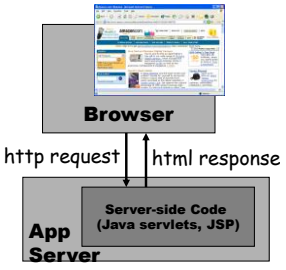
Pure server-side Web Applications with Java, JSP

- Discussion of network-level http requests and responses
- Using the Java programming language (Java servlets and JSPs)
- Key lesson: The role of *appl*ication *servers*
  - The "OS" of web apps
  - Data contained in app server's request, session, application scopes



Application Servers: the Essential Tool of Server-Side Programming

- Java servlet containers, responsible for
  - facilitating the http communications
  - Providing web app context
  - …
- May also (but not necessarily) operate as web servers, I.e., serve static pages
- Tomcat is an app server and the reference implementation of the Java servlet and JSP specifications
  - Also serves static pages
  - The statement "Tomcat is a Web server" is not accurate

Install and Check Tomcat

Discussion

Installing Tomcat

- Install stable production release
  - Do not install alpha, beta, "milestone", or "nightly" builds
- You need a J2SE or J2SDK (at least 1.4)
- If installed in directory X, set environment variable JAVA_HOME to X
- Use self-extracting .exe and follow directions
- Set CATALINA_HOME to directory where Tomcat is installed

Starting and Testing Tomcat

- Start Tomcat using `bin/startup.bat` or "Start Tomcat" icon in program group
  - Preferrably do not set up Tomcat as an "automatic start" service
- Browse to `http://localhost:8080/`
  - You should see Jakarta project home page
  - If failure, come to discussion
- Run `http://localhost:8080/examples/jsp/dates/date.jsp`

HTTP Requests and Responses

HTTP Basics

- TCP/IP protocol used by Web servers, clients
- Synchronous
  - i.e., client sends request waits for response
- Stateless
  - i.e., all info needed by server-side must be contained in http request
  - Using appropriate session management techniques app servers go around restrictions of statelessness
- We show next the request and response message strings that go back and forth in interactions
  - Only for educational purposes.
  - You will never code such strings directly. App server will do it for you.

http too slow ?

- Yes
- We will later discuss websockets, in the context of content-rich and live visualizations

Syntax of an HTTP Request

- <method> <request URI> <HTTP-version>
  - Important ones: GET & POST
  - See reference for explanations of other methods: HEAD, PUT, DELETE, CONNECT, OPTIONS, TRACE
- Header fields
  - `Accept: text/html, text/xml, …` (acceptable response types)
- Message body (optional) (after blank line)

Example HTTP request

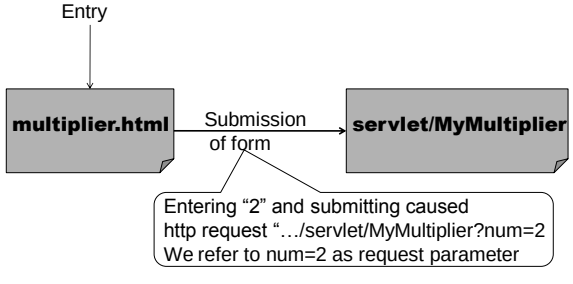
```
GET / HTTP/1.1
Host: www.db.ucsd.edu
User Agent: IE/8.0
Accept: text/html, text/xml
….
```

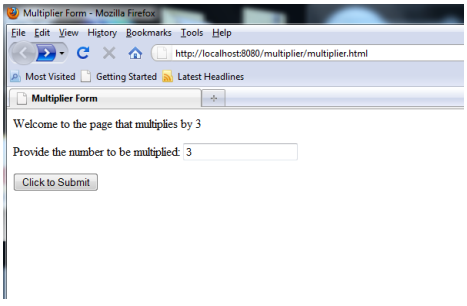
Syntax of an HTTP response

- Reminds email syntax
- <HTTP-version> <status-code> <reason>
  - E.g., status codes from 500-599 indicate server-side errors
- Header fields
  - `Content-Type: text/html` (or other type)
- Message body (optional) (after blank line)

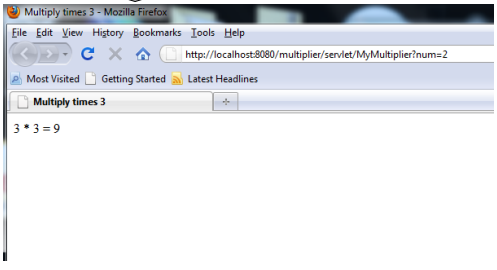
Communicating Data From Browser to Server via Forms: GET, POST and parameters

- Overview of the "multiplier" application





Issuing a /servlet call directly is not supported any more since Tomcat 6.0 because it is a security liability (see later why). For simplicity, let us assume it is Supported and we will see a few slides later how you can actually invoke a servlet



Communicating Data Provided in Forms: GET, POST and parameters

- The HTML of **multiplier.html**

```
<HTML>
 <HEAD><TITLE>Multiplier Form</TITLE></HEAD>
 <BODY>
  Welcome to the page that helps you multiply times 3
  <p>
  <FORM METHOD="GET" ACTION="servlet/MyMultiplier">
   Provide the number to be multiplied:
   <INPUT TYPE="TEXT" NAME="num"/> <p>
   <INPUT TYPE="SUBMIT" VALUE="Click Here to Submit"/>
  </FORM>
 </BODY>
</HTML>
```

If you are not fluent HTML try to write your resume in HTML using just a text editor

POST vs GET (mechanics)

- Upon submitting "2" the browser emits URL
  - `http://localhost:8080/multiplier/servlet/MyMultiplier?num=2`
  - `GET /multiplier/servlet/MyMultiplier?num=2 HTTP/1.1`
    `Host: localhost:8080`
- If HTML form may create more than 255 characters use `<FORM METHOD=POST …`
  - Form data will be in body of http request
  - `POST /multiplier/servlet/MyMultiplier HTTP/1.1`
    `Host: localhost:8080`

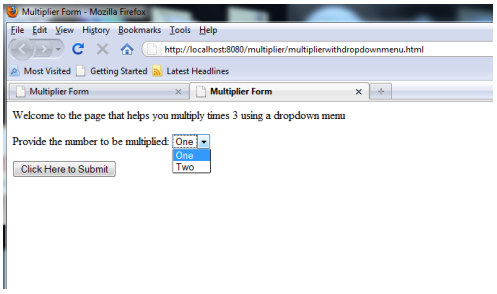
    `num=3`

GET vs POST; when to use

- GET
  - Supposed to retrieve a resource from the server
  - Bookmarking friendly
  - Easy fiddling of parameters (security hole)
  - Caching bug friendly (more later)
- POST
  - Supposed to change server state
  - Can transmit far larger arguments
  - Arguments not displayed on the URL
  - Browser says "data will be POSTed again"

More Input Forms: Dropdown menus

```
<HTML>
 <HEAD><TITLE>Multiplier Form</TITLE></HEAD>
 <BODY>
  Welcome to the page that helps you multiply times 3
using a dropdown menu<p>
  <FORM METHOD="GET" ACTION="servlet/MyMultiplier">
   Provide the number to be multiplied:
   <SELECT NAME="num">
    <OPTION value="1">One</OPTION>
    <OPTION value="2">Two</OPTION>
   </SELECT>
   <p>
   <INPUT TYPE="SUBMIT" VALUE="Click Here to Submit"/>
  </FORM>
 </BODY>
</HTML>
```



Encoding URIs

- HTTP only permits letters, digits, underscores and a few more
- Browsers take care of "special" symbols, using the RFC2277 encoding

Example of Encoding Characters in a URI Using the RFC2277

- Consider a page asking for emails

```
<HTML> <TITLE>Email Submit Page</TITLE> <BODY>
 <FORM METHOD=GET
      ACTION=http://gyro.ucsd.edu:8080/subemail.jsp>
  Type your e-mail here:
  <INPUT TYPE="text" NAME="eml"/> <P>
  <INPUT TYPE="SUBMIT" VALUE="Click Here"/>
 </FORM> </BODY> </HTML>
```

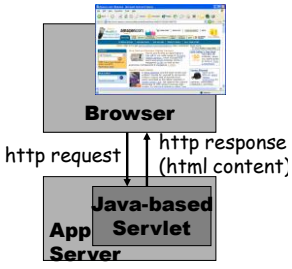
- User types yannis@cs.ucsd.edu

```
  -GET /subemail.jsp?eml=yannis%40cs.ucsd.edu HTTP/1.1
    Host: gyro.ucsd.edu:8080
```

Servlets: The Assembly Language of Java-based Web Server-Side Programming

Java-Based Server-Side Programming 101: Servlets

- Servlet: Java program run inside the app server (Tomcat in 135)
- Inputs http requests
  - App server provides request data to servlet in appropriate object format
- Typically (but not necessarily) return http responses of html content type



Multiplication example revisited: Browser -> App Server -> Servlet

- Create Web app (directory) `multiplier` under `webapps`
- Place `multiplier.html` in it
- Browse to `http://localhost:8080/multiplier/multiplier.html`
- When form is submitted browser issues http GET request
  - ACTION specifies URL to be invoked
  - URL of servlet may be relative (as below)
    - "servlet" is not directory; simply indicates it is servlet
  - Or absolute (would be http://localhost:8080/multiplier/servlet/MyMultiplier
  - further issues if servlet is in package

Multiplication example revisited: Browser -> App Server -> Servlet

- Application server knows where compiled code MyMultiplier.class resides
  - Details coming up
- Activates MyMultiplier.class, passing the request parameters in object format
  - Details coming up
- MyMultiplier.class prints html in the http response
- Next: The Java code of MyMultiplier.java

```
import java.io.* ;
import java.text.* ;
/* following packages encapsulate Servlet API */
import javax.servlet.* ;
import javax.servlet.http.* ;

public class MyMultiplier extends HttpServlet {
 /* Overides doGet coming with HttpServlet */
 public void doGet(HttpServletRequest req,
                   HttpServletResponse res)
             throws ServletException, IOException {
```

```
res.setContentType("text/html");

PrintWriter out = res.getWriter() ;

 out.println("<HTML><HEAD><TITLE>
              Multiply times " + 3 +
              "</TITLE></HEAD> “
             );
 out.println("<BODY>") ;

 String parameter = req.getParameter("num") ;

 /* Ignoring the possibility that parameter is not integer */
 out.println(parameter + " * " + 3 + " = " +
          3 * (Integer.parseInt(parameter))) ;
 out.println("</BODY>") ;
 out.println("</HTML>") ;
 }
```

Compiling & Deploying the Servlet

- Place `MyMultiplier.java` in `multiplier/src`
  - Not necessary, but good principle to separate java sources from classes
- Compile `MyMultiplier.java`
  - Include in CLASSPATH environment variable `<CATALINA_HOME>\common\lib\servlet.jar`
- Make sure the following appears in `<CATALINA_HOME>\conf\web.xml`

```
<servlet-mapping>
    <servlet-name>invoker</servlet-name>
    <url-pattern>/servlet/*</url-pattern>
</servlet-mapping>
```

- Place `MyMultiplier.class` in `multiplier/WEB-INF/classes`
- Restart Tomcat

Servlet Life Cycle

- First time a servlet is called:
  - `init()` method is called
    - Normally provided by `HttpServlet`
    - Unless you want to set up resources that exist for the whole lifetime of the servlet (rare)
  - Object (extending `HttpServlet`) is instantiated and becomes memory resident from now on
    - Class variables exist for entire life of object
- Series of GET, POST, … HTTP calls lead to doGet(), doPost(), etc calls to the object
- Servlet removed with `destroy()`
  - Tomcat may call `destroy()` any time
  - you may write your own `destroy()` to save state upon receiving `destroy()`

Handling POST Method Calls

- Whether parameters are communicated by GET or POST is normally irrelevant to your code
- However you have to provide (override) `doPost()` of `HttpServlet`

```
public void doPost(HttpServletRequest req,
     HttpServletResponse res)
  throws ServletException, IOException {
 doGet(req, res) ;
}
```

Handling the Other Method Calls

- DELETE, HEAD, OPTIONS, PUT, TRACE
- Corresponding `doDelete()`, `doHead()`, etc
- Normally developer does nothing
- `HttpServlet` provides defaults

Deployment Descriptor and URL Mapping

- Provide configuration/deployment information in `WEB-INF/web.xml`
- Use URL mapping
  - if you do not want users to know that you use servlets (and which servlets you use)
  - by mapping the servlet's actual name to a URL pattern (aka servlet alias)
  -
```
<web-app>
  <!- … other stuff we saw ..>
  <servlet-mapping>
       <servlet-name>multiplier</servlet-name>
       <url-pattern>/multiply</url-pattern>
  </servlet-mapping>
</web-app>
```
- Can access servlet by http://localhost:8080/multiplier/multiply?num=5

Wildcards in URL Patterns

- URL pattern may include *
```
<servlet-mapping>
   <servlet-name>action</servlet-name>
   <url-pattern>*.do</url-pattern>
</servlet-mapping>
```
- Any URL pattern matching `*.do` will invoke the `action` servlet
  - Disambiguation rules

Servlet Initialization Parameters: Definition in web.xml

- Assume we want to change the multiplication factor without having to change and recompile the `MyMultiplier.java` servlet
- Add in web.xml initialization parameter

```
<servlet>
 <!-- … servlet stuff we've seen..>
 <init-param>
   <param-name>TIMES</param-name>
   <param-value>5.0</param-value>
 </init-param>
</servlet>
```

Servlet Initialization Parameters: Use in servlets

- Access to initialization parameters with `getInitParameter`
- `String times = getInitParameter("TIMES");`

Servlet Context Path

- Default context name of Web application is the name of the `webapps` subdirectory
  - in running example, `multiplier`
- Create alias context name if you want to hide the subdirectory name or effect non-default actions on your app's servlets
- Add `Context` element in `conf/server.xml`, inside `<Host name="localhost" …>`
- `<Context path="/mult" docbase="multiplier"/>`
- Path is matched against URLs' beginning
  - must be unique
  - Try `http://localhost:8080/mult/multiply?num=10`

Automatic Reload

- Default configuration does not check whether class files are replaced
  - Appropriate setting in production mode
- We can avoid stopping and restarting Tomcat during development/compilation
- by enabling automatic reloading of servlet class files
  - to effect for an individual web app edit `server.xml` and add `reloadable` attribute
  - `<Context …"this web app"… reloadable="true"/>`
  - To effect automatic reload for all applications add
  - `<DefaultContext reloadable="true"/>`

What is Wrong with Servlets

- The "look" of the resulting HTML is buried in println() statements
- Web designers cannot work this way
- Business logic and presentation horribly mixed
- other issues…

Some Additional Items for Your "To Do" List

- Automatic Reloading of Servlets
- **Deploy and modify the programs we've seen**

Java Server Pages: Embedding Java Code in Static Content

Why JSPs?

- Need to separate
  - the business logic implementation
    - done by web developer
  - from implementing the look-and-feel
    - done by web designer

The Key Idea Behind JSPs

- HTML page with embedded Java code (in the form of JSP elements)

```
<HTML>
 <HEAD>
  <TITLE>Date JSP (Textbook Listing 5.1)</TITLE>
 </HEAD>
 <BODY>
  <BIG>
   Today's date is <%= new java.util.Date() %>
  </BIG>
 </BODY>
</HTML>
```

Deploying JSPs

- JSP file has .jsp suffix
- Store JSP file (in text) in app directory
  - Recall, under webapps
- Invoke as
  `http://<host>/<web-app>/<file>.jsp`

Compilation

- At first access of JSP
  - Jasper translator generates Java servlet code
    - Loads in <CATALINA_HOME>`/work/Standalone/`<host>`/`<web app>
  - Jasper compiler generates Java Servlet class file
    - Loads in same directory

```
package org.apache.jsp;

/* Automatic Imports */
import javax.servlet.*;
import javax.servlet.http.*;
import javax.servlet.jsp.*;
import org.apache.jasper.runtime.*;

public class date_jsp extends HttpJspBase {


  private static java.util.Vector _jspx_includes;

  public java.util.List getIncludes() {
    return _jspx_includes;
  }

  /* Similar to doGet() */
  public void _jspService(HttpServletRequest request,
                          HttpServletResponse response)
        throws java.io.IOException, ServletException {
```

Implicitly Declared Objects

- You may use the following objects in the Java code of your JSP
- **`request`**: well-known HttpServletRequest object
  - transfers parameters
- **`response`**: still important for writing non-body fields of HTTP response
- **`session`**: maintain parameters accessed by all steps of a session
  - Very important, we'll come back to it
- **`application`**: maintain parameters accessed by all jsp's of a web application

```
    /* Implicit objects defined next */
    JspFactory _jspxFactory = null;
    javax.servlet.jsp.PageContext pageContext = null;
    HttpSession session = null;
    ServletContext application = null;
    ServletConfig config = null;
    JspWriter out = null;
    Object page = this;
    JspWriter _jspx_out = null;


    try {
      /* Initialization of implicit objects */
      _jspxFactory = JspFactory.getDefaultFactory();
      response.setContentType("text/html;charset=ISO-8859-1");
      pageContext = _jspxFactory.getPageContext(this, request, response,
                  null, true, 8192, true);
      application = pageContext.getServletContext();
      config = pageContext.getServletConfig();
      session = pageContext.getSession();
      out = pageContext.getOut();
      _jspx_out = out;
```

```
      /* Output of HTML code of jsp */
      out.write("<HTML>\r\n ");
      out.write("<HEAD>\r\n  ");
      out.write("<TITLE>Date JSP (Textbook Listing 5.1)");
      out.write("</TITLE>\r\n ");
      out.write("</HEAD>\r\n ");
      out.write("<BODY>\r\n  ");
      out.write("<BIG>\r\n   Today's date is ");
      out.print( new java.util.Date() );
      out.write("\r\n  ");
      out.write("</BIG>\r\n ");
      out.write("</BODY>\r\n");
      out.write("</HTML>\r\n");
    } catch (Throwable t) {
      out = _jspx_out;
      if (out != null && out.getBufferSize() != 0)
        out.clearBuffer();
      if (pageContext != null) pageContext.handlePageException(t);
    } finally {
      if (_jspxFactory != null) _jspxFactory.releasePageContext(pageContext);
    }
  }
}
```

JSP Elements

- JSP Directives
  - Includes, imports, etc
- JSP Scripting Elements
  - Java code, expressions, variable declarations
- JSP Action Elements
  - Beans, tag libraries, etc
  - We'll discuss later

JSP Directives

- <%@ directive { attr="value" }* %>
- <%@ include file="file.html" %>
- <%@ page import="package name" %>

```
<HTML>
 <HEAD>
  <TITLE>dateWithImport.jsp</TITLE>
 </HEAD>
 <BODY> <BIG>
   <%@ page import="java.util.*" %>
   Today's date is <%= new Date() %>
 </BIG> </BODY>
</HTML>
```

  - Recall: some packages automatically imported

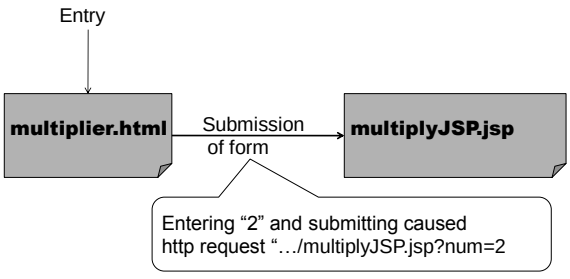
JSP Scripting Elements

- Expressions
  - <%= Java_expression %>
  - Example: <%= i+1 %>
  - Evaluates expression, casts into String, places in output
- Scriptlets
  - <% Java_code %>
  - Example:

```
<% int times ;
       times = 3 ; %>
```

  - Code inlined in _jspService()
- Scriptlets have semicolons, expressions don't

Multiplier example, revisited in jsp



Multiply.html

```
<html>
 <head>
  <title>Multiplier Form</title>
 </head>
 <body>
 Welcome to the page that multiplies by 3
 <p />
 <form method="GET" action="multiplyJSP.jsp">
  Provide the number to be multiplied:
  <input type="text" name="num"/>
  <p />
  <input type="submit" value="Click to Submit"/>
 </form>
</body>
</html>
```

multiplyJSP.jsp

```
<html>
  <head>
    <title>Multiply by 3 (JSP)</title>
  </head>
  <body>
    <%
      int times = 3;
      String param = request.getParameter("num");
    %>
    <%= param + " * " + times + " = " + times *
(Integer.parseInt(param)) %>
  </body>
</html>
```

Two kinds of declarations in JSP Scripting Elements

- Local variables simply part of scriptlets
  - See code of <CATALINA_HOME>`/work/Standalone/localhost/jmultiplier/jmultiply_jsp.java`
- Class variables (*not* in `_jspService()`)

```
<%! int times ; %>
```

  - See `jMultiplyWithClassVariable.jsp`
  - If we have in JSP sciptlet

```
<% times = times + 1; %>
```

  - It will be incremented every time JSP is called
    - from same or different sessions

Deployment Revisited

- All uses of servlet names also apply to JSP's
  - Eg, you may not want someone to know that you have used (a particular) .jsp to implement your page and you want to use URL mapping to hide name
- Declaration of name almost same with servlets

```
<servlet-name>Multiplier</servlet-name>
<jsp-file>jmultiplier.jsp</jsp-file>
```

Scope Issues in JSPs

How to store data in the app server and control which http requests get access to them

- Application
  - Information accessible/shared by all requests of same application (same app context)
- Session (most important)
  - Session: Set of requests from same browser process
    - Browser windows may be in same process
  - Share information within session
  - Non-obvious how given HTTP statelessness
- Request
  - Share information within http request
- Page (almost useless)

Application Level Attributes

- `application` implicit variable of JSP
- In servlet obtained by `application=getServletContext()`
- Exchange attribute info across all calls
  - `application.getAttribute(`name`)`
  - `application.setAttribute(`name, object`)`
  - Can do the same with class variables
  - Or with a database
    - At higher cost but with persistence
  - No synchronization and ACID properties

Counter Example

```
<HTML>
 <HEAD>
  <TITLE>Counter Web Application</TITLE>
 </HEAD>
 <BODY>
  <% Integer i =
       (Integer)(application.getAttribute("counter"));
     if (i == null) { i = new Integer(0) ; }
     else { i = new Integer(i.intValue() + 1) ; }
     application.setAttribute("counter", i) ;
   %>
  Your application has visited <%= i %> times this page.
 </BODY>
</HTML>
```

Getting Web Application Initialization Parameters

- Define application initialization parameters in the deployment descriptor

```
<web-app>
 <!—other stuff we've seen..>
 <context-param>
  <param-name>developer</param-name>
  <param-value>yannis@cs.ucsd.edu</param-value>
 </context-param>
<!—other stuff we've seen..>
</web-app>
```

- `application.getInitParameter(`name`)`

Session Level Attributes

- HTTP is stateless
- But your applications most often involve stateful sessions
- Session-level attributes pass data across the requests of a session
- App server provides implicit `session` object
- In servlets: `req.getSession()`, where `req` is the `HttpServletRequest` parameter
- Behind the scenes Tomcat employs cookies and/or URL rewriting to implement the session object

Maintaining Session Information with the Implicit **`session`** Object

```
<HTML>
 <HEAD>
  <TITLE>Counter Web Application</TITLE>
 </HEAD>
 <BODY>
  <% Integer i=(Integer)(session.getAttribute("counter"));
     if (i == null) { i = new Integer(0) ; }
     else { i = new Integer(i.intValue() + 1) ; }
     session.setAttribute("counter", i) ;
   %>
  Your session has visited <%= i %> times this page.
 </BODY>
</HTML>
```

Session Duration

- Session data are automatically deleted after
  - client is inactive for a period
    - Tomcat default is 30 minutes
  - call of `HttpSession.invalidate()`
- Dynamic reset of session duration with `HttpSession.setMaxInactiveInterval()`
  - In seconds
- Set the default for all web applications following path
  `web-app/session-config/session-timeout` in <CATALINA_HOME>`/conf/web.xml`

Other Methods of passing Information

Direct Use of the **`response`** Object

- Set values for various headers
  - `response.setContentType(String` <MIME type>`)`
- Add extra HTTP headers
  - **`addHeader`**`(java.lang.String` name, `java.lang.String` value`)`
  - Other "versions" for `int`, `Date`, etc types
- Add cookies (discussed next)
- Send error responses

Cookies

- Way to store information on the client side
- Server includes `Set-Cookie` header
  - Eg, `Set-Cookie: multiply5Fid=%7BE2; path=/`
  - Implicitly associated with URL of server that provided
  - Explicitly associated with provided `path`
- Web client stores on cookie repository
  - if cookies from this site are enabled
  - Until expiration
    - Default is the browser session

Cookies (cont'd)

- When web client makes subsequent http request to domain/path all matching cookies are attached
  - Eg, `Cookie: multiply5Fid =%7BE2`
- Constructor `javax.servlet.http.Cookie(String name, String value)`
- `response.addCookie(Cookie value)`
- `request.getCookies()` returns `Cookie[]`
- Bunch of setter methods for changing default path, id, lifetime properties of cookie

When Should One Use Cookies?

- Use cookies if
  - No confidential info is released
  - You have to utilize their longevity
    - Cookies that live across browser startup/shutdown
  - Web app does not fall apart if cookies are disabled by client
- Example: preset some forms
- Do not use for standard session management aspects

Hidden Fields

- Passing (non-user input) information across requests
- You need an HTML form to be present
  - Not applicable with HTML links
- `<INPUT TYPE="HIDDEN" NAME="<parameter>" VALUE="<value>">`
- Prefer POST forms if you need to hide the hidden field from the URL
- Database keys are typical hidden fields
  - Example in databases section.

Putting it all together with the students example

- A "database" of students maintained in an application-scoped attribute "database"
  - "database" is a Java Map structure

Highlight points:

- "Model 1" programming paradigm
- **Extensive use of hidden id's to capture**
  - **which one of the many forms of the page has been submitted**
  - **which one of the many links has been clicked**

What is Wrong with JSPs?

- Business logic & html content (presentation) mixed together
- Especially hard to maintain/evolve a program
- Still not very clean separation of web designer and web developer tasks