Graphical User Interfaces
April 29, 2003

(Incomplete) History of GUIs

• 1973: Xerox Alto
  – 3-button mouse, bit-mapped display, windows
• 1981: Xerox Star
  – Double-clicking, overlapping windows, dialogs
• 1983: Apple Lisa
  – Pull-down menus and menu bars
• 1984: Apple Macintosh, X Windows
• 1985: Microsoft Windows
(from http://toastytech.com/guis/guitimeline.html)

Why a GUI Toolkit/API?

• Easier to build GUIs

• Consistency of interface
  – Among applications
  – Between platforms (in Java)

GUI Basics

• Interface consists of many components
  – Windows, menus, buttons
• User can perform variety of operations
  – Move window
  – Click button
  – Press key
• These are events

A Note on AWT versus Swing

• Abstract Window Toolkit (AWT)
  – Original Java GUI
  – Still supported, but being replaced
• Swing -- souped-up AWT
  – Pluggable look-and-feel
  – More, better widgets
• AWT class X has corresp. Swing class JX
  – E.g. Button vs. JButton

Creating Components

• Components are the usual widgets
  – JButton, JPopupMenu, JScrollBar
  – Components know how to draw themselves
  – But they (generally) don’t say where they are

• In Swing, components live in containers
  – JFrame, JDialog, JApplet
  – Containers decide how to layout components
  – Various layout algorithms
Observer pattern

Adding Observers (Listeners)

• Components have a set of listeners
  – `void addActionListener(ActionListener l)`
  – `void addKeyListener(KeyListener l)`
  – `void addMouseListener(MouseListener l)`

  *Possible listeners vary with component*

Programming with Events

• Initialize objects
  – Create everything on the screen
  – Register your event handlers (observers)

• Then toolkit takes over with event loop
  ```
  while (true) {
      e = getEvent();
      findEventHandler(e).actionPerformed(e);
  }
  ```

Listener Interfaces

```java
public interface ActionListener {
    void actionPerformed(ActionEvent e);
}
```

```java
public interface MouseInputListener {
    void mouseClicked(MouseEvent e);
    void mouseEntered(MouseEvent e);
    void mousePressed(MouseEvent e);
    ...
}
```

Events

• Events objects contain the detailed info
  ```java
  public class MouseEvent {
      int getClickCount();
      Point getPoint();
  }
  ```

• Tradeoff between number of event classes and amount of info in each event
  – Does the system filter or do the observers?

SwingApplication.java

• (Optional) Step 1: Install look and feel
  ```java
  public static void main(String[] args) {
      try {
          UIManager.setLookAndFeel(
              UIManager.getSystemLookAndFeelClassName());
      } catch (Exception e) { }
      ...
  }
  ```

• Default is to use “native” look and feel
Step 2: Make the Components

```java
JFrame frame = new JFrame("SwingApplication");
SwingApplication app = new SwingApplication();
Component contents = app.createComponents();
frame.getContentPane().add(contents, BorderLayout.CENTER);
```

- Frames are windows
  - ContentPane is the display area (w/o menu bar)
- Contents added to the frame
  - Laid out as BorderLayout.CENTER

Step 3: Install any Listeners

```java
frame.addWindowListener(new WindowAdapter() {
    public void windowClosing(WindowEvent e) {
        System.exit(0);
    }
});
```

- WindowAdapter implements WindowListener
  - Contains default do-nothing methods
- Notice we ignore the value of e

Step 4: Make Window Visible

```java
frame.pack();
frame.setVisible(true);
```

- pack() sizes window to fit subcomponents
- setVisible(true) shows the window
  - Not drawn until this is set
- main(String[] args) exits
  - Swing event thread handles events

Layout and Painting

- Swing places components according to layout manager
  - Don’t need to worry about screen size etc.
  - (Not really true)
- Window painted from back to front
  - Component paints itself before subcomponents
  - Double-buffered so painting looks smooth

The Event-Dispatching Thread

- All events are dispatched by a single thread
  - Implies events dispatched in order
  - Also implies next event not processed until current event dispatch returns
    - Need to make event dispatch fast
  - (Re)-painting also done in event-dispatching thread
- What if another thread needs to modify GUI?
  - Swing library mostly *not* thread safe

Single-Thread Rule

“Once a Swing component has been realized, all code that might affect or depend on the state of that component should be executed in the event dispatching thread.”

java.sun.com tutorial

- A component is realized after
  - setVisible(true) (== deprecated show())
  - pack()
Dealing with Threads

• Wait a second, what about the example?
  
  ```java
  f.pack();  // f is realized here
  f.setVisible(true);  // so isn’t this unsafe?
  ```
  – Apparently this “usually” works, so it’s OK (?)

• A few methods can be used from any thread
  • SwingUtilities.invokeLater(Runnable r)
    – Event-dispatching thread will invoke r
    – (after all pending events dealt with)

Making Event Dispatch Fast

• Standard problem in event or interrupt-driven systems
  – Short tasks in response to events are fine

• Divide long tasks into top half, bottom half
  – top half is quick; typically, buffers
  – bottom half runs in separate thread
    • consumes data from buffer
    • can use invokeLater() if it eventually updates GUI