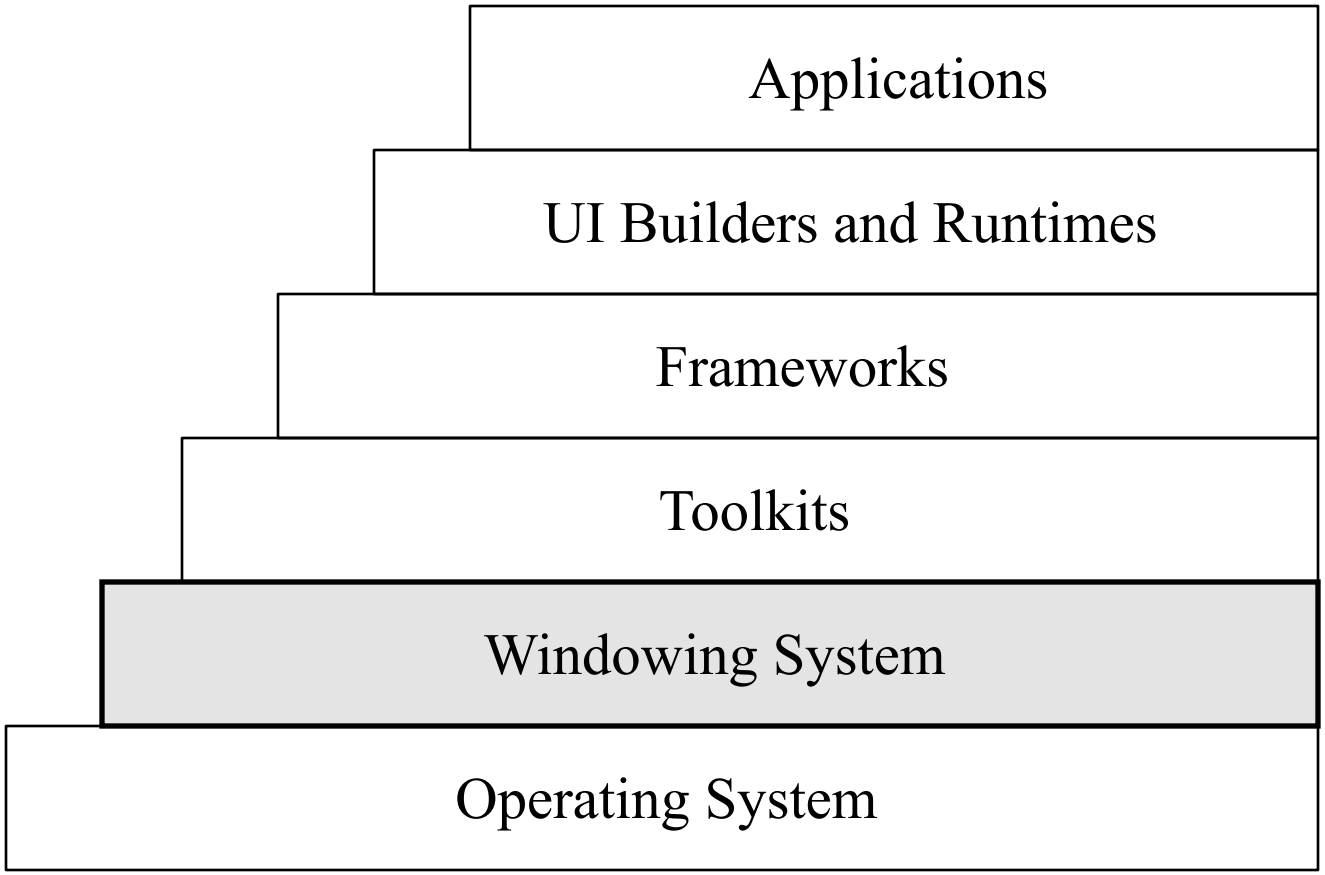
Windows and Events

created originally by Brian Bailey

Announcements

- Review next time
- Midterm next Friday

UI Architecture



Windowing System

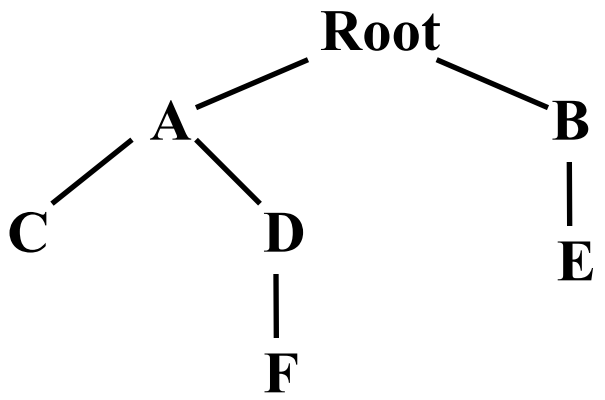
- **Manages windows and their relationships**
  - window hierarchy
- **Manages events and dispatch of events to individual windows**
  - an event is a notification of an occurrence such as mouse click, key press, or timer pop

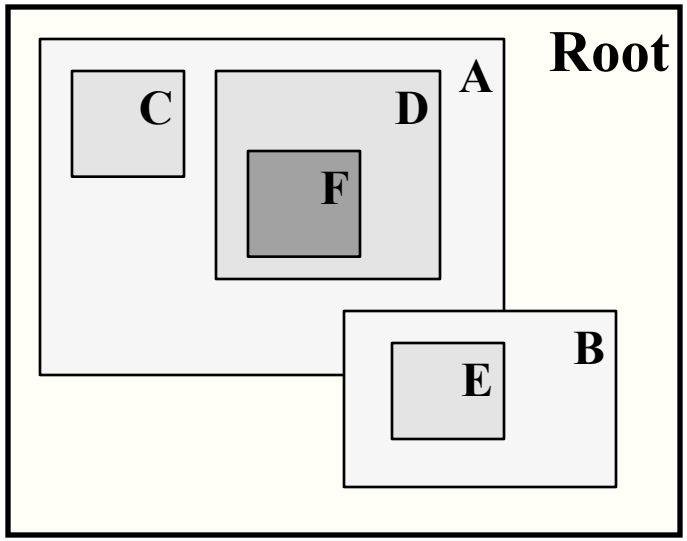
Windows

- **A window is a rectangular area on screen**
  - enables a user to view output
  - enables app to solicit input events from area
  - inexpensive to create and manage
- **A window has properties**
  - visibility, size, border, color, and more
- **Almost every widget maps to a window**
- **Windowing system manages the windows**

Window Hierarchy

- **Windows arranged in a tree (root desktop)**
  - defines a *stacking order* of the windows





Window Hierarchy

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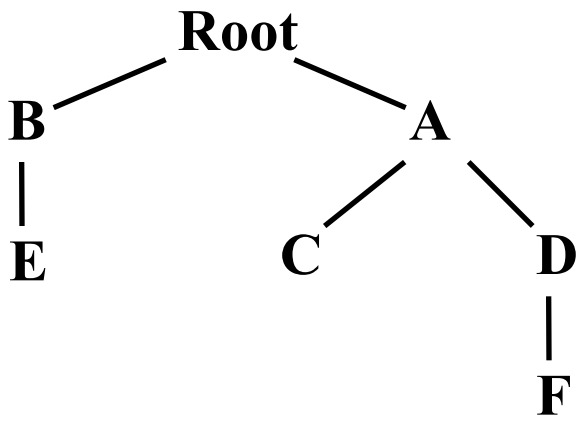
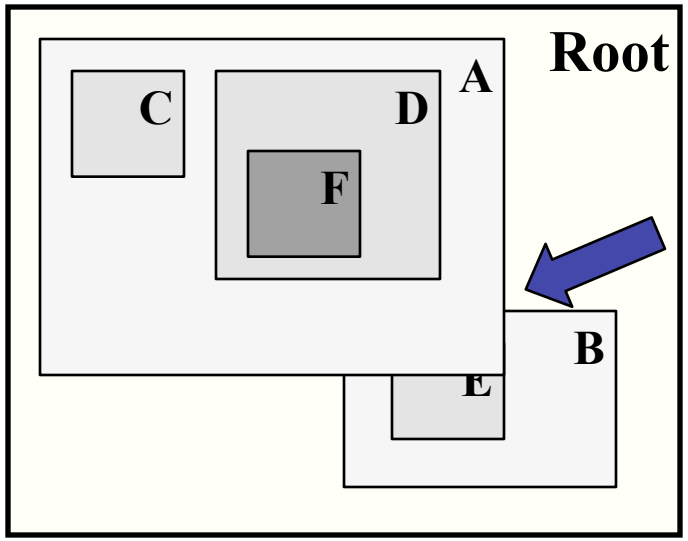
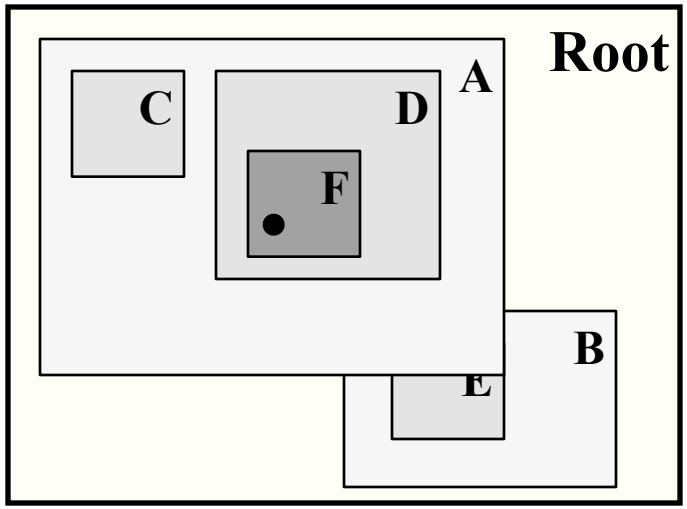




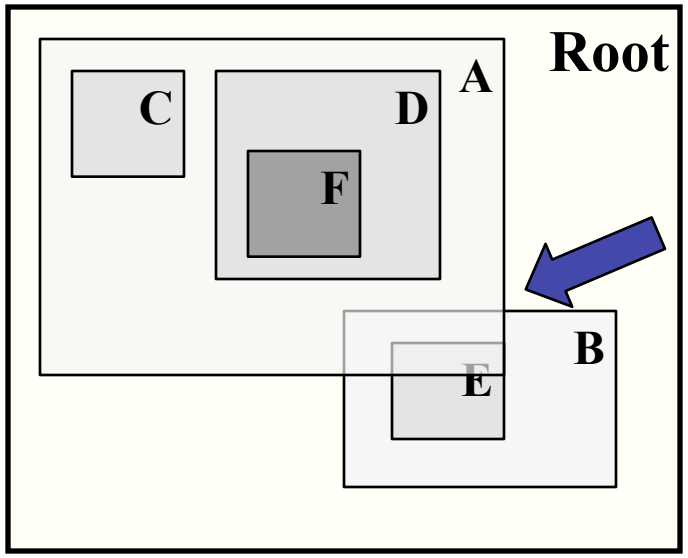
Window Hierarchy

- **Windows arranged in a tree**
  - defines a *stacking order* of the windows
  - Point P (black circle) is *in* a window if it is contained within its visible area



Window Exposure

- **User brings B forward**
  - parts of B and E have become *exposed*
- **Should**
  - B receive one expose event and E just one?
  - B receive one expose event and redraw E?
- **Managing is difficult!**



Draw/Redraw Windows

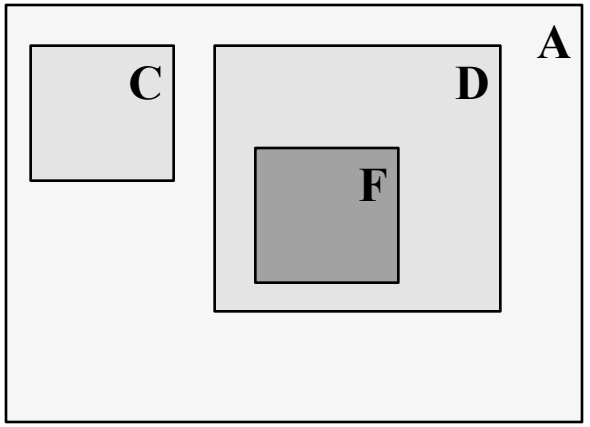
- **When window is first displayed**
  - after being created
  - re-displayed after having been minimized
- **When window content is updated**
  - e.g., when the display is manipulated
- **When obscuring windows are moved**

When is Drawing Actually Done

- Right away?
- After next input event?
- When idle?
- When idle or within time limit?

Window Coordinates

- **Use pixels as the coordinates**
- **Origin is at the upper-left hand corner**
  - X increases toward the right
  - Y increases toward the bottom
- **Coordinates always relative to a specific window**



UI Events

- **An event is an *asynchronous* notification of user action, timer pop, status change**
- **UI applications are *event-driven***
  - loop of waiting for an event and responding
  - contrast to top-down sequential flow

Event Sources

- **Physical objects**
  - Keyboard: key pressed, released, typed
  - Mouse: button pressed/released/clicked, mouse motion, mouse drag …
- **Virtual objects**
  - Window: expose, enter, leave, resize, focus…
  - Widget: child added/removed
  - Selection: item selected in tree, list control…

Event Structure

- Event type (e.g., mouse press, key press, exposure, focus change, etc.)
- Window identifier
- (X, Y) position of mouse
- Time of event
- Modifiers (shift, caps lock, etc)
- Much more

Windows and Events

- **Windowing system associates events with a specific window (usually focus window)**
  - mouse, keyboard, and window events
- **Windowing system continuously tracks mouse and which window contains it**
  - containing window != the focus window
- **Windowing system appends an event onto an application's event queue**
  - uses the application that owns the window
  - application retrieves event and handles it

Example Event Flow

- **Mouse click generates hardware interrupt**
- **OS maps interrupt to system handler (a routine in the windowing system)**
- **Windowing system**
  - identifies window associated with event and application that owns the window
  - constructs the event structure
  - appends event onto the application's event queue
- **Application**
  - removes event from event queue
  - maps window and event to a registered handler
  - invokes that handler

Event-Driven Programming

- **Applications respond to events**
  - no central flow of control
  - setup interface, handle events, and clean-up
- **Core of the application is the event loop**
  - wait for event, handle event, repeat
  - input handlers must be fast - [50, 500ms]

The Event Loop

```
While (true) {
   Event event = get_next_event();
   Handler handler = lookup_handler(event);
   handle(event);
}
```

Note: handlers are indexed in a table by event type, window, and other detail

Program Structure

- **Substantial initialization code**
  - construct data objects and user interface
  - register event handlers
  - do any setup processing
- **Event loop core**
  - provided by most toolkits
- **Special cases**
  - Modal dialogs

Java History

- **Gosling et al. envisioned merger of consumer and computing devices**
  - developed a language to enable development and be portable across devices
  - ahead of its time in a niche market
- **Language found a new home on the Web where it could bring static pages to life**

Java Language

- **Object-oriented language**
  - classes, objects, inheritance, polymorphism, exceptions, interfaces, etc.
  - very clean and pure language model
- **Applications are cross-platform**
  - compile code into a “byte code”
  - develop a virtual machine for each platform that can interpret the byte code
- **Well-documented and supported**
  - lots of java books available

AWT and Swing

- **AWT is the windowing system**
  - support basic building blocks from which to construct higher-level controls for toolkits
- **Swing is higher-level toolkit built on AWT**
  - buttons, sliders, edit boxes, menus, …

AWT and Swing (cont.)

- **Java 1 (or most of it) used a peer model**
  - each widget created in the AWT maps to a widget in the platform-specific toolkit
  - difficult to maintain cross-platform feel because a widget may behave differently on different platforms
  - must write AWT part of the JVM for each platform
- **Java 2 uses a pluggable look and feel model**
  - use a single window and drawing commands
  - do everything else in Java
  - pluggable look and feel, but performance deficient

Simple Window

```
import java.awt.*;
import java.awt.event.*;

    public class SimpleWindow extends Frame …{

     public static void main(String args[]) {
        SimpleWindow sw = new SimpleWindow();
        sw.pack();
        sw.show();
        sw.setBounds(225, 250, 640, 48
     }

     public SimpleWindow() {
        setTitle("Simple Window");
            …
```

Where is the Event Loop?

Drawing in the Window

```
public class SimpleWindow extends Frame … {
    …
    public void paint(Graphics g) {
        super.paint(g);
        g.setColor(new Color(235, 235, 235));
        g.fillRect(0, 380, 150, 100);

        g.setStroke(new BasicStroke(4.0f));
        g.setColor(Color.blue);
        g.drawRect(0, 380, 150, 100);

        g.setColor(Color.black);
        g.drawString("X: " + mousex + "      Y: " + mousey, 20, 400);

        g.drawString(eventString, 20, 430);
```

Expose Events

```
...

public void paint(Graphics g) {
        ...
        Rectangle area = g.getClipBounds();
        System.out.println(area);
        ...

        g.drawString(area, 20, 430);
}
```

The clipping rectangle in the graphics object identifies the exposed region

Enter/Leave Events

```
public class SimpleWindow extends Frame implements MouseListener
{
        public SimpleWindow() {
        …
                addMouseListener(this);
        }

        public void mouseEntered(MouseEvent e) {
                eventString = "mouse entered";
                repaint();
        }

        public void mouseExited(MouseEvent e) {
                eventString = "mouse exited";
                repaint();
        }
```

Java uses a publisher/ subscribe event model

Mouse Motion Events

```
public class SimpleWindow extends Frame implements …
    MouseMotionListener {
    private int mousex, mousey;
    …
    public SimpleWindow() {
        …
        addMouseMotionListener(this);
        mousex = mousey = 0;
    }

    public void mouseMoved(MouseEvent e) {
        mousex = e.getX();
        mousey = e.getY();
        repaint(0, 380, 150, 100);
    }
    …
```

Retrieve context from the event object

Higher-level Components

- **Construct a simple push button from a window and low-level events**
  - demo constructed push button
- **Required about 100 lines of code and many desired features were not implemented**
  - changing font size, centering text, support for icons, registering callbacks, etc.
- **Lesson: Construct higher-level interaction components and place them in a toolkit!**
  - Swing, MFC, Motif, Cocoa, etc..

UI Toolkits

- **Programming at the low level is absurd**
  - hundreds of lines of code to manage a single button on the screen
  - handle expose, enter, leave, click events, position text for different font metrics, etc.
- **Large applications are almost impossible when programming at this level**
- **Need higher-level programming abstractions**

Toolkits Provide

- **Widgets**
  - interaction vocabulary
- **Geometry management**
  - widget layout
- **Resource management**
  - defaults, user overrides, internationalization