Programming Languages and Techniques (CIS1200)

Lecture 33

Swing II: Inner Classes, Layout, MoD

Chapters 29 and 30

Announcements

- HW08: ChatterBot
  - Available now; due on Thursday, April 17th
  - Practice with I/O and Collections

- HW9: Game Project
  - TAs will give you feedback soon
  - Final Program Due: Tuesday, April 29th at 11:59pm
  - Grade based on demo with your TA during/after reading days
  - *NO LATE SUBMISSIONS PERMITTED*

Announcements

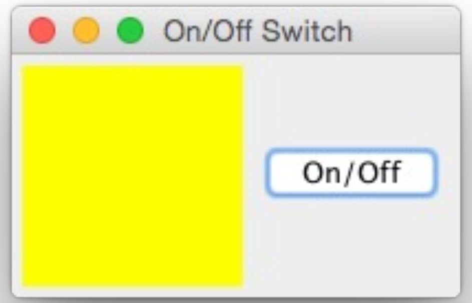
- TA position applications are available
  - CIS 1100, 1200, 1600, 1210 (see link on Ed)
  - Other CIS classes (see https://www.cis.upenn.edu/ta-information/)
  - Accepting applications until Friday, April 18th

- Guest Lecturer (Dr. Zdancewic) Wednesday and Friday
  - Today: “Swing II: Inner Classes and Layout”
  - Friday: “Code *is* Data”

Recap: Swing User Interaction

Start Simple: Light Switch

Task: Program an application that displays a button. When the button is pressed, it toggles a "lightbulb" on and off.



Key idea: use a ButtonListener to toggle the state of the lightbulb

OnOffDemo

The Lightbulb GUI program in Swing.

Display the Lightbulb

```
class LightBulb extends JComponent {
    private boolean isOn = false;

    public void flip() {
        isOn = !isOn;
    }

    public void paintComponent(Graphics gc) {
        if (isOn) {
            gc.setColor(Color.YELLOW);
        } else {
            gc.setColor(Color.BLACK);
        }
        gc.fillRect(0, 0, 100, 100);
    }

    public Dimension getPreferredSize() {
        return new Dimension(100,100);
    }
}
```

Remember the private state of the lightbulb

Draw the Light bulb here using the graphics context

Set the size of the window

Main Class

```
public class OnOff implements Runnable {
  public void run() {
     JFrame frame = new JFrame("On/Off Switch");
     JPanel panel = new JPanel();
     frame.getContentPane().add(panel);
     LightBulb bulb = new LightBulb();
     panel.add(bulb);
     JButton button = new JButton("On/Off");
     panel.add(button);
     button.addActionListener(new ButtonListener(bulb));
     frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
     frame.pack();
     frame.setVisible(true);
  }
  public static void main(String[] args) {
      SwingUtilities.invokeLater(new OnOff());
  }
}
```

Open frame and make a panel

Create bulb and button

Start the (Swing) application

Making the Button Do Something

```java
class ButtonListener implements ActionListener {
    private LightBulb bulb;
    public ButtonListener (LightBulb b) {
        bulb = b;
    }

    @Override
    public void actionPerformed(ActionEvent e) {
        bulb.flip();
        bulb.repaint();
    }
}
```

Note that "repaint" does not necessarily do any repainting right now! It is simply a notification to Swing that something needs repainting. (This is a difference from our OCaml GUI library.) But it is required.

An Awkward Comparison

```
class ButtonListener implements ActionListener {
    private LightBulb bulb;
    public ButtonListener (LightBulb b) {
        bulb = b;
    }
    @Override
    public void actionPerformed(ActionEvent e) {
        bulb.flip();
        bulb.repaint();
    }
}

// somewhere in run …
LightBulb bulb = new LightBulb();
JButton button = new JButton("On/Off");
button.addActionListener(new ButtonListener(bulb));
```

Java

```
let bulb, bulb_flip = make_bulb ()
let onoff,_, bnc = button "On/Off"
;; bnc.add_event_listener (mouseclick_listener bulb_flip)
```

OCaml

Too much “boilerplate”!

- ButtonListener really only needs to do bulb.flip() and repaint
- But we need all this extra boilerplate code to build the class
- Often we will instantiate a given Listener class in a GUI *exactly one time*

```
class ButtonListener implements ActionListener {
    private LightBulb bulb;
    public ButtonListener (LightBulb b) {
        bulb = b;
    }
    @Override
    public void actionPerformed(ActionEvent e) {
        bulb.flip();
        bulb.repaint();
    }
}
```

This is a job for…

Inner Classes

Inner Classes

- Useful in situations where objects require “deep access” to each other’s internals

- Replace tangled workarounds like the “owner object” pattern
  - Solution with inner classes is easier to read
  - No need to allow public access to instance variables of outer class

- Also called “dynamic nested classes”

Basic Example

Key idea: Classes can be *members* of other classes…

```
class Outer {
  private int outerVar;
  public Outer () {
    outerVar = 6;
  }
  public class Inner {
    private int innerVar;
    public Inner(int z) {
      innerVar = z;
    }
    public int getSum() {
      return outerVar + innerVar;
    }
  }
}
```

The name of this class (i.e., the static type of objects that this class creates) is Outer.Inner

Inner classes can have their own fields and methods.

Inner class can refer to a to field bound in the outer class

34: In Java, which makes sense for creating an object of type Outer.Inner?

0

```
class Outer {
  private int outerVar;
  public Outer () {
    outerVar = 6;
  }
  public class Inner {
    private int innerVar;
    public Inner(int z) {
      innerVar = z;
    }
    public int getSum() {
      return outerVar +
             innerVar;
    }
  }
}
```

new Outer.Inner(2) 0%

(new Outer()).new Inner(2) 0%

new Inner(2) 0%

Outer.Inner.new (2) 0%

Constructing Inner Class Objects

```java
class Outer {
  private int outerVar;
  public Outer () {
    outerVar = 6;
  }
  public class Inner {
    private int innerVar;
    public Inner(int z) {
      innerVar = z;
    }
    public int getSum() {
      return outerVar +
             innerVar;
    }
  }
}
```

Based on your understanding of the Java object model, which of the following make sense as ways to construct an object of an inner class type?

1. `Outer.Inner obj =`
   `new Outer.Inner(2);`

2. `Outer.Inner obj =`
   `(new Outer()).new Inner(2);`

3. `Outer.Inner obj =`
   `new Inner(2);`

4. `Outer.Inner obj =`
   `Outer.Inner.new(2);`

Answer: 2 – the inner class instances can refer to non-static fields of the outer class (even in the constructor), so the invocation of "new" must be relative to an existing instance of the Outer class.

Object Creation

- Inner classes can refer to the instance variables and methods of the outer class
- Inner class instances usually created by the methods/constructors of the outer class

```
public Outer () {
   Inner b = new Inner ();
}
```

I.e., `this.new`

- Inner class instances *cannot* be created independently of a containing class instance

```
Outer.Inner b = new Outer.Inner()
```

🚫

```
Outer a = new Outer();
Outer.Inner b = a.new Inner();
```

✓

```
Outer.Inner b = (new Outer()).new Inner();
```

✓

Anonymous Inner Classes

We can define a class and create an object from it *all at once* inside a method body

```
final LightBulb bulb = new LightBulb();
JButton button = new JButton("On/Off");

button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        bulb.flip();
        bulb.repaint();
    }
});
```

Anonymous Inner Classe

”Create an object by instantiating an anonymous class implementing the ActionListener interface, with a method actionPerformed…”

```
quit.addActionListener(new ActionListener() {
   public void actionPerformed(ActionEvent e) {
       System.exit(0);
   }
 });
```

Puts button action with button definition

```
line.addActionListener(new ActionListener() {
   public void actionPerformed(ActionEvent e) {
       shapes.add(new Line(…));
       canvas.repaint();
   }
});
```

Can access fields and methods of outer class, as well as (final) local variables

Anonymous Inner Classes

- New *expression* form: define a class and create an object from it all at once

new keyword

```
new InterfaceOrClassName() {
    public void method1(int x) {
        // code for method1
    }
    public void method2(char y) {
        // code for method2
    }
}
```

Normal class definition, no constructors allowed

Static type of the expression is the interface / superclass named after the new

Dynamic class of the created object is anonymous! Can't refer to it.

Like first-class functions…

- Anonymous inner classes are a Java equivalent of OCaml’s first-class functions
- Both create "delayed computations" that can be stored in a data structure and run later
  - E.g., code stored by the event / action listener
  - Code only runs when the button is pressed
  - Could run once, many times, or not at all
- Both sorts of computation can refer to variables in the current scope
  - OCaml: Any available variable
  - Java: only variables marked `final` (i.e., immutable)

But we can do even better…

“Lambdas” are Anonymous Inner Classes

- Often the implementation of an anonymous class is simple
  - e.g., an interface that contains only one method
- *Lambda* expressions*
  - treat functionality as method argument, or code as data
  - Java's version of first-class functions
- Pass functionality as an argument to another method,
  - e.g., what action should be taken when someone clicks a button.
- *Any* interface that has exactly one method can be implemented via a "lambda" (anonymous function).
  - Method’s "name" implicitly determined by the type at which the lambda is used
  - https://docs.oracle.com/javase/tutorial/java/javaOO/lambdaexpressions.html

*The term "lambda" comes from the *lambda calculus,* which was introduced by Alonzo Church in the 1930s. The lambda calculus forms the theoretical basis of all functional programming languages.

Lambda Expressions

- Java includes *lambda expressions,* which can implement classes that define only a single method

```
final LightBulb bulb = new LightBulb();
JButton button = new JButton("On/Off");

button.addActionListener((ActionEvent e) -> {
        bulb.flip();
        bulb.repaint();
   });
```

- Any interface with exactly one method is a *functional interface*
- Syntax:

```
x -> { body }                 // type of x inferred
(T x) -> { body }             // arg x has type T
(T x, W y) -> { body }        // multiple arguments
```

Lambdas In A Nutshell

Lambda Notation	"Ordinary" Java Notation
`x -> x + x`	`int method1(int x) { return x + x; }`
`(x,y) -> x.m(y)`	`int method2(A x, B y) { return x.m(y); }`
`(x,y) -> { System.out.println(x); System.out.println(y); }`	`void method3(String x, String y) { System.out.println(x); System.out.println(y); }`

```
x -> x + x
```

```
int method1(int x) {
  return x + x;
}
```

```
(x,y) -> x.m(y)
```

```
int method2(A x, B y) {
  return x.m(y);
}
```

```
(x,y) -> {
  System.out.println(x);
  System.out.println(y);
}
```

```
void method3(String x,
             String y) {
  System.out.println(x);
  System.out.println(y);
}
```

Method names and types are inferred from the context.

Swing Layout Demo

LayoutDemo.java