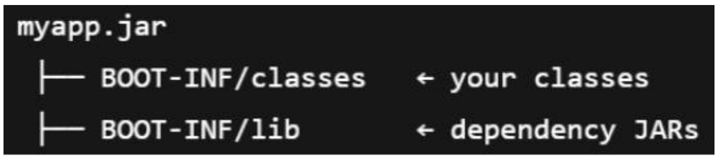
How Spring Boot Works?

- **dependencies** are nothing but **.jar** files which contains the *classes* that we want to use.
- **maven** just download the **JAR**s, and puts them on the **compile + runtime classpath.**
- **modules** are **JARs** with extra responsibilities.
  - spring-web, spring-context, spring-jdbc, spring-data-jpa
- When you run your application, **JVM** searches for all the **.class** files inside the **classpath** which is provided by **maven** (I.e. **classpath** list is provided by Maven).
  - **target** folder is one of the classpaths; but it is not the only classpath;
  - **.jar** files present in the External Libraries are stored in **local Maven Cache**. Which is not inside the project.
    - ~/.m2/repository/org/springframework/spring-webmvc/6.1.x/spring-webmvc-6.1.x.jar
- Then how **JVM** gets to know about the **.class** files that will be used?
  - **Maven** creates a **classpath** where all the list of paths are present.
  - **JVM** sees this and use those classes.
  - **External Libraries** are nothing but the **classpaths** that are not inside your project.
- When you create **.jar** file of your application, the **self created classes** and the **external libraries classes** will be stored separately.
  - 

```
myapp.jar
 ├── BOOT-INF/classes    ← your classes
 ├── BOOT-INF/lib        ← dependency JARs
```

  - **classes** will contain the **self created classes.**
  - **lib** will contain the **external libraries classes.**

Maven vs JVM

- **maven** works at **build** time and **JVM** works at **run time.**
- Initially **maven** is run when you trigger the commands like **mvn test**, **mvn compile**, **mvn package**, **mvn spring-boot:run** .
  - It downloads the dependencies after reading the **pom.xml** and stores them in ~/.m2/repository (*maven cache path*).
  - Then it **compiles** the **.java** files and convert those to **.class** files (bytecodes) *(if the command that was executed was **mvn compile**)*

        - Depending upon the maven command executed, it'll do the thing.
        - One important thing: **maven** is also written in **java**. So it also needs one **JVM** to run it. It is called **Maven JVM** (its not any special JVM, just normal JVM only)
        - Inside this Maven JVM, **maven modules** are being used, not **spring modules**.
        - After finishing its work, Maven creates files on disk (JAR, class files). Later, a separate JVM loads those files and runs the Spring Boot application..
    - Now **JVM** part comes.
        - **JVM** never reads **pom.xml**, it is just read by **maven** to download the dependencies and provide those to **JVM**.
        - **JVM** use those dependencies to run the application.
- There is one plugins that is present in the **pom.xml** which is **"maven-compiler-plugin"**.
    - **maven-compiler-plugin invokes javac behind the scenes, passing all the required flags, paths, and options.**
    - Needful flags means
        - -classpath → where dependencies are
        - -processorpath → where annotation processors (like Lombok) are
        - -source / -target (or --release) → Java version
        - -d target/classes → where compiled .class files go
        - list of .java source files
- **spring-boot-maven-plugin**
    - spring-boot-maven-plugin does NOT run your application logic.
    - It prepares and packages your Spring Boot application so it can be run easily by the JVM.
    - Without this the dependencies won't be there in the **.jar** file, you would have to copy and paste those dependencies to run the application.
    - Also it copies the **tomcat jars** into that.

Spring Boot Work-Flow

- Dependencies are JAR files that contain reusable classes.
- Maven reads pom.xml, downloads dependencies into ~/.m2/repository, and manages build steps.
- Plugins are used by Maven to compile, test, package, and run the application.
- Maven helps prepare classpath information, but the JVM actually uses the classpath to load .class files.
- IntelliJ shows dependency JARs from Maven cache under External Libraries.

Runtime Flow

- JVM starts and executes main()
- SpringApplication.run() processes @SpringBootApplication
- Auto-configuration classes listed in the AutoConfiguration.imports file are considered
- Beans are created only if conditions match, using conditional annotations

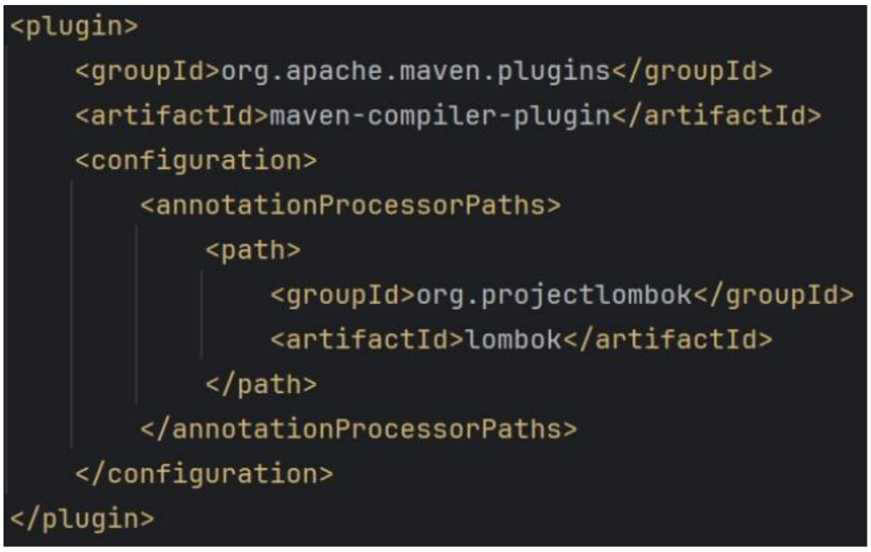
Maven vs JVM

- Maven works at build time
- JVM works at run time
- Maven downloads and prepares dependency JARs
- JVM loads classes from those JARs and runs the application

Plugins

- maven-compiler-plugin
  - Invokes javac with required flags
  - Handles annotation processing (Lombok)
- spring-boot-maven-plugin
  - Packages the app into an executable fat JAR
  - Bundles dependencies (including embedded Tomcat)
  - Makes java -jar app.jar possible

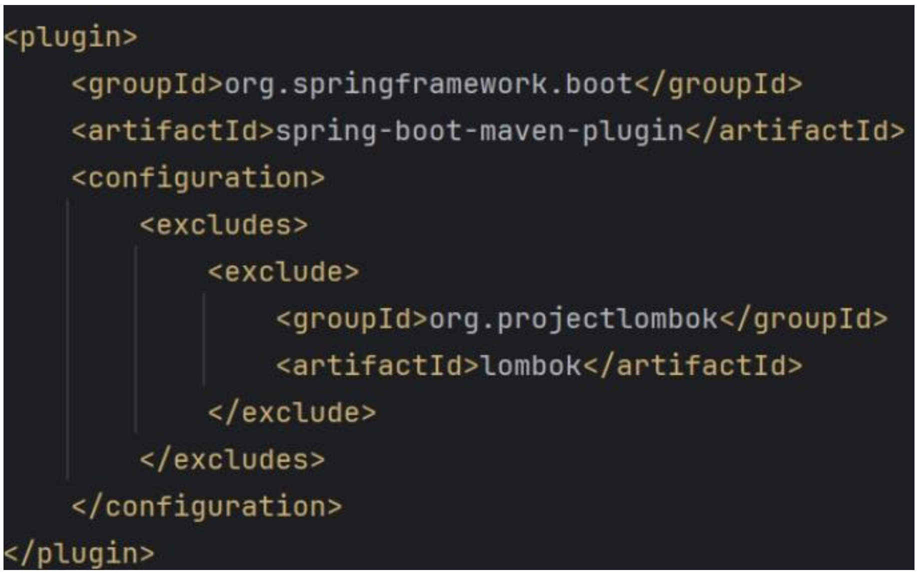
- In the **plugins** sections, under **maven-compiler-plugin**, there is something called **annotationProcesssorPaths**



```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-compiler-plugin</artifactId>
    <configuration>
        <annotationProcessorPaths>
            <path>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
            </path>
        </annotationProcessorPaths>
    </configuration>
</plugin>
```

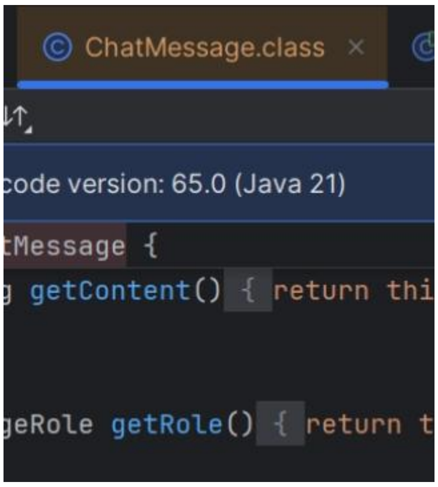
  - **annotationProcessorPaths** tells javac which **JARs** contain **annotation processors** and should be loaded during **compilation**.
  - Lombok must be available on the annotation processor path for its annotations (@Getter, @Setter, etc.) to work.
  - Annotation processors are **compile-time** tools that analyze annotations and modify or generate code before **.class** files are created.
  - The order of entries in annotationProcessorPaths does not control execution order; processors do not run sequentially.
- In case of **lombok** and **MapStruct**, why **lombok-mapstruct-binding** is needed?
  - Lombok does not generate new classes; it modifies existing classes at **compile time** by altering the compiler's internal representation (AST: Abstract Syntax Tree).
  - MapStruct generates new mapper classes and relies on the annotation-processing API to inspect methods.
  - Lombok's AST modifications are not fully visible to MapStruct by default.
  - **lombok-mapstruct-binding** acts as a bridge, making Lombok-generated getters and setters visible to MapStruct during annotation processing.
  - **This problem is about visibility, not execution order.**

- Also you can see below, in this plugin **lombok** is included in the **excludes** list



```
<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>
```

  - This is because, **lombok** doesn't provide any **.class** files that JVM needs to run the application.
  - It just injects the **getters** and **setters** to the existing classes during **compile-time**.
  - When you see the **.class** files, you'll see the **getters** and **setters** method's implementations there; **lombok** runs during **compilation-time**; as the **getters** and **setters** are already generated, hence there is no need ot including **lombok** in the **.jar** file.



```
ChatMessage.class ×

code version: 65.0 (Java 21)
tMessage {
g getContent() { return thi

geRole getRole() { return t
```

-

How Auto-Configuration works?

- **The imports file inside the auto-configure jar is read**
  - Spring reads this fie:

    -
      ```
      META-INF/spring/org.springframework.boot.autoconfigure.AutoConfiguration.imports
      ```
  - This file contains a list of auto-configuration classes, like

    -
      ```
      org.springframework.boot.autoconfigure.web.servlet.DispatcherServletAutoConfiguration
      org.springframework.boot.autoconfigure.orm.jpa.HibernateJpaAutoConfiguration
      ```
- **Spring loads those classes, and evaluates their annotations.**
- **Then it checks the conditional annotations**
  - Each auto-config class has things like the below:

    -
      ```
      @ConditionalOnClass(DataSource.class)
      @ConditionalOnMissingBean(DataSource.class)
      @ConditionalOnProperty(...)
      ```
  - Spring checks:
    - Is the required class present? Is the required property set? Is a user-defined bean already present?
  - If all the conditions pass, then only bean is auto-configured.
- **If the bean already exists, it will NOT create one**
  - Lets say we have manually configured one bean, like

    -
      ```
      @Bean
      public DataSource myDataSource() { ... }
      ```
  - Then the below condition will fail

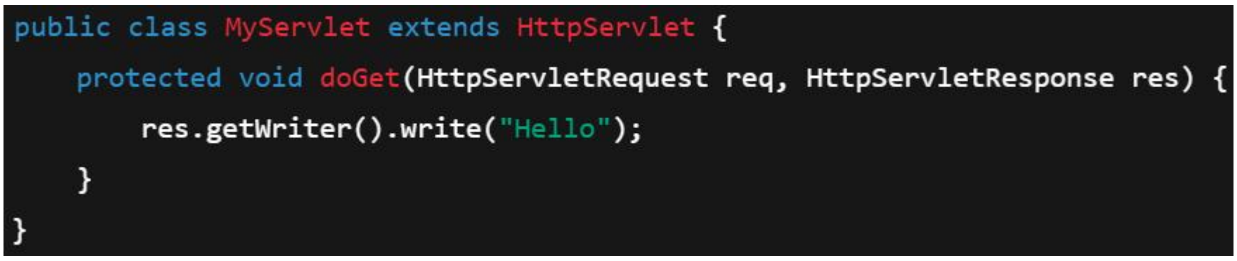
    -
      ```
      @ConditionalOnMissingBean(DataSource.class)
      ```
    - Because this bean is already created.
- **Overall flow**

  -
    ```
    @SpringBootApplication
             ↓
    @EnableAutoConfiguration
             ↓
    Read AutoConfiguration.imports
             ↓
    Load AutoConfig classes
             ↓
    Check @Conditional annotations
             ↓
    If conditions match → create beans
    Else → skip
    ```

- So, in simple terms: **Spring Boot auto-configuration works by scanning predefined auto-configuration classes and conditionally creating beans based on classpath presence, configuration properties, and existing user-defined beans.**
- Write **debug=true** inside the *application.properties* file to see the beans being auto-configured.
-

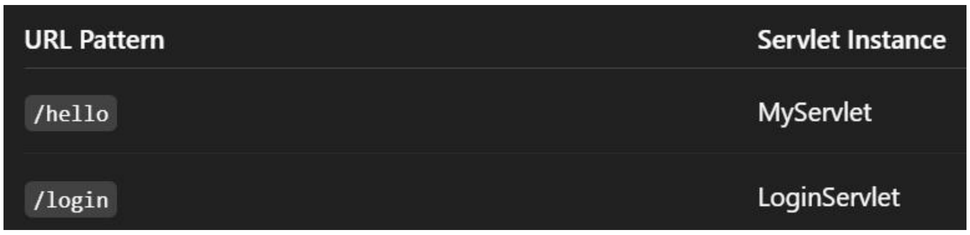
➢ Spring Web

- Servlet:
  - It’s a Java class that receives HTTP requests and sends HTTP response.
  - Browser → Servlet → Business Logic → Servlet → Browser
- Tomcat
  - Tomcat is a **web server + servlet container.**
  - A Servlet is a Java class that Tomcat loads, manages, and calls when an HTTP request arrives.
  - Tomcat does 2 jobs:
    - Listens for HTTP requests (like a normal web server)
    - Runs **Servlets** to handle those requests.
  - So it has 2 parts:
    - **HTTP Server + Servlet Container**
- Servlet
  - **Servlet** is just a normal Java class that **extends HttpServlet.**
  - HttpServlet has methods like doGet(), doPost() ..etc



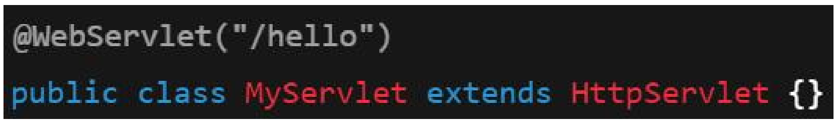
```java
public class MyServlet extends HttpServlet {
    protected void doGet(HttpServletRequest req, HttpServletResponse res) {
        res.getWriter().write("Hello");
    }
}
```

- A servlet does nothing on its own; unless and until *tomcat* calls it.
- How **Tomcat** calls the servlets?
  - It maintains a mapping table from **URL pattern** to **Servlet instance**



URL Pattern	Servlet Instance
`/hello`	MyServlet
`/login`	LoginServlet

  - There are basically **3** ways to create this mapping:
    - **@WebServlet**



```java
@WebServlet("/hello")
public class MyServlet extends HttpServlet {}
```

- **web.xml** (old way)

```
<servlet>
    <servlet-name>myServlet</servlet-name>
    <servlet-class>com.MyServlet</servlet-class>
</servlet>

<servlet-mapping>
    <servlet-name>myServlet</servlet-name>
    <url-pattern>/hello</url-pattern>
</servlet-mapping>
```

- Programmatic (Spring Boot style)

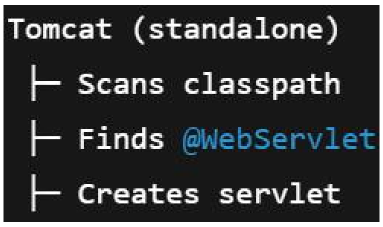
```
ServletRegistrationBean
```

- Lets say you trigger a GET request on the URL: *http://localhost:8080/hello* . Then the following steps happens:
  - Browser sends HTTP request
  - Tomcat receives request
  - Tomcat checks URL mapping table
  - Finds: "/hello" → MyServlet
  - Tomcat creates (or reuses) MyServlet instance
  - Calls doGet() method
  - Response returned to browser
- **Tomcat calls your servlet — not Spring**
- **NOTE:** The **servlet instance** is created by **Tomcat**; not by **YOU**; not by **Spring**;
  - You can just create the class extending HttpServlet; that's it;

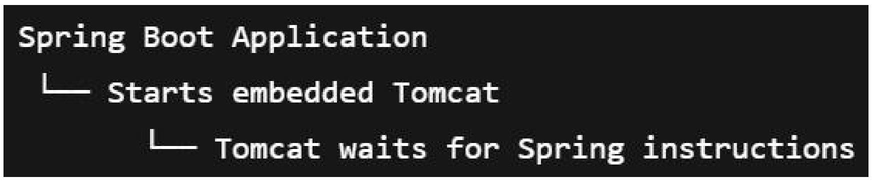
```
@Component
@WebServlet("/hello")
public class MyServlet extends HttpServlet {}
```

  - Even if you write like this it'll not work; because here the **instance** (i.e. **bean**) is created by Spring; not Tomcat;
  - ❌ **Spring** DOES NOT scan **@WebServlet** by default
  - ❌ **Tomcat** DOES NOT scan **Spring beans**
- You can say why to write **@Component**, just write **@WebServlet("/hello")** and move on.
  - Because we want **tomcat** to notice this not **spring**.

    - But, in Spring Boot application, tomcat is handled by Spring.

- 2 scenarios are there:
    - **Traditional Tomcat (war deployment)**
        - 

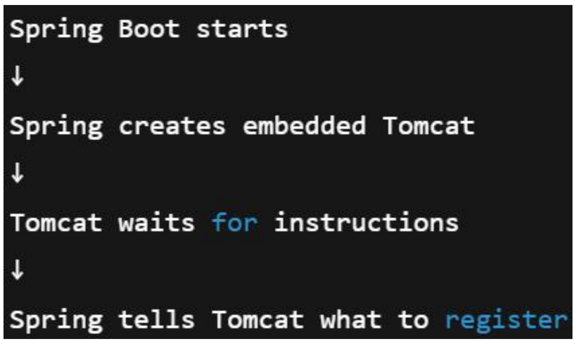
```
Tomcat (standalone)
 ├─ Scans classpath
 ├─ Finds @WebServlet
 ├─ Creates servlet
```

        - **@WebServlet** works automatically
        - No Spring involvement needed
    - **Spring Boot (Embedded Tomcat)**
        - 

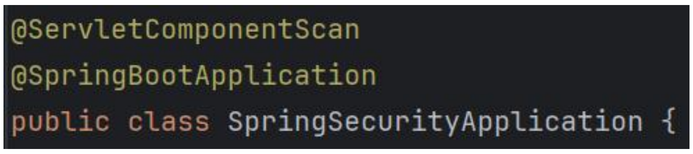
```
Spring Boot Application
 └── Starts embedded Tomcat
          └── Tomcat waits for Spring instructions
```

        - ❗ Tomcat does NOT scan for **@WebServlet** on its own
        - ❗ It only registers what Spring explicitly tells it to

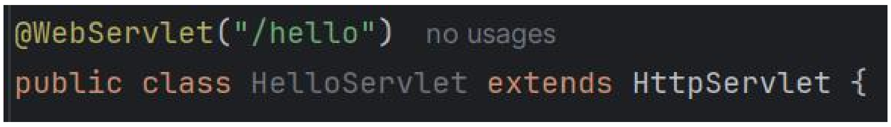
➢ What happens in **Tomcat** in **Spring Boot Application?**

- Key points which is TRUE every time
  - Tomcat always creates servlet instances.
  - Spring NEVER creates servlet instances for Tomcat to use.
- In traditional **Tomcat**, it *itself* scans for **@WebServlet** and create instance of those and map.
- But in Spring Boot application, **Spring embeds Tomcat inside itself**;
  - Spring itself start that Tomcat server.
  - And in here, **Tomcat** doesn't scan for the @WebServlet, rather it waits for Spring to give it instruction to do the scan (if we write **@ServletComponentScan**), after that **Tomcat** scans and registers those servlets.
  - 

```
Spring Boot starts
↓
Spring creates embedded Tomcat
↓
Tomcat waits for instructions
↓
Spring tells Tomcat what to register
```

- 

```
@ServletComponentScan
@SpringBootApplication
public class SpringSecurityApplication {
```

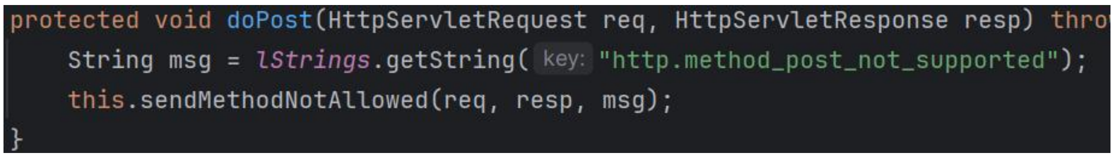
- 

```
@WebServlet("/hello")  no usages
public class HelloServlet extends HttpServlet {
```

  - No need to write **@Component**
-

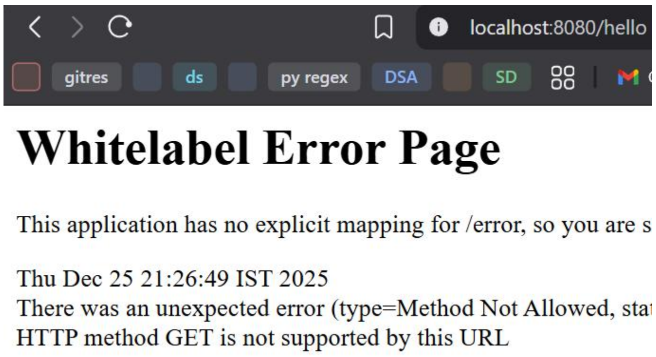
Creating Custom Servlet extending HttpServlet class

- HttpServlet
  - You can see, all the methods inside **HttpServlet** only add some **error content** in the response.
  - **NOTE**: the method doesn't return anything; they do have **request** and **response** objects, they just add some content to the **response** object.



```
protected void doPost(HttpServletRequest req, HttpServletResponse resp) thro
    String msg = lStrings.getString( key: "http.method_post_not_supported");
    this.sendMethodNotAllowed(req, resp, msg);
}
```

  - If you see here, it is just adding some **error** to the response via the method **sendMethodNotAllowed**.
  - HttpServlet is the base class which is to be extended to write custom servlet. But you need to override the method and implement by your own; otherwise error response will be visible.

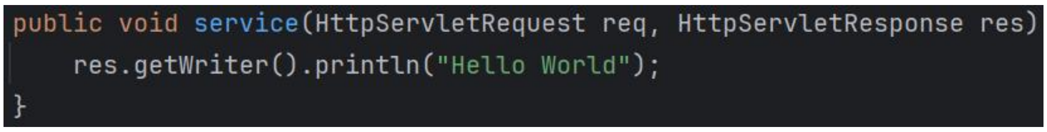


Whitelabel Error Page

This application has no explicit mapping for /error, so you are s

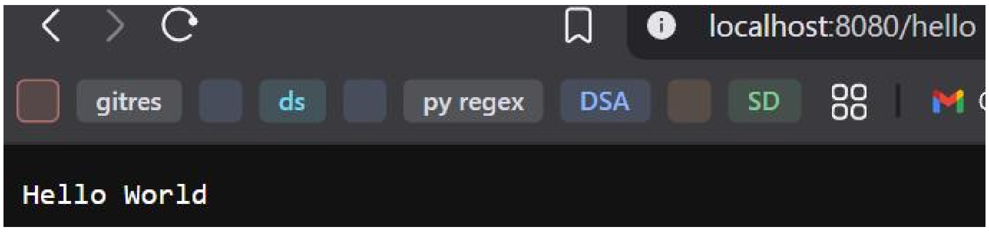
Thu Dec 25 21:26:49 IST 2025
There was an unexpected error (type=Method Not Allowed, sta
HTTP method GET is not supported by this URL

  - I overridden the <span>service</span> method and added in the response



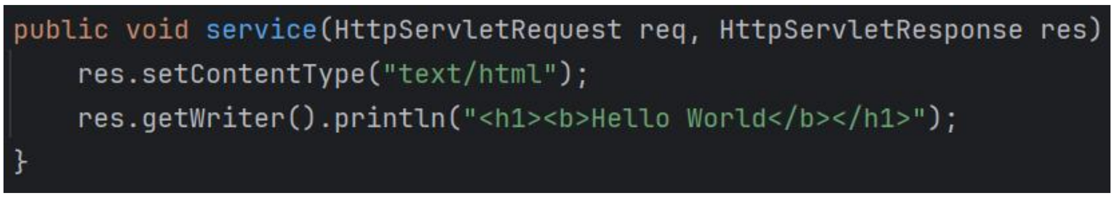
```
public void service(HttpServletRequest req, HttpServletResponse res)
    res.getWriter().println("Hello World");
}
```

  - Now the response is coming in the browser.



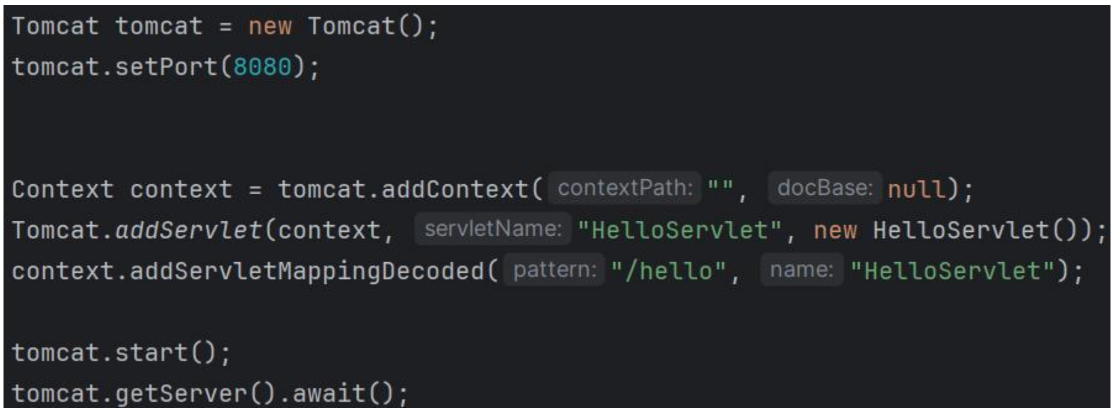
```
Hello World
```

- You can set the content type of the response as well.



```java
public void service(HttpServletRequest req, HttpServletResponse res)
    res.setContentType("text/html");
    res.getWriter().println("<h1><b>Hello World</b></h1>");
}
```

➢ You can also manually configure the **Tomcat** without the help of Spring Boot



```java
Tomcat tomcat = new Tomcat();
tomcat.setPort(8080);


Context context = tomcat.addContext( contextPath: "", docBase: null);
Tomcat.addServlet(context, servletName: "HelloServlet", new HelloServlet());
context.addServletMappingDecoded( pattern: "/hello", name: "HelloServlet");

tomcat.start();
tomcat.getServer().await();
```

- **SpringApplication.run** is not there. And also **@WebServlet** is not written in HelloServlet class.
- **port** will be *8080* by default & for this you don't need to set the port explicitly; if you want to run on some other port then you can set the port;

➢

➢ How all the mappings are being done in Spring Boot Application?

- As we know, **Tomcat** has a mapping table where the **end points** are mapped to **servlets**, according to the end-point, **tomcat** calls the **specific servlets**.
- But in case of Spring Boot Application, only one servlet is there which is **DispatcherServlet** (it also extend *HttpServlet* only); it is auto-configured.
  - **Tomcat** maps **DispatcherServlet** for all the end-points which is "**/***"
  - After that, **DispatcherServlet** calls the controllers to update the *response object*.
  - Tomcat doesn't know about the controllers at all.
-

➢ <u>Injection of Beans to the variable of type ancestor Interface?</u>

- Lets say one interface is there **I**
- Lets say we create one class **C** implementing that interface **I** and we are creating a bean of this class.
- Lets say one more class is there **Cx** implementing that interface **I** which is already being auto-configured by Spring.
- In this case, whatever variables are there which are of type **I**, our bean i.e. **object of type *C*** will be auto-injected to those variables of type **I.**

➢ Spring Filter Behind the Scene

- What we see, **chain of filters are being executed in between Servlet Container and Servlet.**
  - One **servlet containers** can have many filters, many servlets; but in case of spring we have only one Servlet which is **DispatcherServlet**.
  - And, its not by limitation, but by design spring make sure only one **Filter** should be there in between **Servlet Container** (tomcat in our case) and **Servlet** (DispatcherServlet).
  - So, only **one Filter** should be able to handle **multiple Filter Chains** where **each chain contains multiple Filters.**
    - its like **one object** is equivalent to **list of *list of the same object*.**
  - So, **FilterChainProxy** was introduced which implements **Filter**. And it contains the list of **SecurityFilterChain** objects.
    - And the thing is, this ***SecurityFilterChain*** class contains a method **getFilters()** which returns a list of **Filter** objects.
  - So now, we can return **FilterChainProxy** object instead of **Filter** because *FilterChainProxy* is nothing but the child of *Filter*.
    - And also it contains *list of SecurityFilterChain* which means ***list of (list of (Filter)).***
-