Server-Side Web Programming: Java

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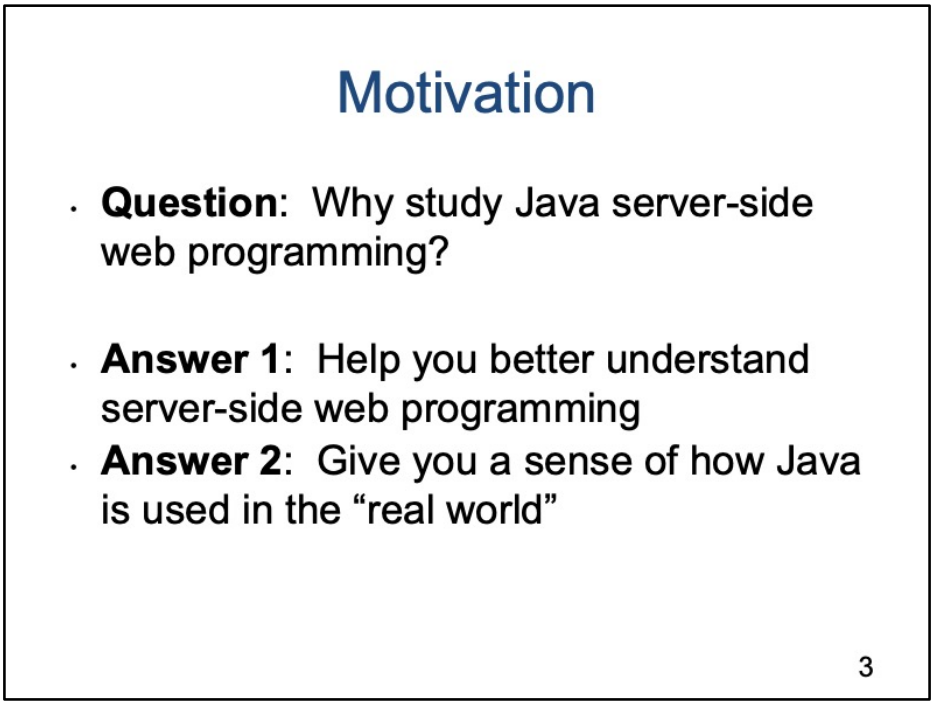
Objectives

- We will cover:
  - Aside: Python lambda expressions
  - Some advanced Java features
  - Server-side web programming in Java, via…
  - Servlets
  - The Spark web app framework
  - The Velocity template engine

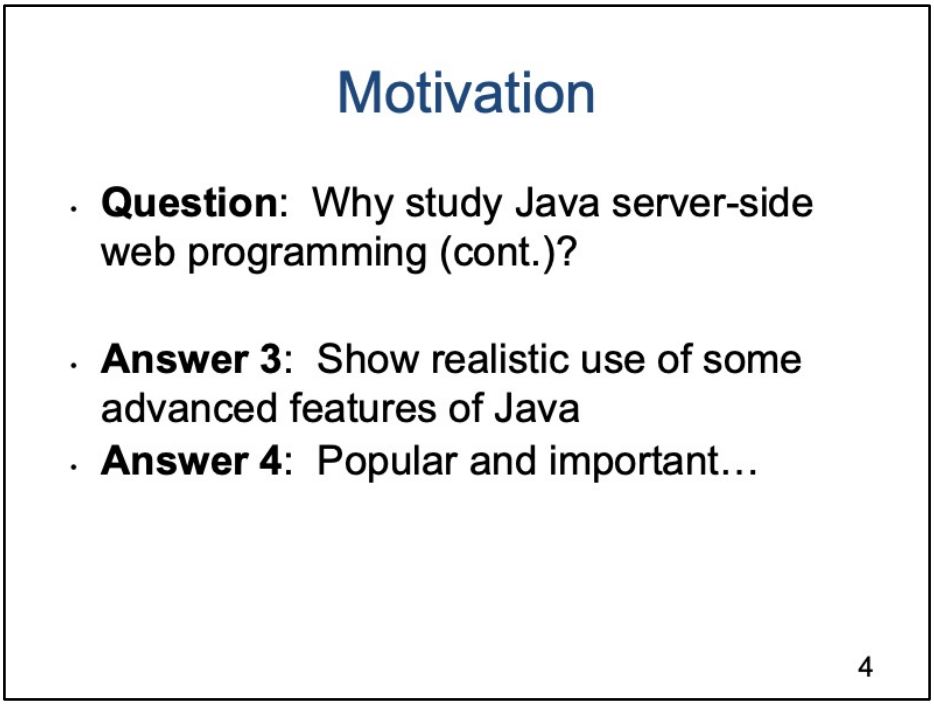


Motivation

Question: Why study Java server-side web programming?

Answer 1: Doing so will help you better understand server-side web programming
Help you get a sense of what is common across server-side web programming environments and what is language-specific

Answer 2: Doing so will give you a sense of how Java is used in the "real world"
COS 126 uses Java to cover the fundamentals of programming
COS 226 uses Java to cover algorithms & data structures
To some extent, "real world" Java programming differs from the kind of academic programming that you did in 126 and 226.



Motivation

Question: Why study Java server-side web programming (cont.)?

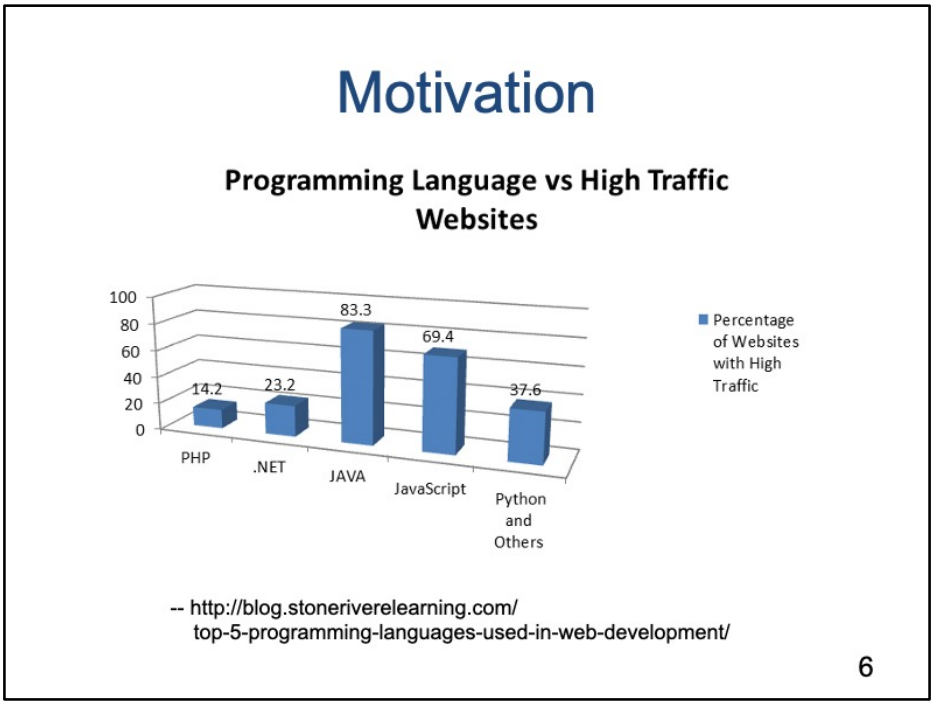
Answer 3: Doing so will introduce some advanced features of Java that might be new to you

Answer 4: Java server-side Web programming is popular and important…

Motivation

Website	Front End	Back End
Google.com	JavaScript	C, C++, Go, Java, Python
Facebook.com	JavaScript	Hack, PHP, Python, C++, Java, Erlang, D, Xhp, Haskell
YouTube.com	JavaScript	C, C++, Java, Python, Go
Yahoo	JavaScript	PHP
Amazon.com	JavaScript	Java, C++, Perl
Wikipedia.org	JavaScript	PHP, Hack
Twitter.com	JavaScript	C++, Java, Scala, Ruby
Bing	JavaScript	ASP.net
eBay.com	JavaScript	Java, JavaScript, Scala
MSN.com	JavaScript	ASP.net

https://en.wikipedia.org/wiki/Programming_languages_used_in_most_popular_websites



Motivation

If you consider all websites that experience high traffic…

Java is used in 83.3% of them
(Python and others) are used in 37.6% of them

Agenda

- **Aside: Python lambda expressions**
- Some advanced Java features
- Servlet programming
- The Spark Web application framework
- The Velocity template engine

Python Lambda Expressions

- ***Lambda expression***
  - From Alonzo Church
  - 1930s
  - A nameless function
  - Implemented in both Python and Java

8

Lambda Expressions

Lambda expression
- A nameless function
- From Alonzo Church
  - Alumnus of Princeton
  - Prof of philosophy and mathematics at Princeton for many years
  - Contemporary of Alan Turing
  - 1930s
  - Developed some important theoretical results independent of and working with Turing
- Lambda expressions are implemented in both Python and Java

Python Lambda Expressions

- In Python:
  - The keyword `lambda`
  - (optionally) Parameters separated by commas
  - A colon
  - A single expression that uses the parameters

Python Lambda Expressions

Without using a lambda expression:

```
def mult(x, y):
   return x * y
…
prod = mult(5, 6)
print(prod)   # prints 30
```

Using a lambda expression:

```
mult = lambda x, y: x * y
…
prod = mult(5, 6)
print(prod)   # prints 30
```

Using a lambda expression:

```
print( (lambda x, y: x * y)(5, 6) )   # prints 30
```

Python Lambda Expressions

Without lambda expression:

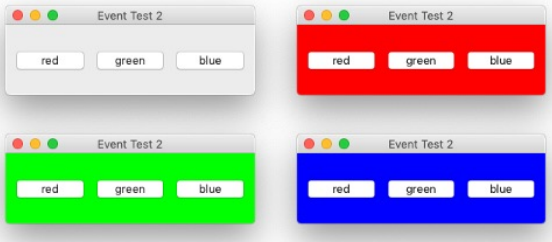
```
def compare_lengths(word1, word2):
    return len(word1)-len(word2)
…
words.sort(compare_lengths)
…
```

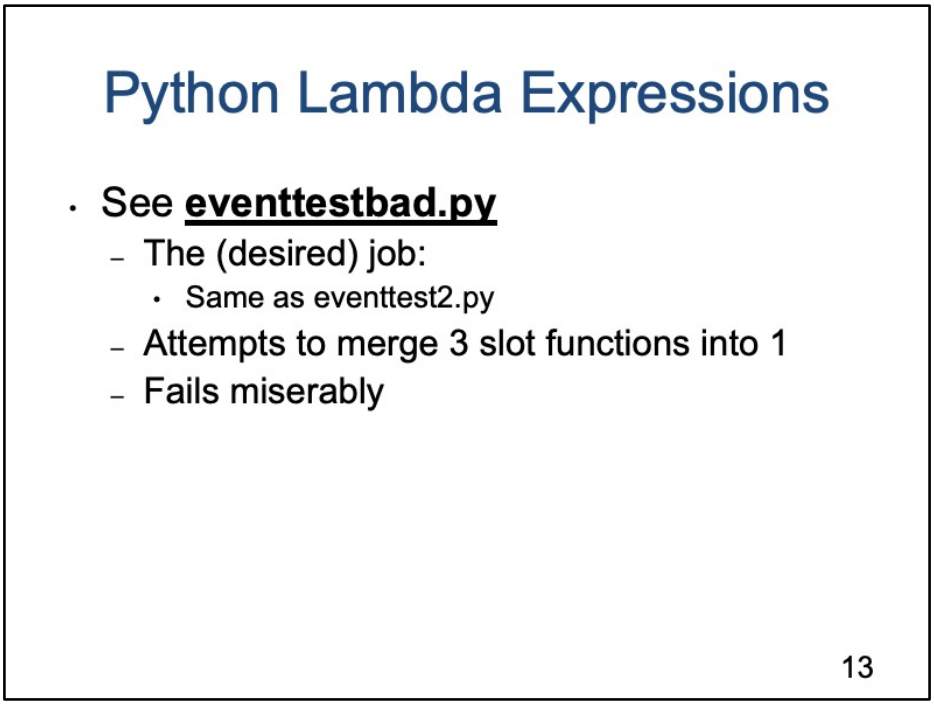
With lambda expression:

```
…
words.sort(
    lambda word1,word2: len(word1)-len(word2) )
…
```

Python Lambda Expressions

- Recall **eventtest2.py**
  - The job:
    - Handle events on `QPushButton` objects



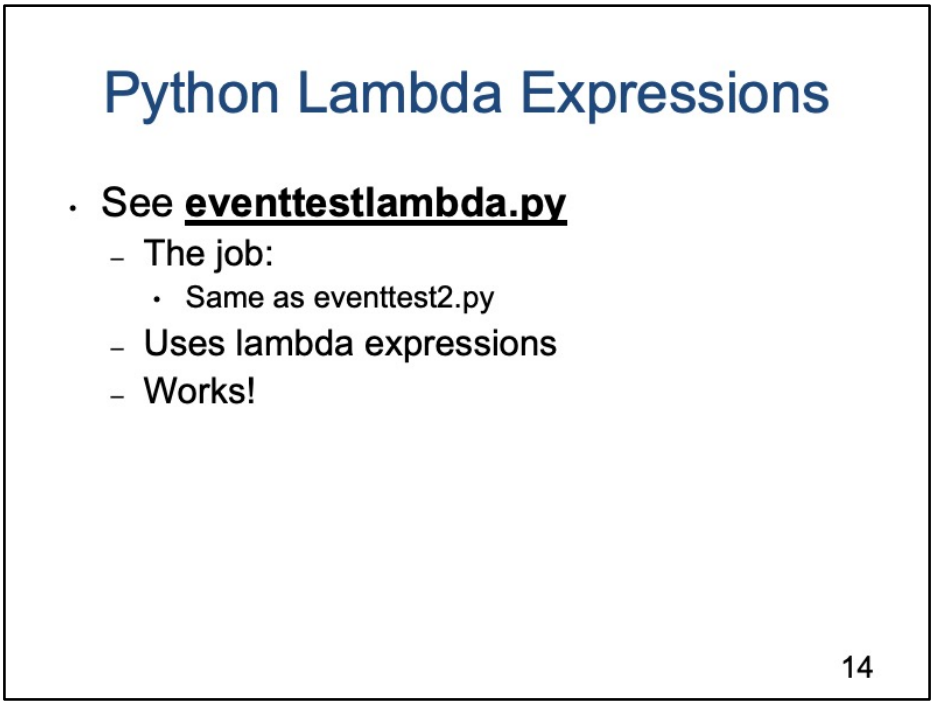


Lambda Expressions

[see slide]

Code notes:

The argument passed to connect() should be a function (pointer)
Here, the argument passed to connect() is None



Lambda Expressions

[see slide]

Code notes:

An (arguably) nicer approach
Use lambda expressions

Agenda

- Aside: Python lambda expressions
- **Some advanced Java features**
- Servlet programming
- The Spark Web application framework
- The Velocity template engine

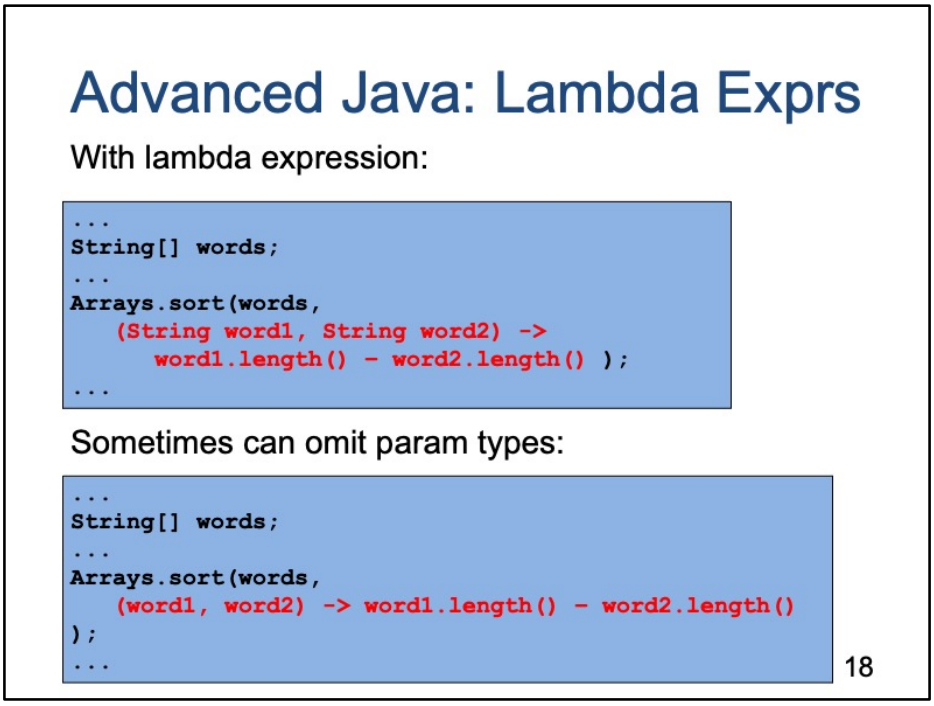
Advanced Java: Lambda Exprs

- Java lambda expressions
  - New to Java SE 8
  - Examples…

Advanced Java: Lambda Exprs

Without lambda expression:

```
class LengthComparator implements Comparator<String>
{
   public int compare(String word1, String word2)
   {
      return word1.length() - word2.length();
   }
}
...
String[] words;
...
Arrays.sort(words, new LengthComparator());
...
```



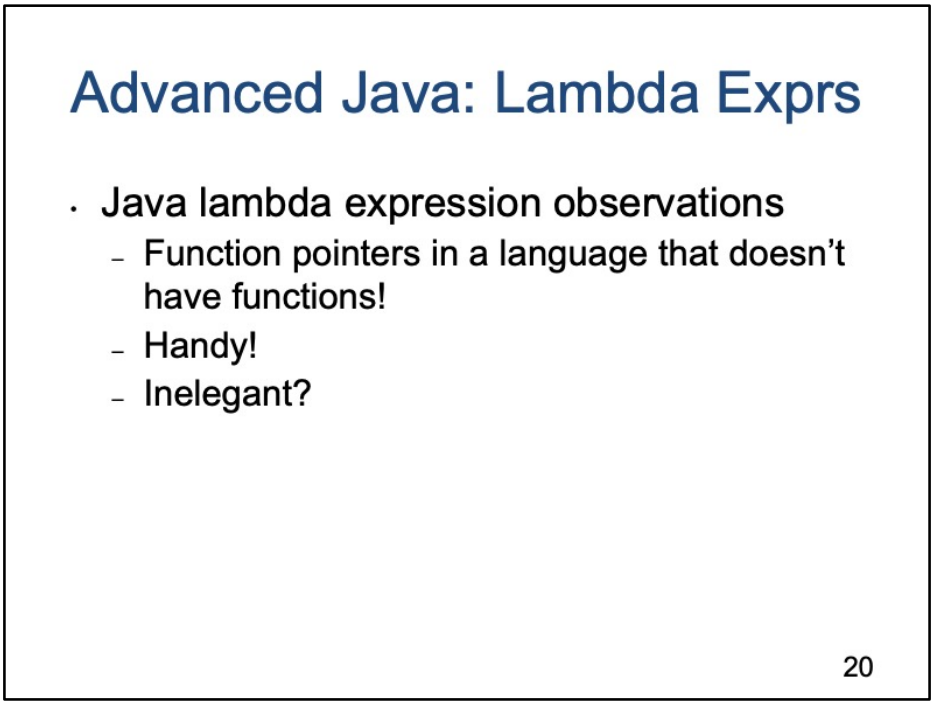
Advanced Java: Lambda Exprs

[see slide]

Can omit the parameter types if the compiler can infer them.

Advanced Java: Lambda Exprs

- Generalizing…
- ***Functional interface***
  - An interface that declares a single method
- Can use a lambda expression in lieu of an object of a class that implements a functional interface



Some Advanced Java Features

Lambda expression observations

> "It's best to think of a lambda expression as a function, not an object, and to accept that it can be passed to a functional interface." -- Horstmann

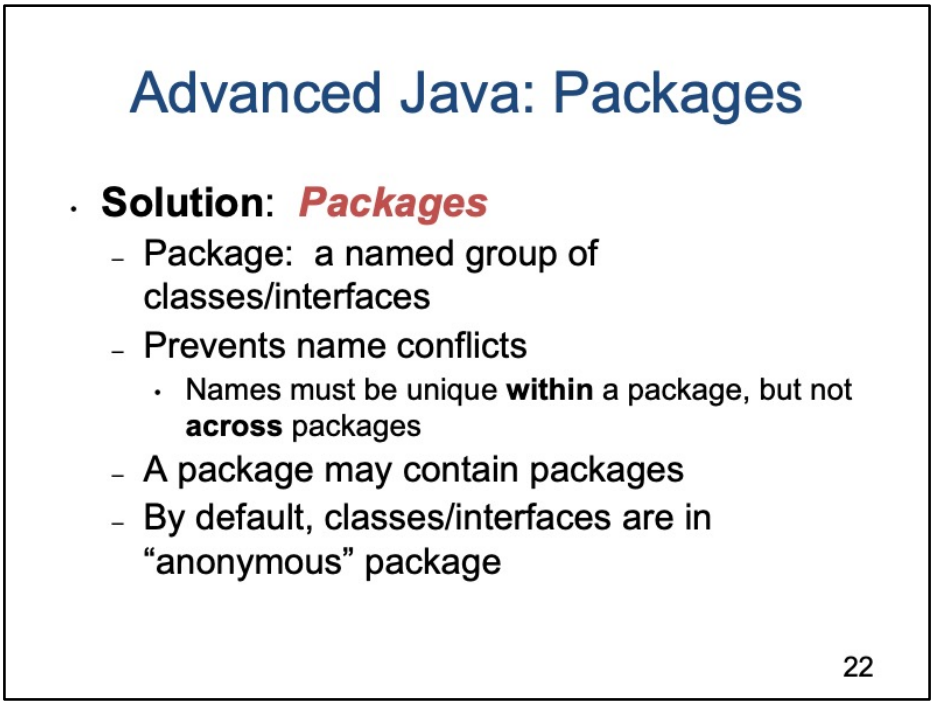
> Function pointers in a language that doesn't have functions!
> Handy!
> Inelegant?

Advanced Java: Packages

- **Problem**: Different vendors may use conflicting class names

```
class Book {…} // From vendor A

class Book {…} // From vendor B
```



Packages

Solution: ***Packages***

Package: a named group of classes/interfaces
Prevents name conflicts
A package may contain packages
By default, classes/interfaces are in "anonymous" package

Advanced Java: Packages

- **Using** a package

```
…
java.lang.Math.sqrt(x);
…
```

```
import java.lang.Math;
…
Math.sqrt(x);
…
```

Advanced Java: Packages

- **Creating** a package

```
// Book.java

package edu.princeton.penny;

// All names defined subsequently are
// in the edu.princeton.penny package.

class Book{ … }
```

  - Defines class edu.princeton.penny.Book
  - Book.java must be in edu/princeton/penny directory

Advanced Java: Maven

- ***Maven***
  - Java **build** tool
    - C : make
    - Java : Maven
  - Java **package management** tool
    - Python: pip & PyPi
    - Java: Maven & Maven central repo

Advanced Java: Maven

- Maven as a package manager
  - Manages the central Maven repository, and…
  - Your local Maven repo (~/.m2), such that…
  - Your local Maven repo is a subset of the central Maven repo, and…
  - Your local Maven repo contains all .jar files required by your app

Advanced Java: Maven

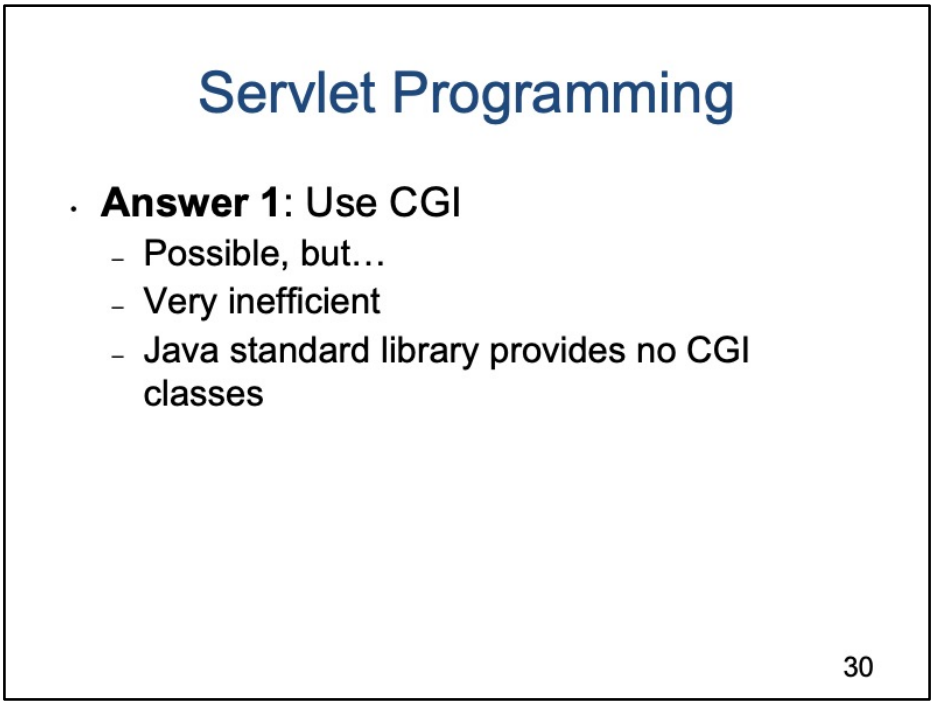
- Maven as a package manager
  - Programmer defines **pom.xml** file for app
    - Specifies .jar files on which app depends
  - Maven downloads .jar files, as necessary, from central Maven repo to your local Maven repo
  - Does so recursively!
- Related/competing tools:
  - **Ant**, **Gradle**

Agenda

- Aside: Python lambda expressions
- Some advanced Java features
- **Servlet Programming**
- The Spark Web Application Framework
- The Velocity Template Engine

Servlet Programming

- **Question**: How does one do web programming in Java?
- **Answer 1**: Use CGI
- **Answer 2**: Use Servlets
- **Answer 3**: Use a Java web app framework



Servlet Programming

Answer 1: Use CGI

Possible, but…

Very inefficient

Each HTTP request forks a new child process and execs a new JVM!

Java standard library provides no CGI classes

No “real” website would use them anyway

(I composed some for my own use; see me if you want)

Servlet Programming

- **Question**: How does one do web programming in Java?
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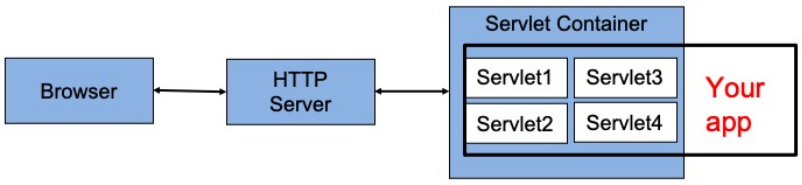
Servlet Programming

- ***Servlets***
  - "A servlet is a Java technology-based Web component, managed by a ***container***, that generates dynamic content."
    - Servlet specification at:
    - http://download.oracle.com/.../servlet-3_0-final-spec.pdf

Servlet Programming

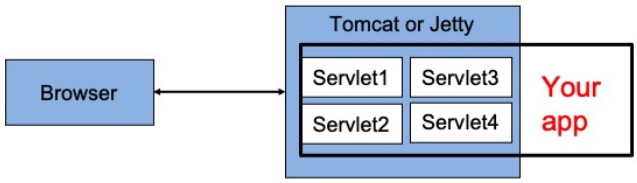


Popular servlet containers:

Apache Tomcat

Eclipse Jetty

Servlet Programming



Tomcat or Jetty can be both servlet container and HTTP server

We'll use that configuration
We'll use Jetty

Servlet Programming

- **Python**: *WSGI specification* connects HTTP server and your Python app
  - **Programmers compose** Python code to conform to WSGI spec
  - **Sys admins deploy** Python code with HTTP server

Servlet Programming

- **Java**: *Servlet specification* connects HTTP server and your Java app
  - **Programmers compose** Java code to conform to Servlet spec
  - **Sys admins deploy** Java code with Servlet container and HTTP server

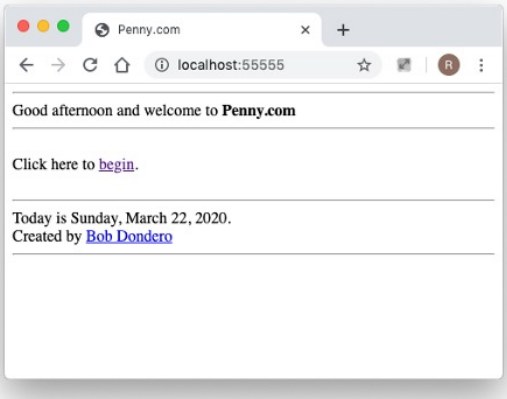
Servlet Programming

- See **PennyServlets** app

```
$ mvn clean
$ mvn compile
$ ./runserver 55555
```

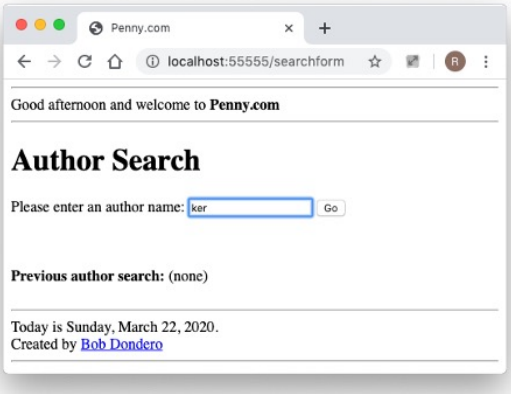
Servlet Programming

- See **PennyServlets** app (cont.)



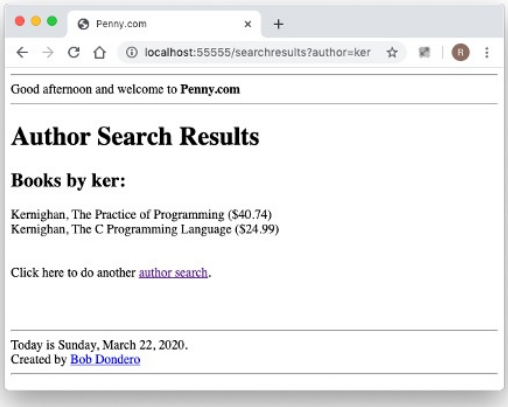
Servlet Programming

- See **PennyServlets** app (cont.)



Servlet Programming

- See **PennyServlets** app (cont.)



Servlet Programming

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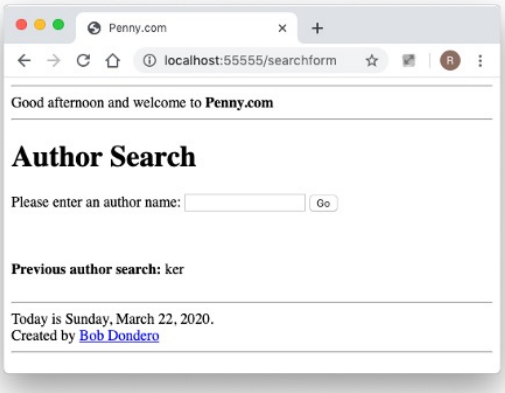
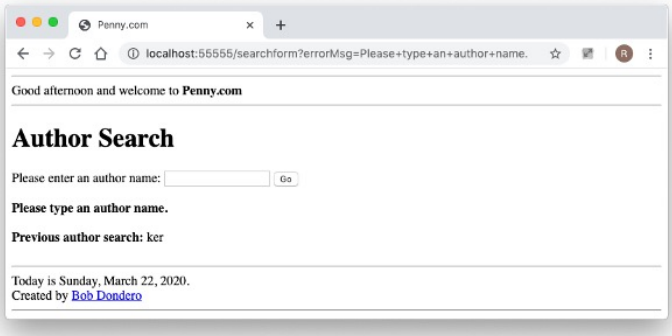
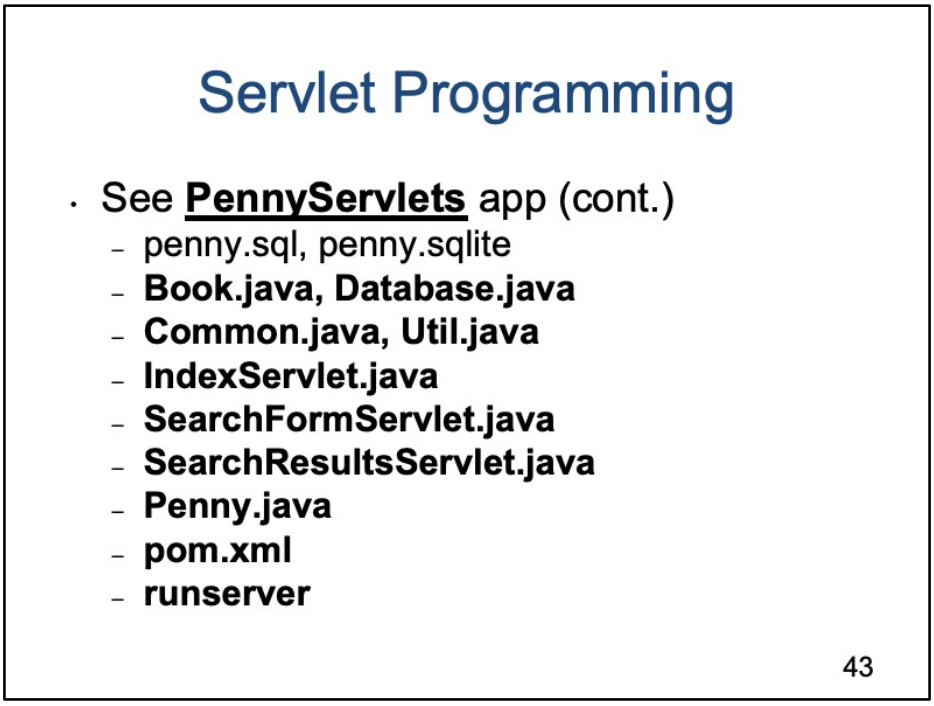


Servlet Programming

- See **PennyServlets** app (cont.)





Servlet Programming

[see slide]

Code notes: **Book.java**
In edu.princeton.penny package

Code notes: **Database.java**
In edu.princeton.penny package
Uses Java database driver to access SQLite database

Code notes: **Common.java**
In edu.princeton.penny package
Defines static methods used by multiple classes

Code notes: **Util.java**
In edu.princeton.penny package
getCookie() method accepts cookie name, returns cookie value (or null)

Code notes: **IndexServlet.java**
In edu.princeton.penny package

Called to generate the index page

Code notes: **SearchFormServlet.java**
- In edu.princeton.penny package
- Called to generate the search form page
- Gets value associated with given name
- Gets cookie with given name

Code notes: **SearchResultsServlet.java**
- In edu.princeton.penny package
- Called to generate the search results page
- Performs redirection
- Creates a cookie
- Accesses database

Code notes: **Penny.java**
- Define main() method
- Maps HTTP requests to Servlet classes

Code notes: **pom.xml**
- Configures Maven
  - Use JDK 1.8
  - The app depends upon the 5 specified .jar files

Code notes: **runserver**
- Bash shell script
- Uses Maven to run Jetty Web server…
- Which serves the app

Servlet Programming

```
PennyServlets
   pom.xml
   runserver
   src
      main
         java
            edu
               princeton
                  penny
                     Book.java
                     Common.java
                     Database.java
                     IndexServlet.java
                     Penny.java
                     SearchFormServlet.java
                     SearchResultsServlet.java
                     Util.java
         resources
            penny.sql
            penny.sqlite
```

Agenda

- Aside: Python lambda expressions
- Some advanced Java features
- Servlet programming
- **The Spark Web application framework**
- The Velocity template engine

Spark

- **Question**: How does one do web programming in Java?
- **Answer 1**: Use CGI
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Spark

- **Who**: Per Wendel
- **When**: 2011, rewritten for Java 8 in 2014
- **Descrip**: “A micro framework for creating web applications in Kotlin and Java 8 with minimal effort”
  – Spark website

Spark

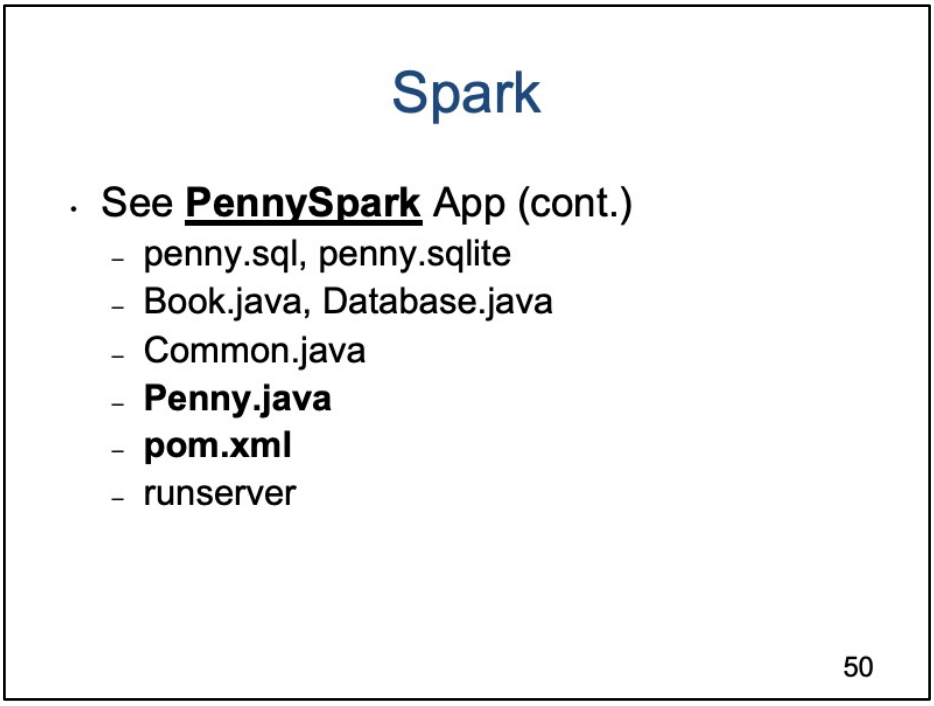
- Why study Spark?
  - (Instead of some other framework)
  - Easy to learn
    - Simple
    - Good documentation and tutorial
    - Integrated with Jetty container/server

Spark

- See **PennySpark** app

```
$ mvn clean
$ mvn compile
$ ./runserver 55555
```

All pages identical to those of PennyServets app



Servlet Programming

[see slide]

Code notes: Penny.java
In edu.princeton.penny package
Used to generate all pages
Uses lambda expressions

Code notes: pom.xml
Only 2 dependencies!
sqlite-jdbc
spark-core
Maven recursively fetches all child dependencies automatically

Spark

```
PennySpark
   pom.xml
   runserver
   src
      main
         java
            edu
               princeton
                  penny
                     Book.java
                     Common.java
                     Database.java
                     Penny.java
         resources
            penny.sql
            penny.sqlite
```

Spark

- Spark provides utility methods
  - Methods to fetch `name=value` pairs
  - Methods to fetch/create cookies
  - Methods to implement HTTP redirect

Agenda

- Aside: Python lambda expressions
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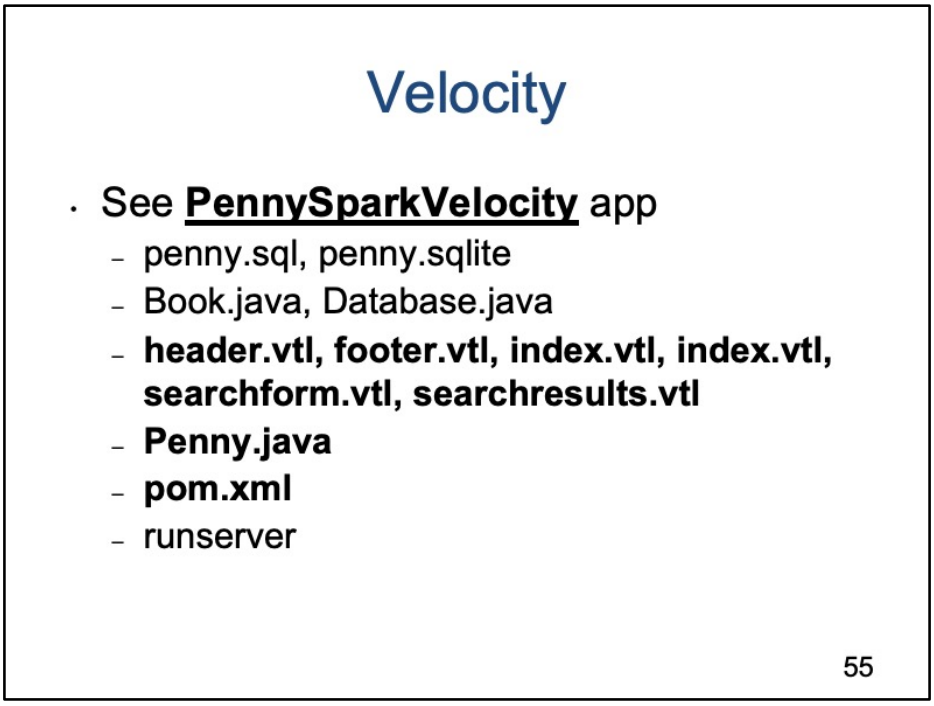
- **The Velocity template engine**

Velocity

- Problem:
  - Code contains many assignment statements to compose HTML code
  - Bulky; awkward; slow; error prone
- Solution:
  - ***Templates***
  - In this case via…
  - The ***Apache Velocity*** template engine



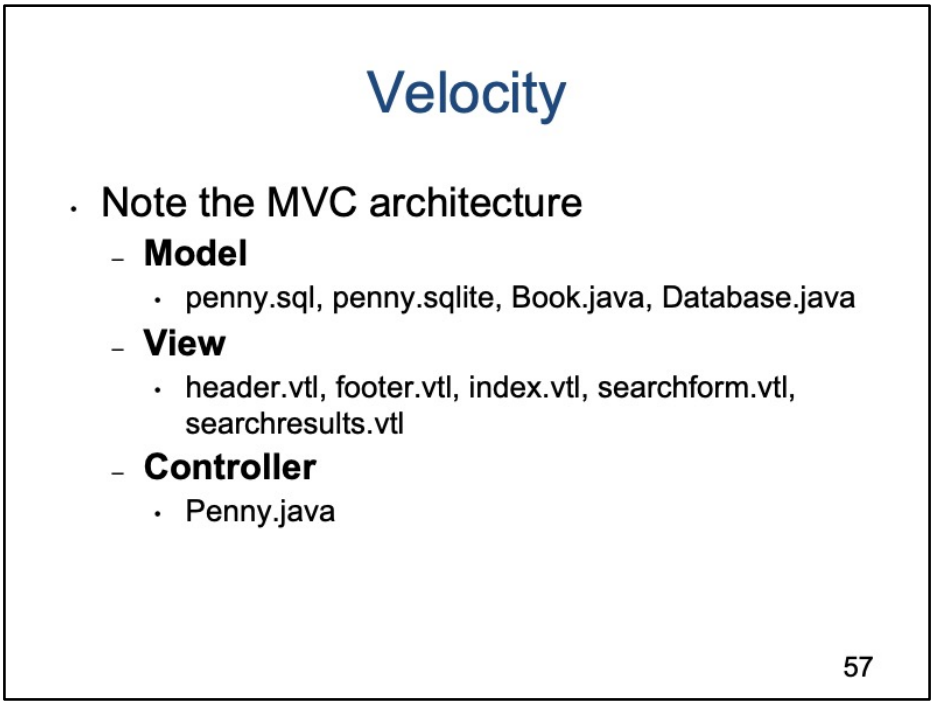
The Velocity Template Engine

[see slide]

Code notes: footer.vtl
A Velocity template containing a placeholder
Code notes: index.vtl
A Velocity template containing a placeholder
Code notes: searchform.vtl
A Velocity template containing a placeholder
Code notes: searchresults.vtl
A Velocity template containing a placeholder
Also contains some logic expressed in the Velocity template language (not Java)
Code notes: Penny.java
Instantiates Velocity templates

Velocity

```
PennySparkVelocity
   pom.xml
   runserver
   src
      main
         java
            edu
               princeton
                  penny
                     Book.java
                     Common.java
                     Database.java
                     Penny.java
         resources
            penny.sql
            penny.sqlite
            header.vtl
            footer.vtl
            index.vtl
            searchform.vtl
            searchresults.vtl
```



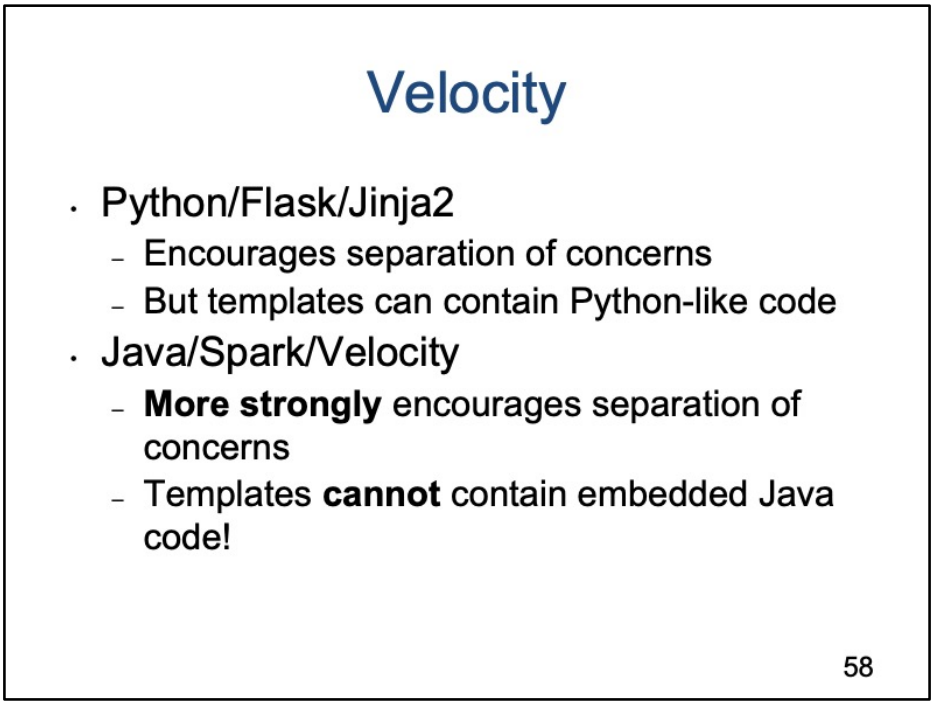
The Velocity Template Engine

Note the MVC architecture

Model
penny.sql, penny.sqlite, Book.java, Database.java
Concern of DB admins

View
header.vtl, footer.vtl, index.vtl, searchform.vtl, searchresults.vtl
Concern of Web designers

Controller:
Penny.java
Concern of programmers



The Velocity Template Engine

Python/Flask/Jinja2

- Encourages separation of concerns
- But templates can contain Python-like code

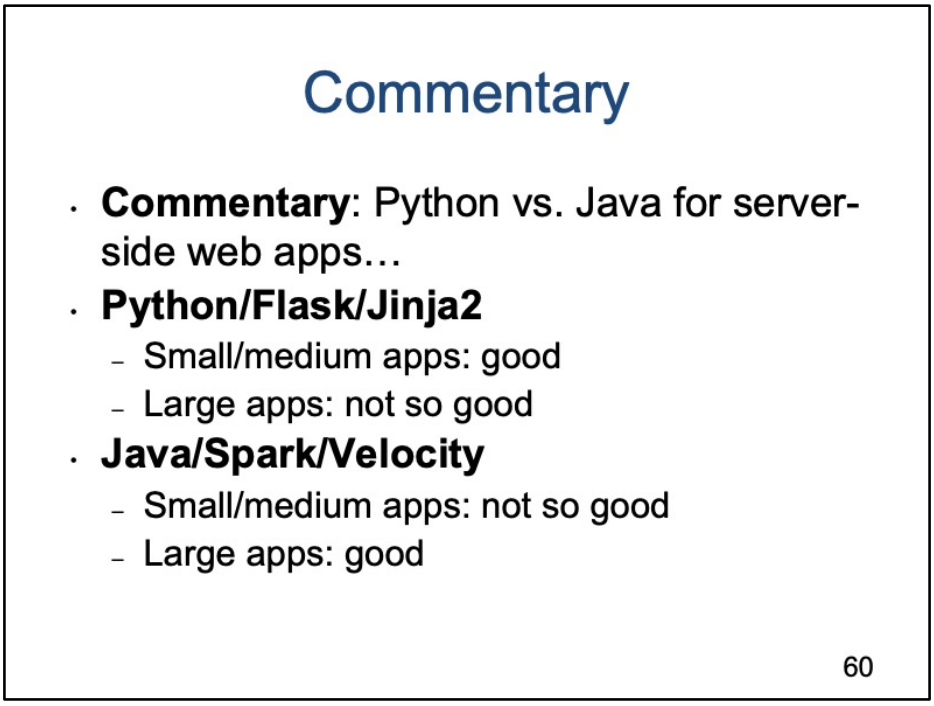
Java/Spark/Velocity

- More strongly encourages separation of concerns
- Templates **cannot** contain embedded Java code!
- Instead use a special purpose (Apache Velocity) language

More Spark and Velocity!

- There is much more to Spark and Velocity
- Spark website:
  - http://sparkjava.com/
- Velocity website:
  - http://velocity.apache.org/engine/1.7/vtl-reference.html

- *Don't confuse **Spark** (sometimes called **SparkJava**) with **Apache Spark** (an open-source cluster-computing framework)*



Commentary

Commentary: Python vs. Java for server-side web apps…

Python/Flask/Jinja2

Small/medium apps (4 programmers, a few months): good
Simple, succinct
Large apps (40 programmers, a few years): not so good
Dangerous (weak/duck typing, no privacy)
Relatively poor performance

Java/Spark/Velocity

Small/medium apps: not so good
Complex, verbose
Large apps: good
Safe (strong typing, privacy)
Good performance

Summary

- We have covered:
  - Aside: Python lambda expressions
  - Some advanced Java features
  - Server-side web programming in Java, via…
  - Servlets
  - The Spark web app framework
  - The Velocity template engine