Spring, esp. Spring Boot

Class 13 (Mar. 10): Intro to servlets and tomcat

A servlet is Java code executed inside a web server for a certain application. One app could have several servlets.

Tomcat is a web server that can handle servlets (unlike many Apache servers)

Tomcat gets an HTTP request, figures out which servlet it's for, calls into that servlet (our Java code) to handle it and produce HTML for tomcat to send back to the user.

URL accessing my pizza3-specific tomcat installation: http://pe07.cs.umb.edu:9002/welcome.html (recall hw3 page flow problem)

Here the pizza3 app owns the whole website served by this tomcat, an "embedded tomcat".

We'll use it this simpler (embedded) way when developing webapp projects, using Spring Boot 2.

There is a shared tomcat web server running on port 8080 on pe07. It can handle multiple apps, much like Apache, but also supports Java. We looked at some simple JSPs running there. Each JSP compiles into a servlet. We finally saw code (JSP) that captures user input from a form.

Web apps using tomcat

We have discussed servlets and tomcat, the servlet-capable web server, and saw how tomcat can handle incoming requests to a “service endpoint”, a particular URL.

From slide 8 of class 13, about the pizza3 webapp:

- Consider the access to welcome.html, using URL http://pe07.cs.umb.edu:9002/welcome.html
- Here GET command is GET /welcome.html HTTP/1.1, done after TCP connection to pe07.cs.umb.edu on port 9002.
- Tomcat interprets the local path: /welcome.html, sees that / belongs to the servlet of pizza3, and checks if /welcome.html is registered as a path of interest (“endpoint”) to that servlet. It is.
- So tomcat hands off the handling of this request to the servlet code.

- Obvious loose ends here: how are endpoints registered, how does the handoff work?
- Quick answers: via web.xml or equivalent annotation, by call to doGet() in the servlet.

Spring Boot Roadmap

- Spring Boot is now the leading framework for Java web apps: see IBM page on it
- It's really Spring, made easier to use by having a tool called Spring initializr to set up projects to be built using Maven or Gradle

Major Spring Features we will cover, in this order:

1. Using its supported **embedded tomcat** for much easier servlet/webapp development

2. Using **Spring beans** for our singletons, with "auto-wiring": get Spring to set up the basic system. Spring knows the three layers of the web app.

3. Using **Spring controllers** for our service endpoints (URLs that access the web app), so we no longer need to write full servlets, only the code needed to handle the various requests

- FYI coverage: Spring JPA Repositories with their no-code finders.

First Spring Boot example: ch05emailS

- We can run **embedded tomcat** by just running the app that embeds it.
- The first example app, ch05emailS (S for Spring) is available. See run.sh and run.cmd for running it. It uses a servlet explicitly, very much like the Murach's example in Chap. 5. ch05email.
- Port 9000 is what we'll use for ch05emailS on home systems. Find your pe07 port in CS636Ports.html and follow the README in ch05emailS's directory.
- Its service endpoint (home case, or on-pe07 case) is http://localhost:9000/emailList
- The URL doesn't contain "ch05emailS" because the app owns the root of the website in the embedded case, i.e., it has free use of top-level URLs there like /emailList.
- This uses Spring Boot only for jar version control and embedded tomcat. It doesn't use "Spring beans" as we are expecting to do for the pizza and music projects. It doesn't use "Spring controllers" to simplify handling web requests as we also want to do.

First Spring Boot example: ch05emailS

- The code for this example is very close to that of Murach's ch05email described in the book. It uses a servlet to receive the requests, and "forwards" to thanks.jsp. Thanks.jsp (its servlet, really) constructs the HTML to return to the user's browser.
- Embedded tomcat is a boon for web development, but it isn't expected to be a production vehicle like shared tomcat, i.e., full-featured tomcat. Spring Boot supports builds for shared tomcat as well, with different entries in pom.xml.
- So once a web app is working based on development on embedded tomcat, it can be rebuilt for the "real" tomcat. We aren't going to bother with this last step, however.
- An example of an additional feature of a production tomcat is the ability to add a servlet to a running system. On embedded tomcat, we would have to restart the program for this.

Book coverage

Readings on Servlets: Murach Chap 2, then later tackle Murach Chap. 5

Note that the email list examples in Chapter2 and Chapter 5 are identical in Java code, and almost identical otherwise.

So start by reading Chapter 2 and then continue in Chap. 5.

Look at the slides for Chap 2.

Later, Chap. 6-9.

Parts of ch05email (AKA ch02email) project, and mostly same in ch05emailS:

- Pictures of app's pages: pg. 35 (also good for ch05emailS)
- First page: index.html: pg. 37 (also good for ch05emailS)
- Servlet code: pg. 41 (one line (class annotation) different in ch05emailS)
- web.xml: pg. 43 (but we will use that class annotation for this in ch05emailS)
- User.java: pg. 45 (also good for ch05emailS)
- thanks.jsp to generate second page: pg. 47 (also good for ch05emailS)
- Picture of second page in browser, method="get" case, showing URL with query string: pg. 135 (also relevant for ch05emailS)

Servlet processing of formdata

- We need to understand how an incoming query string is processed, so the servlet code can get the user input items.
- When tomcat receives this GET or POST request, it parses the parameters and attaches them to the request object provided to the servlet in the incoming doGet call, doGet(request, response)
- In the servlet, we can pick up the parameter value from the request object by

```
String firstName =
  request.getParameter("firstName");  // makes firstName = "John" in this case
```

- See pg. 139.

How does the servlet pass on this User object to thanks.jsp (i.e. its servlet)?

- First, the servlet attaches the User object to the request as a **request attribute**. Specifically, it creates a new User object named user to represent the person joining, and does:

```
request.setAttribute("user", user); //create request attr
```

- Then the servlet does a "forward" to thanks.jsp. This invokes the servlet for thanks.jsp directly in the server, and passes the request and response objects to that other servlet. (Recall that each JSP compiles into a servlet).
- The thanks.jsp servlet can access the attributes of the request object. Once attached to the request object, the User object becomes a "request variable".

How does thanks.jsp get the User info out into its response HTML so the real user can see it?

- The short answer is “using EL”, the **JSP expression language**, which is covered in Chap. 6 (intro) and Chap. 8. EL lets us access request variables easily, including dotting into them to get their properties.
- We saw some examples of EL in class 13: look for ${…}

```
${1+2+3}
```

```
<h1>  Today's date is ${date} </h1>
```

- In thanks.jsp, we see

```
${user.firstName},
```

- and this compiles to `user.getFirstName()` in its servlet, where `user` is a **request variable**:

```
User user = request.getAttribute(“user”);  // extracting req. var.
```

A servlet is at the heart of a Java web app

- We have seen how a servlet can receive requests, and use JSP to create a nice response in HTML. This is an important pattern to understand.
- That doesn't mean we have to code servlets in our projects—they are somewhat low level.
- Spring allows us to abstract the ideas of service endpoints and the code that needs to execute on their behalf, into **Spring controllers**. Of course there has to be a servlet underneath the covers.
- But before we launch into that, let's explore the most classic Spring constructs, the **Spring beans** that we have foreshadowed when we looked at the singletons (in the "big picture") we were using.

Spring beans

Note that Spring Boot is just Spring with some help doing its configuration, otherwise a big chore. Plus the capability of running tomcat as an embedded server.

We have already been using the version control of Spring Boot in pizza2, with the help of maven's ability to catalog the jar files by version.

See pizza2's pom.xml. In particular, the <parent>

Look at intro to Spring at DZone (just the intro paragraphs).

We have been using the DI dependency injection/IoC ideas since pizza1: create DAOs, then hand them to service objects, so the service objects never do "new DAO()".

Now all those singletons are "beans", Spring-managed beans in the Spring container. We let Spring create them for us, based on annotations we write.

Crucial terminology for Spring

- **bean**: a POJO or Java Bean, in our use (and other simple setups) a singleton object
- **Spring container, or Bean Factory, or ApplicationContext**: collection of beans for an app
- **Component:** a bean (singleton), whose class is marked with a class annotation @Component, or one of its specializations:

  @Service (for service objects),

  @Repository (DAO objects)

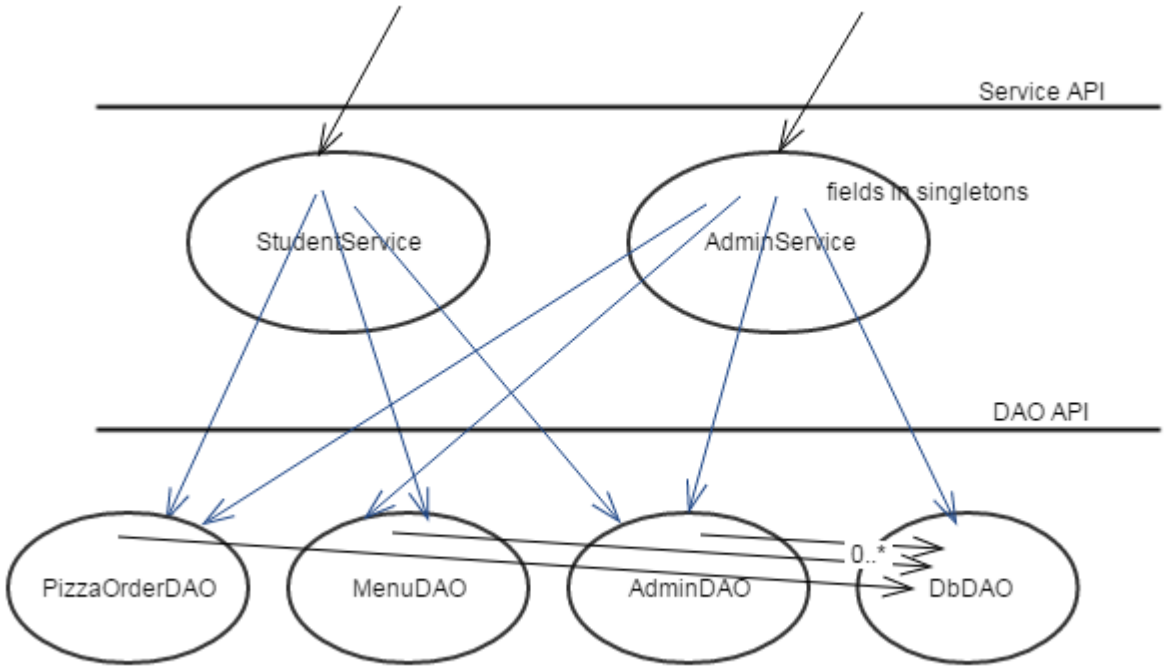
  @Controller (web app bean, in presentation)

➢ Note that Spring projects are expected to have a service layer, not just a DAO layer as we have seen with Murach's code.

Our Spring Boot pizza projects

- Pizza2S: like pizza2, this is client-server with JPA
  - This version uses Spring Boot's support of transactions and JPA, including JPA Spring Repositories with their amazing no-code DAOs.
  - You don't need to study this one, it's FYI
- Pizza3: like pizza1, this just uses JDBC directly in the DAOs
  - This version uses Spring Boot's web support to do the needed web request controllers, and we will use embedded tomcat.
  - This one is the model for Project 2, so needs study.

Same big picture, now Spring beans...



Our setup of beans for pizza2S and pizza3: Note the each is uniquely identified by its class name, i.e., there's on one of class StudentService, etc.

← 2 @Service beans

← 4 @Repository beans

Creating the beans

Now each bean class is annotated with @Component or one of its specializations:

*Service.java has @Service
*DAO.java has @Repository

There is one more @Component-marked class: ClientRun, which we could put at the top of the diagram in presentation, with refs to StudentService and AdminService.

At app startup, Spring searches the classes and creates beans for the ones with these class annotations.

We used to create the singletons in PizzaSystemConfig: now that code is gone.

How does Spring know what classes to search?

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The top-level annotation (on the class with the main() in it) tells it where to "scan“ the annotations:

```
@SpringBootApplication(scanBasePackages = { "cs636.pizza" })
public class ClientApplication {
    public static void main(String[] args) {
     …
```

Note that this class is the one you can select in eclipse, and right-click, Run>as Java Application, to run with H2 and SystemTest.

How do we get Spring to create the needed bean-to-bean references?

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The references between classes are marked by @Autowired

For example, in StudentService.java

```
@Service
public class StudentService {
    @Autowired
    private PizzaOrderDAO pizzaOrderDAO;
    @Autowired
    private MenuDAO menuDAO;
    @Autowired
    private AdminDAO adminDAO;
    @Autowired
    private DbDAO dbDAO;
```

Spring finds an @Autowired annotation on a field, finds ***the*** singleton of that class, and fills in the field with its ref. All this happens at program startup, in main of ClientApplication..

Autowiring in action

The autowiring happens at program startup, in code called from main of ClientApplication, here simplified a bit:

```
// This specifies where to look for @Components, ets.
@SpringBootApplication(scanBasePackages = { "cs636.pizza" })
public static void main(String[] args) {
  SpringApplication app = new SpringApplication(ClientApplication.class);
  System.out.println("starting ClientRun...");
  app.run(args);  ←calling into SpringApplication code, creating beans, autowiring
  System.out.println("... ending ClientRun");
}  ← end of main, exit whole program
```

Mystery: how do we regain control here?

We just saw execution disappearing into Spring Boot code, eventually returning, and then the program exits, since this is main.

How can we do app-specific startup actions?

The deal: if we set up a @Component (i.e. bean) of interface type **CommandLineRunner**, Spring will find it and run it (call its run method), using main's command line args as args to it. This will happen after all the beans are created and autowired.

This interface is a "functional interface", i.e., has a single method traditionally called "run" but no longer required to (to accommodate lambda functions), with String array arguments (like main) and void return value.

`void run(String… args)` (required method, traditional form, how we'll do it)

Our CommandLineRunner: ClientRun

- We see that class ClientRun in pizza2S, or CommandRun in pizza3, which is a @Component and thus a bean in the container, implements CommandLineRunner, so it is the one called here, with args from the original main's args.
- The code of the CommandLineRunner has our app-specific code to start up the system. Armed with refs to the service objects, it can create SystemTest or TakeOrder or AdminApp, or set up things for the web case.
- We have skipped over one important initial config here: the database we're using. This has to be done really early, so that the right DAO objects are created in the bean-creation phase.

How can we specify which database to use?

This has to be done really early, so that the right DAO objects are created in the bean-creation phase.

In pizza2S, the args are parsed at the start of main to get the database params, before Spring Boot gets control. Then those parameters are used to create a custom emf bean for JPA. When you create a bean of a certain type, it overrides the default bean, so the system uses the custom emf, and thus the desired database.

In pizza3, we use the mechanism of “profiles” to handle the different params of the three databases. There are profiles named h2, mysql, and oracle, each with a file of properties in src/main/resources. These profiles can be specified on the command line executing the jar file, and are read early in the startup sequence, specifying the jdbc parameters for the run.

How can pizza3 run a webapp, or run SystemTest or …?

The default app.run() in ClientApplication starts up embedded tomcat, so when we just want to run SystemTest, we configure that `app` object like this, turning off tomcat execution this way:

// code in ClientApplication for pizza3

```
if (!appCase.equals("web")) {  // appCase is "SystemTest" or "web" or …
   System.out.println("have arg " + appCase + " ,
                              assuming client execution");
   app.setBannerMode(Banner.Mode.OFF);
   app.setWebApplicationType(WebApplicationType.NONE); // don't start tomcat
}
app.run(args);  // get tomcat running if appropriate
```

Summary on annotations in pizza2S, pizza3

- Classes in domain have JPA class annotations @Entity, etc. get managed by the em, in pizza2S but not in pizza3, where they are the same as in pizza1 (no annotations)
- In both projects, Classes in *Service in service and *DAO in dao, have Spring annotations, @Service or @Repository, specializations of @Component, making them beans (singletons) in the Spring container.
- In both projects, there is a CommandLineRunner marked as a @Component (and thus a bean) that does the app-specific startup work, such as creating a SystemTest object.
- In both projects, @Autowired is used to mark fields of bean-to-bean refs.

Some classes have no class annotations

- PizzaSystemConfig: just has methods called from elsewhere, never new'd. No longer sets up singletons.
- ServiceException: created as needed, very lightweight
- SystemTest, ShopAdmin, TakeOrder: get created explicitly in ClientRun as needed. They could be made into @Components, but then would all be created when only one is needed.
- PizzaOrderData: created just for data transport, not "important"