CSE 331
Software Design and Implementation

Lecture 19
GUI Events

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Announcements

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- Quiz 7 due Thursday 8/9
- Homework 8 due Thursday 8/9
  - HW8 has a regression testing component: HW5, 6, 7 tests must pass.

GUI Events

The plan

User events and callbacks
- Event objects
- Event listeners
- Registering listeners to handle events

Anonymous inner classes

Proper interaction between UI and program threads

Code Exploration! (Bouncing balls app)

Event-driven programming

Many applications are *event-driven* programs (most GUIs!):
- Program initializes itself, then enters an *event loop*
- Abstractly:

```
do {
    e = getNextEvent();
    process event e;
} while (e != quit);
```

Contrast with application- or algorithm-driven control where program expects input data in a particular order
- Typical of large non-GUI applications like web crawling, payroll, simulation, …

Kinds of GUI events

Typical *events* handled by a GUI program:
- Mouse move/drag/click, button press, button release
- Keyboard: key press or release, sometimes with modifiers like shift/control/alt/etc.
- Finger tap or drag on a touchscreen
- Joystick, drawing tablet, other device inputs
- Window resize/minimize/restore/close
- Network activity or file I/O (start, done, error)
- Timer interrupt (including animations)

Events in Java AWT/Swing

Many (most?) of the GUI widgets can generate events (button clicks, menu picks, key press, etc.)

Handled using the Observer Pattern:
- Objects wishing to handle events register as observers with the objects that generates them
- When an event happens, appropriate method in each observer is called
- As expected, multiple observers can watch for and be notified of an event generated by an object

Event objects

A Java GUI event is represented by an *event object*

- Superclass is **`AWTEvent`**
- Some subclasses:
  - **`ActionEvent`** – GUI-button press
  - **`KeyEvent`** – keyboard
  - **`MouseEvent`** – mouse move/drag/click/button

Event objects contain information about the event

- UI object that triggered the event
- Other information depending on event. Examples:
  - **`ActionEvent`** – text string from a button
  - **`MouseEvent`** – mouse coordinates

Event listeners

Event listeners must implement the proper interface: **`KeyListener`**, **`ActionListener`**, **`MouseListener`** (buttons), **`MouseMotionListener`** (move/drag), …

- Or extend the appropriate library *abstract class* that provides empty implementations of the *interface* methods

When an event occurs, the appropriate method specified in the interface is called: **`actionPerformed`**, **`keyPressed`**, **`mouseClicked`**, **`mouseDragged`**, …

An event object is passed as a parameter to the event listener method

Example: button

Create a **`JButton`** and add it to a window

Create an object that implements **`ActionListener`**

- (containing an **`actionPerformed`** method)

Add the listener object to the button's listeners

`ButtonDemo1.java`

Which button is which?

Q: A single button listener object often handles several buttons. How to tell which button generated the event?

A: an **`ActionEvent`** has a **`getActionCommand`** method that returns (for a button) the "action command" string

- Default is the button name (text), but usually better to set it to some string that will remain the same inside the program code even if the UI is changed or button name is translated. See button example.

Similar mechanisms to decode other events

Listener classes

ButtonDemo1.java defines a class that is used only once to create a listener for a single button

- Could have been a top-level class, but in this example it was an inner class since it wasn't needed elsewhere
- But why a full-scale class when all we want is to create a method to be called after a button click?
  - Alas, no lambdas (function closures) before Java 8

A more convenient shortcut: *anonymous inner classes*

Anonymous inner classes

Idea: define a new class directly in the **new** expression that creates an object of the (new) anonymous inner class

- Specify the superclass to be extended or interface to be implemented
- Override or implement methods needed in the anonymous class instance
- Can have methods, fields, etc., but not constructors
- But if it starts to get complex, use an ordinary class for clarity (nested inner class if appropriate)

Warning: ghastly syntax ahead

Example

```
button.addActionListener(new ActionListener(){
      public void actionPerformed(ActionEvent e) {
        model.doSomething()
      }
    }
);
```

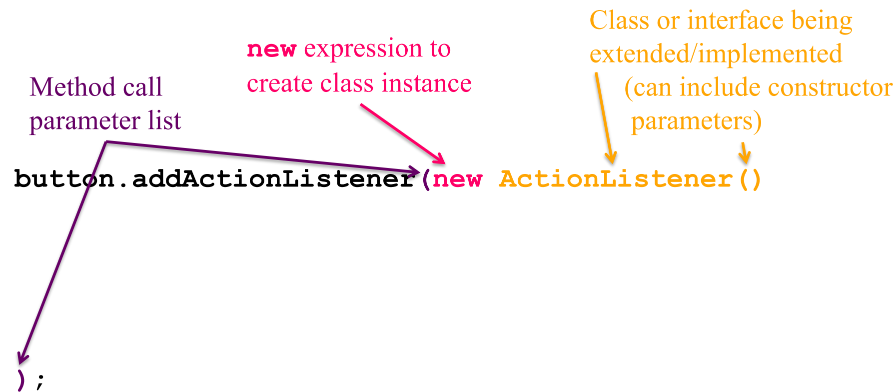
Example

Method call
parameter list

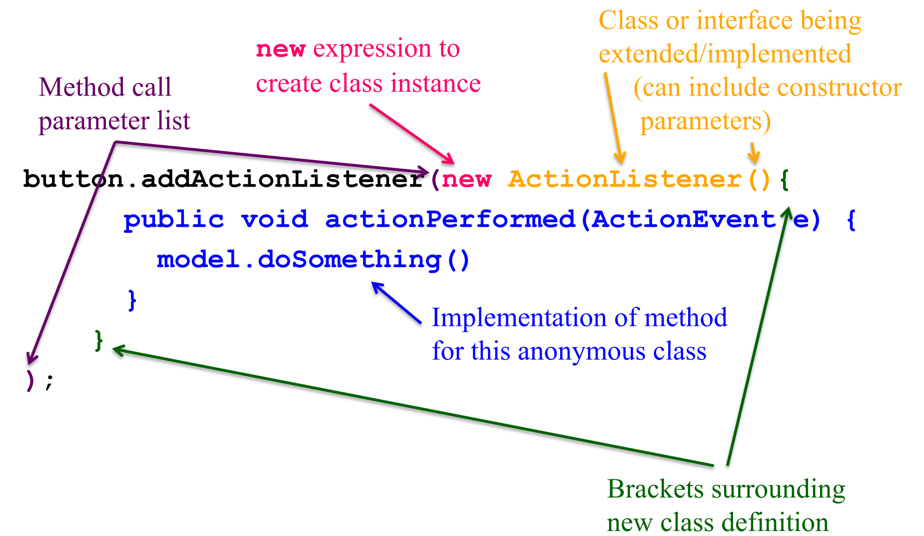
```
button.addActionListener(

);
```

Example



Example



Example

`ButtonDemo2.java`

Program thread and UI thread

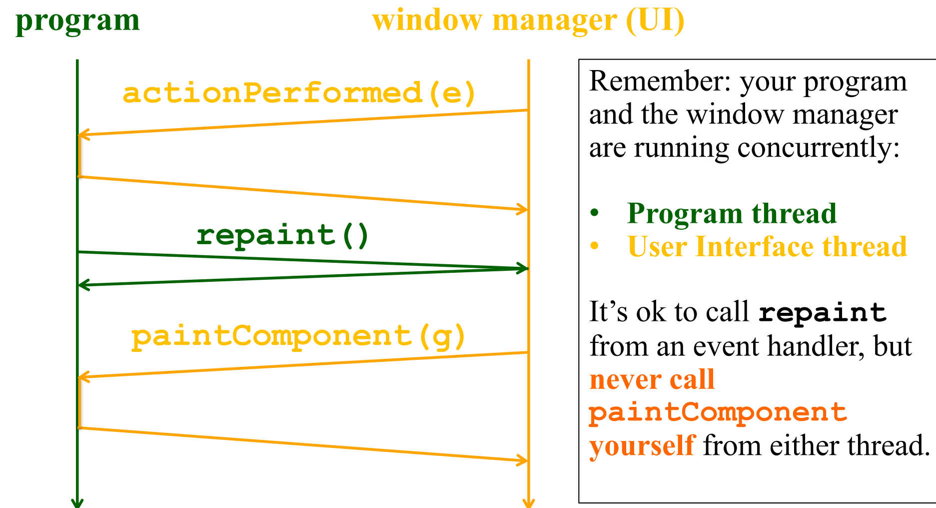
Recall that the program and user interface are running in separate, concurrent threads

All UI actions happen in the UI thread – *including the callbacks* like **`actionListener`** or **`paintComponent`**, etc. defined in your code

After event handling and related work, call **`repaint()`** if **`paintComponent()`** needs to run. **Don't** try to draw anything from inside the event handler itself (as in ***you must not do this!!!***)

> Remember that **`paintComponent`** must be able to do its job by reading data that is available whenever the window manager calls it

Event handling and repainting



Remember: your program and the window manager are running concurrently:

- **Program thread**
- **User Interface thread**

It's ok to call **`repaint`** from an event handler, but **never call `paintComponent` yourself** from either thread.

Working in the UI thread

Event handlers should not do a lot of work

- If the event handler does a lot of computing, the user interface will appear to freeze up
  - (Why?)
- If there's lots to do, the event handler should set a bit that the program thread will notice. Do the heavy work back in the program thread.
  - (Don't worry – finding a path for campus maps should be fast enough to do in the UI thread)

Synchronization issues?

Yes, there can be synchronization problems
- (cf. CSE332, CSE451, …)

Not usually an issue in well-behaved programs, but can happen

Some advice:
- Keep event handling short
- Call **`repaint`** when data is ready, not when partially updated
- Don't update data in the UI and program threads at the same time (particularly for complex data)
- Never call **`paintComponent`** directly
  - (Have we mentioned you should never ever call **`paintComponent`**? And don't create a new **`Graphics`** object either.)

If you are building industrial-strength UIs, learn more about threads and Swing and how to avoid potential problems

Larger example – bouncing balls

A hand-crafted MVC application. Origin is somewhere back in the CSE142/3 mists. Illustrates how some swing GUI components can be put to use.

Disclaimers:
- Not the very best design
- Unlikely to be directly appropriate for your project
- Use it for ideas and inspiration, and feel free to steal small bits if they *really* fit

Enjoy!

Larger example – bouncing balls

Download:
- course website --> lec19 GUI Events --> sim-example.zip

To run (command line):

```
> javac BallSimMain.java
> java BallSimMain
```

- Click to create a new random ball at click location

Code exploration
- Identify buttons and button listeners
  - see **`BallSimControl.java`**
- Notice where repaint is called when the model changes (in **`BallGraphicsView`**, called by **`SimModel.cycle`**)
  - What would happen if repaint were not called here?

Larger example – bouncing balls

More code exploration
- Notice **`ActionListener`** in **`BallSimControl`** class
  - can call **`pause`**, **`resume`**, or **`stop`** in the model
  - these methods do very little and execute very fast!
  - What would happen if you introduced a 3000 milisecond sleep in the resume method?
- Identify components of the Model, View, and Controller classes
  - Is there anything you'd change?
- Fix the bug!
  - Balls can get stuck outside frame when you make frame smaller

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