CS11 – Java

Fall 2014-2015

Lecture 3

Today's Topics

- Class inheritance
- Abstract classes
- Polymorphism
- Introduction to Swing API and event-handling
- Nested and inner classes

Class Inheritance

- A third of the “four big OOP concepts”
- A class can extend another class to build on its functionality
- Terminology:
  - Parent class, or superclass, or base class
  - Child class, or subclass, or derived class
- Child classes inherit all methods and fields within parent class
  - Can add new functionality
  - Can also override parent-class methods

Class Inheritance (2)

- Class inheritance models an “is-a” relationship
  - Example class hierarchy:

    Vehicle

    └ Wheeled Vehicle └ Water Vehicle

    └ Dump Truck └ Sailboat └ Barge
- The child class is a specialization of the parent class
- Child class also has characteristics of parent class
  - Can treat child class as if it were any parent-type
    - “A dump truck is a wheeled vehicle.”
    - “A sailboat is a vehicle.”
    - “A water vehicle is a vehicle.”

Class Inheritance (3)

- Example class hierarchy:

  Vehicle

  └ Wheeled Vehicle └ Water Vehicle

  └ Dump Truck └ Sailboat └ Barge

- Sibling types *do not* model an "is-a" relationship!
  - These statements are clearly false:
    - "A dump truck is a water vehicle."
    - "A wheeled vehicle is a barge."
- What about these statements?
    - "A vehicle is a dump truck."
    - "A water vehicle is a sailboat."
  - Depends on the actual vehicle being considered!
    - Need to examine a specific vehicle to verify the statement

Example Class Hierarchy

- The number classes in Java

```
java.lang.Object
  └ java.lang.Number
      └ java.lang.Integer
```

  - **`Integer`** “is a” **`Number`**, “is an” **`Object`**
  - **`Integer`** extends **`Number`**, which extends **`Object`**
  - **`Integer`** inherits all methods that **`Object`** defines
    - `boolean equals(Object o)`
    - `int hashCode()`
    - `String toString()`
    - `Class getClass()`
  - **`Integer`** also overrides some of these methods

Overriding `Object.toString()`

- Really useful idea, especially for debugging
- Used in string concatenation
  - You type this:

```
String msg = "Point is " + pt;
```

  - Compiler automatically does this:

```
String msg = "Point is " + pt.toString();
```

- Simple to define:

```
@Override
public String toString() {
    return "(" + xCoord + "," + yCoord + ")";
}
```

Classes and Objects

- A class' parent-class methods can be called without any special syntax.

```
Integer intObj = new Integer(53);
...
Class c = intObj.getClass();  // Get type info
```

  - **`Integer`** is also an **`Object`** – can call methods declared and/or implemented on **`Object`**
- Child class can also provide its own methods

```
System.out.println("Value is " + intObj.intValue());
```

  - **`Integer`** *extends* **`Object`**'s functionality
    - **`intValue()`** returns an **`int`** version of the **`Integer`**

Reference Types

- Every reference has a class-type associated with it

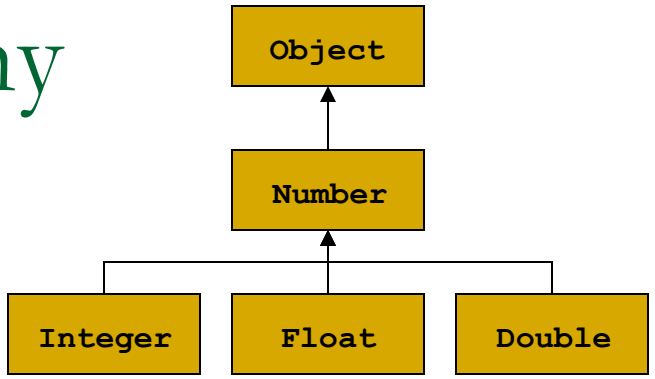
```
Object obj;     // A reference of type Object
Integer val;    // A reference of type Integer
```

- The variable's type dictates what is accessible
- Example:

```
Object obj = new Integer(38);
...
System.out.println(obj.intValue());    COMPILE ERROR
```

  - Compile error, because **`Object`** doesn't define **`intValue()`**
  - **`intValue()`** is declared in **`Number`** class (parent of **`Integer`**)
  - Even though **`obj`** refers to an **`Integer`** object, only the **`Object`** methods are visible

Navigating the Hierarchy



- Number hierarchy is like this:

- Moving down the hierarchy requires a run-time test.

```
Object obj = new Integer(453);
...
int i = ((Integer) obj).intValue();    // Cast obj
```

  - You could also try this:

```
float f = ((Float) obj).floatValue(); // Runtime error
```

    - This code compiles, but it will report an error at runtime
  - Java can't assume the actual object-type at compile time!
    - (Even when it's obvious to a human…)
  - So, we have a runtime type-check, and a potential error.

What Child Classes Don't Get

- Child classes cannot access **`private`** members in parent classes
- **`protected`** access-modifier allows the child class to access parent-class' members
  - Only available within the class, and to subclasses
  - Looser than **`private`**, but still not **`public`**!
- Child classes also don't inherit static fields and methods
  - They can be accessed, but they are not inherited

A Generic Task Class

```
public class Task {
    private String name;
    private boolean done;

    public Task(String taskName) {
        name = taskName;
        done = false;
    }

    /** Just record that the task is done. */
    public void doTask() {
        done = true;
    }

    /** Report if the task is done or not. */
    public boolean isDone() {
        return done;
    }
}
```

Making Useful Tasks

- Our **`Task`** class is *very* generic…
  - …so generic that it's nearly useless!
- Extend **`Task`** class to provide useful tasks

```
public class FileUploadTask extends Task {
    public FileUploadTask() {
        // Call parent-class constructor
        super("upload file");
    }

    ...
}
```

  - Parent-class constructors are *not* inherited!
  - If parent class doesn't have a default constructor, we must *explicitly* call one in the child class, using **`super`** keyword

Overriding Parent-Class Methods

- **`FileUploadTask`** should provide its own implementation of **`doTask()`**

```
public class FileUploadTask extends Task {
    ...

    /** Perform the file-upload operation. */
    @Override
    public void doTask() {
        ... // Open a connection, read a file, etc.
    }
}
```

  - Method's signature is same as parent-class' method signature
  - This overrides Task's implementation of doTask()

Polymorphism

- Now we want to upload a file:

```
Task t = new FileUploadTask();
t.doTask();
```

  - Which implementation of **`doTask()`** does this call?
- In Java, all instance-methods are virtual
  - Even though **`t`** is a **`Task`** reference, the **`FileUploadTask`** implementation is called
  - Reason: **`t`** refers to an object of type **`FileUploadTask`**
- This is called polymorphism
  - The fourth “Big OOP Concept”
  - A statement’s behavior changes, depending on the type of the objects involved

Calling Parent-Class Methods

- Problem:
  - **`FileUploadTask.doTask()`** doesn't set **`done`** to **`true`**
  - Also, **`done`** is private!
- One solution:
  - **`FileUploadTask.doTask()`** implementation can call the parent-class implementation:

```
/** Perform the file-upload operation. */
@Override
public void doTask() {
    ... // Open a connection, read file, etc.

    // All done!
    super.doTask();
}
```

The `Task` Abstraction

- Actually doesn't make much sense for `Task` to have an implementation of `doTask()`
  - Change `Task` to be an abstract class
  - An abstract class declares a set of behaviors, but only *partially* defines it.
- Abstract classes cannot be instantiated
  - Child classes must be provided, that implement the missing functionality
  - Example: `FileUploadTask` must provide an implementation of `doTask()`, that uploads a file.

The New, Abstract **`Task`** Class

- Our abstract Task class:

```
// A class that represents a generic task
public abstract class Task {
    private String name;
    private boolean done;

    public Task(String taskName) {
        name = taskName;
        done = false;
    }

    // Child classes implement this method.
    public abstract void doTask();

    ... // Rest of class
}
```

- Abstract classes can still have fields and non-abstract methods

The New `FileUploadTask`

- **`FileUploadTask`** doesn't "override" **`doTask()`**
  - There's nothing to override!
  - **`FileUploadTask`** *implements* **`doTask()`**
- Again, the signatures must match up

```
/** Implement doTask() to upload a file. */
public void doTask() {
    ... // Open a connection, read the file, etc.
}
```

  - (Without the **`abstract`** modifier, of course!)
  - Of course, we can't do **`super.doTask()`** anymore
- Child class *must* provide an implementation of every abstract parent-class method
  - If not, child class must also be declared abstract.

Completing the Abstraction

- How can a task be marked as done?
- A simple solution: set **`done`** to be protected
- Another good solution:
  - **`Task`** can provide another protected method to do this:

```
protected void reportTaskDone() {
    if (done) {
        ...  // Task was already done!  Complain.
    }
    done = true;
}
```

  - Now only child classes can report that the task is done
- Which solution is more extensible?
  - Might want to add other processing when a task is finished
  - Can easily add this to **`reportTaskDone()`** later

`Task` References

- You can't instantiate the abstract **`Task`** class

```
Task t = new Task("send e-mail");     COMPILE ERROR
```

  - The implementation of **`Task`** is incomplete!
- You *can* have a **`Task`**-reference

```
Task t = new FileUploadTask();
t.doTask();     // Calls FileUploadTask.doTask()
t = new SendEMailTask();
t.doTask();     // Calls SendEMailTask.doTask()
```

  - The correct implementation of **`doTask()`** gets called because of polymorphism
- APIs are made generic by using the base-class type

```
void enqueueTask(Task t) {
    pendingList.store(t);
}
```

Swing: A Quick Tour

- First GUI framework in Java was the AWT
  - Abstract Windowing Toolkit
  - Could perform basic operations
  - Not very pretty, or extensible
- Java 1.2 introduced the Swing API
  - Built on top of some AWT functionality
  - Reimplemented many higher-level AWT classes
  - Customizable look-and-feel
  - Very extensible, feature-rich API
  - A bit slower than AWT, since it's "Pure Java"

Swing Classes

- Most Swing classes are in **`javax.swing`** package (and some sub-packages)
- Quite a few AWT classes are used by Swing!
  - Events, event-handlers, geometry, images, drag-and-drop, etc.
- Swing UI widgets derive from **`JComponent`**
  - Represents *any* UI component in Swing
  - **`JComponent`** derives from **`java.awt.Container`**
  - Custom Swing components can also use **`JComponent`** as their parent class

Heavyweight Components

- AWT UI components are “heavyweight”
  - Each component has its own native graphics resources
  - Components don’t use “pure Java” code to draw their graphics
    - Actually use operating-system calls
  - Overlapping components overwrite each other

Lightweight Components

- Swing UI components are “lightweight”
  - Components use only Java to draw themselves
  - Native graphics resources are shared by Swing components, as much as possible
  - Example:
    - A popup menu fully within an app’s window is drawn using that window’s resources
    - A popup menu extending outside an app’s window will get its own window
  - Swing can provide transparent regions more easily, since components share graphics resources

Mixing AWT and Swing

- Lightweight and heavyweight components don't mix well!
  - Heavyweight components are *always* drawn on top of lightweight components.
- Avoid mixing Swing UI components and AWT components if possible

Windows and Containers

- **`JWindow`** represents simple windows
  - …but no title bar, menus, min/max/close buttons!
- **`JFrame`** represents application windows
  - Complete with title bar, menus, window-buttons
  - Typically use this for Java GUI applications
- **`JPanel`** groups together UI components
  - A lightweight, general purpose container
  - Great for building up structure in your GUI!
- Use **`add(...)`** method to add child-components
  - Child-components can also be containers, e.g. **`JPanel`**

Laying Out Components

- Containers position/size child-components with layout managers
  - Call **`setLayout(LayoutManager lm)`** on the container
  - **`java.awt.LayoutManager`** is an interface
- Many different layout managers
  - **`FlowLayout`** – arranges components line-by-line; wraps to next line when current line is full
  - **`BoxLayout`** – arranges components in a single row or column
  - **`BorderLayout`** – can place a component in one of five regions: **`NORTH`**, **`SOUTH`**, **`EAST`**, **`WEST`**, and **`CENTER`**
  - **`GridLayout`** – arranges components in a fixed-size 2D grid
  - **`GridBagLayout`** – very sophisticated layout manager
  - And several more! (See implementers of **`LayoutManager`**…)
- ★ Default layout manager is **`FlowLayout`**

Events and Listeners

- When something happens, UI widgets fire events
  - User clicks mouse on something
  - User presses some keys
  - Window is closed or minimized
  - User moves or drags mouse
  - etc.
- To catch events, must implement event-listeners in your program
  - Listeners are exposed as interfaces to implement
  - Contained in **`java.awt.event`** package
  - Typically named **`[Something]Listener`**

`ActionListener` Interface

- Example: **`java.awt.event.ActionListener`**
  - One method to implement:

    ```
    void actionPerformed(ActionEvent e)
    ```

  - **`ActionEvent`** contains details of what happened
    - What UI component reported the event
    - When the event occurred
    - Any modifier keys (Ctrl, Alt, Shift, etc.)
    - Other things too! (See API docs…)
  - **`ActionEvent`** is reported by most Swing components

Implementing **`ActionListener`**

- Swing components provide a registration method:

```
addActionListener(ActionListener l)
```

- Implement **`ActionListener`**:

```
public class ActionHandler implements ActionListener {
    ...
    public void actionPerformed(ActionEvent e) {
        ...  // Do something clever.
    }
}
```

- Register your listener:

```
ActionHandler handler = new ActionHandler();
JButton button = new JButton("Start");
button.addActionListener(handler);
```

Other AWT/Swing Listener Interfaces

- **`MouseListener`** – mouse enter/exit/click events
- **`MouseMotionListener`** – mouse move/drag events
- **`KeyListener`** – keyboard press/release events
- **`FocusListener`** – component gets/loses focus
- **`ComponentListener`** – component shown, hidden, resized
- **`WindowListener`** – window opened, closed, maximized, minimized

Listeners and Adapters

- Some listeners are more complicated:
  - **`MouseListener`** interface specifies these methods:
    - **`mouseEntered()`**, **`mouseExited()`**
    - **`mousePressed()`**, **`mouseReleased()`**
    - **`mouseClicked()`**
- Frequently only want to implement one or two of these…
- Java often provides adapters for event-listener interfaces
- Example: **`java.awt.event.MouseAdapter`**
  - Implements **`MouseListener`** interface, among others
  - All provided implementations are no-ops
  - Derive your event-handler from **`MouseAdapter`**, and then override just the methods you want to implement

Nested Classes in Java

- Can declare a class within a class
  - Called a *nested class*

```
class Outer {
    /* A nested class */
    class Inner {
        ...
    }
}
```

  - When **`Outer.java`** is compiled, compiler generates two files: **`Outer.class`** and **`Outer$Inner.class`**

Nested Classes in Java (2)

- The nested class is a member of the outer class, and can have an access modifier
  - e.g. a private nested class cannot be referred to directly from outside the outer class
- The nested class can also be declared with or without the **`static`** keyword
  - Has some dramatic impacts on how the nested class can be used, and what it can do!

```
class Outer {
    static class StaticNested { ... }
    class NonStaticNested { ... }
}
```

Static Nested Classes

- Static nested classes are simply related classes "contained within" the outer class
- Example: **`java.awt.geom.Rectangle2D`**
  - An abstract class that represents 2D rectangles
- Contains two static nested classes:
  - **`Rectangle2D.Double`** derives from **`Rectangle2D`**, and specifies coordinates of type **`double`**
  - **`Rectangle2D.Float`** is similar, but **`float`** coords
- To use:
  - **`import java.awt.geom.Rectangle2D;`**
  - Refer to nested classes by **`Rectangle2D.Float`** or **`Rectangle2D.Double`**

Non-static Nested Classes

- Non-static nested classes are also called inner classes
- Like instance methods, inner classes *must be* used in the context of a containing object!
  - They actually reference their containing object
  - They can directly access the containing object's fields and methods
- *Cannot* create inner-class objects in a static method on the outer class!
  - Can only create in instance methods

Inner Classes and Event Listeners

- Inner classes are *great* for event-listeners!
  - Listeners often need to access application state
  - Inner class can even access private members of the outer class
- Also keeps outer class' public interface clean
  - Don't want to have a whole bunch of public listener interface-methods exposed on outer class
- When necessary, can also create multiple inner-class objects associated with a single outer-class object

Event Handler, Inner Class Style

```
public class MyApp {
    /** Current state of application. **/
    private boolean started;

    /** Handler for ActionEvents. **/
    private class ActionHandler implements ActionListener {
        public void actionPerformed(ActionEvent e) {
            started = true;
        }
    }

    ...
    void initUI() {
        // Create button, then use inner class to handle events
        JButton button = new JButton("Start");
        button.addActionListener(new ActionHandler());
    }
}
```