specific installation document available at https://docs.wildfly.org/.

To demonstrate how to package the application components as a WAR file and deploy it in the WildFly application server, we'll use the Course Tracker Spring Boot application that we've developed in the earlier chapters.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-war

To package the components as WAR files, you need two changes:

1. In the `pom.xml` file, the packaging type should be `war` as shown in Listing 9.9:

Listing 9.9 Package type as war type in pom.xml file

```
...
<groupId>com.manning.sbip.ch09</groupId>
<artifactId>course-tracker-app-war</artifactId>
<version>1.0.0</version>
<packaging>war</packaging>
<name>course-tracker-app-war</name>
...
```

2. Define an instance of a `WebApplicationInitializer` to run the application from a WAR deployment. The `WebApplicationInitializer` lets us configure the `ServletContext` programmatically in a Servlet 3.0+ environment. If you create your Spring Boot application through Spring Initializr (available at https://start.spring.io) with packaging type as `war`, then by default Spring Boot provides a class called `ServletInitializer`. This class extends the `SpringBootServletInitializer` class which is an instance of `WebApplicationInitializer`. The `SpringBootServletInitializer` class is an opinionated `WebApplicationInitializer` implementation provided by Spring Boot to run a Spring Boot application in a WAR deployment. If you are not creating your Spring Boot application from Spring Initializr, you have to perform this step manually.

Listing 9.10 shows the ServletInitializer class:

Listing 9.10 The ServletInitializer Class

```
package com.manning.sbip.ch09;

import org.springframework.boot.builder.SpringApplicationBuilder;
import org.springframework.boot.web.servlet.support.SpringBootServletInitializer;

public class ServletInitializer extends SpringBootServletInitializer {

  @Override
  protected SpringApplicationBuilder configure(SpringApplicationBuilder application) {
    return application.sources(CourseTrackerSpringBootApplication.class);
  }

}
```

In listing 9.10, we are adding the `CourseTrackerSpringBootApplication` class in `SpringApplicationBuilder`. Later on, this `SpringApplicationBuilder` is used to build an instance of `SpringApplication` instance which is run to start the Spring Boot application.

Next, let us exclude the `logback-starter` dependency from the `spring-boot-starter-web dependency` in the `pom.xml` as shown in listing 9.11:

Listing 9.11 Excluding the logback-classic dependency from spring-boot-starter-web

```
<dependency>
       <groupId>org.springframework.boot</groupId>
       <artifactId>spring-boot-starter-web</artifactId>
       <exclusions>
         <exclusion>
                 <groupId>ch.qos.logback</groupId>
                 <artifactId>logback-classic</artifactId>
         </exclusion>
       </exclusions>
</dependency>
```

We are excluding this dependency as it conflicts with the `slf4j-jboss-logmanager-1.1.0.Final.jar` of the WildFly server. Next, let the define the context root of the application to "/". Listing 9.12 shows the associated configuration for `jboss-web.xml` file located at `src\main\webapp\WEB-INF` folder:

Listing 9.12 The jboss-web.xml file

```
<?xml version="1.0" encoding="UTF-8"?>
<jboss-web>
       <context-root>/</context-root>
</jboss-web>
```

We are done with all the configurations. Let us now package the application and deploy it into the WildFly server. To package the application, you need to execute the `mvn package` command from a terminal from the directory where the application's `pom.xml` file is located. Post successful build, you'll notice that the application is packaged as a war file. You can deploy this war file on the WildFly server.

Before starting deployment, you need to ensure an instance of the WildFly application server is running. You can then open a browser window and access the http://localhost:9990 URL and you'll notice the WildFly server management console. Click on the `Deployments` menu and then the `Upload Deployment` button as shown in figure 9.2:

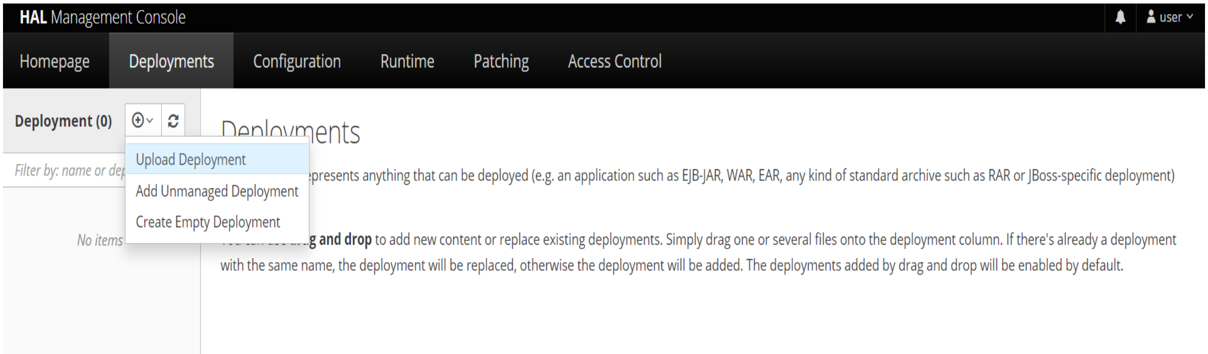


Figure 9.2 WildFly server Upload Deployment screen to upload a deployment

In the next window, upload the previously generated war file (e.g. course-tracker-app-war-1.0.0.war) from the target directory and click the `Next` button and then in the next screen click the `Finish` button. Post successful deployment, you'll notice the successful deployment message as shown in figure 9.3:

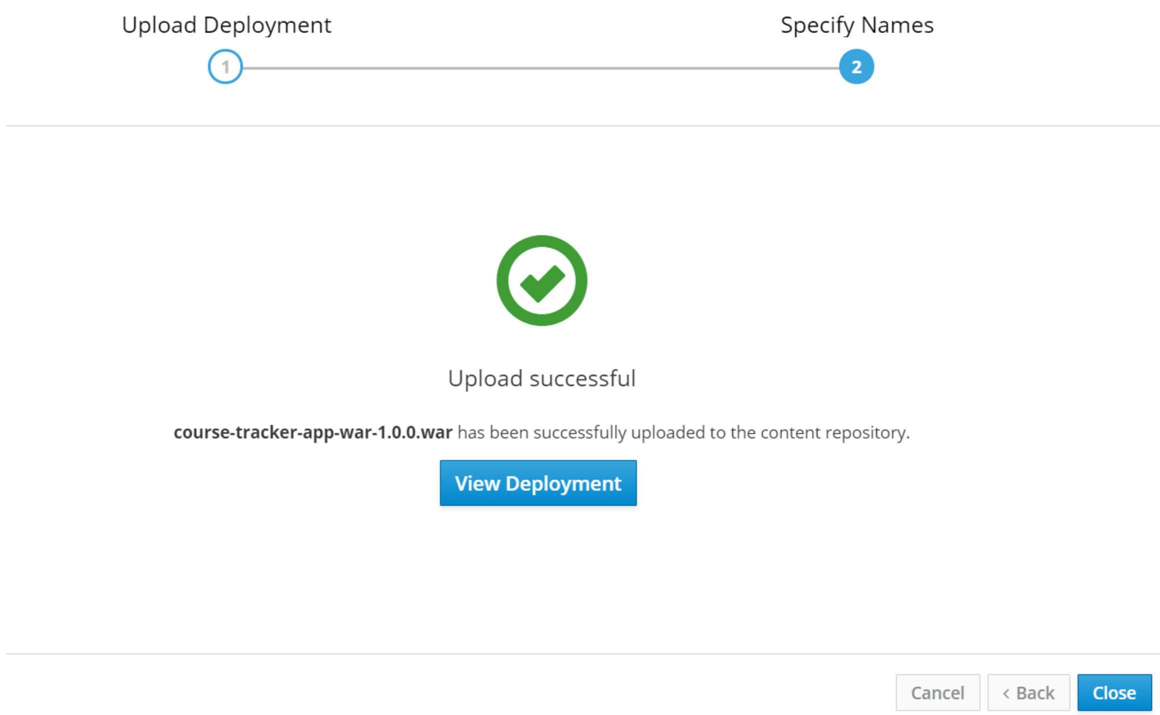


Figure 9.3 The Course Tracker war file uploaded successfully into the server. This indicates the application deployed successfully and can be accessed

Click on the `Close` button and the Course Tracker application is ready to be accessed. Let us open a browser window and access http://localhost:8080 URL. You'll notice the index page of the Course Tracker application as shown in figure 9.4:

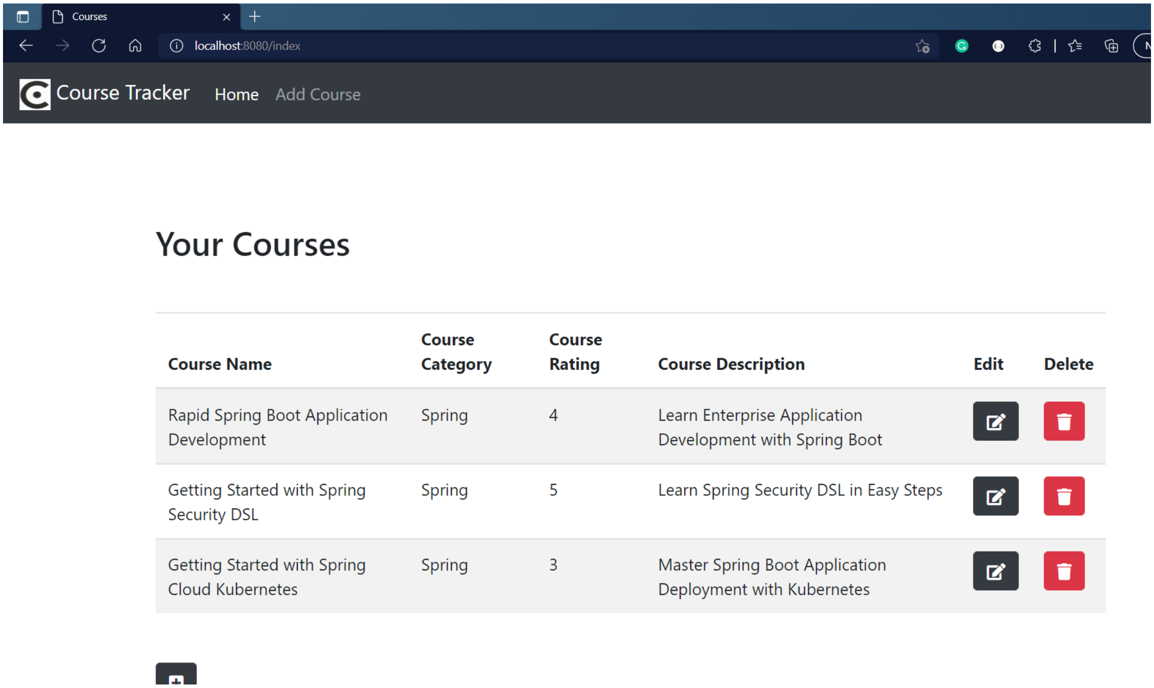


Figure 9.4 The Course Tracker application index page. This page is served by the WildFly server.

If you are performing frequent deployments and need to automate the deployment process, you can use the `wildfly-maven-plugin` Maven plugin to automatically deploy the generated war file.

Source Code

The final version of the Spring Boot project with `wildfly-maven-plugin` is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-war-mvn-plugin

To use the `wildfly-maven-plugin`, you need to add the associated configuration in the Course Tracker `pom.xml` file. Following is the summary of the changes. Listing 9.13 shows the updated `pom.xml` file:

Listing 9.13 Updated pom.xml file with `wildfly-maven-plugin` configuration

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
       https://maven.apache.org/xsd/maven-4.0.0.xsd">
       <modelVersion>4.0.0</modelVersion>
```

```
<parent>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-parent</artifactId>
  <version>2.5.3</version>
  <relativePath/>
  <!-- lookup parent from repository -->
</parent>
<groupId>com.manning.sbip.ch09</groupId>
<artifactId>course-tracker-app-war-mvn-plugin</artifactId>
<version>1.0.0</version>
<packaging>war</packaging>
<name>course-tracker-app-war-mvn-plugin</name>
<description>Spring Boot application for Chapter 09</description>
<properties>
  <java.version>11</java.version>
 # To deploy the Spring Boot application war file through the plugin, you need to
configure the server username, password and the war file name that needs to be
deployed. We are refering these properties from settings.xml file. We've provided
relevant settings.xml in next listing

  <wildfly.deploy.user>${ct.deploy.user}</wildfly.deploy.user>
  <wildfly.deploy.pass>${ct.deploy.pass}</wildfly.deploy.pass>
  <plugin.war.warName>${project.build.finalName}</plugin.war.warName>
</properties>
<dependencies>
  <dependency>
          <groupId>org.springframework.boot</groupId>
          <artifactId>spring-boot-starter-web</artifactId>
          <exclusions>
                  <exclusion>
                          <groupId>ch.qos.logback</groupId>
                          <artifactId>logback-classic</artifactId>
                  </exclusion>
          </exclusions>
  </dependency>
  <dependency>
          <groupId>org.springframework.boot</groupId>
          <artifactId>spring-boot-starter-tomcat</artifactId>
          <scope>provided</scope>
  </dependency>
  <dependency>
          <groupId>org.springframework.boot</groupId>
          <artifactId>spring-boot-starter-data-jpa</artifactId>
  </dependency>
  <dependency>
          <groupId>com.h2database</groupId>
          <artifactId>h2</artifactId>
          <scope>runtime</scope>
  </dependency>
  <dependency>
          <groupId>org.projectlombok</groupId>
          <artifactId>lombok</artifactId>
  </dependency>
  <dependency>
          <groupId>org.springframework.boot</groupId>
          <artifactId>spring-boot-starter-validation</artifactId>
  </dependency>
  <dependency>
          <groupId>org.springframework.boot</groupId>
```

```
            <artifactId>spring-boot-starter-thymeleaf</artifactId>
  </dependency>
  <dependency>
            <groupId>org.webjars</groupId>
            <artifactId>bootstrap</artifactId>
            <version>4.4.1</version>
  </dependency>
  <dependency>
            <groupId>org.webjars</groupId>
            <artifactId>jquery</artifactId>
            <version>3.4.1</version>
  </dependency>
  <dependency>
            <groupId>org.webjars</groupId>
            <artifactId>webjars-locator</artifactId>
            <version>0.38</version>
  </dependency>
  <dependency>
            <groupId>org.springframework.boot</groupId>
            <artifactId>spring-boot-starter-test</artifactId>
            <scope>test</scope>
            <exclusions>
                    <exclusion>
                            <groupId>org.junit.vintage</groupId>
                            <artifactId>junit-vintage-engine</artifactId>
                    </exclusion>
            </exclusions>
  </dependency>
</dependencies>
<build>
  <plugins>
            <plugin>
                    <groupId>org.springframework.boot</groupId>
                    <artifactId>spring-boot-maven-plugin</artifactId>
            </plugin>
            <plugin>
                    <groupId>org.wildfly.plugins</groupId>
                    <artifactId>wildfly-maven-plugin</artifactId>
                    <version>2.1.0.Beta1</version>
                    <configuration>
                            <hostname>localhost</hostname>
                            <port>9990</port>
                        # Properties defined in the properties section of
this pom.xml
                            <username>${wildfly.deploy.user}</username>
                            <password>${wildfly.deploy.pass}</password>

  <name>${project.build.finalName}.${project.packaging}</name>
                    </configuration>
                    <executions>
                            <execution>
                                    <id>undeploy</id>
                                    <phase>clean</phase>
                                    <goals>
                                            <goal>undeploy</goal>
                                    </goals>
                                    <configuration>

  <ignoreMissingDeployment>true</ignoreMissingDeployment>
```

```
                                                <configuration>
                                        </execution>
                                        <execution>
                                                <id>deploy</id>
                                                <phase>install</phase>
                                                <goals>
                                                        <goal>deploy</goal>
                                                </goals>
                                        </execution>
                                </executions>
                        </plugin>
        </plugins>
      </build>
</project>
```

To use the `wildfly-maven-plugin`, you've defined the server configuration such as host, port, username and password. Besides, we've defined two execution configurations – one to perform the deployment in the Maven `install` phase, and one is to perform undeployment in the Maven `clean` phase. For security reasons, we've not configured the username and password in the pom.xml file. We'are referring those from the Maven `settings.xml` file. Listing 9.14 shows the Maven `settings.xml` profile configuration:

Listing 9.14 Maven settings.xml profile configuration inside profiles section

```
...
<profile>
      <id>course-tracker-prod</id>
          <activation>
            <activeByDefault>true</activeByDefault>
          </activation>
          <properties>
            <ct.deploy.user>user</ct.deploy.user>
            <ct.deploy.pass>password</ct.deploy.pass>
          </properties>
    </profile>
...
```

We refer to the properties `ct.deploy.user` and `ct.deploy.pass` in the `pom.xml` properties configuration in the listing 9.13 so that the username and password could be used by `wildfly-maven-plugin` to perform the deploy and undeploy operations.

Open a terminal window and browse to the `course-tracker-app-war-mvn-plugin` application's `pom.xml` directory and execute the `mvn install` command. You'll notice that the application deployed successfully. Listing 9.15 shows the `mvn install` command's output:

Listing 9.15 The mvn install command output for successful deployment

```
...
...
[INFO] --- spring-boot-maven-plugin:2.5.3:repackage (repackage) @ course-tracker-app-war-
       mvn-plugin ---
[INFO] Replacing main artifact with repackaged archive
[INFO]
[INFO] <<< wildfly-maven-plugin:2.1.0.Beta1:deploy (deploy) < package @ course-tracker-app-
       war-mvn-plugin <<<
[INFO]
[INFO]
[INFO] --- wildfly-maven-plugin:2.1.0.Beta1:deploy (deploy) @ course-tracker-app-war-mvn-
       plugin ---
[INFO] JBoss Threads version 2.3.3.Final
[INFO] JBoss Remoting version 5.0.12.Final
[INFO] XNIO version 3.7.2.Final
[INFO] XNIO NIO Implementation Version 3.7.2.Final
[INFO] ELY00001: WildFly Elytron version 1.9.1.Final
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
```

You can now open a browser window and access the http://localhost:8080/ URL to access the Course Tracker application. You'll notice the Course Tracker application index page. If you need to undeploy the application, you can execute the `mvn clean` command and the application will be undeployed as shown in Listing 9.16:

Listing 9.16 mvn clean to undeploy the deployed war file

```
$course-tracker-app\target>mvn clean
[INFO] Scanning for projects...
[INFO]
[INFO] ------< com.manning.sbip.ch09:course-tracker-app-war-mvn-plugin >-------
[INFO] Building course-tracker-app-war-mvn-plugin 1.0.0
[INFO] --------------------------------[ war ]---------------------------------
[INFO]
[INFO] --- maven-clean-plugin:3.1.0:clean (default-clean) @ course-tracker-app-war-m
[INFO] Deleting C:\sbip\repo\ch09\course-tracker-app-war-mvn-plugin\target
[INFO]
[INFO] --- wildfly-maven-plugin:2.1.0.Beta1:undeploy (undeploy) @ course-tracker-app
[INFO] JBoss Threads version 2.3.3.Final
[INFO] JBoss Remoting version 5.0.12.Final
[INFO] XNIO version 3.7.2.Final
[INFO] XNIO NIO Implementation Version 3.7.2.Final
[INFO] ELY00001: WildFly Elytron version 1.9.1.Final
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
```

Discussion

In this technique, you've learned to deploy a Spring Boot application in an application server. We've discussed two approaches to achieve this. In the first approach, you build the war file through the `mvn install` command and then manually deploy the war file through the application server's web interface. In the second approach, you've used the `wildfly-maven-plugin` to automatically deploy the generated war file in the application server.

Now that you've explored both approaches, you may ask which approach is better? I would recommend the `wildfly-maven-plugin` based approach as this enables a more automated way of deployment and requires less manual intervention.

9.3 Deploying Spring Boot applications in Cloud Foundry

In the previous sections, we've discussed two traditional approaches with JAR and WAR files to package and deploy a Spring Boot application. In this section, we'll look into an alternative application deployment approach through Cloud Foundry.

Note

Cloud Foundry provides a much straightforward and easier model to build, test and deploy applications. As you'll notice shortly, Cloud Foundry lets you push your source code to the Cloud Foundry server and perform the build and deployment from the source code. Finally, it makes the application available to the end-users.

Cloud Foundry is a large topic and offers several features. It is beyond the scope of this text to provide in-depth coverage of this. Refer to the Cloud Foundry documentation available at https://docs.cloudfoundry.org/.

These days cloud platforms let us deploy applications and make them available across the globe in a short period. Besides, the cloud platforms also let us scale the application on demand without worrying much about infrastructure and its scalability. Figure 9.5 shows various layers of technology stacks used in an application:

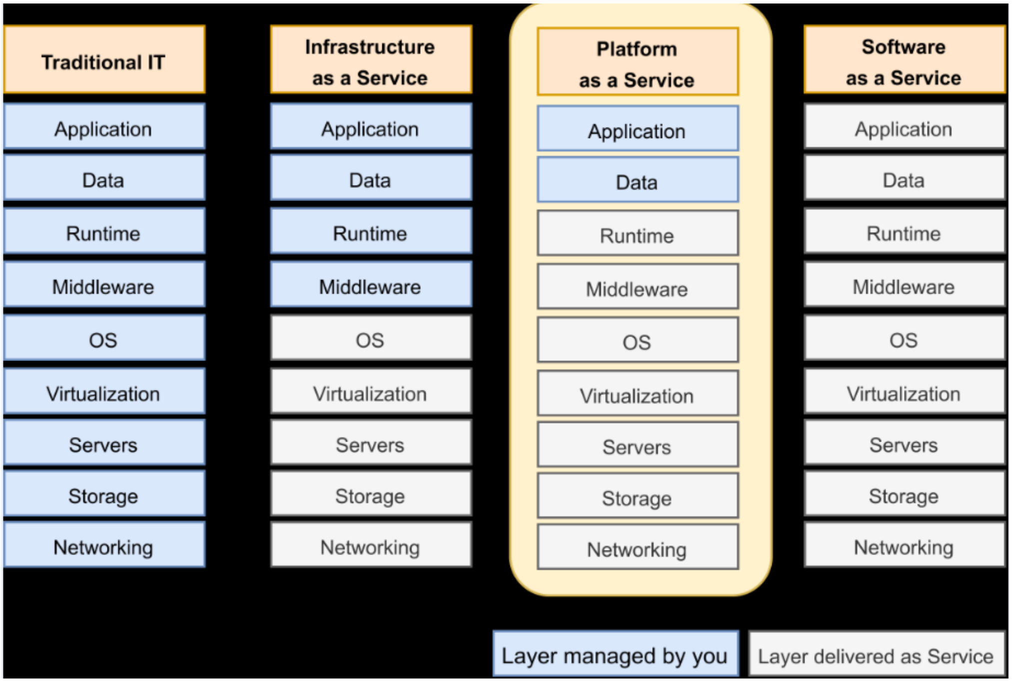


Figure 9.5 Layers of technology stack required by an application. In traditional IT, all layers of infrastructure are managed by you. In the IaaS model, the core infrastructure is delivered as a Service. In the PaaS model, only the application and data need to be managed by you and the rest of all layers are delivered as Service. In the SaaS model, all layers are delivered as Service. We've highlighted the PaaS model as Cloud Foundry belongs to this model

Cloud Foundry belongs to the Platform-as-a-Service model where only the Data and Application is managed by you, and all remaining layers are managed by the Cloud Foundry. But what is Cloud Foundry in the first place? It is an open-source cloud application platform that lets you select the cloud platform you want to use, offers several developer frameworks, and other application services. One of the major benefits of Cloud Foundry over the traditional deployments is that it makes application building, testing, deployment and scaling faster and easier.

In the next technique, let us explore how to deploy a Spring Boot application in Cloud Foundry.

TECHNIQUE DEPLOY A SPRING BOOT APPLICATION TO CLOUD FOUNDRY

Problem

Your Spring Boot application is currently running as a standalone JAR file in a Unix server. You need to deploy it to a cloud platform through Cloud Foundry

Solution

In this technique, we'll explore how to deploy a Spring Boot application in a Cloud Foundry cloud platform. To deploy your application in Cloud Foundry, you need a Cloud Foundry instance. You can either run Cloud Foundry yourself, use a company provided Cloud Foundry instance or use a hosted solution. There are several hosted solutions available such as anynines (https://paas.anynines.com/), SAP (https://developers.sap.com/tutorials/hcp-create-trial-account.html) which provides a trial version of the Cloud Foundry instance. In this technique, we'll use the SAP Cloud Foundry instance. You can browse the SAP link and follow the steps to set up your trial account.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-cf

Once you are done with the Cloud Foundry instance set up, you'll need to install the Cloud Foundry command-line interface (CLI). You'll use this CLI tool to interact with the Cloud Foundry instance. The CLI runs on a terminal window and makes REST calls to the Cloud Foundry API. Browse to the https://github.com/cloudfoundry/cli#downloads link to install CLI on your computer. Once the installation is completed successfully, run the `cf version` command from your terminal and it should return the installed Cloud Foundry CLI version.

The next step is to log in to the Cloud Foundry instance and you can do that using the `cf login` command. Listing 9.17 shows the complete login command:

Listing 9.17 Cloud Foundry Login

```
cf login -a <CLOUDFOUNDRY_API_ENDPOINT> -u <USERNAME>
```

The `CLOUDFOUNDRY_API_ENDPOINT` is the Cloud Foundry instance URL. If you are using SAP, you'll find this on the SAP account page. The `USERNAME` is your login id. For SAP, this is the email id of the SAP account you just created.

Invoking the command of listing 9.17 with the API endpoint and the username will prompt you to enter the password. Enter your SAP account login password. Listing 9.18 shows a sample command and the associated output:

Listing 9.18 Login to Cloud Foundry

```
cf login -a https://api.cf.eu10.hana.ondemand.com/ -u ****@gmail.com
API endpoint: https://api.cf.eu10.hana.ondemand.com/

Password:

Authenticating...
OK

Targeted org 6****986trial.

Targeted space dev.

API endpoint:   https://api.cf.eu10.hana.ondemand.com
API version:    3.102.0
user:           ****@gmail.com
org:            6****86trial
space:          dev
```

Next, let us build the Course Tracker Spring Boot application using the `mvn clean install` command. We'll use the generated jar file to push to the Cloud Foundry instance. Instead of pushing the raw jar file, we'll define a `manifest.yml` file in the application root directory so that Cloud Foundry CLI can read it and perform the deployment. Listing 9.19 shows the `manifest.yml` file:

Listing 9.19 The manifest.yml file to deploy into Cloud Foundry

```
applications:
- name: course-tracker-app-cf
  instances: 1
  memory: 1024M
  path: target/course-tracker-app-cf-1.0.0.jar
  random-route: true
  buildpacks:
  - java_buildpack
```

This is a relatively simple configuration file with bare minimum details. We've specified the application name, the number of instances requires, the memory that needs to be allocated, the application executable path. The route details indicate Cloud Foundry to assign a random route for the deployed application. The buildpacks configuration let Cloud Foundry select a java build pack to run the application.

You can now run the `cf push` command (from any OS user) to start the deployment as shown in Listing 9.20:

Listing 9.20 Cloud Foundry push command to start deployment

```
cf push
```

The command takes a while to upload the artifacts and the deployment begins. Once the command returns, you can execute the `cf apps` command to find the running application and the associated URL. Listing 9.21 shows a sample output of the `cf apps` command:

Listing 9.21 Sample output of the cf apps command

```
> cf apps
Getting apps in org 6****986trial / space dev as ****@gmail.com...

name                    requested state   processes           routes
course-tracker-app-cf   started           web:1/1, task:0/0   course-tracker-app-cf-active-
       genet-qh.cfapps.eu10.hana.ondemand.com
```

In the above example, the `course-tracker-app-cf-active-genet-qh.cfapps.eu10.hana.ondemand.com` is the application route (URL). In your case, you might notice a different routes name. You can copy the routes and access the URL in a browser window. You'll notice that you are redirected to the Course Tracker application index page.

Discussion

In this technique, we've demonstrated how to deploy your Spring Boot application to cloud Foundry. To keep things simple, we've used the Course Tracker application with an in-memory database. In a production application, you'll also have other application components such as database, messaging, caching etc.

Based on the Cloud Foundry service provider, you can use the offerings from the provider. To find the list of offerings, you can execute the `cf marketplace` command and it will return the available services and their details. Based on the need, you can enable one or more services. To know more about a service offering, you can execute the `cf marketplace -e <SERVICE_OFFERING>` command. Replace the `SERVICE_OFFERING` placeholder with the actual service name.

To create a new service, you can use the `cf create-service <SERVICE> <SERVICE_PLAN> <SERVICE_INSTANCE>` command. Further, you can find the list of services by invoking the `cf services` command. You can bind service with your application using the `cf bind-service <APP_NAME> <SERVICE_INSTANCE>` command.

Lastly, once you have the services defined, you may need to access the service-specific environment variables. For instance, if you've created a database, you need the database URL, username, password etc to connect and access it. Spring provides the `CloudFoundryVcapEnvironentPostProcessor` (https://docs.spring.io/spring-boot/docs/current/api/org/springframework/boot/cloud/CloudFoundryVcapEnvironmentPostProcessor.html) class that takes all the Cloud Foundry environment variables and provides in form of Spring `Environment`. If you have configured Spring `spring-boot-starter-actuator` and enabled the env actuator endpoint, you'll find the Cloud Foundry properties through `/actuator/env` endpoint. You can also refer to the `java-cfenv` library (https://github.com/pivotal-cf/java-cfenv) on how to use Cloud Foundry environment variables.

9.4 Deploying Spring Boot applications in Heroku

In the previous section, you've seen how to deploy an application in Cloud Foundry. In this section, we'll discuss deploying a Spring Boot application in Heroku (https://www.heroku.com/). Heroku is another PaaS solution that lets you build, run, and execute applications in the cloud. It can run applications written in Ruby, Node.js, Java, Python, Clojure, Scala, Go and PHP.

Heroku takes the application source code along with the dependencies the application requires and prepares an artifact that can be executed. For instance, a Spring Boot application takes the Spring Boot application source code and the `pom.xml` for the required dependencies. Heroku uses Git distributed version control system for deploying the application. Lastly, Heroku uses Dynos (https://devcenter.heroku.com/articles/dynos) to execute the applications. Dynos are lightweight Linux containers in which Heroku runs the application.

In the next technique, let us explore how to deploy a Spring Boot application on Heroku.

TECHNIQUE DEPLOY A SPRING BOOT APPLICATION IN HEROKU

Problem

You need to deploy the application in the Heroku cloud platform

Solution

Heroku is a PaaS solution that lets you deploy a Spring Boot application in the Heroku cloud platform with a few steps. To demonstrate this, we'll use the previously used Course Tracker Spring Boot application to deploy into Heroku.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-heroku

To begin with, you need to create a user account in Heroku. You can browse to the https://signup.heroku.com/ URL and sign up for a new account. Next, you need to install Heroku Command Line Interface (CLI) tool on your machine. This CLI provides a set of commands to interact with the Heroku cloud platform and also lets you deploy the application. Refer to https://devcenter.heroku.com/articles/heroku-cli URL on how to install the CLI in your machine. You are now ready to start deploying your application.

First, log in to Heroku from your terminal so that you can execute the next set of commands to proceed with your deployment. Open a terminal and type `heroku login`. This command provides an option to authenticate yourself through a browser-based login. Once authenticated, you will find output similar to listing 9.22:

Listing 9.22 Login to Heroku

```
heroku login
heroku: Press any key to open up the browser to login or q to exit:
Opening browser to https://cli-auth.heroku.com/auth/cli/browser/d4da08df-3725-44b6-bf28-
       c0a78fbe54e3?requestor=SFMyNTY.g2gDbQAAAA8xMDMuMjE1LjIyNC4xNTFuBgDw-
       iCkewFiAAFRgA.6fS4ju_OBxvr9_YQNkSn5Z7UK68CQNULUhh9VEzCVxQ
Logging in... done
Logged in as *****@gmail.com
```

Next, as mentioned earlier Heroku uses Git distributed version control system for deployment. Thus, we need to create a Git repository for the Course Tracker application. Browse to the root directory of the Course Tracker application and execute the commands as shown in Listing 9.23:

Listing 9.23 Creating a Git repository for the Course Tracker application

```
# Initializes an empty local git repository
git init
# Add all the files to the repository
git add .
# Commits the changes in the local git repository
git commit -am "Course Tracker first commit"
```

Next, to deploy the application in Heroku, we need to provision a new Heroku application. We will do that by executing the `heroku create` command as shown in Listing 9.24:

Listing 9.24 Provisioning the Heroku application

```
heroku create
Creating app... done, ⬢ secure-journey-03985
https://secure-journey-03985.herokuapp.com/ | https://git.heroku.com/secure-journey-
       03985.git
```

The command in the listing also creates a remote repository called heroku and adds its reference in your local git repo. Heroku generates a random name (in this case secure-journey-03985) for your Spring Boot application.

In the Course Tracker application, to keep the example simple and easy to execute, we've used the H2 in-memory database. However, it is seldom the case in a production application. To demonstrate how to use a mainstream database, we've used PostgreSQL in the application. Refer to the application `pom.xml` file for related configuration. Before we proceed with the deployment, let us attach a PostgreSQL database to the application. Execute `heroku addons:create heroku-postgresql` command from your terminal to create a PostgreSQL database add-on. Once the add-on is created, Heroku will automatically populate the environment variables `SPRING_DATASOURCE_URL`, `SPRING_DATASOURCE_USERNAME`, and `SPRING_DATASOURCE_PASSWORD`. These environment variables allow the Course Tracker application to connect to the database. Refer to the `application.properties` file of the Course Tracker application.

Next, let us deploy the code by pushing the changes to the remote Heroku master branch. Listing 9.25 shows this:

Listing 9.25 Deploying the Spring Boot application in Heroku

```
c:\sbip\repo\ch09\course-tracker-app-heroku>git push heroku master
Enumerating objects: 41, done.
Counting objects: 100% (41/41), done.
Delta compression using up to 8 threads
Compressing objects: 100% (30/30), done.
Writing objects: 100% (41/41), 64.32 KiB | 5.85 MiB/s, done.
Total 41 (delta 3), reused 0 (delta 0)
remote: Compressing source files... done.
remote: Building source:
remote:
remote: -----> Building on the Heroku-20 stack
remote: -----> Determining which buildpack to use for this app
remote: -----> Java app detected
remote: -----> Installing JDK 11... done
remote: -----> Executing Maven
remote:        $ ./mvnw -DskipTests clean dependency:list install
…
…
remote:        https://secure-journey-03985.herokuapp.com/ deployed to Heroku
remote:
remote: Verifying deploys... done.
To https://git.heroku.com/secure-journey-03985.git
 * [new branch]      master -> master
```

In listing 9.25, you can notice that Heroku uses the Maven wrapper (`.mvnw`) to deploy the application. Once the application is successfully built and deployed, it is accessible through https://secure-journey-03985.herokuapp.com URL. For you, this URL could be different as Heroku uses a random name for the application. You can also run the `heroku open` command to automatically open the application URL in a browser window. You can check the Spring Boot startup logs by accessing the `heroku logs` command.

Discussion

In this technique, you've seen to deploy a Spring Boot application in the Heroku cloud platform. As you've noticed, it is extremely easy to build and deploy a Spring Boot application in Heroku. By using a few commands, you've got a running application with an HTTPS URL from your source code. The complexity of building, packaging, and deploying are taken care of by the platform. To make things further simplified, for Maven projects, Heroku provides the `heroku-maven-plugin` (https://github.com/heroku/heroku-maven-plugin). This plugin lets you deploy the application without using a Git repository. You can find a detailed discussion on how to use the plugin at https://devcenter.heroku.com/articles/deploying-java-applications-with-the-heroku-maven-plugin.

You can refer to the Heroku documentation available at https://devcenter.heroku.com/ for a detailed discussion on various offerings and configurations.

9.5 Running Spring Boot applications as Docker Container

In previous sections, we've learned a few deployment techniques. The traditional deployments where you package and deploy the application yourself into some server. The

Cloud Foundry based deployment where you push the executable to the platform and it takes care of the deployment. Lastly, we've seen the Heroku cloud platform in which you provide your source code to the platform, and it does the build, deployment, and execution.

A container image is a lightweight, standalone, executable software package that includes everything the application requires to run itself. These include application components, runtime, system tools, settings, and libraries. A container image turns into a Container at its runtime as shown in figure 9.7.

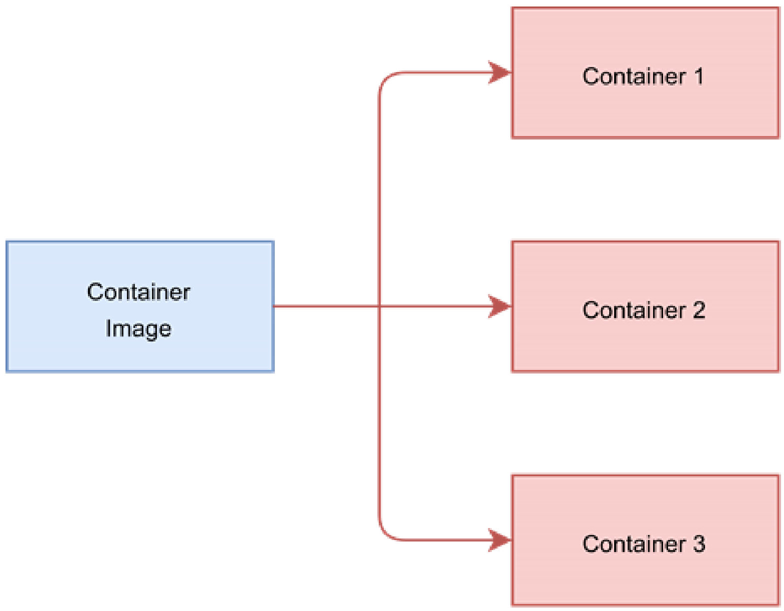


Figure 9.6 A container image can be used to create one or more containers.

The various components to run a container is shown in figure 9.7:

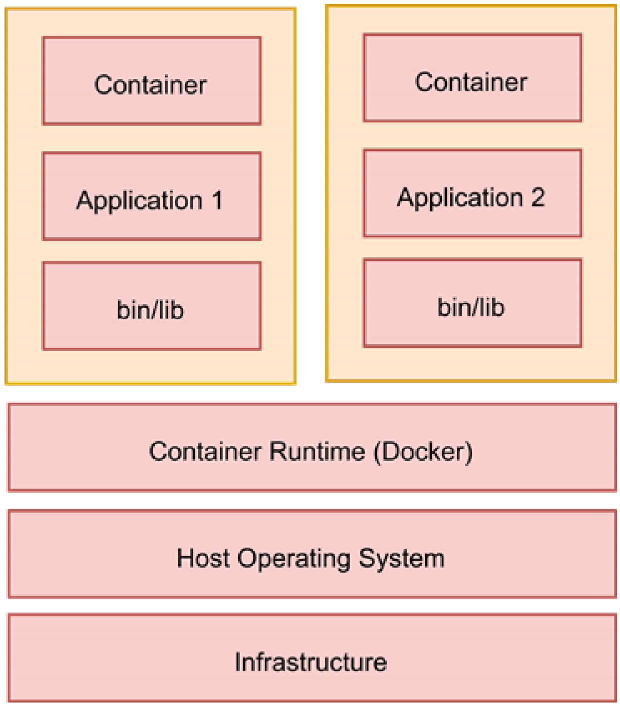


Figure 9.7 Various components to run a container. The infrastructure is at the bottom and host operating systems run on top of it. A container runtime environment such as Docker runs on top of the host operating systems. The containers are run by the container runtime.

One of the most important reasons to use a container in the first place is due to its promise of reliable execution from one environment to another environment. It is a relatively common occurrence that in a typical infrastructure, applications may behave differently. For instance, we often found that applications working perfectly in the Dev environment may have some issues while running in UAT. Containers remove this problem as it is a standalone package that contains everything the application requires to run. Thus, if the same image is used to run the application in Dev or UAT, it is expected to run uniformly.

Docker is the most popular and dominant container technology platform and can be used to deal with container and container images. Docker is so popular that it is almost synonymous with container and container technology. However, there are other container platforms other than Docker such as rkt (pronounced 'rocket') from RedHat, LXD (pronounced "lexdi"). In this section, we'll focus on Docker and see how to create a Docker image and run the image as a container.

TECHNIQUE CREATE A CONTAINER IMAGE AND RUN A SPRING BOOT APPLICATION AS A CONTAINER

Problem

You are running the Course Tracker application in your Unix server through the WildFly application server. However, you've heard a lot of good things about containers and want to run the application as a container.

Solution

To proceed with the next technique, you need to install and configure Docker. You can refer to Docker documentation available at https://www.docker.com/get-started for a detailed discussion on how to install and configure Docker. Besides, you can also refer to Docker in Practice (https://www.manning.com/books/docker-in-practice-second-edition) book from Manning Publications for an in-depth understanding of Docker.

In this section, we'll explore the following approaches to *dockerized* the Course Tracker application:

1. Use `Dockerfile` to create the container image and then run the image to create the container
2. Use Spring Boot built-in containerization (Requires Spring Boot version >=2.3). This uses the Paketo buildpacks (https://paketo.io/) to build the image

In these approaches, we'll use H2 in-memory database with the application to keep the examples simple.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-dockerfile

Let us begin with the first approach. We'll use a `Dockerfile` to create the Docker image for the Course Tracker application. Before we define the Dockerfile, let us execute the `mvn clean install` command to generate the JAR file of the Course Tracker application.

Let us now define the `Dockerfile` for the Course Tracker application. A `Dockerfile` is a text file that contains all the commands needed to assemble and create the image. You can refer to https://docs.docker.com/engine/reference/builder/ for further details on Dockerfile. Listing 9.26 shows the sample `Dockerfile` we've created for the Course Tracker application. This file is located under the root directory of the application:

Listing 9.26 Dockerfile to create the docker image for Course Tracker

```
FROM adoptopenjdk:11-jre-hotspot
ADD target/*.jar application.jar
ENTRYPOINT ["java", "-jar","application.jar"]
EXPOSE 8080
```

In listing 9.23, the Dockerfile contains the following:

- FROM: We are using `adoptopenjdk:11-jre-hotspot` as the base image for our image. A base image is an image upon which your application Docker image is built

- ADD: We then add the jars from the target directory as `application.jar` in the image
- ENTRYPOINT: This is the entry point when you run the image
- EXPOSE: We expose HTTP port 8080 in the container

We can now build an image for the Course Tracker application.

Next, let us execute the command as shown in Listing 9.27 to create the image. You need to execute the command from the location where the `Dockerfile` is located.

Listing 9.27 Building docker image for Course Tracker application

```
docker build --tag course-tracker:v1 .
```

In listing 9.27, note the period (.) at the end of the command. This indicates that the `Dockerfile` is available in the current directory. Besides, we tag the image with the name `course-tracker:v1` to refer to the image while creating a container from the image. Once you execute the command, it will take a while to build the image. Once the image is successfully built, you can list the image using the command as shown in Listing 9.28:

Listing 9.28 Listing the docker images

```
docker image ls
```

You can now run the image and a Docker container will be created. Listing 9.29 shows the command to run the image:

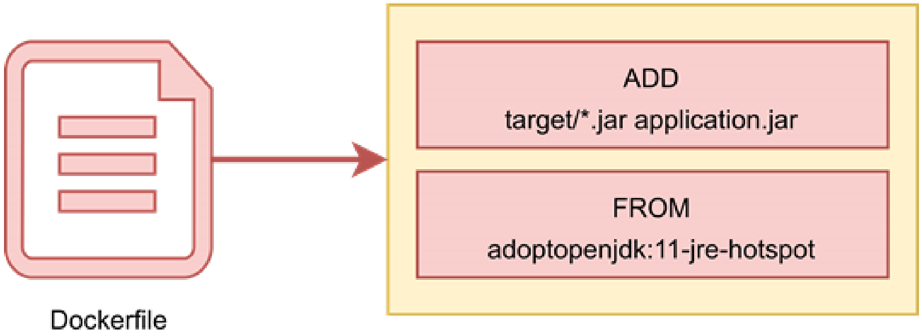
Listing 9.29 Docker run command to run the course-tracker image

```
docker run -p 8080:8080 course-tracker:v1
```

We have used the `docker run` command to run the container image. Also, we've used a port mapping of local machine HTTP port 8080 to the container's HTTP port 8080. This ensures that the HTTP request to the port 8080 in the local machine is forwarded to the container's port 8080.

Once the command runs successfully, you'll notice the console log of the Course Tracker application. Open a browser window and access the http://localhost:8080 URL, you'll be redirected to the Course Tracker index page.

Let us now briefly discuss the container image structure that we've created in listing 9.24. Your Docker container image consists of multiple layers. If you recall we've started with the base image (adoptopenjdk:11-jre-hotspot). In our `Dockerfile`, we've performed additional activities such as adding the Jar file from the target location to the image. This has created an additional layer on top of the base image. Figure 9.7 shows the notion of layers in a Docker image.



If you are interested to see the various layers of the Docker image, you can use the Dive tool (https://github.com/wagoodman/dive) to view the various layers of the created image. To view the layers, install Dive and execute `dive course-tracker:latest`. Figure 9.9 shows the layers:

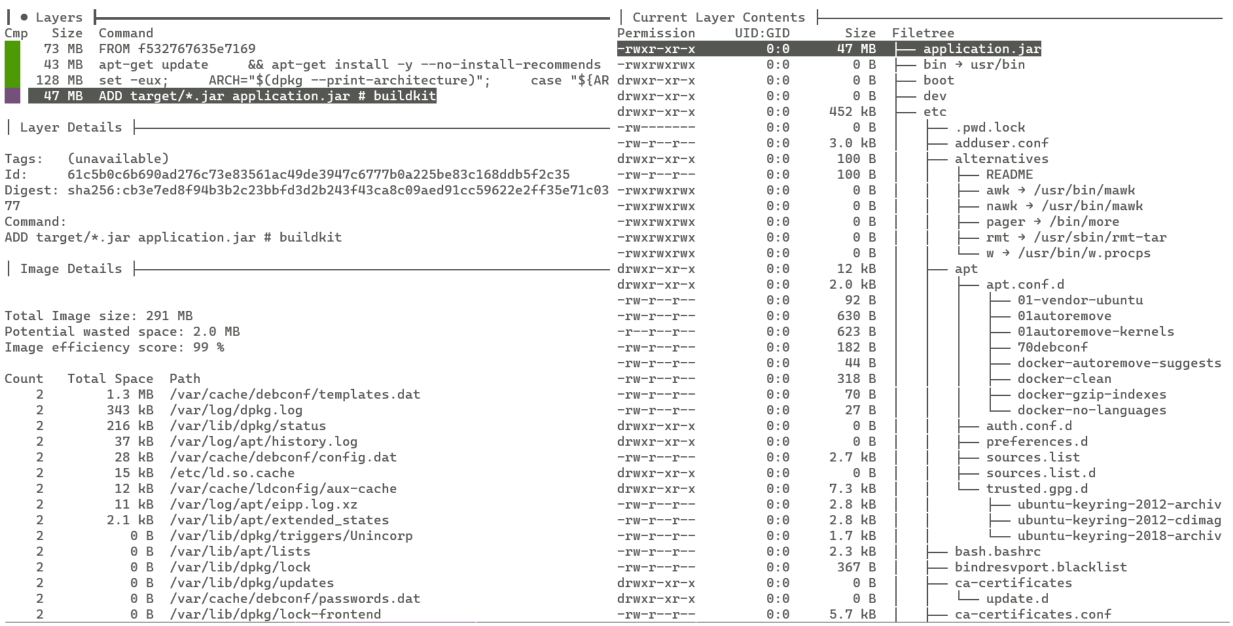


Figure 9.9 Using dive tool to view the layers inside a Docker image. In the top-left corner is the list of layers. The first few layers are from the OpenJDK, the last layer is formed by adding the jars from the target directory.

In the above Dockerfile, we've added the fat jar inside the image. However, we could write a better Dockerfile for Spring Boot applications. Instead of adding the complete jar, we could add the layers from the generated JAR file. Recall from section 9.1 that Spring Boot provides a means to layer the JAR file through the layers.xml file. Besides, it provides the jarmode option to view and extract the layers. Let us add the JAR layers in the Docker image instead of adding the complete JAR file. Listing 9.30 shows the updated Dockerfile:

Listing 9.30 Dockerfile to create a better docker image

```
FROM adoptopenjdk:11-jre-hotspot as builder
WORKDIR application
ARG JAR_FILE=target/*.jar
COPY ${JAR_FILE} application.jar
RUN java -Djarmode=layertools -jar application.jar extract

FROM adoptopenjdk:11-jre-hotspot
WORKDIR application
COPY --from=builder application/dependencies/ ./
COPY --from=builder application/spring-boot-loader/ ./
COPY --from=builder application/snapshot-dependencies/ ./
COPY --from=builder application/application/ ./
ENTRYPOINT ["java", "org.springframework.boot.loader.JarLauncher"]
```

Listing 9.30 contains a multi-stage Dockerfile. The builder stage (the first part of the Dockerfile) extracts the directories that are used later. Each of the COPY commands relates to the layers extracted by jarmode. Finally, we've used the org.springframework.boot.loader.JarLauncher is the entry point for the application. You can build the image using the same command as shown in listing 9.27. Figure 9.10 shows the image layers:

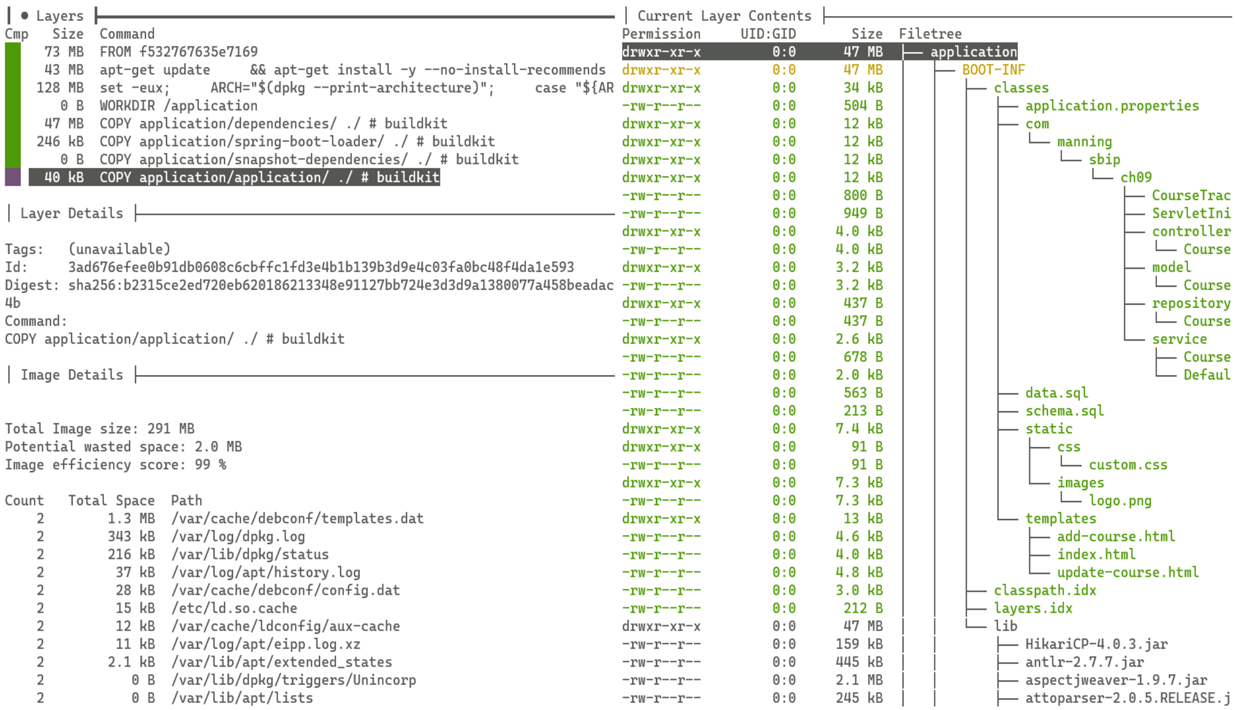


Figure 9.10 Layers of the course-tracker:v2 docker image. Instead of the fat jar, the directories are added as layers.

Now that you've seen to create an image using `Dockerfile`, let us move on to building the Docker image using Spring Boot's built-in approach. Previously, you've noticed the deployment using Heroku or Cloud Foundry. With Heroku, you just provided the source code and the platform does the rest to build the code, add a runtime and make the application available for the end-users. Similarly, Spring Boot provides support to directly build a Docker image from the source code through Spring Boot Maven (and also Gradle) plugins. Spring Boot uses Cloud Native Buildpacks (https://buildpacks.io/) to achieve this.

Buildpacks are the part of the platform (e.g. Cloud Foundry) that takes the application code and converts it into something that the platform can run. For instance, in the Cloud Foundry example, its Java buildpack noticed that you're pushing a .jar file and it automatically adds a relevant JRE. The Buildpacks lets us build a Docker compatible image that we can run anywhere. Let us see this in action. You can run the command as shown in listing 9.31 to generate the image:

Listing 9.31 Building a Docker image with Spring Boot Maven Plugin

```
mvn spring-boot:build-image -Dspring-boot.build-image.imageName=course-tracker:v3
```

The command in listing 9.31 builds a Docker image with the name `course-tracker:v3`. By default, Spring Boot uses the `artifactId:version` to build the image. We've used the `-Dspring-boot.build-image.imageName=course-tracker:v3` to customize the image name to `course-tracker:v3`. You can run the image in the same manner you've executed the earlier images.

Discussion

In this technique, we've learned how to build a Docker image from a Spring Boot application and run the image as a Docker container. Containers provide excellent portability support as the container images can be run anywhere reliably. In this section, we've executed the Docker images manually using the `docker run` command. Although this approach works well, it does not scale. Imagine if you need to run hundreds of containers for your applications. It becomes quite tedious to run, update, manage them. For instance, in a production system, if a container gets terminated for any reason, you need to ensure that you can bring up a new container. It will be excellent if there is a tool that could orchestrate the container management process. Thankfully, Kubernetes is there to address these concerns. Let's discuss Kubernetes in the next section.

9.6 Deploying Spring Boot applications in Kubernetes Cluster

These days there is a trend to use containers to package and deploy applications. Specifically, containers are an excellent choice to package microservices along with their dependencies and configurations. Based on the demand for microservices, you can increase the number of containers. However, as the applications grow into multiple containers and span across multiple servers, it becomes quite difficult to manage them.

Kubernetes provides an open-source API to manage how and where to run the containers. It orchestrates a set of virtual machines known as a Kubernetes cluster in which it schedules and runs the containers. In Kubernetes, containers are packed inside a Pod which is the fundamental operational unit.

Note

In this section, we'll use a single-node Kubernetes cluster created in the local machine and focus on how to deploy a Spring Boot application into a Kubernetes cluster. If you are not familiar with Kubernetes, you can refer to Kubernetes documentation at https://kubernetes.io/ for an understanding and installation.

TECHNIQUE DEPLOY A SPRING BOOT APPLICATION IN A KUBERNETES CLUSTER

Problem

You've explored containerization and are fascinated by the way it works. However, you understand that manually managing containers for a large application is a tedious task as there will be so many containers. You heard that Kubernetes is a container orchestration tool that can orchestrate the containers automatically and want to try it out.

Solution

In the previous technique, we've created a Docker container image for the Spring Boot application. We'll use the same `course-tracker:v3` image in this technique. However, before proceeding with Kubernetes deployment let us tag the image. Listing 9.32 shows the command to tag the image:

Listing 9.32 Docker tag command to tag the image

```
docker tag course-tracker:v3 musibs/course-tracker
```

In listing 9.32, we've used the `docker tag` command to tag the image. The first part of the docker tag (`course-tracker:v3`) command specifies the existing image and the later part (`musibs/course-tracker`) is the tagged image with the format `repository/image`. We haven't specified any version here and the docker takes version as default value `latest`.

Source Code

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-dockerfile

Once you are done with the tagging, you may push the image to the Docker registry. The Docker registry is a storage and distribution system for Docker images. You can pull images to your local machine from the Docker registry or push images from your local machine to it.

In this example, we'll use the Docker Hub (https://hub.docker.com/) as the Docker registry to store the image. Kubernetes pulls the Docker image from the Docker registry into the `kubelet` (the node where the image is run in a Kubernetes Pod) which are not usually connected to the docker daemon. In this example, though, as we are using the Kubernetes cluster in the local machine, you can skip this step. For completeness, be aware that you can use the `docker push` command (e.g. `docker push musibs/course-tracker`) to push the image to the docker hub.

Now that we are ready with the docker image of the application, we are ready to run the application in Kubernetes. We need the following two things:

1. The Kubernetes CLI (kubectl)
2. A Kubernetes cluster to deploy the application

To interact with Kubernetes, you use the `kubectl` command to run commands against the Kubernetes cluster. Refer to https://kubernetes.io/docs/tasks/tools/ to install `kubectl`. For a Kubernetes cluster, we'll use Kind (https://kind.sigs.k8s.io/) to create a local Kubernetes cluster. Once Kind is installed, run the following command as shown in Listing 9.33 to create a Kubernetes cluster:

Listing 9.33 Create a local Kubernetes cluster with Kind

```
kind create cluster

Creating cluster "kind" ...
 ✓ Ensuring node image (kindest/node:v1.20.2) 🖼
 ✓ Preparing nodes □
 ✓ Writing configuration □
 ✓ Starting control-plane 🕹□
 ✓ Installing CNI □
 ✓ Installing StorageClass □
Set kubectl context to "kind-kind"
You can now use your cluster with:

kubectl cluster-info --context kind-kind

Thanks for using kind! □
```

Once the cluster is successfully created, Kind automatically configures the Kubernetes CLI to point to the newly created cluster. To view everything is set up as expected, execute the command as shown in Listing 9.34:

Listing 9.34 Kubernetes Cluster Information

```
kubectl cluster-info

Kubernetes control plane is running at https://127.0.0.1:49672
KubeDNS is running at https://127.0.0.1:49672/api/v1/namespaces/kube-system/services/kube-
      dns:dns/proxy

To further debug and diagnose cluster problems, use 'kubectl cluster-info dump'.
```

To deploy an application to Kubernetes, you specify the configurations in a YAML configuration file. However, instead of defining the configurations manually, let us use the `kubectl` command to generate them for us. Create a new directory called `k8s` anywhere in your machine and run the command as shown in Listing 9.35 from the k8s directory.

Listing 9.35 Generate the deployment YAML file

```
kubectl create deployment course-tracker --image musibs/course-tracker --dry-run=client -
      o=YAML > deployment.yaml
```

The command in listing creates the `deployment.yaml` configuration file in the k8s directory. The `--dry-run=client` option in listing 9.35 allows us to preview the deployment object that the `kubectl create deployment` command creates. The -o option specifies that the command output is to be written in `YAML` format. Listing 9.36 shows the contents of the generated file:\

Listing 9.36 The generated deployment.yaml file

```
apiVersion: apps/v1
kind: Deployment
metadata:
  creationTimestamp: null
  labels:
    app: course-tracker
  name: course-tracker
spec:
  replicas: 1
  selector:
    matchLabels:
      app: course-tracker
  strategy: {}
  template:
    metadata:
      creationTimestamp: null
      labels:
        app: course-tracker
    spec:
      containers:
      - image: musibs/course-tracker
        name: course-tracker
        resources: {}
status: {}
```

The `deployment.yaml` file contains the specification such as the image to be used, how many containers to run etc. Refer to the Kubernetes documentation for a detailed discussion on the purpose of various tags.

The `deployment.yaml` file specifies Kubernetes how to deploy and manage the application, but it does not let the application be a network service to other applications. To do that, we need a Kubernetes `Service` resource. Execute the command as shown in Listing 9.37 in the `k8s` directory to generate the YAML for the service resource:

Listing 9.37 The Kubectl command to create a service

```
kubectl create service clusterip course-tracker-service --tcp 80:8080 -o yaml --dry-
       run=client > service.yaml
```

Listing 9.38 shows the generated YAML configuration for the service:

Listing 9.38 The generated service.yaml file

```
apiVersion: v1
kind: Service
metadata:
  creationTimestamp: null
  labels:
    app: course-tracker-service
  name: course-tracker-service
spec:
  ports:
  - name: 80-8080
    port: 80
    protocol: TCP
    targetPort: 8080
  selector:
    app: course-tracker-service
  type: ClusterIP
status:
  loadBalancer: {}
```

Let us now apply the YAML files (from the k8s directory) to Kubernetes as shown in Listing 9.39:

Listing 9.39 Apply the configuration in Kubernetes Cluster through kubectl

```
kubectl apply -f .
```

The command in listing creates a new Deployment and a Service. Execute the command in listing 9.40 to get a status of the created `Deployment` and `Service`:

Listing 9.40 Get the status of all Kubernetes components

```
kubectl get all
```

You'll notice an output similar to listing 9.41:

Listing 9.41 Status of all Kubernetes components

```
NAME                                  READY   STATUS    RESTARTS   AGE
pod/course-tracker-84f4d94d5d-gbw99   1/1     Running   0          25m

NAME                             TYPE        CLUSTER-IP     EXTERNAL-IP   PORT(S)   AGE
service/course-tracker-service   ClusterIP   10.96.54.100   <none>        80/TCP    25m
service/kubernetes               ClusterIP   10.96.0.1      <none>        443/TCP   3h36m

NAME                             READY   UP-TO-DATE   AVAILABLE   AGE
deployment.apps/course-tracker   1/1     1            1           25m

NAME                                        DESIRED   CURRENT   READY   AGE
replicaset.apps/course-tracker-84f4d94d5d   1         1         1       25m
```

The last change we need to perform is to use port forward so that we can make an HTTP request to the application. This is needed as the service we've defined is accessible in the Kubernetes cluster network and not accessible outside. Let us execute the following `port-forward` command as shown in listing 9.40. Note that this command runs foreground and the command does not return. Thus you can open a new terminal window and execute the command:

Listing 9.42 Port forwarding to enable HTTP requests to the application

```
kubectl port-forward pod/course-tracker-84f4d94d5d-gbw99 8080:8080
```

In your case, the pod name could be different. You can find the pod name (highlighted in bold) in listing 9.41 Once the command runs successfully, you'll see the following output as shown in Listing 9.43:

Listing 9.43 Successful Port Forward Output

```
Forwarding from 127.0.0.1:8080 -> 8080
Forwarding from [::1]:8080 -> 8080
```

That's all. You can now open a browser window and access the http://localhost:8080 URL. You'll notice that you are redirected to the application index page.

Discussion

In this technique, we've explored how to run a container image in a Kubernetes cluster. We created a local Kubernetes cluster with the use of Kind. We then defined a deployment and service using the kubectl command. Post that, we applied the configurations so that the resources could be created by Kubernetes. Lastly, we have applied port forwarding to the Kubernetes pod so that the application is accessible outside of the Kubernetes Cluster.

9.7 Deploying Spring Boot applications in RedHat OpenShift

RedHat OpenShift is an enterprise Kubernetes platform with support for several cloud providers. Previously you've explored how to deploy a Docker container in a local Kubernetes cluster. RedHat OpenShift provides the managed Kubernetes platform where you can deploy your application. You can find more details about various RedHat OpenShift offerings available at https://cloud.redhat.com/learn/what-is-openshift.

In this section, we'll demonstrate how to deploy a Spring Boot application in the RedHat OpenShift platform through the RedHat OpenShift developer console.

TECHNIQUE DEPLOYING A SPRING BOOT APPLICATION IN REDHAT OPENSHIFT PLATFORM

Problem

OpenShift provides a self-service platform to create, modify, and deploy applications, and provides faster development and release cycles. You need to deploy the Course Tracker application into the RedHat OpenShift platform

Solution

In this technique, you'll learn how to deploy a Spring Boot application in the RedHat OpenShift platform. There are several ways a Spring Boot application can be deployed in OpenShift – Dockerfile, container image, from Git etc. In this section, we'll demonstrate how to deploy an application through GitHub.

The final version of the Spring Boot project is available at https://github.com/spring-boot-in-practice/repo/tree/main/ch09/course-tracker-app-openshift

To begin with, you need to create a RedHat account to access the OpenShift platform. You can click to https://www.redhat.com/en/technologies/cloud-computing/openshift for Developer sandbox account. If you don't have an existing RedHat account, create a new one with the required details. If you already have an account, then log in with the credentials. Once successfully logged in, you can access the OpenShift Developer sandbox account. You'll find a page similar to figure 9.11 :

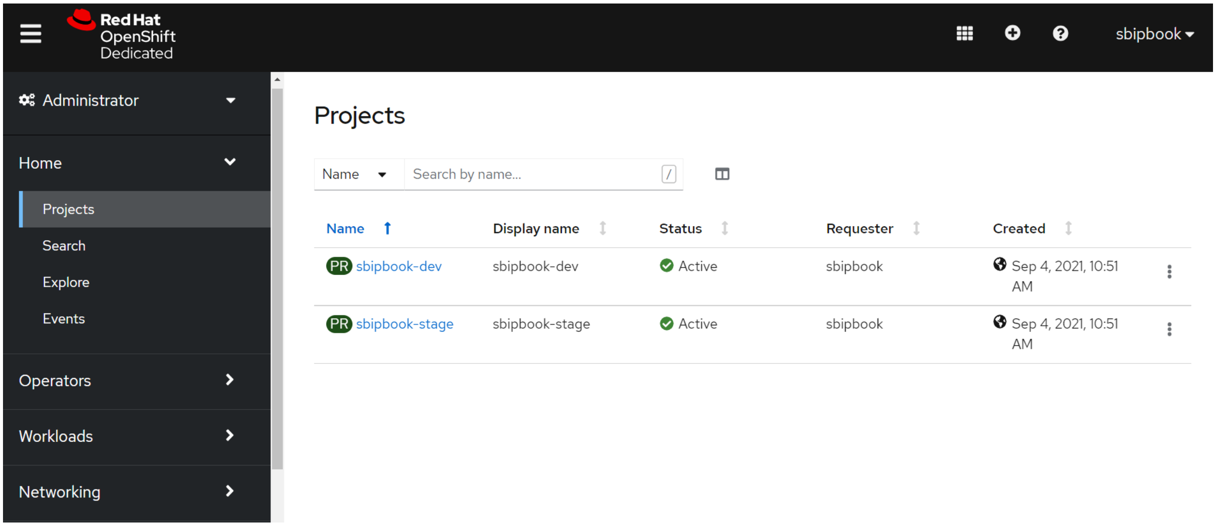


Figure 9.11 RedHat Developer sandbox home page with Administrator views. By default, RedHat creates two projects dev and stage for us.

In the top left corner, switch to the Developer view from the Administrator view and you'll find a screen similar to figure 9.12:

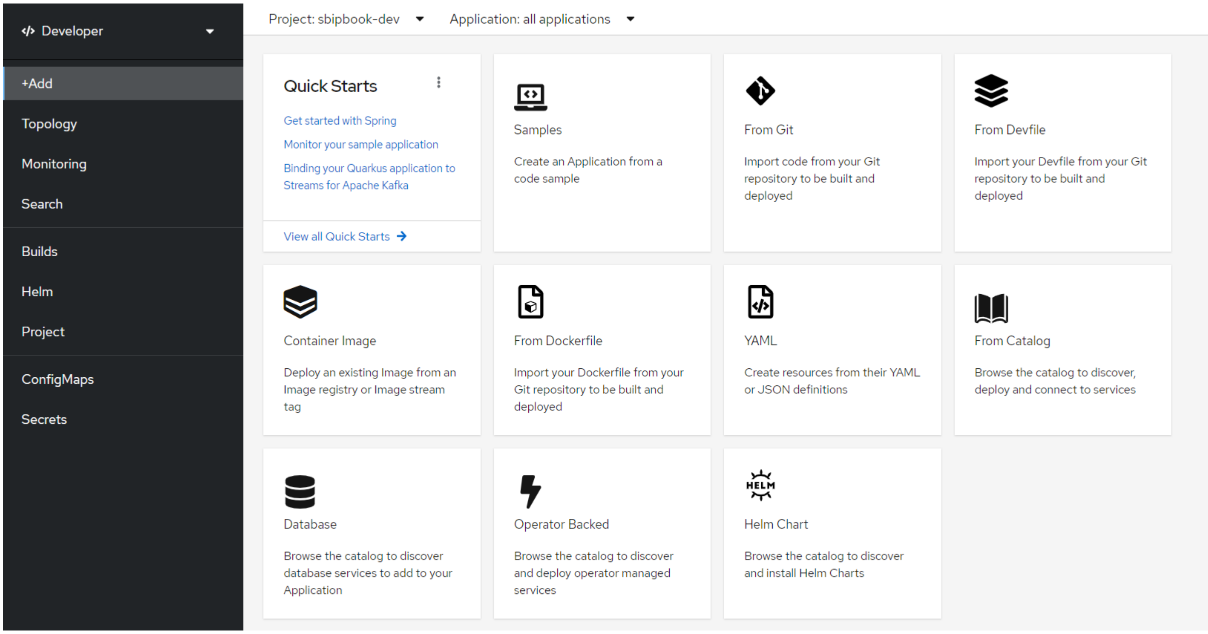


Figure 9.12 RedHat sandbox Developer view. From this screen, you can select your application configuration for deployment. For instance, you can select From Git option and provide your Git repository path.

In this technique, we'll show you how to deploy a Spring Boot application using From Git option. We've already created a GitHub repository for the Course Tracker application and we'll use the same. You can access this repository available at https://github.com/spring-boot-in-practice/course-tracker-app-openshift.git.

Click on the From Git option in the Developer sandbox page and you'll be redirected to the next page as shown in figure 9.13:

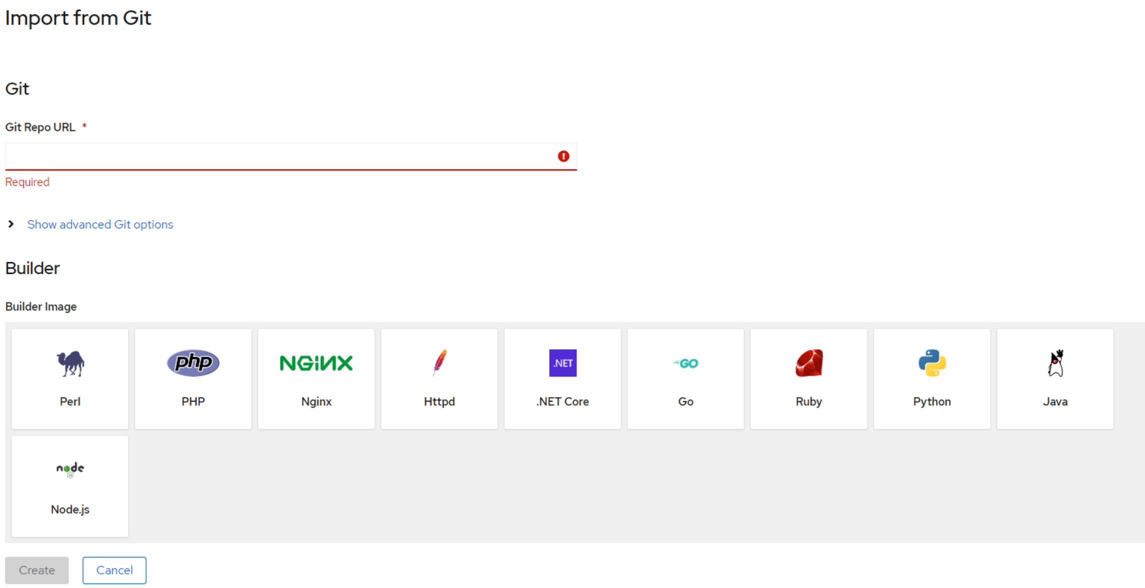


Figure 9.13 The import from git page to create a deployment from git

Provide the GitHub repository URL for the Course Tracker application and click create. Post successful deployment, you'll find a page similar to figure 9.14:

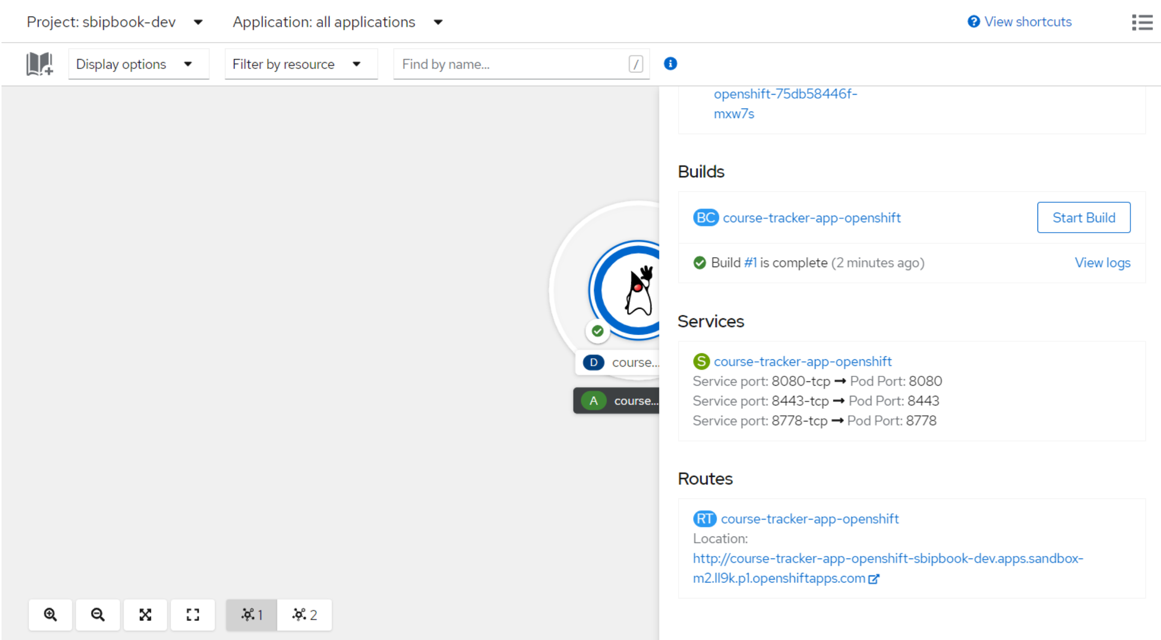


Figure 9.14 Course Tracker application deployed successfully

You can find the application URL in the bottom right corner in the Routes section. Click on the link and you'll be redirected to the index page of the Course Tracker application.

Discussion

In this technique, you've explored how to deploy a Spring Boot application in the RedHat OpenShift platform. OpenShift supports a variety of approaches to deploy an application. For instance, in this example, you've provided the application source code from the GitHub repository and OpenShift does the heavy lifting for us. It has taken the source code, build it, deployed it into a Kubernetes Pod and made the application available to the external world.

OpenShift provides a lot of features and configurations that you can use in your application. For instance, in your application, you can add various health checks such as start-up probe, readiness probe, liveness probe etc. These probes let you verify your application status. For instance, the liveness probe checks whether the application container is running. Failure of the liveness probe means that the container is killed.

To understand more about OpenShift, you can play around with the OpenShift Developer sandbox available at https://developers.redhat.com/developer-sandbox.

9.8 Chapter Summary

- Deploy a Spring Boot application as an executable JAR file and deploy as a WAR file in the WildFly application server
- Deploying Spring Boot applications to Cloud Foundry and Heroku
- Running Spring Boot applications as Docker container and deploy into Kubernetes Cluster
- Deploy a Spring Boot application as a container in the RedHat OpenShift platform

A

Generating and Building Spring Boot Projects

In chapter one, you've learned the need for Spring Boot, and its features and various components. In this section, you'll learn the Spring Initializr tool, and subsequently, explore Spring Boot Command Line Interface (CLI).

A.1 Generating Spring Boot Applications with Spring Initializr

In this section, let us introduce the Spring Initializr tool, and learn various techniques to generate a Spring Boot project through it.

A.2.1 Introducing Spring Initializr

Spring Initializr (https://start.spring.io/) is a project generation utility that lets you generate Spring Boot projects. It also enables you to inspect the generated project structure before you download or share it. The generated project includes detail such as the Spring Boot version, the project language such as Java, Kotlin, or Groovy, the build framework such as Maven or Gradle, and few other configuration parameters.

Spring Initializr has an extensible API, which means that you can customize it to suit your requirement. You can use the web version of Spring Initializr API through a web browser by accessing https://start.spring.io URL. Besides, you can also use the embedded version of this API integrated into popular IDEs such as IntelliJ IDEA, Spring Tool Suite, and Microsoft Visual Studio Code.

Maven or Gradle?

Spring Initializr lets you choose the build framework while you generate a Spring Boot project. It supports two popular build frameworks – Apache Maven (https://maven.apache.org/) and Gradle (https://gradle.org/). Both frameworks have their merits and demerits. Many developers are comfortable with Maven due to its widespread usage and familiar XML-based syntax. Whereas some developers prefer Gradle due to its conciseness, flexibility, and performance.

Either way, feel free to use your preferred build framework. In this book, our primary focus is on the Spring Boot features with minimal reference to the build tool. Thus, your selection of a build framework plays a little role in continuing with the techniques presented in this book.

We'll use Apache Maven as the default build tool in all techniques as most readers are familiar with it. However, if you prefer Gradle over Maven, it should not be difficult to port the code snippets to Gradle based project.

TECHNIQUE: GENERATE A SPRING BOOT APPLICATION WITH SPRING INITIALIZR WEB USER INTERFACE

Problem

You want to generate a Spring Boot Project through Spring Initializr Web User Interface

Solution

Spring Boot provides a default instance of Spring Initializr at https://start.spring.io. This application has a web-based user interface that lets you choose various options to generate a Spring Boot project. These options include the project build tool (e.g., Maven or Gradle), language (e.g., Java, Kotlin, or Groovy), Spring Boot release version, and other options.

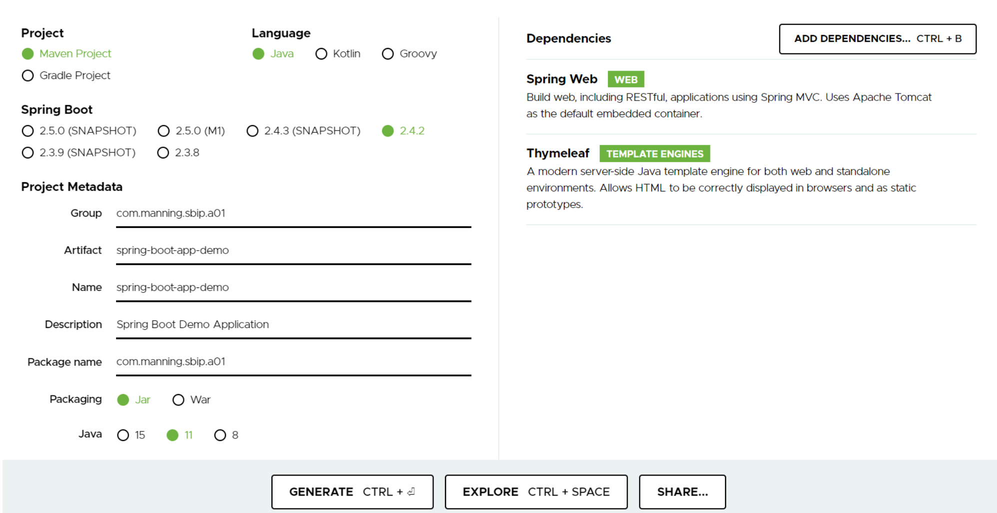


Figure A.1 Spring Initializr Web User Interface at https://start.spring.io

Figure A.1 shows the https://start.spring.io web page with the required details. Along with the basic details such as the Spring Boot version, project metadata, you've also selected `Spring Web` dependency in this example. This dependency provides necessary supports for web application development.

Spring Initializr changes its user interface periodically. Thus, you may find an altered user interface based on when you are reading the book. Besides, you may also find a different Spring Boot version if a new Spring Boot version is released.

Following are the list of supported Spring Initializr options to generate a Spring Boot project:

Specify all the parameters in the https://start.spring.io page and select the required dependencies, as shown in Figure A.1. You can then press the **Generate** button to generate and download the project to your machine. Spring Initializr provides a ZIP archive of the generated project. Figure A.2 shows the folder structure of the generated Spring Boot maven project:

```
C:\sbip\repo\appendix01\spring-boot-app-demo>tree /f
Folder PATH listing for volume OS
Volume serial number is 8EF3-F5B9
C:.
│   .gitignore
│   HELP.md
│   mvnw
│   mvnw.cmd
│   pom.xml
│
├───.mvn
│   └───wrapper
│           maven-wrapper.jar
│           maven-wrapper.properties
│           MavenWrapperDownloader.java
│
└───src
    ├───main
    │   ├───java
    │   │   └───com
    │   │       └───manning
    │   │           └───sbip
    │   │               └───a01
    │   │                       SpringBootAppDemoApplication.java
    │   │
    │   └───resources
    │       │   application.properties
    │       │
    │       ├───static
    │       └───templates
    └───test
        └───java
            └───com
                └───manning
                    └───sbip
                        └───a01
                                SpringBootAppDemoApplicationTests.java
```

Figure A.2 Spring Boot Maven Project Structure

The generated project contains the following components:

Spring Initializr provides a Maven wrapper to build the generated project. The purpose of it is that you can build the Spring Boot application with Maven without explicitly installing Maven on your machine. You can use the `mvnw install` command to build the application, as shown in Figure A.3. Similarly, if you've generated a Gradle-based project, Spring Initializr provides a Gradle wrapper to build the application without explicitly installing Gradle in your machine.

```
C:\sbip\repo\appendix01\spring-boot-app-demo>mvnw install
[INFO] Scanning for projects...
[INFO]
[INFO] ------------< com.manning.sbip.a01:spring-boot-app-demo >-------------
[INFO] Building spring-boot-app-demo 0.0.1-SNAPSHOT
[INFO] --------------------------------[ jar ]--------------------------------
[INFO]
[INFO] --- maven-resources-plugin:3.2.0:resources (default-resources) @ spring-boot-app-demo ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Using 'UTF-8' encoding to copy filtered properties files.
[INFO] Copying 1 resource
[INFO] Copying 0 resource
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:compile (default-compile) @ spring-boot-app-demo ---
[INFO] Changes detected - recompiling the module!
[INFO] Compiling 1 source file to C:\sbip\repo\appendix01\spring-boot-app-demo\target\classes
[INFO]
[INFO] --- maven-resources-plugin:3.2.0:testResources (default-testResources) @ spring-boot-app-demo ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Using 'UTF-8' encoding to copy filtered properties files.
[INFO] skip non existing resourceDirectory C:\sbip\repo\appendix01\spring-boot-app-demo\src\test\resources
[INFO]
[INFO] --- maven-compiler-plugin:3.8.1:testCompile (default-testCompile) @ spring-boot-app-demo ---
[INFO] Changes detected - recompiling the module!
[INFO] Compiling 1 source file to C:\sbip\repo\appendix01\spring-boot-app-demo\target\test-classes
[INFO]
[INFO] --- maven-surefire-plugin:2.22.2:test (default-test) @ spring-boot-app-demo ---
[INFO]
```

Figure A.3 Building the generated application with Maven wrapper

In the project source code, Spring Initializr generates a Java class with the `main` method in the generated Spring Boot application (e.g., `SpringBootAppDemoApplication.java`). This class lets you start the Spring Boot application. You can run this Java file using your IDE's application start option and see the generated Spring Boot project has started in the HTTP port 8080.

In the project test code, Spring Initializr provides an empty test class (e.g., `SpringBootAppDemoApplicationTests.java`) to write test cases for your project. Spring Boot automatically includes few commonly used testing frameworks such as JUnit, Mockito (https://site.mockito.org/), XMLUnit (https://www.xmlunit.org/) in your project.

In the `resources` folder, the generated Spring Boot project has an empty configuration file named `application.properties`. You can use this file to provide additional configuration to control the application's behavior. For instance, if you want to run the project in a different HTTP port other than the Spring Boot default port `8080`, you can configure it here by specifying the `server.port` property. Besides, as we've selected `Spring Web` dependency, Spring Initializr has also created the `static` and `template` folders for the static web resources such as CSS files, images, and HTML template files, respectively.

Spring Initializr also provides two additional features to view and share the generated project for convenience:

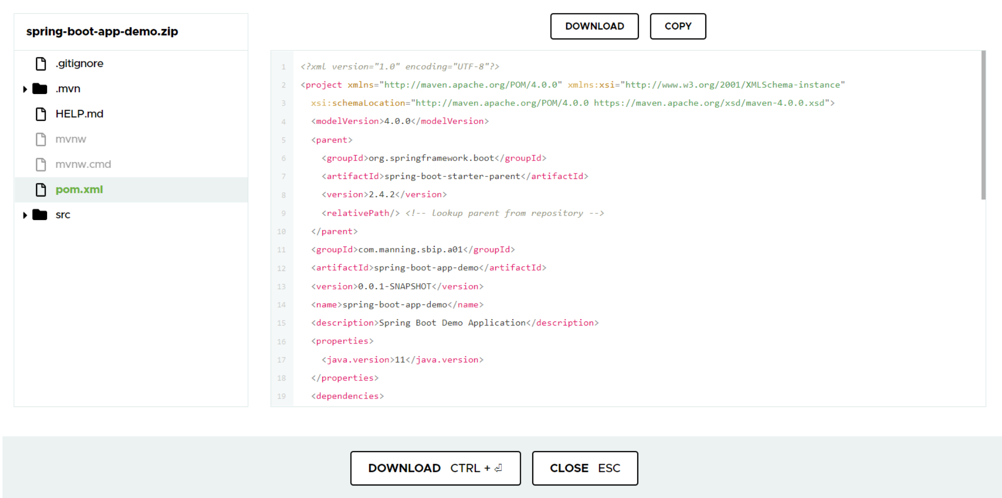


Figure A.4 Exploring the project structure of generated Spring Boot project in https://start.spring.io

Listing A.1 Sharable URL of the Generated Project

```
https://start.spring.io/#!type=gradle-
      project&language=kotlin&platformVersion=2.4.3.RELEASE&packaging=war&jvmVersion=15&gr
      oupId=com.manning%2Csbip.a01&artifactId=spring-boot-app&name=spring-boot-
      app&description=Spring%20Boot%20project%20for%20Appendix%20A&packageName=com.manning
      %2Csbip.a01.spring-boot-app&dependencies=web
```

Discussion

Sprint Initializr is a fantastic tool that has made Spring Boot project generation an extremely easy task. The web-based UI lets you provide the configuration parameters needed to generate the project and in a single click, you've a workable project. Besides, it also lets you inspect the generated project structure before you download it to your machine.

Although the web-based version is useful, you'll eventually need to import the generated project into an IDE to continue with the application development. To make this process further simplified, Spring Initializr provides an extensible API that major IDE vendors embed so that you can generate the project in the IDE itself. Let's see that in the next technique.

TECHNIQUE: GENERATE A SPRING APPLICATION WITH SPRING INITIALIZR IN INTELLIJ IDEA IDE

Problem

You want to generate a Spring Boot project through Spring Initializr in IntelliJ IDEA IDE

Solution

Spring Initializr is a flexible API and is frequently used in standalone mode through the web and the CLI. However, to further simplify the project generation, major IDE vendors have embedded Spring Initializr support into their IDEs. In this technique, you'll see how to generate a Spring Boot project in IntelliJ IDEA IDE using its built-in Spring Initializr support. You can find the generated project in the companion GitHub repository of this book at https://github.com/spring-boot-in-practice/repo/tree/main/appendix01/spring-boot-app-idea.

IntelliJ IDEA Editions

IntelliJ IDEA is available in two editions – Community and Ultimate (https://www.jetbrains.com/idea/download/). Community Edition does not have built-in support for Spring Initializr. However, the Ultimate Edition, the paid version of the IDE, supports Spring Initializr. If you want to use the steps provided in this technique, you need to use the Ultimate edition. Although it is a paid version, the Ultimate edition is available for trial for 30 days so that you can try out the features it offers.

If you don't have access to the Ultimate Edition, you can continue with the Community edition by generating the Spring Boot project through the https://start.spring.io as shown in the previous Technique and import the extracted archive in the IDE.

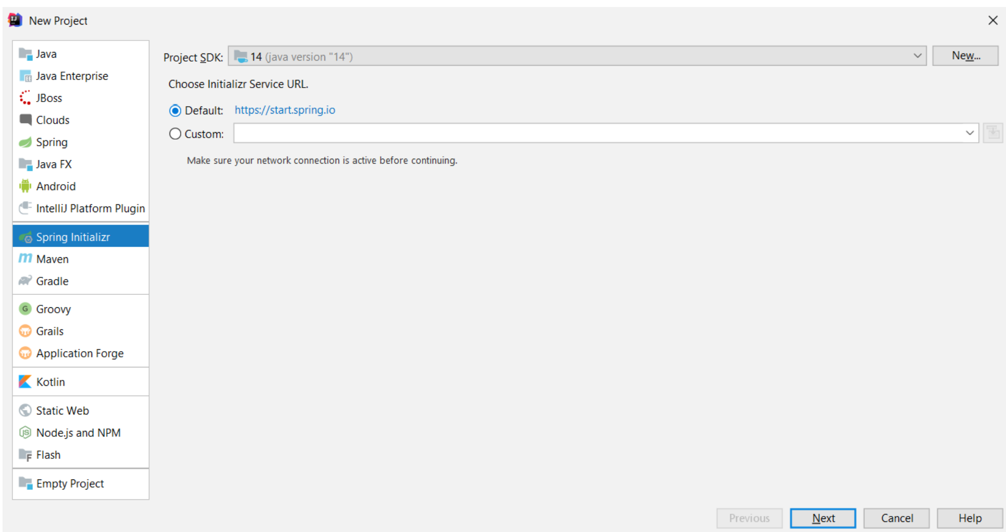


Figure A.5 Generating a Spring Boot Project in IntelliJ IDEA with built-in Spring Initializr support

To generate a Spring Boot project, browse to **File > New > Project** options and Select **Spring Initializr**, as shown in Figure A.5. By default, the IDE selects https://start.spring.io as the Initializr service URL. Alternatively, you can provide your own Spring Initializr URL if you have customized the Initializr Service.

On the subsequent page, you'll see the options to provide additional project metadata such as project coordinates (group id, artifact id, version), language, packaging type, Java version, as shown in Figure A.6:

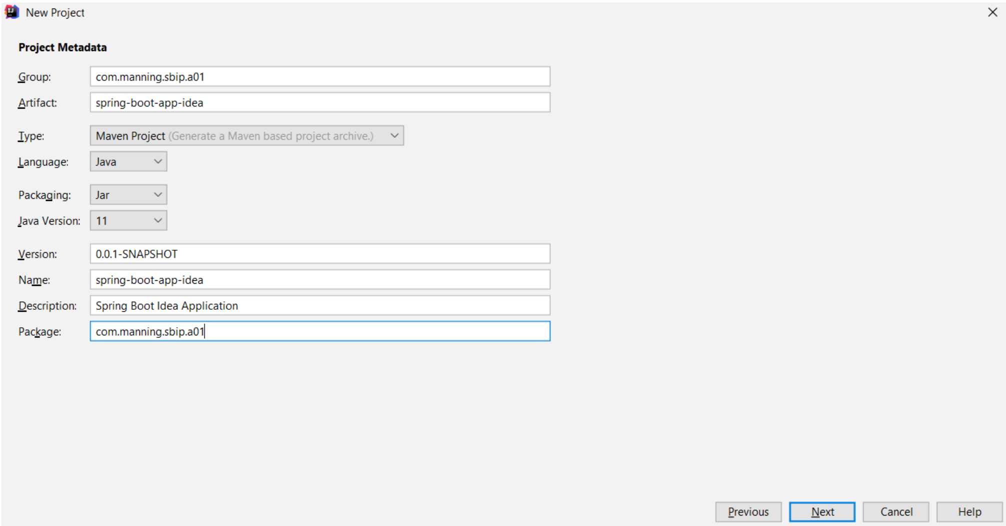


Figure A.6 Providing Project Metadata for the generated Spring Boot Project in IntelliJ IDEA

On the next page, you can choose the dependencies required for your project and the Spring Boot version, as shown in Figure A.7:

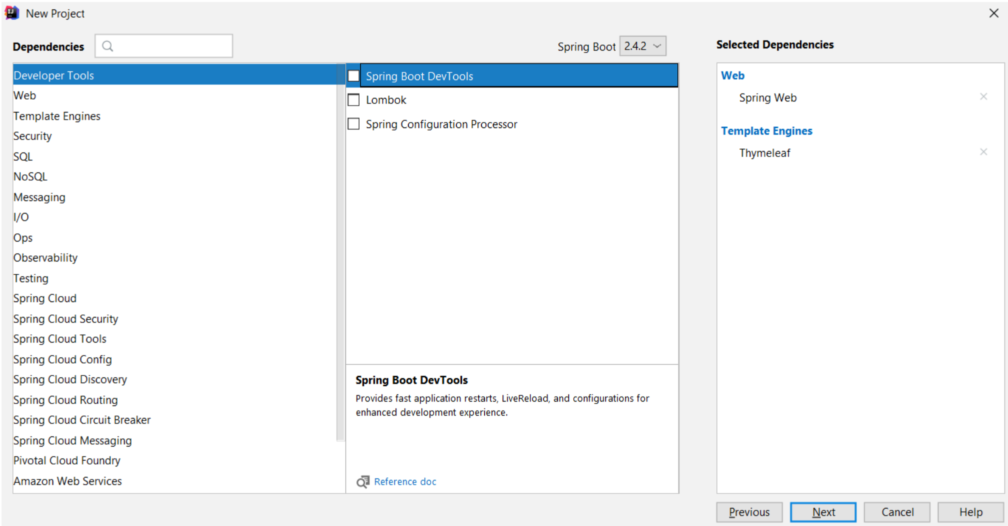


Figure A.7 Spring Boot Dependencies list in IntelliJ IDEA

As shown in Figure A.7, you can find the dependencies are categorized in the relevant headers, and all the related dependencies are listed under each category. After selecting the required dependencies, you can choose the project name and location and generate the project.

The IDE pulls the selected dependencies from the central repository and configures the project. Figure A.8 shows the final generated project in the IntelliJ IDEA:

Figure A.8 Generated Spring Boot Project in IntelliJ IDEA

If you run the `SpringBootAppIdeaApplication` using the IDEs run option, you'll see the generated Spring Boot project starts in the default HTTP 8080 port.

Discussion

In this technique, you've seen how to generate a Spring Boot project in IntelliJ IDEA IDE. The IDE lets you specify the Spring Initializr options to generate the project. Once you've provided all the required details, it generates the project and shows it in the project explorer. In the next technique, let's learn how to generate a Spring Boot project in the Spring Tool Suite.

TECHNIQUE: GENERATE A SPRING BOOT APPLICATION WITH SPRING INITIALIZR USING SPRING TOOL SUITE (STS)

Problem

You want to generate a Spring Boot application through built-in Spring Initializr in Spring Tool Suite

Solution

Spring Tool Suite (https://spring.io/tools) is an eclipse-based IDE by the Spring team for Spring-based application development. Similar to the IntelliJ IDEA, STS also has built-in integration with Spring Initializr service and lets you generate a Spring Boot project through the IDE.

To create a Spring Boot application in STS, click on **File > New > Spring Starter Project**, and you'll see the following screen, as shown in Figure A.9. You can find the generated project in the companion GitHub repository of this book at https://github.com/spring-boot-in-practice/repo/tree/main/appendix01/spring-boot-app-sts.

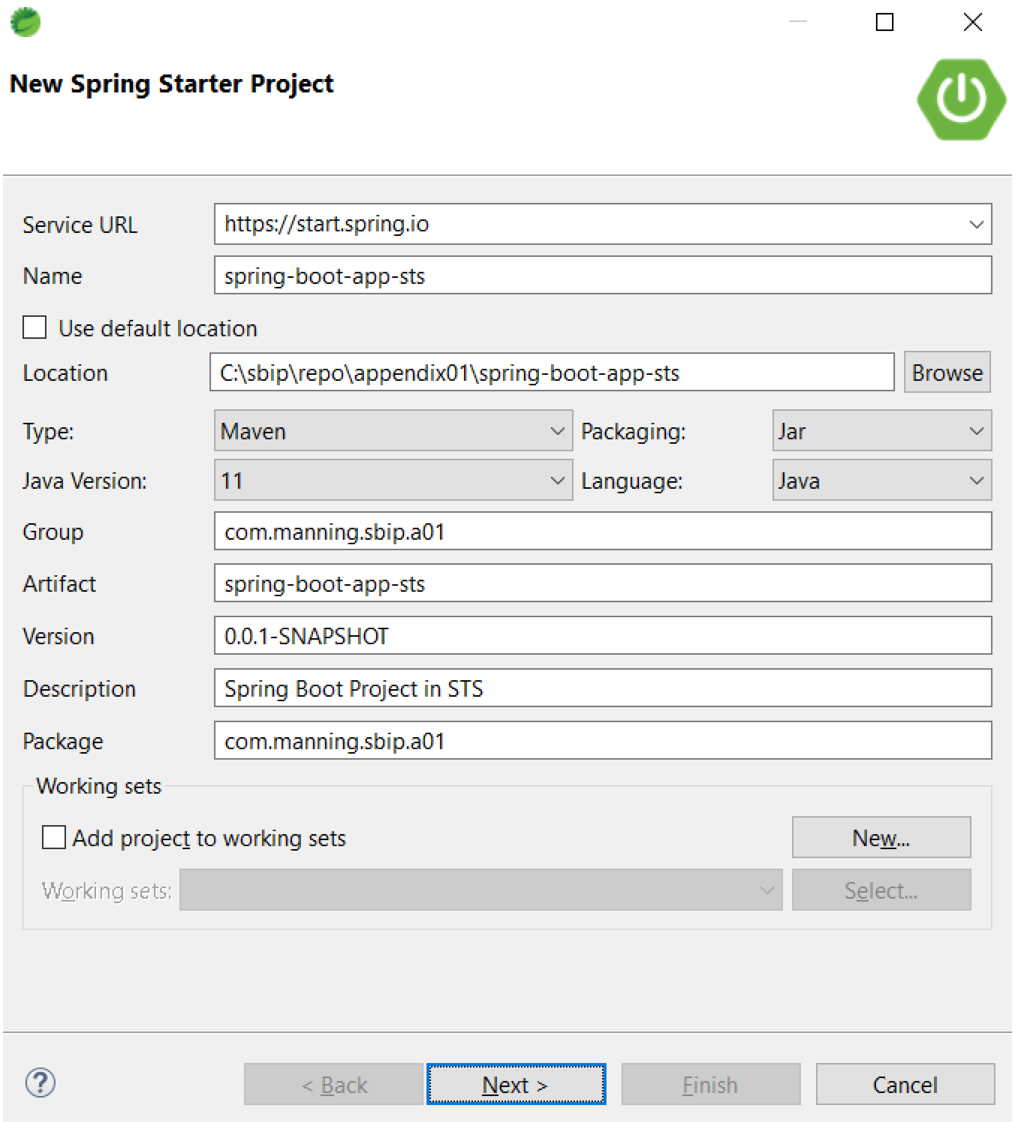


Figure A.9 Generating a Spring Boot project in Spring Tool Suite

STS loads these parameters and the default values from https://start.spring.io. On the next page, STS lets you select the Spring Boot version, and specify the required dependencies for your project, as shown in Figure A.10:

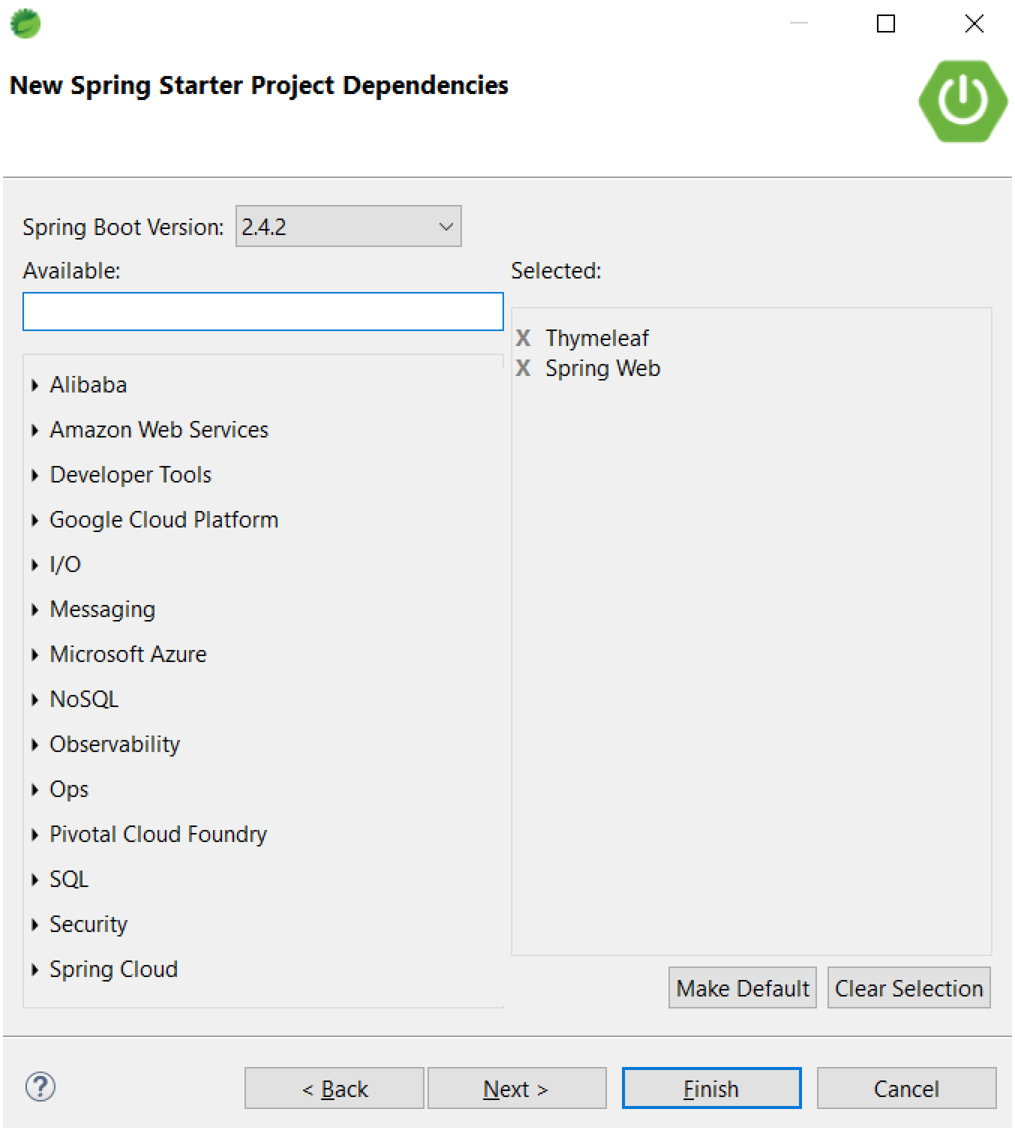


Figure A.10 Spring Boot Version and Dependencies list in Spring Tool Suite

After selecting the dependencies, STS generates the Spring Boot project and loads the selected dependencies, as shown in figure A.11:

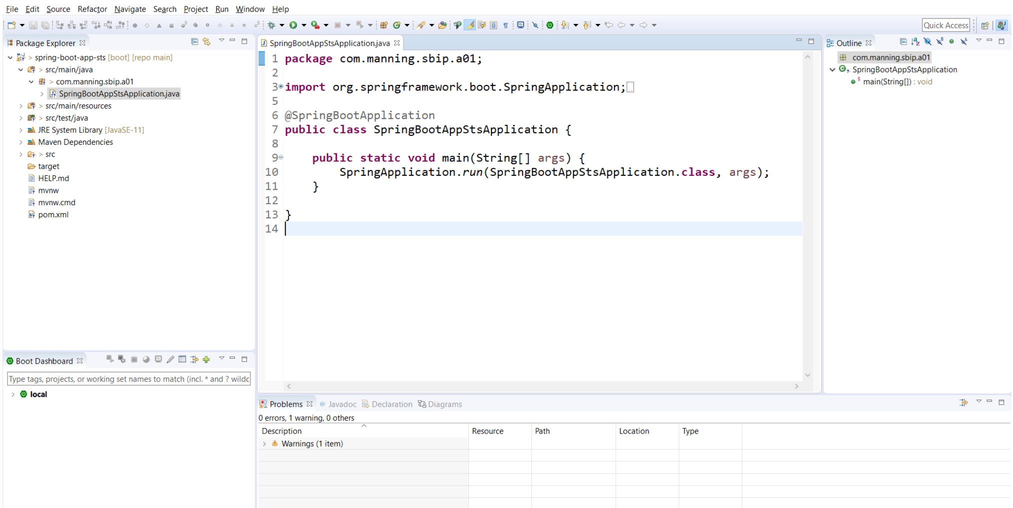


Figure A.11 Generated Spring Boot Project and the Spring Boot Dashboard in Spring Tool Suite

STS provides a *Boot Dashboard* for developer convenience. It displays all Spring Boot projects available in the workspace and provides quick control to let you perform several activities such as restart and debug your application. You can run the `SpringBootAppStsApplication` Java file using the IDE's run option and see STS starts the generated Spring Boot project in the default HTTP port 8080.

Discussion

In this technique, you've learned how to generate a Spring Boot project in Spring Tool Suite. Spring Tool Suite which is a customized version of eclipse for Spring application development also implements Spring Initializr API and lets you specify the required options to generate the project. The generated project is then displayed in the project explorer. In the next technique, let us learn how to generate a Spring Boot project in Microsoft Visual Studio Code, one of the most popular code editors across the technology spectrum.

TECHNIQUE: GENERATE A SPRING APPLICATION WITH SPRING INITIALIZR IN VISUAL STUDIO CODE

Problem

You want to generate a Spring Boot application with Spring Initializr in Visual Studio Code

Solution

Visual Studio Code (https://code.visualstudio.com/) is an extension-based popular text-editor from Microsoft. This code editor is a lightweight alternative to the popular IDEs to develop Spring Boot applications.

To able to generate a Spring Boot project in Visual Studio Code or VS Code in short, you need to install the following extensions:

Configuring JAVA_HOME

You need to configure the Java home path for Visual Studio Code to use the appropriate Java version. You can do this by configuring `java.home` variable in Visual Studio Code. To set `java.home` browse to File > Preferences > Settings > Workspace and search for `java.home`. You can find the option `Edit in settings.json` and provide the Java version of your choice.

Note that Visual Studio Code does not let you select the Java version while you generate the Spring Boot Project with it. By default, it selects `Java 1.8` while generating the project. You can edit the generated project's `pom.xml` (for Maven) or the `build.gradle` (for Gradle) file to provide the Java version you have configured in `java.home`.

Pivotal (The company behind Spring Framework) provides an extension pack to develop Spring Boot application applications in VS Code. This pack consists of several extensions including the three mentioned earlier. You can install this *Spring Boot Extension Pack* to access the complete extension suite. To install the extension pack, browse to the extensions option in the editor and search for *Spring Boot*, as shown in figure A.12:

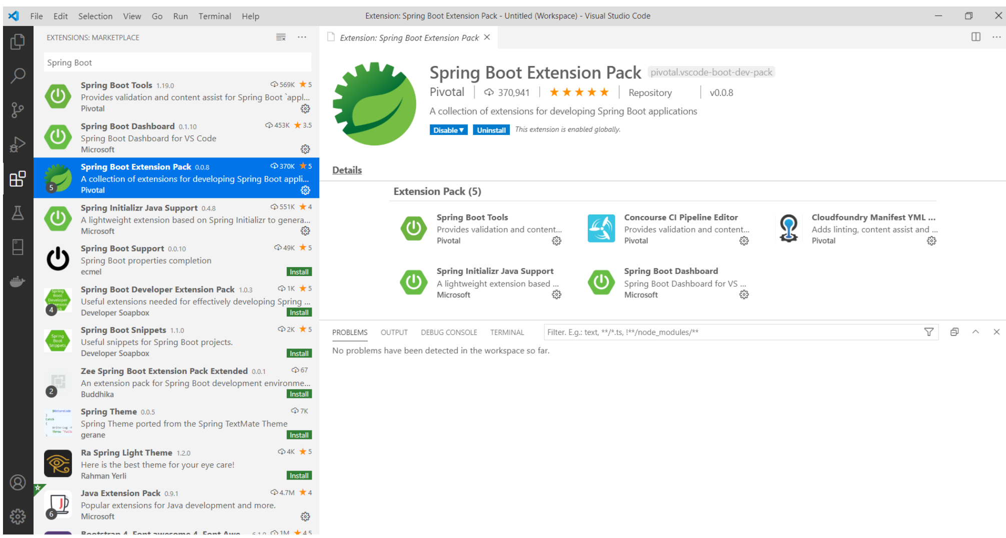


Figure A.12 Spring Boot Extensions in Visual Studio Code

After successfully installing the extension pack you can create Spring Boot projects in the editor. To start creating a Spring Boot project in open the *Command Palette* by browsing to **View > Command Palette** options and search for Spring Initializr. You'll find options to create a Maven or Gradle based Spring Boot application, as shown in Figure A.13:

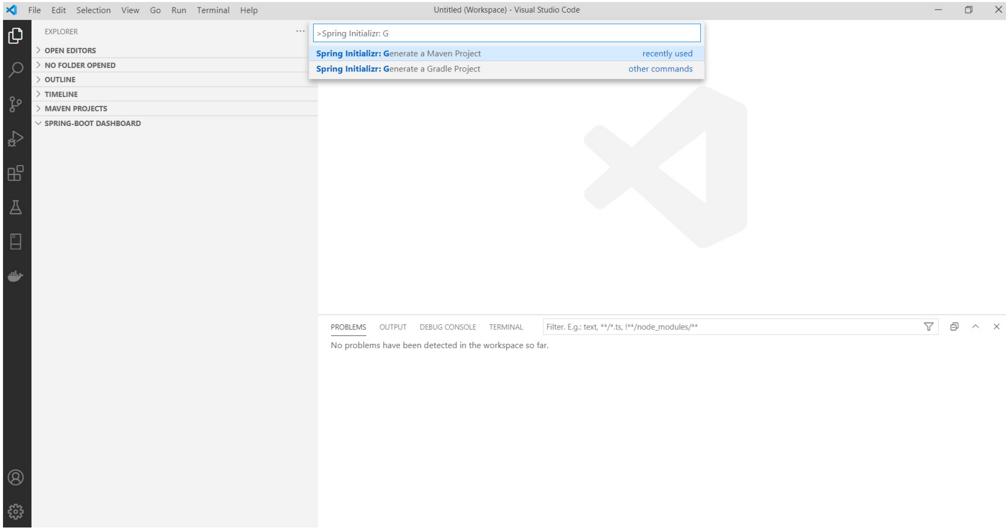


Figure A.13 Generating a Maven or Gradle Project in Visual Studio Code

To create a project, select the required options, and follow along with the parameters. After the project is successfully generated, you will find the folder structure, as shown in Figure A.14. On the left side, there is the generated project structure, Spring Boot dashboard to start/stop the application, and in the editor, you can explore the project components.

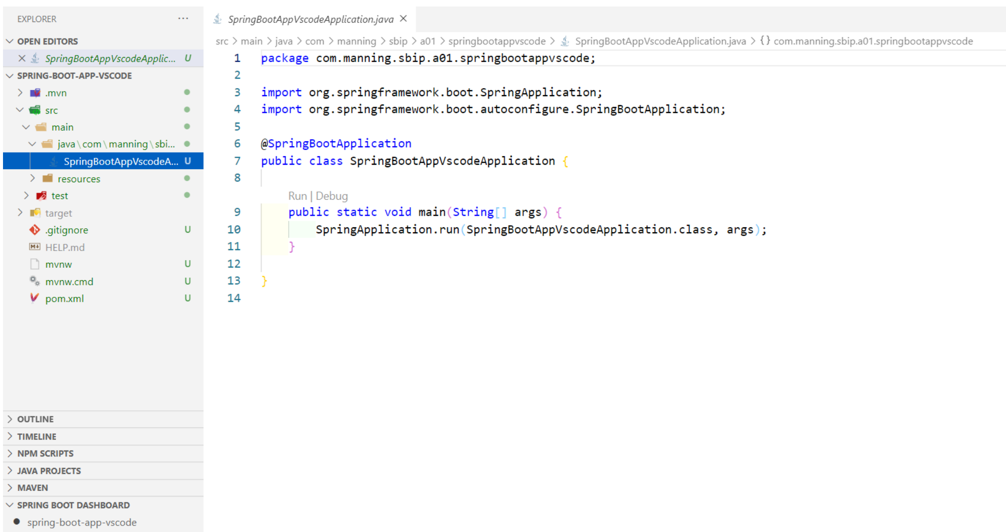


Figure A.14 Generated Spring Boot Project in Visual Studio Code

You can find the generated project in the companion GitHub repository of this book at https://github.com/spring-boot-in-practice/repo/tree/main/appendix01/spring-boot-app-vscode.

After the project generation, if you need to add additional dependencies, you can do it by using the *Edit Starters* option of the editor. You can navigate to the `pom` file and right-click to select the *Edit Starters* option. You'll see the editor displays you the previously selected dependencies with the right tick symbol and let you specify additional dependencies as shown in Figure A.16:

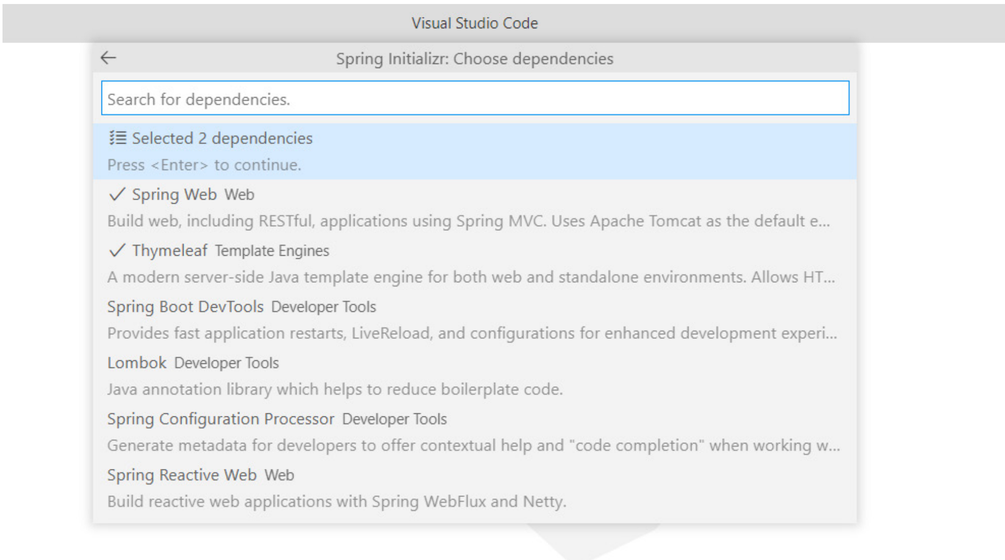


Figure A.15 Editing Starter Dependencies in Visual Studio Code

In Figure A.15, we have selected the *Edit Starters* option, and the Visual Studio Code shows us the previously selected dependencies with the right-tick symbol. We have additionally selected *Spring Boot DevTools Developer Tools* dependency this time.

As shown in Figure A.16, you can start the application from *Spring-Boot Dashboard* by clicking the start button and see the generated Spring project has started in default HTTP port 8080. Application start-up logs are visible in the debug console.

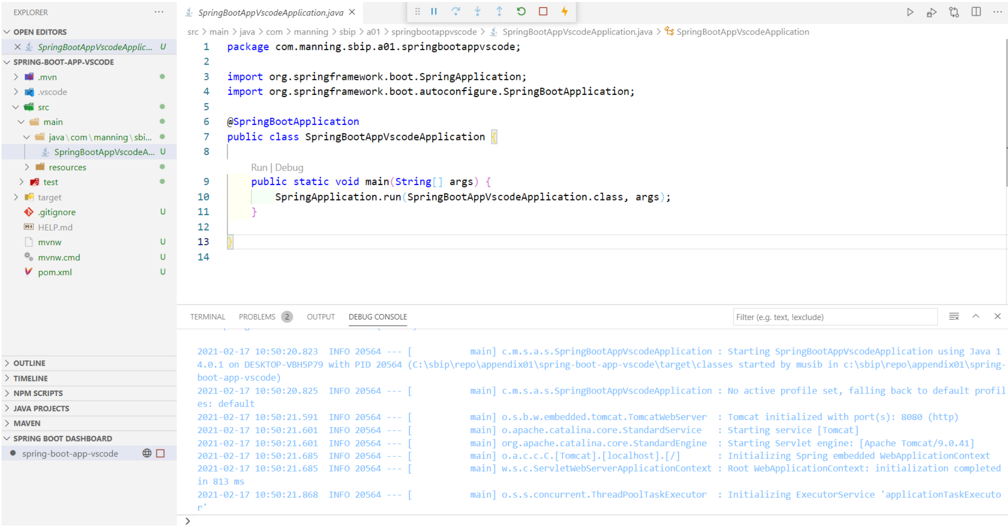


Figure A.16 Spring Boot Dashboard and Debug Console in Visual Studio Code

Discussion

In this technique, you've seen how to enable Spring Boot support in VS Code editor and generate a Spring Boot project. VS Code is a popular code editor, and many developers prefer this lightweight alternative for Spring Boot application development.

So far, you've seen the UI-based approaches to generate Spring Boot applications. However, there is a community of developers that prefers command-line utilities for their conciseness and simplicity. In the next technique, you'll see the use of Spring Boot Command Line Interface (CLI) to generate a Spring Boot application.

TECHNIQUE: GENERATE A SPRING BOOT APPLICATION WITH SPRING INITIALIZR USING COMMAND LINE INTERFACE

Problem

You want to generate a Spring Boot Project with Spring Initializr through Command-Line Interface (CLI).

Solution

Spring Initializr has an extensible API and provides various ways to generate a Spring Boot project. The Spring Initializr web interface is one of the popular options for Spring project generations. But many developers prefer to use command-line tools to generate the project. Spring Initializr supports several popular third-party command-line tools such as cURL, HTTPie (https://httpie.org/), and Spring's own CLI to create a Spring Boot project from the command line.

However, one of the drawbacks while using the CLI is that you need to be familiar with the parameter and dependency names beforehand to use those in the CLI command. To avoid this drawback, Spring provides nicely formatted tabular details of Spring Initializr options which consist of the build framework, project parameters, and dependency names. This detail can be obtained by accessing the https://start.spring.io URL.

Let's view these details from your command-line tool using the following command:

```
curl https://start.spring.io
```

```
C:\sbip\repo\appendix01>curl https://start.spring.io
  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
:: Spring Initializr ::  https://start.spring.io

This service generates quickstart projects that can be easily customized.
Possible customizations include a project's dependencies, Java version, and
build system or build structure. See below for further details.

The services uses a HAL based hypermedia format to expose a set of resources
to interact with. If you access this root resource requesting application/json
as media type the response will contain the following links:
+-----------------+-----------------------------------------+
| Rel             | Description                             |
+-----------------+-----------------------------------------+
| gradle-build    | Generate a Gradle build file.           |
| gradle-project  | Generate a Gradle based project archive. |
| maven-build     | Generate a Maven pom.xml.               |
| maven-project * | Generate a Maven based project archive.  |
+-----------------+-----------------------------------------+


The URI templates take a set of parameters to customize the result of a request
to the linked resource.
+-----------------+------------------------------------------+------------------------------+
| Parameter       | Description                              | Default value                |
+-----------------+------------------------------------------+------------------------------+
| applicationName | application name                         | DemoApplication              |
| artifactId      | project coordinates (infer archive name) | demo                         |
| baseDir         | base directory to create in the archive  | no base dir                  |
| bootVersion     | spring boot version                      | 2.4.2                        |
| dependencies    | dependency identifiers (comma-separated) | none                         |
| description     | project description                      | Demo project for Spring Boot |
| groupId         | project coordinates                      | com.example                  |
| javaVersion     | language level                           | 11                           |
| language        | programming language                     | java                         |
| name            | project name (infer application name)    | demo                         |
| packageName     | root package                             | com.example.demo             |
| packaging       | project packaging                        | jar                          |
| type            | project type                             | maven-project                |
| version         | project version                          | 0.0.1-SNAPSHOT               |
+-----------------+------------------------------------------+------------------------------+


The following section has a list of supported identifiers for the comma-separated
list of "dependencies".
+--------------------------------------+--------------------------------------------------------------+--------------------------------+
| Id                                   | Description                                                  | Required version               |
+--------------------------------------+--------------------------------------------------------------+--------------------------------+
| activemq                             | Spring JMS support with Apache ActiveMQ 'Classic'.           |                                |
```

Figure A.17 Accessing https://start.spring.io through cURL

Figure A.17 displays the options of Spring Initializr service into three different sections:

1. The first table provides the available project types. For instance, it lists four project types – `gradle-build`, `gradle-project`, `maven-build`, and `maven-project`
2. The second table provides the set of available parameters, a brief description, and the default values. Most of these parameters are similar to what is available in the web

version with a difference in the `applicationName` and `baseDir`. The application name parameter can be used to define the application name instead of deducing it from the name parameter. The `baseDir` can be used to create a base directory in the generated archive so that you can extract the generated zip without creating a directory for it first

3. The third table lists all the available dependencies that you can use in your project

You can generate a Spring Boot project with these parameters and the dependencies specified with the `-d` parameter. Table A.1 demonstrates the usage of Spring Boot project generation with `cURL` utility:

Table A.1 Using cURL to generate a Spring Boot project

Command	Remarks
curl https://start.spring.io/starter.zip -o demo.zip	This command generates a Spring Boot project with all default parameters. In the command, we are downloading the generated project as demo.zip
curl https://start.spring.io/starter.zip -d dependencies=web,data-jpa -d type=gradle-project	This command generates a Spring Boot Gradle project with Spring Web and Spring Data JPA dependencies
curl https://start.spring.io/build.gradle -d packaging=war -d javaVersion=15 -o build.gradle	This command generates only a Gradle build file (build.gradle) with WAR packaging and Java version 15

Discussion

In this technique, you've seen how to use the Command Line utility `cURL` to generate a Spring Boot project. This CLI approach is flexible and you can control the project generation using the appropriate parameters.

Now that you've learned to generate a Spring Boot project, let's explore the various components of the generated project in the next section

A.2 Bootstrapping and Executing a Spring Boot Application with Spring Boot CLI

The Spring Boot Command Line Interface (CLI) is a command-line utility that lets you create prototypes for Spring applications. It lets you quickly bootstrap a Spring Boot application without the need for a dependency management tool such as Maven or Gradle. Besides, Spring Boot CLI lets you use Groovy (https://groovy-lang.org/) script so that you can use familiar Java-like syntax but with less noisy syntax. For example, Groovy automatically includes several Java packages in your code, and you need not provide import statements for the members from these packages, as shown in Listing A.2:

Listing A.2 Packages Imported by Groovy by default

```
import java.lang.*
import java.util.*
import java.io.*
import java.net.*
```

You will also investigate a few other features of Groovy, where it is less noisy than Java. But before that, you'll install Spring Boot CLI and have some hands-on.

Spring Boot CLI and Groovy

Spring Boot CLI uses Groovy language. The primary agenda of the Spring Boot CLI tool is to quickly prototype a Spring Boot application and try out various features offered by Spring. Spring Boot CLI does not use a dependency management tool such as Maven or Gradle to keep things easy and straightforward. Groovy being a less verbose language, is the choice while working with Spring Boot CLI. Furthermore, much of the Groovy syntax is similar to Java. Thus, to follow along with the code examples in this section, most of your Java knowledge will be sufficient. In the code examples, if we are using features specific to Groovy, we'll explain.

A.2.1 Installing the Spring Boot CLI

Installing the Spring Boot CLI is easy and can be done in several ways. You can follow any of the following approaches to install Spring Boot CLI:

1. **Manual Installation through the Spring Boot CLI ZIP**

   Follow the following steps to configure Spring Boot CLI manually:

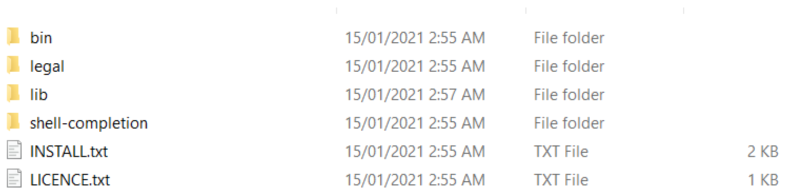


   Figure A.18 Spring Boot CLI Components

2. **Install through the package managers such as Homebrew or Chocolatey**

   A package manager (https://en.wikipedia.org/wiki/Package_manager) is software that automates the process of installing, upgrading, configuring, and removing software on your computer. You can use different package managers to install Spring Boot CLI based on the operating system you are using. For example, if you are using macOS, you can use Homebrew (https://brew.sh/) to install Spring Boot CLI, as shown in Listing A.3:

Listing A.3 Installing Spring Boot CLI in macOS using Homebrew

```
brew tap pivotal/tap
brew install springboot (for macOS)
```

If you are using Windows, you can use Chocolatey (https://chocolatey.org/) to install Spring Boot CLI using the following command as shown in Listing A.4.

Listing A.4 Installing Spring Boot CLI in Windows using Chocolatey

```
choco install spring-boot-cli
```

Note that you need to install the package manager first before you use it to install Spring Boot CLI. You can refer to the links of the package managers for further information on the installation.

3. **Install through the Software Development Kit Manager (SDKMAN)**

   SDKMAN! (https://sdkman.io/) is a software tool to manage Software Development Kits (SDK) in your machine, including Spring Boot CLI. You can download the SDKMAN from their website and install it on your machine. Post that, you can use the command showed in Listing A.5 to install Spring Boot CLI using SDKMAN:

Listing A.5 Installing Spring Boot CLI through SDKMAN

```
 sdk install springboot
```

Once you have installed and configured Spring Boot CLI, you can verify the installation by accessing the CLI. To access Spring Boot CLI, open the command prompt (in Windows) or a terminal (in macOS/Linux) and type the command shown in Listing A.6. You can see the output as the installed CLI version.

Listing A.6 Spring Boot CLI version

```
$ spring --version
Spring CLI v2.3.0.RELEASE
```

You can now use the installed CLI to generate a Spring Boot project. Spring Boot CLI defines an `init` command that connects to https://start.spring.io and lets you generate a project through Spring Initializr. Like the `cURL` command, you can obtain a textual representation of the Spring Initializr service by running the `spring init --list` command. You'll see a similar screen, as shown in Figure A.20:

```
C:\sbip\repo\appendix01>curl https://start.spring.io
  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
:: Spring Initializr ::  https://start.spring.io

This service generates quickstart projects that can be easily customized.
Possible customizations include a project's dependencies, Java version, and
build system or build structure. See below for further details.

The services uses a HAL based hypermedia format to expose a set of resources
to interact with. If you access this root resource requesting application/json
as media type the response will contain the following links:
+-----------------+-------------------------------------------+
| Rel             | Description                               |
+-----------------+-------------------------------------------+
| gradle-build    | Generate a Gradle build file.             |
| gradle-project  | Generate a Gradle based project archive.  |
| maven-build     | Generate a Maven pom.xml.                 |
| maven-project * | Generate a Maven based project archive.   |
+-----------------+-------------------------------------------+


The URI templates take a set of parameters to customize the result of a request
to the linked resource.
+-----------------+-------------------------------------------+------------------------------+
| Parameter       | Description                               | Default value                |
+-----------------+-------------------------------------------+------------------------------+
| applicationName | application name                          | DemoApplication              |
| artifactId      | project coordinates (infer archive name)  | demo                         |
| baseDir         | base directory to create in the archive   | no base dir                  |
| bootVersion     | spring boot version                       | 2.4.2                        |
| dependencies    | dependency identifiers (comma-separated)  | none                         |
| description     | project description                       | Demo project for Spring Boot |
| groupId         | project coordinates                       | com.example                  |
| javaVersion     | language level                            | 11                           |
| language        | programming language                      | java                         |
| name            | project name (infer application name)     | demo                         |
| packageName     | root package                              | com.example.demo             |
| packaging       | project packaging                         | jar                          |
| type            | project type                              | maven-project                |
| version         | project version                           | 0.0.1-SNAPSHOT               |
+-----------------+-------------------------------------------+------------------------------+


The following section has a list of supported identifiers for the comma-separated
list of "dependencies".
+---------------------------------------+---------------------------------------------------------------+-------------------------------+
| Id                                    | Description                                                   | Required version              |
+---------------------------------------+---------------------------------------------------------------+-------------------------------+
| activemq                              | Spring JMS support with Apache ActiveMQ 'Classic'.            |                               |
```

Figure A.19 Accessing https://start.spring.io through cURL

You can generate a Spring Boot project through the CLI by providing the project parameters and dependencies, as shown in Listing A.7:

Listing A.7 Spring Boot CLI to generate a Spring Boot Project

```
spring init --dependencies=web,h2 --type=gradle-project --java-version=15 --packaging=war
        spring-boot-gradle-app.zip
```

The command in Listing A.7 generates a Spring Boot Gradle project with the Spring web and H2 in-memory database dependencies, Java version as Java 15, and project packaging types as War. It stores the generated project artifact with the name `spring-boot-gradle-app.zip`.

TECHNIQUE: DEVELOPING A SIMPLE SPRING BOOT APPLICATION WITH SPRING BOOT CLI

Problem

You have successfully installed Spring Boot CLI on your machine, and you want to create a Spring Boot application with it.

Solution

It is straightforward to create a Spring application using Spring Boot CLI. You can simply start with a text editor. Let us begin by defining a basic REST controller that returns with a message. Although this is a straightforward example, you'll shortly notice the simplicity of the CLI tool and the concise nature of Groovy. It'll also provide an insight into how easy it is to use Spring Boot CLI. Don't worry if you don't know what a REST controller is. You'll learn about it later in the book.

You'll compare this REST controller with the equivalent Java version to understand the verbosity and the boilerplate code you will need to write if the same controller is written with Java. Create a folder named `cli-introduction` in `C:\` drive (in Windows) or in the home directory (in macOS or Linux). Then create a file named `application.groovy` with the following content inside the `cli-introduction` folder as shown in Listing A.8:

Listing A.8 Groovy REST Controller in Spring Boot CLI

```
#Spring Boot REST controller
@RestController
class DemoRestController {

    #Maps all HTTP GET requests to this method
    @GetMapping("/")
    def hello() {
                    #Response to all GET requests. The return keyword is optional and can
       be skipped
        "Welcome to Spring Boot CLI"
    }
}
```

In the above groovy code, you've defined a REST controller, which returns a string *Spring Boot CLI* as the output. You can execute this file using the `run` command of Spring Boot CLI. Open command prompt (in Windows) from `C:\cli-introduction` or a terminal (in macOS and Linux) and execute the command shown in Listing A.9:

Listing A.9 Executing application.groovy with Spring Boot CLI

```
$ spring run application.groovy
```

You can access this REST endpoint through the web browser on http://localhost:8080 and notice the output as shown in Figure A.21:

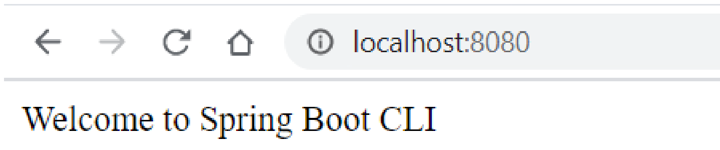


Figure A.20 Spring Boot REST endpoint output

Let us now see the Java equivalent of the Groovy code as shown in Listing A.10:

Listing A.10 Java equivalent code of the Groovy REST Controller

```
package com.manning.spring.boot;

#Required import statements
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.web.bind.annotation.GetMapping;
import org.springframework.web.bind.annotation.RestController;

#A Spring REST controller
@RestController
#Enables Spring Boot Features
@SpringBootApplication
public class DemoSpringBootApplication {

    public static void main(String[] args) {
        SpringApplication.run(DemoSpringBootApplication.class, args);
    }

    #Maps all HTTP GET requests to this method
    @GetMapping
    public String hello() {
         #Response to all HTTP GET requests. The return keyword is optional
        return "Welcome to Spring Boot CLI";
    }
}
```

The Java version has several boilerplate codes compared to the CLI's Groovy version:

1. First, you need to import all the classes and the annotations that you are using in the Java file
2. Second, specify the `@SpringBootApplication` annotation for Spring Boot to perform the auto-configuration of the application
3. Finally, you need to write a `main()` method to start the application and make this REST endpoint available to others

Understanding the Spring Boot CLI Commands

You've already seen how to compile and run the Groovy source code using the Spring Boot CLI *run* command. Below is the complete description of the `run` command:

```
$ spring run [options] <files> [--] [arguments]
```

It takes one or more Groovy files with additional options and arguments. Note that `--` is used to separate the application options from the spring command line arguments. For example, to start the application in a port other than the default 8080, you can specify a different port using the `--server.port` argument:

```
$ spring run application.groovy -- --server.port=9090
```

To find a full list of options supported by the Spring Boot CLI `run` command, you can use the `help` command of Spring Boot CLI. For example, if you execute `spring run help`, you can find the output as shown in figure A.22:

```
C:\sbip\repo\appendix01\cli-introduction>spring help run
spring run - Run a spring groovy script

usage: spring run [options] <files> [--] [args]

Option                        Description
------                        -----------
--autoconfigure [Boolean]     Add autoconfigure compiler transformations
                                (default: true)
--classpath, -cp  <String>    Additional classpath entries
--no-guess-dependencies       Do not attempt to guess dependencies
--no-guess-imports            Do not attempt to guess imports
-q, --quiet                   Quiet logging
-v, --verbose                 Verbose logging of dependency resolution
--watch                       Watch the specified file for changes
```

Figure A.21 Spring Boot CLI run command options

So far, you are running the application through the Spring Boot CLI tool from the command line. However, this might be fine for quick prototyping and to try out Spring Boot features. But you might not always want to run the application from the command line. You may wish to create a runnable jar file or create a war file to deploy the application in any of your environments. With the Spring Boot CLI, you can easily create a runnable jar or a war file.

For example, you can create a runnable jar file by using the below command:

```
$ spring jar app.jar application.groovy
```

The above command produces a runnable jar file that can be executed using the `java -jar` command. Similarly, you can create a War file using the following command:

```
$ spring war app.war application.groovy
```

Grab Hints vs. @Grab annotation

Spring Boot CLI uses two techniques to download the dependencies needed for your application. The first and implicit technique is known as *grab hints*. These hints are mostly in form of Java classes and annotations. If these classes or annotations are present in your application code, Spring Boot CLI automatically detects the relevant dependencies and downloads them. You can refer to Table A.2 for the list of grab hints.

However, as you might have already noticed, these grab hints are limited and might not suffice your needs. The second technique, @Grab annotation resolves this limitation. The `@Grab` annotation lets you explicitly specify the dependencies needed in your application. Spring Boot CLI pulls these dependencies as specified in the `@Grab` annotation.

Groovy includes a `@Grab` annotation, which lets you explicitly declare third-party dependencies in your application. This annotation allows you to download jar files like a dependency management tool such as Maven or Gradle. Spring Boot extends this grabbing technique and attempts to deduce the libraries based on the contents of your code as "grab hints."

For instance, the presence of `@EnableJms` in your code hints Spring Boot CLI to download the necessary libraries required for a Java Messaging Service (https://www.oracle.com/technical-resources/articles/java/intro-java-message-service.html) application. Table A.3 shows the list of "grab hints." Some of the grab hints are classes, and some are annotations. You'll see the use of `@Grab` annotation shortly in this section.

Table A.2 Groovy Grab Hints

Code Item	Grabs
JdbcTemplate, DataSource, NamedParameterJdbcTemplate	Adds dependencies required for a JDBC Application
@EnableJms	Provides dependencies required for a JMS Application
@EnableCaching	Provides Caching Abstractions
@EnableRabbit	Adds dependencies required for a RabbitMQ
@EnableWebSecurity	Provides support for Spring Security
@EnableTransactionManagement	Spring Transaction Management
@Controller, @RestController, @EnableWebMvc	Provides support for a Spring MVC application with embedded Tomcat
@EnableBatchProcessing	Adds support required for a Spring Batch application
@EnableIntegration @MessageEndpoint	Provides support for Spring Integration

You have already seen the use of `@RestController` in the `application.groovy` file. The presence of this annotation lets Spring Boot download necessary dependencies for a Spring MVC application and provides an embedded Tomcat server.

Let us now provide an additional grab hint in our `application.groovy` to demonstrate this feature further. Let's say you want to use Spring Security in the application and leverage the default security features provided by Spring Security. To do so, let us add `@EnableWebSecurity` in the `application.groovy` file, as shown in Listing A.11:

Listing A.11 A simple Spring Boot REST controller

```
@EnableWebSecurity
@RestController
class DemoRestController {

    @GetMapping("/")
    def hello() {
        "Spring Boot CLI"
    }
}
```

Run this application, and you can see that our application now has default Spring Security features enabled. Spring Boot now redirects us to a login page to access the endpoint. You can find the generated password from the console and login with this and user as "user."

Although grab hints seem to be a powerful feature, it is limited as we have a limited number of such hints. You might need to use a third-party library outside of these hints. To remove this limitation, Spring Boot extends Groovy's standard `@Grab` annotation by letting you specify a dependency. Therefore, if there is a Groovy hint already in your application, the framework tries to download them automatically. Later, when no hint is available, you can explicitly add dependencies using `@Grab` annotation.

For instance, we can tweak our previous example and use `@Grab` annotation to add the `spring-boot-starter-security` dependency, as shown in Listing A.12. Thus, by using `@Grab` annotation, you can explicitly specify the dependencies needed in your application:

Listing A.12 Using Groovy @Grab annotation to specify additional dependency

```
@Grab("spring-boot-starter-security")
@RestController
class DemoRestController {

    @GetMapping("/")
    def hello() {
        "Welcome to Spring Boot CLI"
    }
}
```

The above code downloads the `spring-boot-starter-security` dependencies. If you run this file with Spring Boot CLI, you can see the CLI is resolving the dependencies and asking you to log in to access the endpoint.

Discussion

In this technique, you've seen the use of Spring Boot CLI by developing a tiny Spring REST web service. The major takeaway in this technique is the use of Groovy language which lets you write concise code. Besides, you also don't need any build framework for dependency management and application packaging. In the next technique, we'll take this concept further by building a web application consists of UI and database.

TECHNIQUE: BUILDING A WEB APPLICATION USING SPRING BOOT CLI

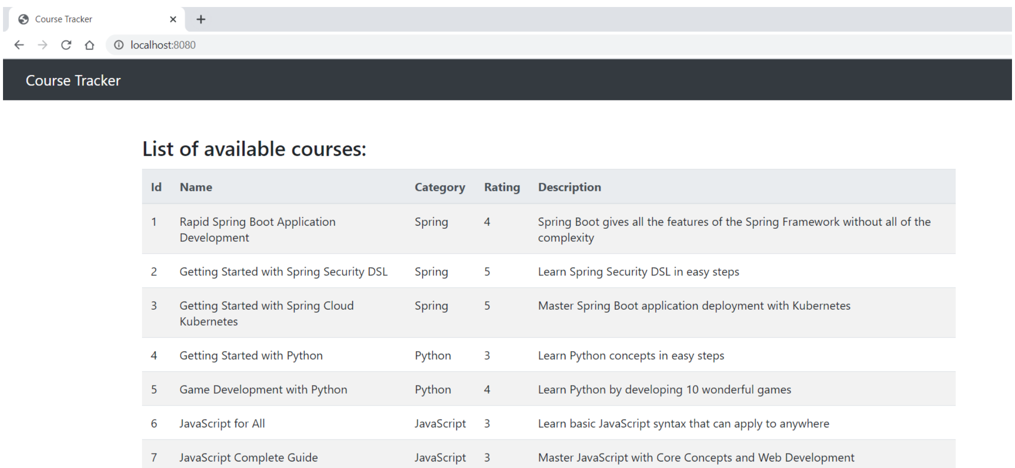
Problem

You want to build a web application with UI and database support using Spring Boot CLI

Solution

In the previous technique, you've explored Spring Boot CLI and learned the major commands to play with it. In this technique, you'll extend that understanding further by developing a web application with the Spring Boot CLI.

You'll build a UI-based application that keeps track of the courses in an e-learning platform. In this application, you will use Thymeleaf (https://www.thymeleaf.org/) to manage the UI components and H2 in-memory database (https://www.h2database.com/html/main.html) to persist the course data. Figure A.22 shows the outcome of the application you will build in this technique.



Id	Name	Category	Rating	Description
1	Rapid Spring Boot Application Development	Spring	4	Spring Boot gives all the features of the Spring Framework without all of the complexity
2	Getting Started with Spring Security DSL	Spring	5	Learn Spring Security DSL in easy steps
3	Getting Started with Spring Cloud Kubernetes	Spring	5	Master Spring Boot application deployment with Kubernetes
4	Getting Started with Python	Python	3	Learn Python concepts in easy steps
5	Game Development with Python	Python	4	Learn Python by developing 10 wonderful games
6	JavaScript for All	JavaScript	3	Learn basic JavaScript syntax that can apply to anywhere
7	JavaScript Complete Guide	JavaScript	3	Master JavaScript with Core Concepts and Web Development

Figure A.22 Course Tracker application using Spring Boot CLI

In the development process, you will explore a few of the Spring Boot features, which will be useful in the subsequent chapters. You can download the completed version of this application from this book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/appendix01/course-tracker-cli.

To begin with, create a folder named `course-tracker-cli`

```
$ mkdir course-tracker-cli
```

This folder acts as the root folder of the application. You'll create two more folders, `config` and `templates` inside the root folder:

```
$ mkdir config templates
```

The `config` folder contains the `application.properties` file and the `templates` folder contains HTML templates. The `application.properties` file contains optional Spring Boot configuration parameters. For instance, if you need to start the application on a different port other than the default port 8080, you can configure the custom port in the `application.properties`. You can also specify your database or logging configurations in this file.

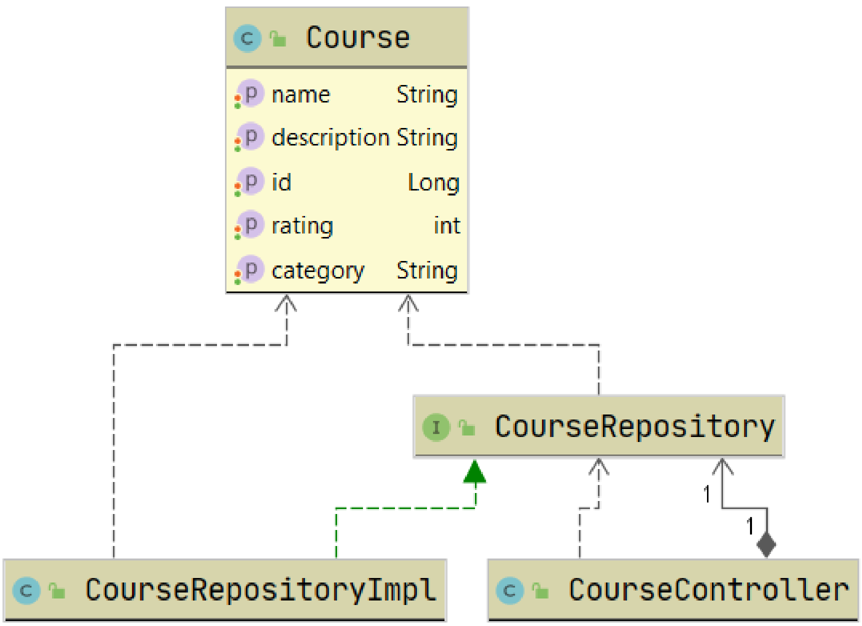


Figure A.23 Conference Tracker application using Spring Boot CLI

Figure A.24 shows the UML class diagram of the application you are going to build. You have a `Course` as the business domain class. A `CourseRepository` interface where you define the data access methods. The default implementation of this interface is represented by the `CourseRepositoryImpl` class. Lastly, you have a `CourseController` class that has an instance of the `CourseRepository`.

In this application, the `Course` is the domain class, which represents a course in the application. A course consists of a course id, name, category, rating, and description. Following is the `course.groovy` class, as shown in Listing A.13:

Listing A.13 Course POJO class

```
class Course {
    long id
    String name
    String category
    int rating
    String description
}
```

You will use Spring JDBC to communicate with the database. Thus, you will need to create the Data Access Layer using Spring `JdbcTemplate`. A `JdbcTemplate` is Spring's template-based approach that simplifies the use of JDBC and lets you avoid common JDBC errors.

Let us define the `CourseRepository` interface inside the `course-tracker-cli` folder with the below data access methods, as shown in Listing A.14. In this interface, you declare different data access methods to find course details.

Listing A.14 Course Repository interface to define data access methods

```
interface CourseRepository {
    Iterable<Course> findAll()
    Iterable<Course> findAllByCourseCategory(String category)
}
```

These data access methods perform the following activities and fetch information from the database:

1. `findAll`: Finds all courses available in the application
2. `findAllByCourseCategory`: Given a course category, it returns all courses that belong to the supplied category

You'll now define `CourseRepositoryImpl` class inside the `course-tracker-cli` folder. This class implements the `CourseRepository` interface and defines the behaviors of the interface methods.

Let us explain the actions you'll perform inside the `CourseRepositoryImpl` class:

Create a file named `CourseRepositoryImpl` inside the root folder of your application with the following content, as shown in Listing A.15:

Listing A.15 CourseRepositoryImpl class

```
#Spring Stereotype annotation indicates that this class is a Spring Data Repository
@Repository
class CourseRepositoryImpl implements CourseRepository {

    #An instance of JdbcTemplate is autowired by Spring. This class lets you access the
       database easily
    @Autowired
    JdbcTemplate jdbcTemplate;

         #Implementation of findAll method to fetch all courses from the database
    Iterable<Course> findAll() {
         jdbcTemplate.query("""SELECT COURSE_ID, COURSE_NAME, COURSE_CATEGORY,
       COURSE_RATING, COURSE_DESCRIPTION FROM COURSES""", {
              resultSet, newRow -> new Course(
                  id : resultSet.getLong(1),
                  name : resultSet.getString(2),
                  category : resultSet.getString(3),
                  rating : resultSet.getInt(4),
                  description : resultSet.getString(5))
         } as RowMapper)
    }

    #Implementation of findAllByCourseCategory method that fetchs all courses belongs to
       the supplied category from the database
    Iterable<Course> findAllByCourseCategory(String category) {
         jdbcTemplate.query("""SELECT COURSE_ID, COURSE_NAME, COURSE_CATEGORY,
       COURSE_RATING, COURSE_DESCRIPTION FROM COURSES WHERE COURSE_CATEGORY=?""", {
              resultSet, newRow -> new Course(
                  id : resultSet.getLong(1),
                  name : resultSet.getString(2),
                  category : resultSet.getString(3),
                  rating : resultSet.getInt(4),
                  description : resultSet.getString(5))
         } as RowMapper, category)
    }
}
```

Now that you are ready with the data access methods let's define a Spring controller class to handle the incoming user requests. You'll create `CourseController` class inside the `course-tracker-cli` folder of the application to do this task, as shown in Listing A.15.

Apart from handling the incoming request, you are performing several additional activities in the controller. Let us explain these step by step:

- `/`: Default endpoint, returns all courses available in our application
- `/{category}`: Provide all courses that belong to the supplied category

Listing A.16 Course REST Controller

```
# Using Groovy's @Grab annotation to tell Spring Boot to get the H2 database and spring-
       boot-starter-dependencies
@Grab("h2")
@Grab("spring-boot-starter-thymeleaf")

# Defines this class as a Spring controller, and HTTP requests can be mapped to this class
@Controller
@RequestMapping
class CourseController {

    # Autowiring the CourseRepository implementation. In this case, CourseRepositoryImpl
       will be injected by Spring here
    @Autowired
    CourseRepository courseRepository;

    # HTTP GET request mapping endpoint to address all GET requests with endpoint "/"
    @GetMapping
    def getAllCourses(Model model) {
        model.addAttribute("courses", courseRepository.findAll());
        "courses";
    }

    # HTTP GET request mapping endpoint to address GET requests with  /{category}. The
       category is a PathVariable and is replaced with the actual course category
    @GetMapping("{category}")
    def getAllCourses(@PathVariable("category") String category, Model model) {
        model.addAttribute("courses", courseRepository.findAllByCourseCategory(category));
        "courses";
    } }
```

You've defined the data access object and the controller class to handle the HTTP incoming requests. Let's now define the *view* of the application. Create a file named `courses.html` inside the `templates` folder of the `course-tracker-cli`, as shown in Listing A.17.

In the view, you've done the following:

Listing A.17 Course Tracker HTML Template

```
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <title>Course Tracker</title>
    <meta charset="utf-8"/>
    <meta name="viewport" content="width=device-width, initial-scale=1"/>
    <link rel="stylesheet"
       href="https://maxcdn.bootstrapcdn.com/bootstrap/4.0.0/css/bootstrap.min.css"/>
    <script
       src="https://ajax.googleapis.com/ajax/libs/jquery/3.3.1/jquery.min.js"></script>
    <script
       src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.12.9/umd/popper.min.js"></sc
       ript>
    <script
       src="https://maxcdn.bootstrapcdn.com/bootstrap/4.0.0/js/bootstrap.min.js"></script>
</head>
<body>
<nav class="navbar navbar-dark bg-dark">
  <div class="container-fluid">
    <div class="navbar-header">
      <a class="navbar-brand" href="#">Course Tracker</a>
    </div>
  </div>
</nav>
<div class="container h-100">
    <div class="row justify-content-left mt-5 mb-1">
        <h3 id="heading">List of available courses:</h3>
    </div>
    <div class="row table-responsive">
        <table class="table table-striped">
            <thead class="thead-light">
            <tr>
                <th>Id</th>
                <th>Name</th>
                <th>Category</th>
                <th>Rating</th>
                <th>Description</th>
            </tr>
            </thead>
            <tbody>
            <tr th:each="course : ${courses}">
                <td th:text="${course.id}">ID</td>
                <td th:text="${course.name}">Name</td>
                <td th:text="${course.category}">Category</td>
                <td th:text="${course.rating}">Rating</td>
                <td th:text="${course.description}">Description</td>
            </tr>
            </tbody>
        </table>
    </div>
</div>
</body>
</html>
```

You are almost done with the application except the database schema definition. If you recall, we are using the `H2` in-memory database to persist the data. Spring Boot uses a convention to detect the schema definition files and the data files. It automatically loads the schema if it finds a file named `schema.sql` and loads the data if it detects a file named `data.sql`. You'll learn more about these in later chapters. But for now, let's create both these files inside the `course-tracker-cli` folder of our application.

Listing A.18 shows the `schema.sql` file in which you are creating the COURSES table:

Listing A.18 The schema.sql file to create the Courses database table

```
create table COURSES (
    COURSE_ID identity not null,
    COURSE_NAME varchar(100) not null,
    COURSE_CATEGORY varchar(10) not null,
    COURSE_RATING tinyint not null,
    COURSE_DESCRIPTION varchar(500) not null
);
```

We also want to load some course details to populate the table with data. Listing A.19 shows the `data.sql` file containing a few SQL insert statements:

Listing A.19 The data.sql file to load the sample data by Spring Boot

```
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(1, 'Rapid Spring Boot Application Development', 'Spring',
       4, 'Spring Boot gives all the features of the Spring Framework without all of the
       complexity');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(2, 'Getting Started with Spring Security DSL', 'Spring',
       5, 'Learn Spring Security DSL in easy steps');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(3, 'Getting Started with Spring Cloud Kubernetes',
       'Spring', 5, 'Master Spring Boot application deployment with Kubernetes');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(4, 'Getting Started with Python', 'Python', 3, 'Learn
       Python concepts in easy steps');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(5, 'Game Development with Python', 'Python', 4, 'Learn
       Python by developing 10 wonderful games');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(6, 'JavaScript for All', 'JavaScript', 3, 'Learn basic
       JavaScript syntax that can apply to anywhere');
INSERT INTO COURSES(COURSE_ID, COURSE_NAME, COURSE_CATEGORY, COURSE_RATING,
       COURSE_DESCRIPTION) VALUES(7, 'JavaScript Complete Guide', 'JavaScript', 3, 'Master
       JavaScript with Core Concepts and Web Development');
```

The last change before you can execute the application is to configure the H2 database. So far, we've only provided the H2 database dependency in the Groovy file. But we also need to provide details such as database username, password, driver class, and URL.

Create a file named `application.properties` inside the `config` folder with the details shown in Listing A.20. Spring Boot reads these details at the application startup and configures the H2 database automatically.

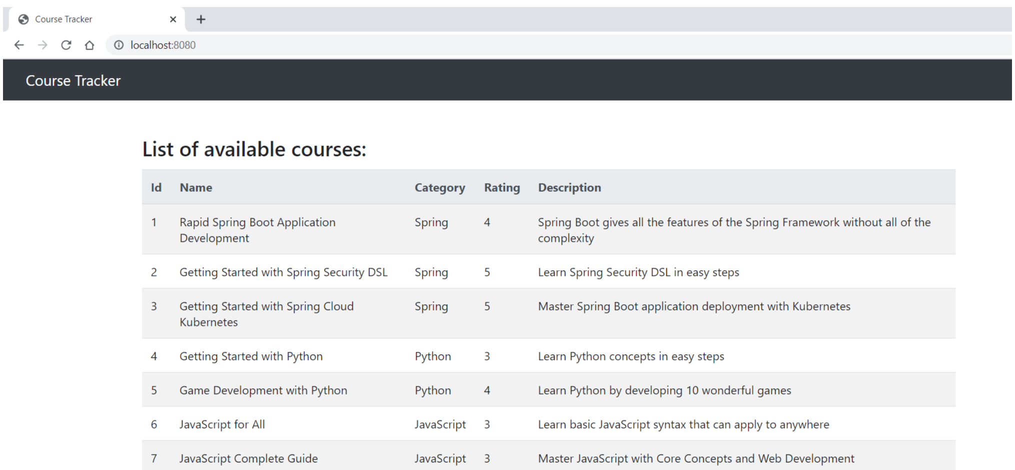
Listing A.20 H2 database configuration

```
#This ensures that you can access the H2 database console through http://localhost:8080/h2-
       console
spring.h2.console.enabled=true
spring.datasource.url=jdbc:h2:mem:testdb
spring.datasource.driverClassName=org.h2.Driver
spring.datasource.username=sa
spring.datasource.password=password
```

Adding the database configuration completes the application development, and you are ready to execute the application. You can run the application by executing the spring Boot CLI `run` command. Open your command prompt or the terminal window and run the following command from the `course-tracker-cli` folder:

```
$ spring run *
```

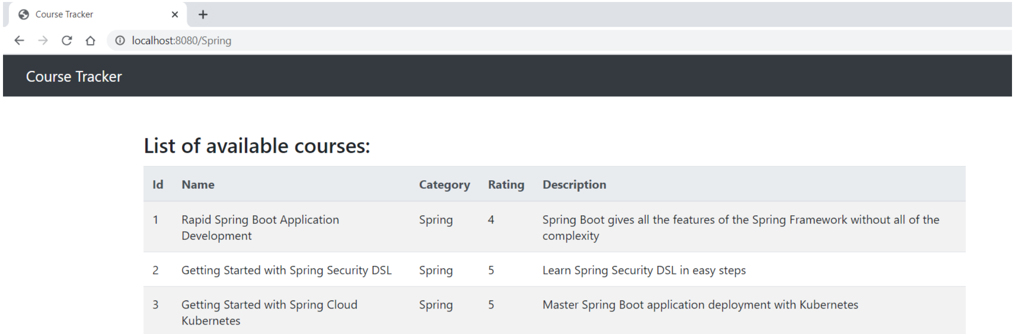
You can see the application starts up and the start-up logs in the console. By default, HTTP port 8080 is used to run the application. If you access http://localhost:8080, you can see the output, as shown in Figure A.25:



Id	Name	Category	Rating	Description
1	Rapid Spring Boot Application Development	Spring	4	Spring Boot gives all the features of the Spring Framework without all of the complexity
2	Getting Started with Spring Security DSL	Spring	5	Learn Spring Security DSL in easy steps
3	Getting Started with Spring Cloud Kubernetes	Spring	5	Master Spring Boot application deployment with Kubernetes
4	Getting Started with Python	Python	3	Learn Python concepts in easy steps
5	Game Development with Python	Python	4	Learn Python by developing 10 wonderful games
6	JavaScript for All	JavaScript	3	Learn basic JavaScript syntax that can apply to anywhere
7	JavaScript Complete Guide	JavaScript	3	Master JavaScript with Core Concepts and Web Development

Figure A.24 Conference Tracker application displaying all Conferences

You can also access other endpoints, such as find all courses that belongs to a category by accessing the http://localhost:8080/{category} URL. For instance, if you access the http://localhost:8080/Spring URL, you can see all courses belong to the `Spring` category. Figure A.25 shows the output.



List of available courses:

Id	Name	Category	Rating	Description
1	Rapid Spring Boot Application Development	Spring	4	Spring Boot gives all the features of the Spring Framework without all of the complexity
2	Getting Started with Spring Security DSL	Spring	5	Learn Spring Security DSL in easy steps
3	Getting Started with Spring Cloud Kubernetes	Spring	5	Master Spring Boot application deployment with Kubernetes

Figure A.25 List of courses belongs to the Spring category

Nice! Thanks to the features of Spring Boot CLI we can track our favorite Spring courses!

Discussion

In this technique, you've seen the use of Spring Boot CLI to build a full-scale web application with a front-end and a backing database. You haven't used any dependency management tool such as Maven or Gradle, instead, Spring Boot CLI manages the dependencies for us.

B
Spring MVC and Thymeleaf Template Engine

In this section, we'll revisit Spring MVC and provide an overview to Thymeleaf Template Engine.

B.1 Revisiting Spring MVC

Spring MVC is one of the important modules of the Spring Framework. The Model-View-Controller (MVC) is the popular design pattern to build UI based web applications. MVC lets you decouple the application design in terms of model, view, and controller. A *model* encapsulates business data which is presented by a *view*. A *controller* is responsible to address the user requests and invoke back-end business services. Post business service invocation, the controller prepares the model with the data for the views to render in the UI.

Spring MVC is the Spring Framework's implementation of the MVC design pattern. One of the powerful and key features of Spring MVC is that it is based on the Spring IoC container and tightly integrated with it to provide a simplistic configuration.

In this section, you'll revisit the important Spring MVC concepts such as the front controller design pattern and various other components that Spring MVC uses heavily while processing the user requests. If you are not familiar with Spring MVC, refer to the Spring MVC documentation (https://docs.spring.io/spring-framework/docs/current/spring-framework-reference/web.html#mvc) or introductory Spring MVC texts. Providing an in-depth guide of Spring MVC is beyond the scope of this text.

B.1.1 Front Controller Design Pattern

Spring MVC is designed around a design pattern known as the front controller pattern. In this design, a central servlet is primarily responsible to handle all the requests. In Spring parlance, this central servlet is known as the dispatcher servlet. Although the dispatcher servlet handles all requests, it delegates the actual request processing task to several configurable delegated components.

In a typical Spring MVC application, you'll need to configure the `DispatcherServlet` in the application's deployment descriptor file (`web.xml`) or in a class that implements `ServletContainerInitializer` interface. Listing B.1 shows a sample configuration to configure a `DispatcherServlet` programmatically:

Listing B.1 Configure a Dispatcher Servlet Programatically

```
public class CourseCourtServletContainerInitializer implements ServletContainerInitializer
       {
    @Override
    public void onStartup(Set<Class<?>> set, ServletContext servletContext) throws
       ServletException {

                  # Create an instance of ApplicationContext
        AnnotationConfigWebApplicationContext applicationContext =  new
       AnnotationConfigWebApplicationContext();
        applicationContext.register(CourseConfiguration.class);
        #Create an instance of DispatcherServlet with the previously created application
       context
        DispatcherServlet dispatcherServlet = new DispatcherServlet(applicationContext);
        #Dynamically register the DispatcherServlet with the ServletContext
        ServletRegistration.Dynamic servletRegistration =
       servletContext.addServlet("course", dispatcherServlet);
        servletRegistration.setLoadOnStartup(1);
        servletRegistration.addMapping("/");
    }
}
```

B.1.2 Understanding Request Processing

Now that you've learned how to configure a dispatcher servlet, let us understand how it processes an incoming request. In this section, you'll explore the steps a dispatcher servlet executes to process the incoming requests. Figure B.1 shows the sequences of steps:

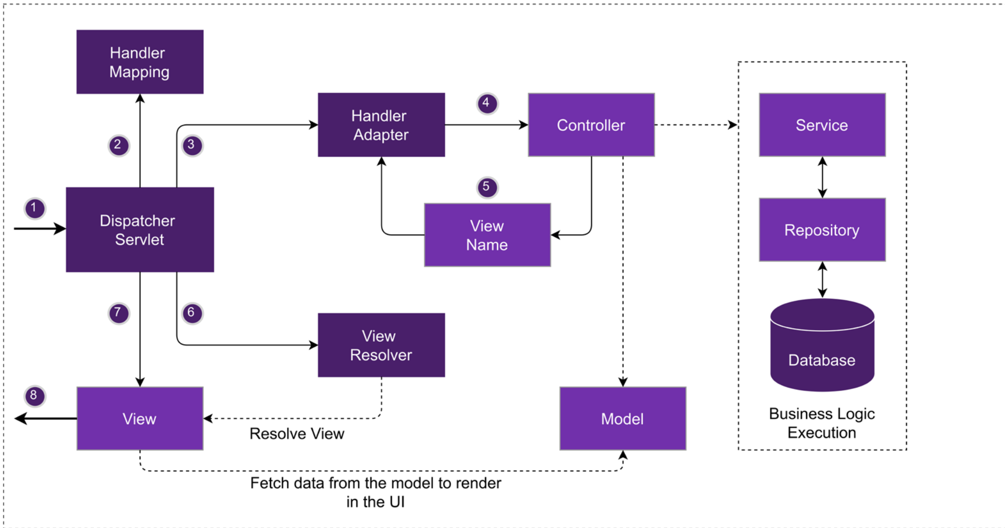


Figure B.1 Spring MVC components. The *DispatcherServlet* is the primary component and it delegates the request to various other components

Following is an overly simplified and high-level step of a request handling by the dispatcher servlet:

1. Any request to a Spring MVC based application is initially addressed by the dispatcher servlet
2. Once a request is received, the dispatcher servlet first delegates the incoming request to a `HandlerMapping`. A `HandlerMapping` finds a Spring controller configured to address the request
3. Once a controller is found, the dispatcher servlet delegates the request to a `HandlerAdapter` that invokes the controller
4. Generally, a controller invokes the business services and retrieve the application data
5. Post business invocation, a controller prepares a model that contains the returned business data. Besides, the controller also returns a logical view name to the dispatcher servlet
6. The `DispatcherServlet` then invokes a `ViewResolver` which maps the logical view name to the actual view
7. The returned view uses the model data and renders it to the screen
8. Once the view is rendered on the screen, the request is considered as addressed

Let's now discuss briefly a few of the Spring MVC components that dispatcher servlet uses for task delegation:

- **HandlerMapping**: This interface provides a mapping between the request URL and the handler objects. Spring MVC includes two major implementations of the `HandlerMapping` interface – `BeanNameUrlHandlerMapping` and `RequestMappingHandlerMapping`. The `BeanNameUrlHandlerMapping` implementation maps the request URL to the bean name of the same name. This is the default implementation used by Spring MVC. A `HandlerMapping` returns a `HandlerExecutionChain` which contains the handler object and a list of interceptors. Based on the configuration (pre/post), these interceptors are invoked while addressing the request
- **HandlerAdapter**: This interface helps the dispatcher servlet to invoke a handler mapped to a request. The main benefit of this interface is that it shields the dispatcher servlet from the implementation details of the handler. Spring MVC provides four implementations of this interface – `RequestMappingHandlerAdapter`, `HttpRequestHandlerAdapter`, `SimpleControllerHandlerAdapter`, and `SimpleServletHandlerAdapter`
- **ViewResolver**: Resolves the logical string-based view names to the actual view. Spring framework provides several `ViewResolver` and `View` implementations. Refer to https://github.com/spring-boot-in-practice/.../ViewResolvers.png for the list of `ViewResolver` implementations
- **LocaleResolver**: This interface lets the dispatcher servlet automatically resolve messages based on the client's locale configuration. For all the incoming requests, the dispatcher servlet asks the configured `LocaleResolver` implementation to resolve the locale and set it in the `HttpServletResponse`. Spring framework provides several `LocaleResolver` implementations. Figure B.2 shows the list of available `LocaleResolvers`. The default implementation used by the Spring MVC is `AcceptHeaderLocaleResolver`

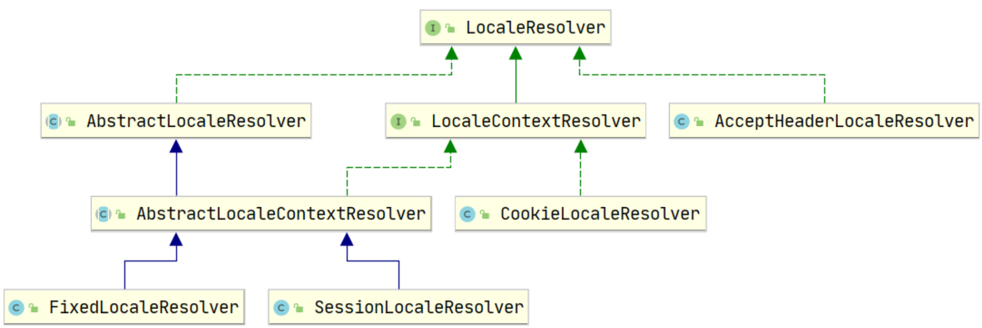


Figure B.2 Spring MVC LocaleResolver Class Hierarchy. The default implementation is AcceptHeaderLocaleResolver

- **HandlerExceptionResolver**: This interface lets resolve exceptions thrown during handler mapping or execution. In case of an exception, the dispatcher servlet delegates to a chain of `HandlerExceptionResolver`. An exception resolver can either choose to handle the exception or delegate to another resolver implementation. A `HandlerExceptionResolver` can do any of the following:
  - Return a `ModelAndView` that points to an error view
  - An empty `ModelAndView` if the exception is already handled in the `HandlerExceptionResolver`
  - Return `null` if the exception is unresolved and the subsequent resolvers should attempt to handle it. If the exception is unresolved till the end, it is finally addressed by the Servlet container.

  The major `HandlerExceptionResolver` implementations are - `SimpleMappingExceptionResolver`, `ExceptionHandlerExceptionResolver`, `ResponseStatusExceptionResolver`, `DefaultHandlerExceptionResolver`

Now that you've refreshed the Spring MVC concepts and their various components, let us discuss Thymeleaf template engine.

B.2 Understanding Thymeleaf

In this section, you'll learn the basics of Thymeleaf, and its integration with Spring Boot. Thymeleaf is a server-side template engine that lets you define several types of template. For instance, a Thymeleaf HTML template is an HTML page that contains HTML tags with special Thymeleaf tags. These Thymeleaf tags are processed at runtime by the Thymeleaf processing engine and replaced with the supplied data and plain HTML content is rendered on the browser.

Thymeleaf supports six types of templates – `HTML`, `XML`, `TEXT`, `JAVASCRIPT`, `CSS`, and `RAW`. Out of these types, `HTML` based template is the most popular and frequently used to develop Java-based web application. In this section and the subsequent technique, you'll learn more about the usage of HTML based Thymeleaf templates in the Spring Boot application.

A detailed explanation of Thymeleaf is beyond the scope of this book. You can refer to the Thymeleaf documentation (https://www.thymeleaf.org/documentation.html) for an in-depth understanding of Thymeleaf. Let us start with the necessary components of Thymeleaf.

Displaying Attributes

Sometimes, you send data from a Spring Boot controller through a model to the view layer to render the data in the UI. Along with the model, you typically send a view name in which the associated model data is rendered. The view name is mapped with the appropriate HTML page and the Thymeleaf processing engine process the Thymeleaf specific tags to replace them with the supplied application data. Figure B.3 shows this process through a block diagram:

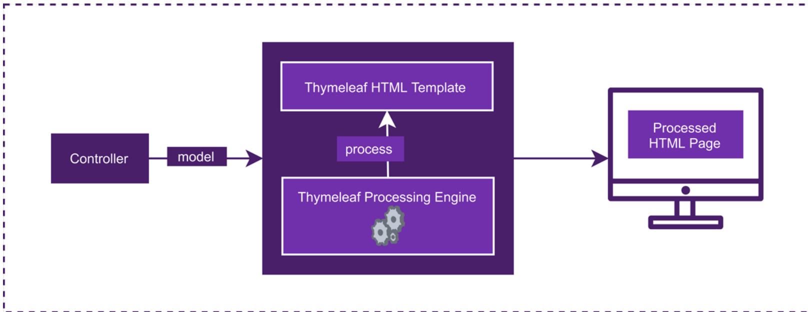


Figure B.3 Processing of Thymeleaf templates with Spring model by Thymeleaf template processing engine

In Spring MVC, a model typically stores the data in a `key-value` pair. If the value is a simple type, you can directly access it in the UI using the `key`. Listing B.2 shows how you can use the `key` provided in the model in the Thymeleaf template:

Listing B.2 Use of the th:text Thymeleaf tag

```
<span th:text=”${key}” />
```

Let us understand the above syntax in detail:

- The `<span>` is an HTML tag that lets you mark up a part of the text
- The `th` specifies the Thymeleaf XML namespace in which all other Thymeleaf specific tags (e.g., `text`) are defined. You can define the `th` tag in the HTML document as shown in Listing B.3:

Listing B.3 The Thymeleaf namespace

```
<html xmlns:th="http://www.thymeleaf.org">
```

- The `${key}` replaces the value of the `key` with the appropriate value

For example, let’s say you need to render the logged-in user’s name in the UI. So, in your controller, you can add the `userName` as a key and the user’s name as the value. In the Spring controller, you define an HTTP endpoint (e.g., `@GetMapping`) and populate the model with the values as shown in Listing B.4:

Listing B.4 Use of Spring model in a Spring controller

```
# Defines an HTTP GET endpoint
@GetMapping
public String getLoggedInUserName(Model model) {
    # Adds the userName attribute with the user name value to the model
    model.addAttribute("userName", user.getName());
    # Returns a view named index
    return "index";
}
```

The associated HTML code to display the value of the `userName` attribute is shown below:

```
Logged In user: <span th:text=”${userName}” />
```

The userName value from the model is rendered in the UI by the key name you have specified. Sometimes, you can have a collection of objects instead of a simple attribute type. For example, you can return a list of courses that should be rendered in the UI. So, in the controller, you add the list of courses as shown below:

```
List<Course> courseList = // Business service returns a list of course
model.addAttribute("courses", courseList);
```

And you can use the Thymeleaf template code to iterate over the list to print the returned object details. For instance, you can display the course details in an HTML table as shown in the Listing B.5:

Listing B.5 Use of the Thymeleaf th:each tag

```
# HTML Table Body
<tbody>
    # The tr tag represents an HTML table row. The th:each tag represents a for loop here.
       You iterate the list of courses and for each course, you access the associated
       properties
    <tr th:each="course: ${courses}">
        # The td tag represents the column data for the row. You access the individual
       property value from the course object and put into the column of the row. Recall
       that for a single property, you can use the th:text tag to access the associated
       value
        <td th:text="${course.id}" />
        <td th:text="${course.name}" />
        <td th:text="${course.description}" />
    </tr>
</tbody>
```

Conditional Evaluation

Sometimes, you want to render texts in the UI based on some condition evaluation. The **`th:if`** tag lets you display a section of the view if the condition is met. On the other hand, **`th:unless`** tag lets you display a section of the view if the condition is not met”. Below snippet shows the complete syntax:

```
th:if=”${condition}”
th:unless=”${condition}”
```

Imagine you’ve an entity called `Author` in your course-tracker application and it has a property named `gender` which can have two possible values (‘M’ or ‘F’) to indicate the author's gender. If you intend to display the words “Male” or “Female” instead of the single ‘M’ or ‘F’ character, we could accomplish this by using the following Thymeleaf code as shown in the Listing B.6:

Listing B.6 Use of th:if and th:unless Thymeleaf tags

```
<td>
    <span th:if="${author.gender} == 'M'" th:text="Male" />
    <span th:unless="${author.gender} == 'M'" th:text="Female" />
</td>
```

If you would like to use `switch` and `case`, you can do that as well. The **`th:switch`** and **`th:case`** tags are used to render content conditionally using the switch statement structure. Imagine that you want to render some information based on the course category. You can use the following `switch-case` code snippet to render different content based on the course content as shown in the Listing B.7:

Listing B.7 Use of Thymeleaf th:switch and th:case tags

```
# Using Thymeleaf switch-case statements to evaluate condition
<div th:switch="${course.category}">
    <div th:case="’Spring’">
          <h2>Spring Course</h2>
    </div>
    <div th:case="’Python’">
          <h2>Python Course</h2>
    </div>
    <div th:case="’JavScript’">
          <h2>JavaScript Course</h2>
    </div>
    <div th:case="*">
          <h2>Some other course:</h2>
       </div>
</div>
```

Notice that you've used the `th:case=”*”` to handle the default case. If the value of the `course.category` is 'Spring', then it renders the message, *Spring Course*. If the course category is none of the Spring, Python, or JavaScript values, then the message, *Some other course* is rendered.

Managing Forms

HTML forms are an essential part of any web application. You can use forms to collect and submit bulk data to the application backend. Besides, you also need to validate the form data to ensure appropriate value is keyed-in in the form fields.

You can manage the form data and validation errors easily with Thymeleaf. You can use the form action and input data with **`th:action`** and **`th:object`** attributes. Listing B.8 shows this syntax:

Listing B.8 Thymeleaf th:action and th:object tag syntax

```
th:action=”@{url}”
th:object=”${object}”
```

The **`th:action`** tag lets you specify the form action URL where the form data needs to be submitted. Notice that the tag name is the same as the `action` attribute of an HTML form.

The tag **th:object** tag lets you specify an object in which the submitted form data is bounded.

The individual fields are mapped using the **th:field="*{name}"** attribute, where the `name` is the property defined in the Java object. For instance, if you are using the **th:object="${course}",** then you can access all properties of the `Course` object in the `th:field`.

As discussed, you also need to show validation error messages to the user if there are any validation error in the field. Thymeleaf provide few functions in the `#fields` object and the **th:errors** attribute for this purpose. The **hasErrors(..)** method of the `#field` object accepts a field expression as a parameter (e.g., name) and returns a `boolean` value specifying whether any validation errors exist for that field. The `th:errors` tag builds a list with all the available errors. The errors are separated by `<br />` tag. Listing B.9 shows an example of the usage of `hasErrors(..)` and `th:errors` tags:

Listing B.9 Thymeleaf #fields.hasErrors and th:errors tag syntax

```
<span th:if="${#fields.hasErrors('name')}" th:errors="*{name}" class="text-danger"></span>
```

Let us understand these concepts by defining a complete HTML form that lets you create a course. The Listing B.10 shows the form snippet:

Listing B.10 The Add Course form with Thymeleaf tag

```
# Defines an HTML form. The th:action invokes the addcourse HTTP endpoint defined in the
       Spring controller. You have also defined the th:object that binds the provided form
       data into the course
<form action="#" th:action="@{/addcourse}" th:object="${course}" method="post">
# You are using Bootstrap library to design the form
    <div class="row">
        <div class="form-group col-md-6">
            <label for="name" class="col-form-label">Name</label>
            <input type="text" th:field="*{name}" class="form-control" id="name"
       placeholder="Name">
             # Checks if there are any error for the name field. If there are any, then
       th:errors list them
            <span th:if="${#fields.hasErrors('name')}" th:errors="*{name}" class="text-
       danger"></span>
        </div>
        <div class="form-group col-md-6">
            <label for="email" class="col-form-label">Description</label>
            <input type="text" th:field="*{description}" class="form-control" id="email"
       placeholder="Description">
            <span th:if="${#fields.hasErrors('description')}" th:errors="*{description}"
       class="text-danger"></span>
        </div>
    </div>
    <div class="row">
        <div class="col-md-6 mt-5">
            <input type="submit" class="btn btn-primary" value="Add Course">
        </div>
    </div>
</form>
```

In the form specified in the Listing B.10, the `/addcourse` is the form action URL. The `course` object in the `th:object` holds the add course form data that is submitted. Let us show the `addcourse` HTTP endpoint which is part of the controller to understand how the form and the controller interacts. Listing B.11 shows the associated HTTP POST endpoint from Course example we are using in this chapter:

Listing B.11 The sample addCourse HTTP POST endpoint

```
# Defines an HTTP POST endpoint with URL /addcourse
@PostMapping("/addcourse")
# The @Valid annotation evalustes all constraints defined in the Course class.BindingResult
       holds the validation errors
public String addCourse(@Valid Course course, BindingResult result, Model model) {
    if (result.hasErrors()) {
        return "add-course";
    }
    // Save the course details in database
    model.addAttribute("courses", //Get all courses from the database);
    return "redirect:/index";
}
```

Although the code snippet in the listing only contains few lines, there are a quite bit of functionalities involved here:

- You've annotated the class with `@PostMapping` to ensure that an HTTP POST request can be addressed by this endpoint. You've also declared the form with `method="post"` attribute. As an HTTP form contains bulk data, it is submitted through the HTTP POST method so that the data can be part of the HTTP request body
- The `@Valid` annotation ensures that all validations defined on the supplied object and its properties are performed. This annotation triggers Spring to invoke the validators associated with the object to be validated
- The `BindingResult` is a Spring object that holds the result of validation and binding. It also contains the errors that might have encountered in validation and binding. If `BindingResult` contains any error, you return to the HTML page where the request came from. In the above code snippet, the form belongs to the add-course HTML page. Thus, we return the associated view name `add-page`
- You've already seen the usage of the model in earlier discussions. In this example, Spring Boot autowire an instance of the model. You then load all course details into the model with key as "courses" and a list of courses as the value
- Finally, you are using the `redirect` prefix to redirect the flow to a view called `index`. This ensured a redirection happened to the index view and it renders in the UI

In this section, you learned the building blocks of Thymeleaf and seen the usage of few tags that you'll typically use frequently with a Spring Boot application. Let us apply this knowledge by building a complete Spring Boot application with Thymeleaf in the next technique.

B.3 Enabling a Template Engine in Spring Boot

Spring Boot applications are heavily used to develop web-based applications. There are two major patterns to develop web applications where Spring Boot suits well:

- In the first type, Spring Boot applications are used as the backend application in conjunction with the Single Page application-based frontends – such as Angular (https://angular.io/) or React (https://reactjs.org/), or Vue JS (https://vuejs.org/). In this pattern, the Spring Boot application is configured with the REST web services which provide data to the frontend for rendering. Figure 2.18 shows a sample pattern through a block diagram:

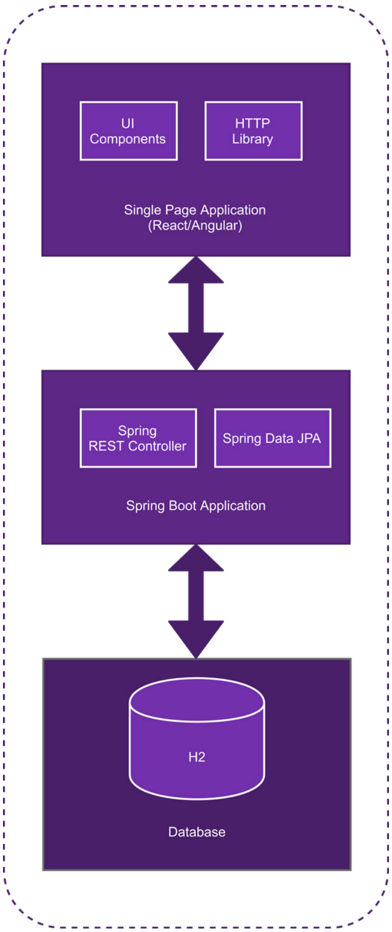


Figure B.4 Web application design pattern with SPA-based frontend and Spring Boot application

In Figure B.4, the single page application requests data through its HTTP library. This request is intercepted by the Spring Boot REST controller. The REST controller uses the underlying Spring Data (JPA) to communicate to the database. The returned result is then handed over to the HTTP library and subsequently rendered in the frontend application UI.

- In the second type, you use a complete Java-based technology stack and don't use JavaScript-based frontend frameworks. In this pattern, you use the traditional Spring MVC (Model-View-Controller) design pattern with frontend template engines such as Thymeleaf (https://www.thymeleaf.org/), Freemarker (https://freemarker.apache.org/), Mustache (https://mustache.github.io/). Out of these template engines, Thymeleaf is a popular and most widely used along with Spring Boot applications. Figure B.5 shows a sample of this pattern through a block diagram:

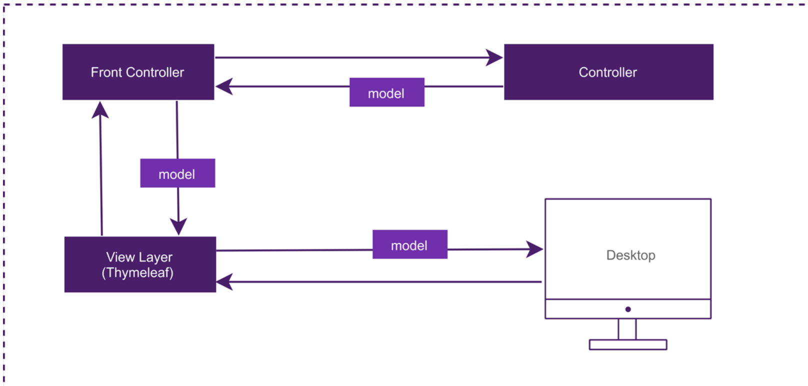


Figure B.5 Web application design pattern with Spring MVC and Thymeleaf

Figure B.5 shows a typical Spring MVC-based design where both the frontend and backend components of the application are part of the same Spring Boot application. In this pattern, the view layer is represented by HTML based template engine such as Thymeleaf. A model is a container that carries application data from the controller to the view layer. The data provided in the model is processed in the view layer by the template engines and rendered on the screen.

B.4 Building an application with Thymeleaf

TECHNIQUE: BUILDING A SPRING BOOT WEB APPLICATION WITH THYMELEAF TEMPLATE

Problem

You want to build a web application with Spring Boot and Thymeleaf template engine.

Solution

Thymeleaf is a popular and widely used server-side frontend template engine that is often used with Spring Boot to develop production-grade web applications. Besides, Thymeleaf provides excellent integration with the Spring framework, and in fact, there is a Spring Boot Thymeleaf starter that lets you directly use Thymeleaf in Spring Boot applications.

To use Thymeleaf in a Spring Boot application, you create Thymeleaf HTML templates and place them into the `src\main\resources\templates` folder. From your Spring Boot controller, you return the logical view name that gets mapped to the HTML pages. You use the Spring Model to send the data that is used in the HTML page.

As usual, to proceed with this technique, you can continue with the Spring Boot project you've used previously. We've added the `spring-boot-starter-thymeleaf` dependency in the `pom.xml` file to enable Thymeleaf support in the application.

You can find the base Spring Boot project for this technique in the book's companion GitHub repository at https://github.com/spring-boot-in-practice/repo/tree/main/appendix02/course-tracker-building-webapp/course-tracker-start. You can clone this project and continue with this technique.

In this technique, you'll build a Spring Boot that uses a Thymeleaf based user interface along with a service layer implementation. Before we proceed further let us add `spring.mvc.hiddenmethod.filter.enabled=true` property in the `application.properties` file. Listing B.12 shows the modified `application.properties`:

Listing B.12 Application.properties file

```
# Property that enables HiddenHttpMethodFilter in the application
spring.mvc.hiddenmethod.filter.enabled=true
```

This property enables `HiddenHttpMethodFilter` in your Spring Boot application. Sometimes in your application, you need to support HTTP methods such as `PUT`, `PATCH`, `DELETE` which are not supported by the browser. To overcome this issue, you add a hidden form field (`_method`) in your HTML form that indicates the actual HTTP method. The `HiddenHttpMethodFilter` performs this conversion. You'll see the usage of this filter in the Update and Delete course operations.

Figure B.6 shows the high-level block diagram of the application flow:

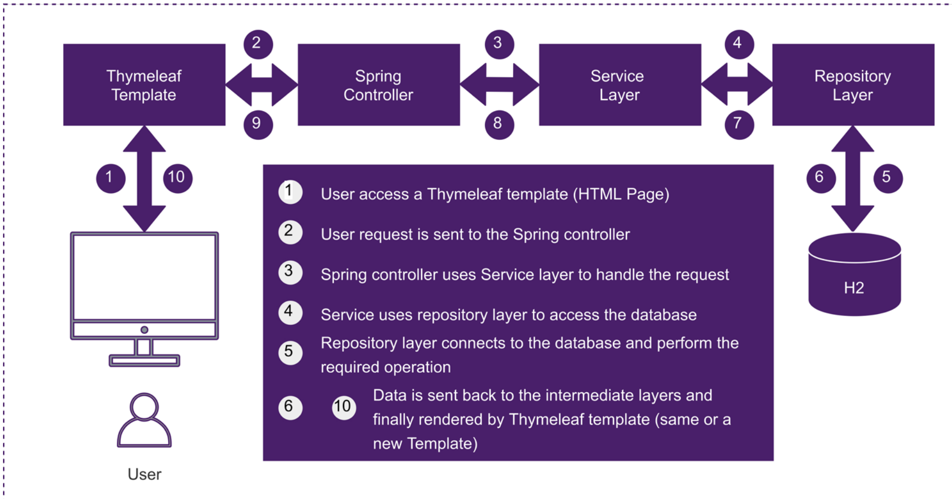


Figure B.6 Spring MVC based web application Thymeleaf flow diagram

In this technique, you are using the `Course` Java POJO as the business domain entity. We've added the `@NotEmpty` annotation in the `rating`, `category`, and `description` properties. This annotation is from `javax.validation.constraints` package that ensures that the supplied fields are not empty. We've added it here only to demonstrate how you can leverage this built-in annotation to perform field validation in the Thymeleaf UI. Listing B.13 shows the updated content of the `Course` entity:

Listing B.13 The Updated Course entity

```
package com.manning.sbip.a02.model;
import javax.validation.constraints.*;

public class Course {

        private int id;

        @NotEmpty(message = "Course name field can't be empty")
        private String name;

        @NotEmpty(message = "Course category field can't be empty")
        private String category;

        @Min(value = 1)
        @Max(value = 5)
        private int rating;

        @NotEmpty(message = "Course description field can't be empty")
        private String description;

        // Constructor, Getter, Setter
}
```

Let us first focus on the service layer of the application. As a practice, you first define an interface that represents the operations supported by the service layer. You can then provide an implementation of it by defining the operations. In this technique, you've defined the `CourseSevice` interface to manage the course CRUD operations. Listing B.14 shows this interface:

Listing B.14 The CourseService interface

```
package com.manning.sbip.a02.service;

import com.manning.sbip.a02.model.Course;

import java.util.Optional;
# Defines the operations supported in the course-tracker application
public interface CourseService {
    # Creates a new Course
    Iterable<Course> createCourse(Course course);
    # Loads a course by the supplied courseID. The Optional return type indicates there
       might not be a course available with the supplied id
    Optional<Course> findCourseById(int courseId);
    # Loads all available courses
    Iterable<Course> findAllCourses();
    # Update a course details
    Iterable<Course> updateCourse(Course course);

    # Deletes a course by the supplied courseId
    Iterable<Course> deleteCourseById(int courseId);
}
```

You can refer to the inline code documentation to learn the purpose of the defined operations.

Let us now provide an implementation of these operations. In this example, we are not connecting to any database, instead of using an in-memory map to store the course information. Listing B.15 shows the `DefaultCourseService` class:

Listing B.15 Default CourseService Implementation

```
package com.manning.sbip.a02.service;

import com.manning.sbip.a02.model.Course;
import org.springframework.stereotype.Service;

import java.util.*;
import java.util.concurrent.atomic.AtomicInteger;
import java.util.stream.Collectors;

# Provides an implementation of the CourseService interface
@Service
public class DefaultCourseService implements CourseService {
    # This map acts as the backing data store for the application as we are not using any
       database
    private Map<Integer, Course> courses;
    # Generates the course Ids
    private AtomicInteger courseIdGenerator;
```

```
    public DefaultCourseService() {
        this.courses = new HashMap<>();
        this.courseIdGenerator = new AtomicInteger(0);
        initializeCourses();
    }

    @Override
    public Iterable<Course> createCourse(Course course) {
        int courseId = course.getId();
        if(courseId == 0){
            courseId = getCourseId();
            course.setId(courseId);
        }else {
            courseId = course.getId();
        }
        courses.put(courseId, course);
        return findAllCourses();
    }

    @Override
    public Optional<Course> findCourseById(int courseId) {
        return Optional.of(courses.get(courseId));
    }

    @Override
    public List<Course> findAllCourses() {
        List<Course> courseList = new ArrayList<>();
        for(Map.Entry<Integer, Course> courseSet : courses.entrySet()) {
           courseList.add(courseSet.getValue());
        }
        return courseList;
    }

    @Override
    public Iterable<Course> updateCourse(Course course) {
        return createCourse(course);
    }

    @Override
    public Iterable<Course> deleteCourseById(int courseId) {
        courses.remove(courseId);
        return findAllCourses();
    }
    # Creates a few sample courses and stores in the map
    private void initializeCourses() {
        Course rapidSpringBootCourse = new Course(getCourseId(), "Rapid Spring Boot
       Application Development", "Spring", 4, "Spring Boot gives all the power of the
       Spring Framework without all of the complexity");
        Course springSecurityDslCourse = new Course(getCourseId(), "Getting Started with
       Spring Security DSL", "Spring", 2, "Learn Spring Security DSL in easy steps");
        Course springCloudKubernetesCourse = new Course(getCourseId(), "Getting Started
       with Spring Cloud Kubernetes", "Spring", 4, "Master Spring Boot application
       deployment with Kubernetes");
        courses.put(rapidSpringBootCourse.getId(), rapidSpringBootCourse);
        courses.put(springSecurityDslCourse.getId(), springSecurityDslCourse);
        courses.put(springCloudKubernetesCourse.getId(), springCloudKubernetesCourse);
    }

    private int getCourseId() {
```

```
        return courseIdGenerator.incrementAndGet();
    }
}
```

You can refer to the inline code documentation of the listing to understand the implemented operations. The purpose of using an interface to define the services is that you can always provide a different implementation based on your requirement.

Let us define the `CourseController` that provides CRUD operations support to the application. You'll use these endpoints from the Thymeleaf templates. Listing B.16 shows the `CourseController` class:

Listing B.16 The CourseController Spring Controller

```
package com.manning.sbip.a02.controller;

import com.manning.sbip.a02.model.Course;
import com.manning.sbip.a02.service.CourseService;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.stereotype.Controller;
import org.springframework.ui.Model;
import org.springframework.validation.BindingResult;
import org.springframework.web.bind.annotation.*;

import javax.validation.Valid;
import java.util.Collections;
import java.util.List;

@Controller
public class CourseController {

    private final CourseService courseService;

        # An instance of the CourseService which is used by the controller to perform the
       CRUD operations. Notice that you've not used the actual implementation
       DefaultCourseService as the dependency. Coding to interfaces is always a best
       practice as this approach lets you switch the implementation at your convenience. In
       this technique, you've only DefaultCourseService implementation. Thus, Spring can
       autowire this instance, If you've more than one service implementation then you can
       use @Qualifier annotation to tell Spring which implementation qualifies for
       autowiring.
    @Autowired
    public CourseController(CourseService courseService) {
        this.courseService = courseService;
    }

    @GetMapping("/")
    public String index() {
        return "redirect:/index";

        # An HTTP GET endpoint that returns all courses that need to be displayed on the
       index HTML page. If the course list is empty, then it returns an empty collection.
       Otherwise, all available courses are provided. You use a Spring model to add the
       courseList along with the key named courses. You also return a string called 'index'
       which is a logical view name. Spring Boot takes this view name and prepares the
       physical view named index.html. All views for Thymelaf are located inside the
       src\main\resources\templates folder.
```

```
@GetMapping("/index")
public String index(Model model) {
    List<Course> courseList = (List<Course>) courseService.findAllCourses();
    model.addAttribute("courses", courseList.isEmpty() ? Collections.EMPTY_LIST :
   courseList);
    return "index";
}

# An HTTP GET endpoint that returns the add-course view name. Based on this name,
   Spring Boot figures out the add-course.html page from the
   src\main\resources\templates directory and renders in the UI
@GetMapping("/addcourse")
public String showAddCourseForm(Course course) {
    return "add-course";
}

#An HTTP POST endpoint that lets you create a course. The @Valid annotation enables
   Spring Boot to run all the validations associated with the Course class. If you
   recall, you've added the @NotEmpty annotation for a couple of the properties. Thus,
   if any of the annotated properties are empty, then the associated validation error
   will be recorded and stored inside the BindingResult.  Also, notice how you've used
   the same endpoint name (/addcourse) in the previous @GetMapping as well. This is a
   general practice to drive the endpoints through the associated HTTP methods. You
   typically show an HTML page (e.g. a form) when the user accesses the endpoint over
   the HTTP GET method. Then once the user submits the form, you invoke the HTTP POST
   endpoint. This enables you to accept the form data through the HTTP body and invoke
   the necessary CRUD operations
@PostMapping("/addcourse")
public String addCourse(@Valid Course course, BindingResult result, Model model){
    if (result.hasErrors()) {
        return "add-course";
    }
    model.addAttribute("courses", courseService.createCourse(course));
    return "redirect:/index";
}

# An HTTP GET endpoint that returns the update-course view name. Based on this name,
   Spring Boot figures out the update-course.html page from the
   src\main\resources\templates directory and renders it in the UI. Notice that you've
   also supplied the course ID as the URL path variable. This ID is used to fetch the
   course details and attach them with the update-course view so that the same can be
   rendered in the UI. This ensures the user sees the current value in the UI and can
   make necessary modifications.
@GetMapping("/update/{id}")
public String showUpdateCourseForm(@PathVariable("id") long id, Model model) {
    model.addAttribute("course", courseService.findCourseById(id).get());
    return "update-course";
}

# An HTTP PUT endpoint that lets you update a course. It first checks whether there are
   any validation errors – such as the fields are blank. It then saves the updated
   course details to the database and redirects the user to the index page with the
   course details. The HTTP PUT operation is used to update an existing entity. Also,
   notice that we've again used the HTTP method to drive the endpoint. The /update/{id}
   for GET returns the HTML page, whereas the PUT method for the same endpoint performs
   the actual update operation
@PutMapping("/update/{id}")
public String updateCourse(@PathVariable("id") long id, @Valid Course course,
```

```
        BindingResult result, Model model) {
         if (result.hasErrors()) {
             course.setId(id);
             return "update-course";
         }
         model.addAttribute("courses", courseService.updateCourse(course));
         return "redirect:/index";
    }

    # An HTTP DELETE endpoint that lets you delete a course by the courseId. It deletes the
       course if it exists and redirects the user to the index page. Notice that you are
       using the DELETE HTTP method to delete an entity which is the designated HTTP method
       to perform a delete operation
    @DeleteMapping("/delete/{id}")
    public String deleteCourse(@PathVariable("id") long id, Model model) {
        model.addAttribute("courses", courseService.deleteCourseById(id));
        return "redirect:/index";
    }
}
```

You've defined all Java components (class and interface) required in the application. Let us now focus to define the HTML-based Thymeleaf templates. There are three Thymeleaf templates:

- **index.html**: Defines the index page of the application. It shows the user all available courses with an option to edit or delete a course. It also provides an option to create a new course. If there are no courses previously created, it let the user create a new course.
- **add-course.html**: It lets you add a new course. Contains an HTML that lets you key-in course properties.
- **update-course.html**: It displays existing course details and provides you an option to update the existing details.

Let's now start with the index page. Listing B.17 shows the created `index.html` page available at `src\main\resources\templates` folder:

Listing B.17 The Index HTML Page with Thymeleaf tags

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <meta charset="utf-8">
    <meta http-equiv="x-ua-compatible" content="ie=edge">
    <title>Courses</title>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    # Links the Bootstrap and Font Awesome libraries. Both the libraries are loaded from
       their respective Content Delivery Network (CDN). A CDN hosts the libraries and the
       specified libraries are loaded when this page is rendered.
    <link rel="stylesheet"
       href="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css">
    <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.4.1/css/all.css">
</head>
<body>
# Uses Thymeleaf switch-case to determine whether the courses list is empty or contains
       course details. Recall that in the CourseController /index endpoint, you are
```

```
       returning an empty list or list of courses based on the course availability.
       Besides, #lists is a utility object from Thymeleaf that lets you perform useful
       operations on a list. In this example, you have used the size method to calculate
       the list size.
<div th:switch="${#lists.size(courses)}" class="container my-5">
    <div class="row">
        <div class="col-md-2"></div>
        <div class="col-md-8">
             # Thymeleaf switch-case if the courses list is empty
            <div th:case="'0'">
                <h2>You haven't added any course yet!</h2>
                <p class="text-success">Add a course by clicking below!</p>
            </div>
             # Thymeleaf switch-case if the courses list is not empty
            <div th:case="*">
                <h2 class="my-5">Courses</h2>
                <table class="table table-striped table-responsive-md">
                    <thead>
                    <tr>
                        <th>Course Name</th>
                        <th>Course Category</th>
                        <th>Course Rating</th>
                        <th>Course Description</th>
                        <th>Edit</th>
                        <th>Delete</th>
                    </tr>
                    </thead>
                    <tbody>
                    <tr th:each="course : ${courses}">
                        <td th:text="${course.name}"></td>
                        <td th:text="${course.category}"></td>
                        <td th:text="${course.rating}"></td>
                        <td th:text="${course.description}"></td>
                          # An HTML anchor tag with Thymeleaf tags. The th:href tag lets
       you build the relative URL. The {id} represents the path variable in Spring
       controller. You set the course id to the path variable using (id=${course.id}) part
       of the URL
                        <td><a th:href="@{/update/{id}(id=${course.id})}" class="btn btn-
       primary"><i class="fas fa-edit"></i></a></td>
                        <td>
                # Here you’ve used the th:action tag as you are submitting a form. The
       th:method tag deserves special attention. Recall that this delete endpoint supports
       only the HTTP Delete method. But from a browser, you can only send HTTP or POST
       requests. The th:method instructs Thymeleaf to include a hidden input param <input
       type="hidden" name="_method" value="DELETE">. This hidden attribute is processed by
       Spring’s HiddenHttpMethodFilter filter and changes the supplied HTTP POST method to
       the HTTP DELETE method.
                            <form action="#" th:action="@{/delete/{id}(id=${course.id})}"
       th:method="delete">
                                <button type="submit" class="btn btn-danger">
                                    <i class="fas fa-trash"></i>
                                </button>
                            </form>
                        </td>
                    </tr>
                    </tbody>
                </table>
            </div>
          # Shows a link to add a new course. If you click this link, it invokes addcourse
```

```
       HTTP GET endpoint
            <p class="my-5"><a href="/addcourse" class="btn btn-primary"><i class="fas fa-
       plus-square"></i></a></p>
        </div>
        <div class="col-md-2"></div>
    </div>
</div>
</body>
</html>
```

Figure B.7 shows the index page with the available courses:

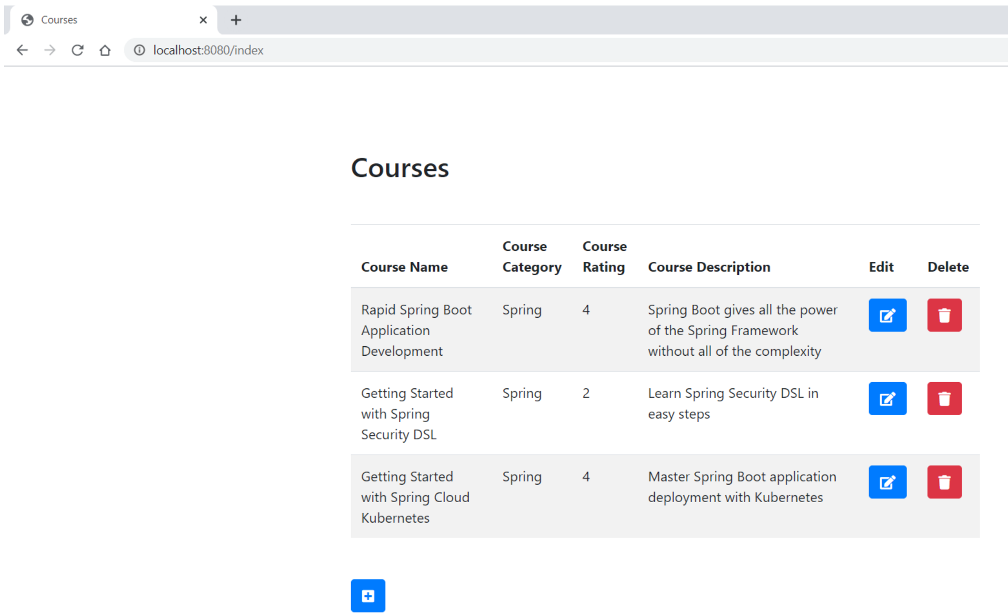


Figure B.7 Spring Boot Thymeleaf Index Page

Let us now add the add course page. Listing B.18 shows the created `add-course.html` page at `src\main\resources\templates` folder. It lets you add a new course. It has an HTML form that contains four fields – course name, category, rating, and description. The `th:object` binds these form data into the `course` object, and is made available to the HTTP endpoint. Once you submit the form, the action (`th:action`) invokes the `/addcourse` HTTP POST endpoint provided in the controller. The `fields.hasErrors(..)` checks if there are any validation errors for any of the fields. The `th:errors` print the error messages if there are any.

Listing B.18 The Add Course HTML Page with Thymeleaf tags

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <meta charset="utf-8">
    <meta http-equiv="x-ua-compatible" content="ie=edge">
    <title>Add a Course</title>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet"
       href="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css">
    <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.4.1/css/all.css">
</head>
<body>
<div class="container my-5">
    <div class="row">
        <div class="col-md-3"></div>
        <div class="col-md-6">
            <h2 class="mb-5">Add a Course</h2>
        </div>
        <div class="col-md-3"></div>
    </div>
    <div class="row">
        <div class="col-md-3"></div>
        <div class="col-md-9">
            <form action="#" th:action="@{/addcourse}" th:object="${course}" method="post">
                <div class="form-row">
                    <div class="form-group col-md-9">
                        <label for="name" class="col-form-label">Name</label>
                        <input type="text" th:field="*{name}" class="form-control"
       id="name" placeholder="Course Name">
                        <span th:if="${#fields.hasErrors('name')}" th:errors="*{name}"
       class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="category" class="col-form-label">Category</label>
                        <input th:field="*{category}" class="form-control" id="category"
       placeholder="Course Category"></input>
                        <span th:if="${#fields.hasErrors('category')}"
       th:errors="*{category}" class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="rating" class="col-form-label">Course Rating</label>
                        <select th:field="*{rating}" class="form-control" id="rating">
                            <option th:value="1">1 (Lowest)</option>
                            <option th:value="2">2</option>
                            <option th:value="3">3</option>
                            <option th:value="4">4</option>
                            <option th:value="5">5 (Highest)</option>
                        </select>
                        <span th:if="${#fields.hasErrors('category')}"
       th:errors="*{rating}" class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="description" class="col-form-label">Description</label>
                        <textarea th:field="*{description}" class="form-control"
       id="description" placeholder="Course Description"></textarea>
                        <span th:if="${#fields.hasErrors('description')}"
       th:errors="*{description}" class="text-danger"></span>
```

```
                    </div>
                </div>
                <div class="row">
                    <div class="col-md-6 mt-5">
                        <input type="submit" class="btn btn-primary center" value="Add
       Course">
                    </div>
                </div>
            </form>
        </div>
        <div class="col-md-3"></div>
    </div>
</div>
</body>
</html>
```

Figure B.8 shows the add course HTML page:

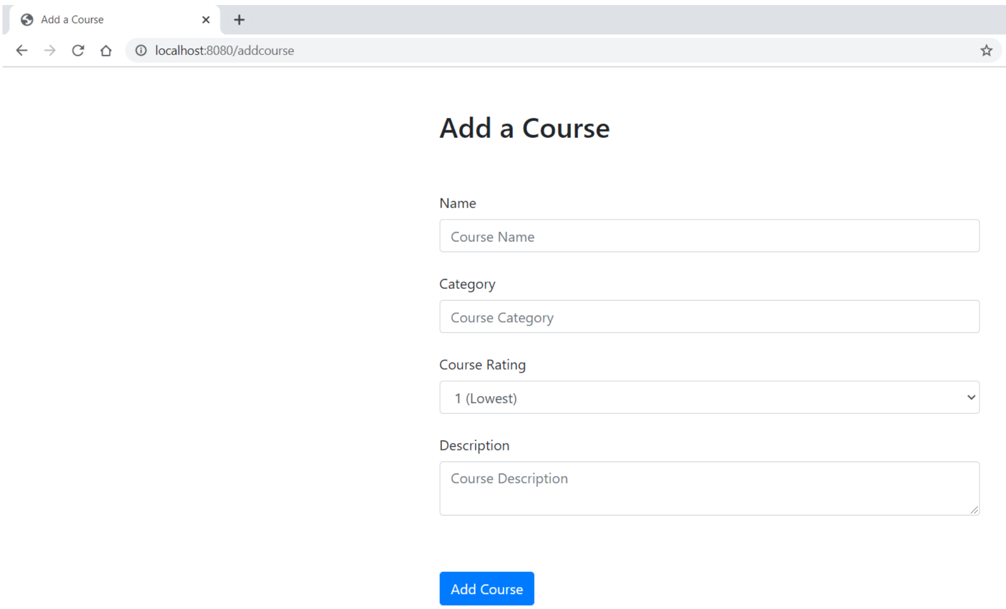


Figure B.8 Spring Boot Thymeleaf Add Course Page.png

You have added the fields `Name`, `Category`, and `Description` fields as mandatory. If you attempt to submit the page without these details, you can now see the inline error messages as shown in Figure B.9:

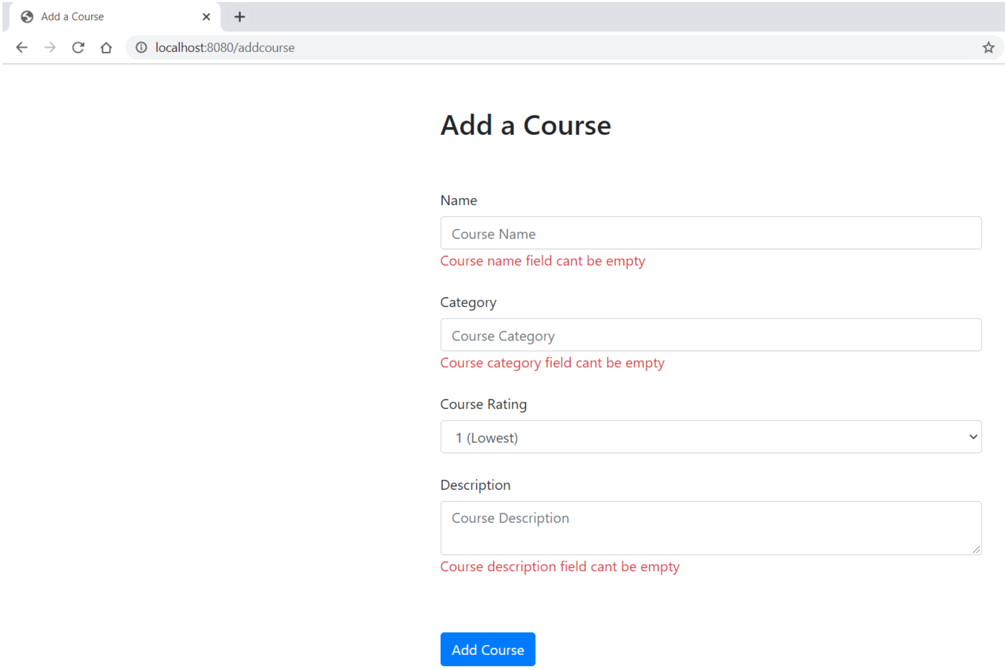
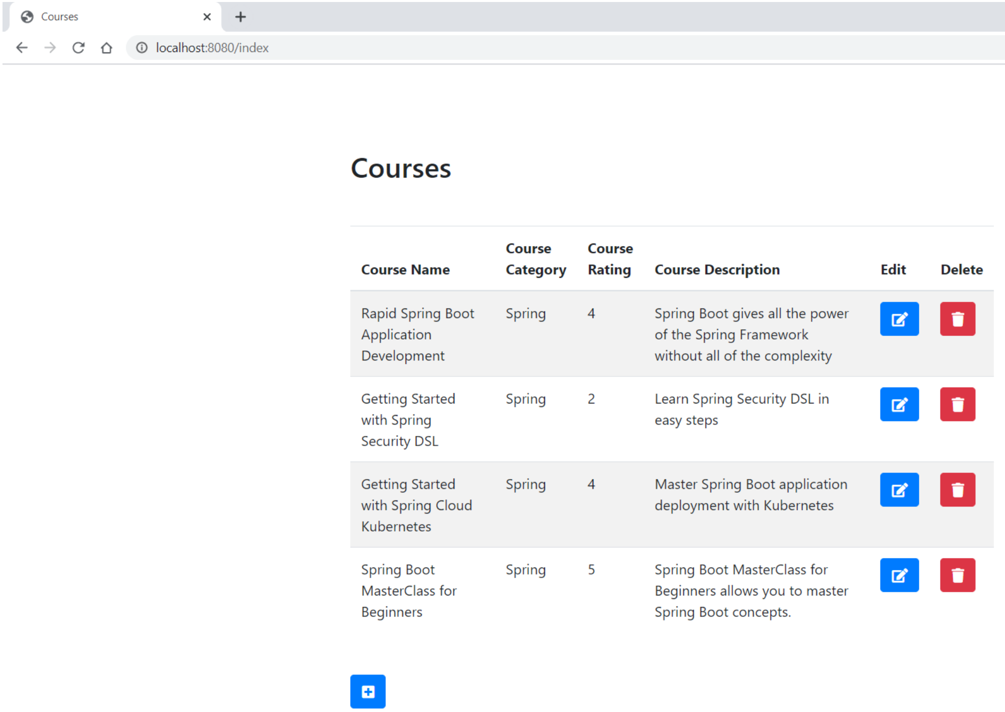


Figure B.9 Spring Boot Thymeleaf Add Course Page

Once you add a course, the course details are stored in the in-memory map, and the user is redirected to the index page. This time the index page shows the course that you have added. Figure B.10 shows the index page with the list of courses:



Course Name	Course Category	Course Rating	Course Description	Edit	Delete
Rapid Spring Boot Application Development	Spring	4	Spring Boot gives all the power of the Spring Framework without all of the complexity		
Getting Started with Spring Security DSL	Spring	2	Learn Spring Security DSL in easy steps		
Getting Started with Spring Cloud Kubernetes	Spring	4	Master Spring Boot application deployment with Kubernetes		
Spring Boot MasterClass for Beginners	Spring	5	Spring Boot MasterClass for Beginners allows you to master Spring Boot concepts.		

Figure B.10 Spring Boot Thymeleaf Index Page With Courses

For each course, you have an option to edit the course details. Besides, you can also delete a course. For example, once you click on the Edit icon, you see the update course HTML page as shown in Figure B.11:

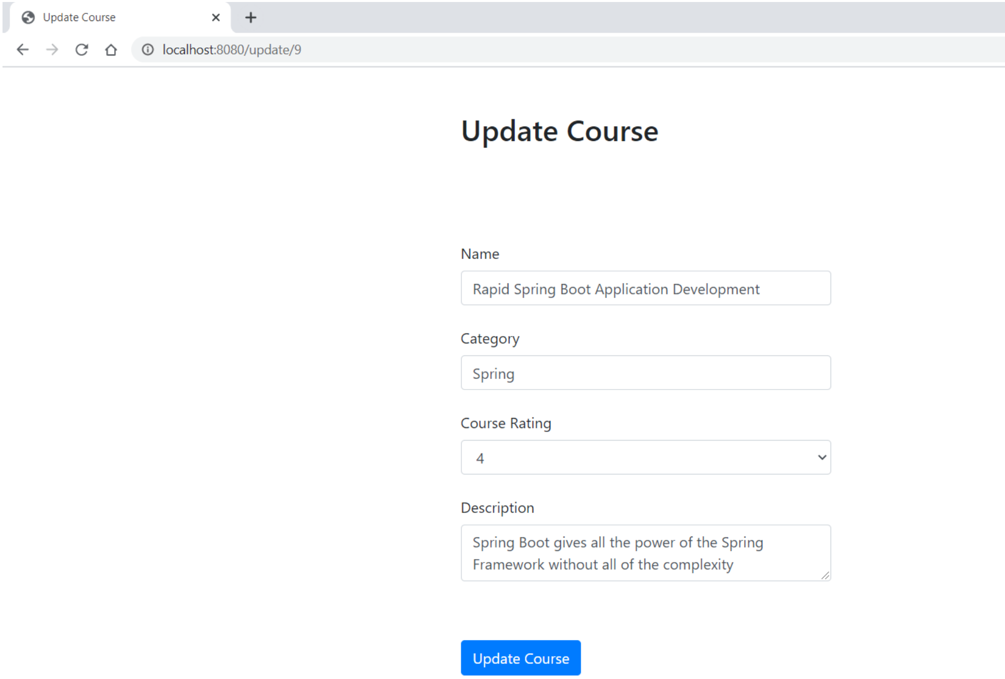


Figure B.11 Spring Boot Thymeleaf Index Page Update Course.png

If you update the course details, you'll be redirected to the index page with the updated course list. The Listing B.19 shows the update course HTML page located at `src\main\resources\template` folder:

Listing B.19 The Update Course HTML Page with Thymeleaf tags

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <meta charset="utf-8">
    <meta http-equiv="x-ua-compatible" content="ie=edge">
    <title>Update Course</title>
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet"
       href="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css">
    <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.4.1/css/all.css">
</head>
<body>
<div class="container my-5">
    <div class="row">
        <div class="col-md-3"></div>
        <div class="col-md-6">
            <h2 class="mb-5">Update Course</h2>
        </div>
    </div>
    <h2 class="mb-5"></h2>
    <div class="row">
        <div class="col-md-3"></div>
        <div class="col-md-6">
            <form action="#" th:action="@{/update/{id}(id=${course.id})}"
       th:object="${course}" method="post" th:method="put">
                <div class="form-row">
                    <div class="form-group col-md-9">
                        <label for="name" class="col-form-label">Name</label>
                        <input type="text" th:field="*{name}" class="form-control"
       id="name" placeholder="Course Name">
                        <span th:if="${#fields.hasErrors('name')}" th:errors="*{name}"
       class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="category" class="col-form-label">Category</label>
                        <input th:field="*{category}" class="form-control" id="category"
       placeholder="Course Category"></input>
                        <span th:if="${#fields.hasErrors('category')}"
       th:errors="*{category}" class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="rating" class="col-form-label">Course Rating</label>
                        <select th:field="*{rating}" class="form-control" id="rating">
                            <option th:value="1">1 (Lowest)</option>
                            <option th:value="2">2</option>
                            <option th:value="3">3</option>
                            <option th:value="4">4</option>
                            <option th:value="5">5 (Highest)</option>
                        </select>
                        <span th:if="${#fields.hasErrors('category')}"
       th:errors="*{rating}" class="text-danger"></span>
                    </div>
                    <div class="form-group col-md-9">
                        <label for="description" class="col-form-label">Description</label>
                        <textarea th:field="*{description}" class="form-control"
       id="description" placeholder="Course Description"></textarea>
                        <span th:if="${#fields.hasErrors('description')}"
```

```
      th:errors="*{description}" class="text-danger"></span>
                    </div>
                </div>
                <div class="row">
                    <div class="col-md-6 mt-5">
                        <input type="submit" class="btn btn-primary" value="Update Course">
                    </div>
                </div>
            </form>
        </div>
        <div class="col-md-3"></div>
    </div>
</div>
</body>
</html>
```

The last operation is to delete the added course. In the index page course list, you have an option to delete a course. If you click on the delete icon, the selected course will be deleted.

You can download the completed version of the Spring Boot project used in this technique at https://github.com/spring-boot-in-practice/repo/tree/main/appendix02/course-tracker-building-webapp/course-tracker-final.

Discussion

In this technique, you built a complete CRUD application with Spring Boot and Thymeleaf. You've seen how seamless it is to integrate Thymeleaf with Spring Boot. You haven't added any special configuration other than adding the Spring Boot Thymeleaf starter dependency. Besides, you've also noticed the several powerful capabilities of Thymeleaf such as conditional rendering, looping through the list, handling validation with the `#field` utility class.