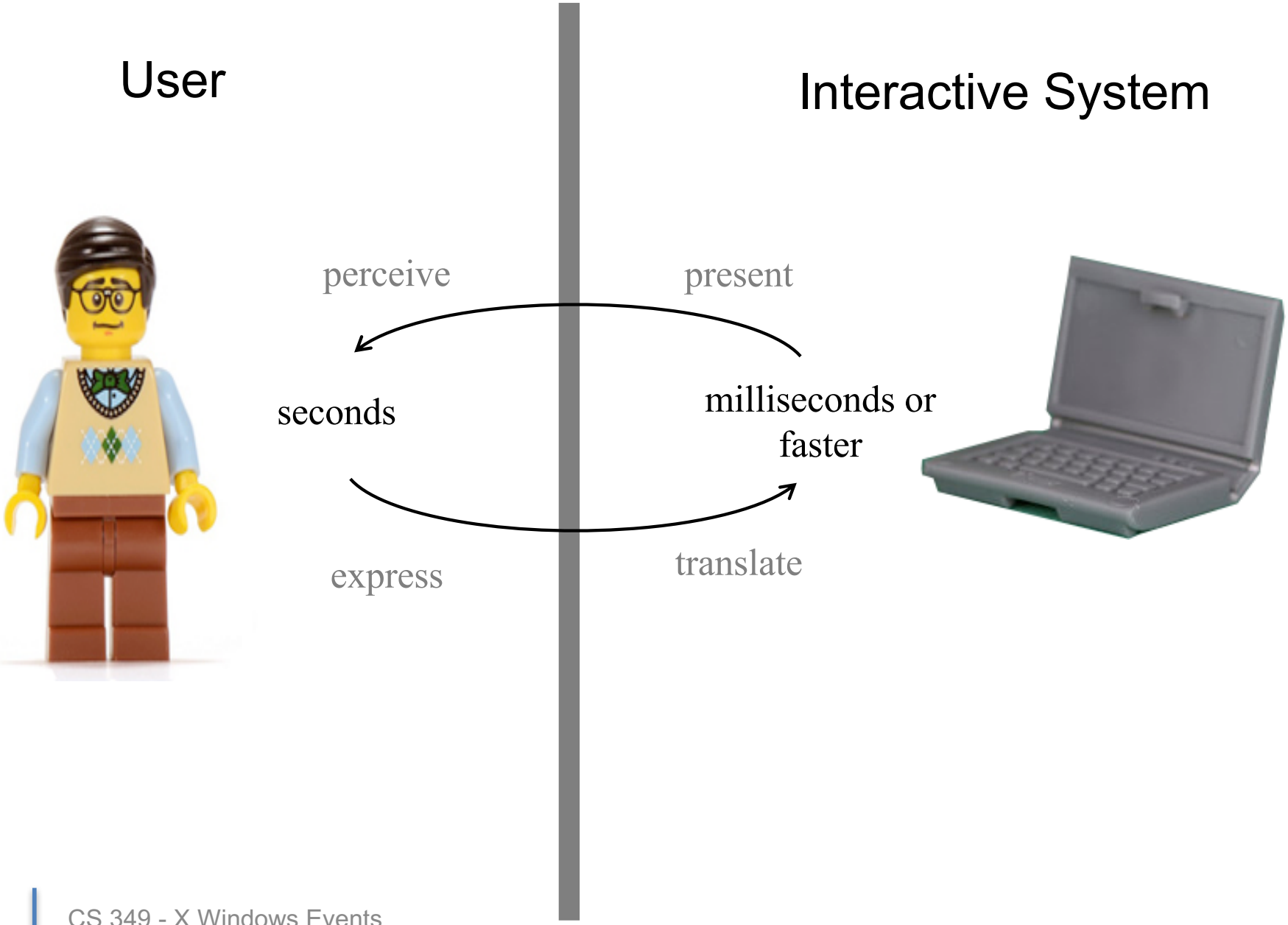
Events Demystified

Events and the Event Loop

Animation

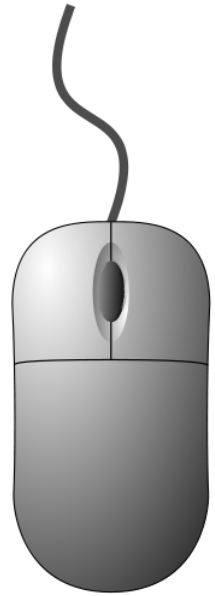
Double Buffering

Human vs. System



Objective

- User interface architectures need to be able to accept input from real-world devices, and map to actions within a system.
  - Support the transformation of input into commands (e.g. “Ctrl” key)
  - We want a general, reusable architecture.



Event-Driven Programming

- “Event-driven programming is a paradigm in which the flow of the program is determined by events such as user actions (mouse clicks, key presses), sensor outputs, or messages from other programs/threads.” -- Wikipedia

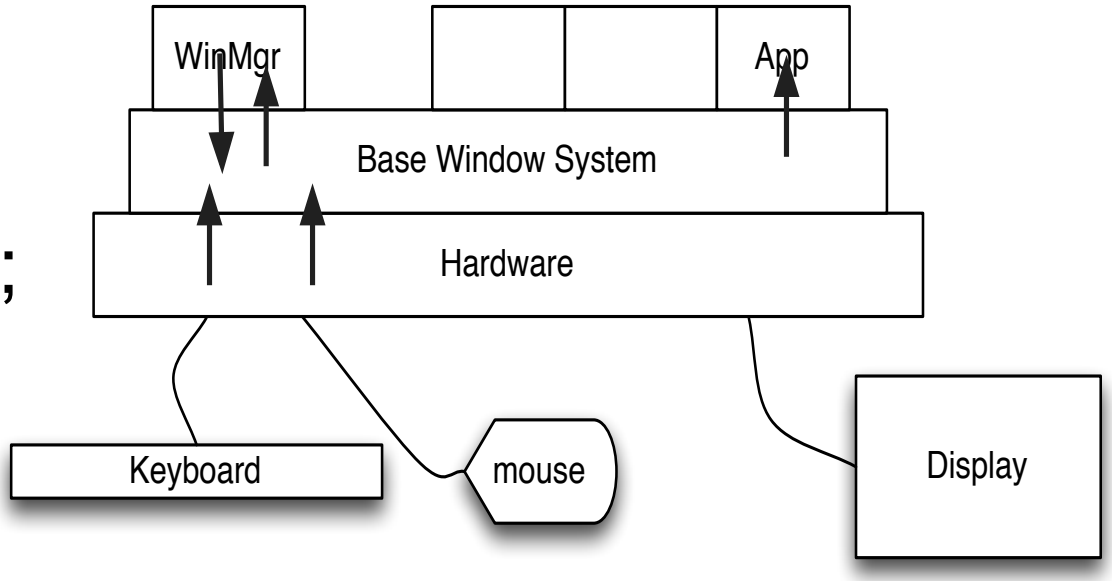
An **event** is a message to notify an application that something happened. Examples include:

- Keyboard (key press, key release)
- Pointer events (button press, button release)
- Input focus (gained, lost)
- Sensor or timer events

Role of the GUI Toolkit, BWS, WM

1. Collect event information
2. Put relevant information in a known structure
3. Order the events by time
4. Decide which application and window should get the event
5. Deliver the event

Some events come from the BWS (user-driven via hardware); some from the window manager.



Role of the Programmer

- Indicate what events you are interested in to BWS/WM, to ensure that events are delivered.
- Write code to:
  - Receive and interpret that event
  - Update program content due to event
  - Redraw display to communicate to user what changed

- In modern languages (Java, C#, Javascript) the process of registering for events and handling events is simplified
  - Java – Listener model
  - C# -- Delegate model
  - Javascript – Looks like a Java/C# hybrid, but is not
    - Apparently simpler, actually worse. See
    - http://www.quirksmode.org/js/introevents.html

Receiving Events

- In X, the application programmer has to manually handle all event processing
  - Applications get the next event using:
    - `XNextEvent(Display* d, XEvent* e)`
      - Gets & removes the next event in the queue.
      - If empty, it blocks until another event arrives.
  - Can avoid blocking by checking if events available using:
    - `XPending(Display* d)`
      - Query number of events in queue, never blocks.

eventloop.min.cpp

```
window = XCreateSimpleWindow(…);
XSelectInput(display, window, PointerMotionMask | KeyPressMask);
XMapRaised(display, window);
XFlush(display);

XEvent event;                          // save the event here
while( true ) {                        // loop until 'exit' event
   XNextEvent( display, &event );      // wait for next event
   switch( event.type ) {
      case MotionNotify:               // mouse movement
         cout << event.xmotion.x << "," << event.xmotion.y << endl;
         break;
      case KeyPress:                   // any keypress
         exit(0);
         break;
      // Handle other kinds of events
   }
   repaint( ... ); // call my repaint function
}
XCloseDisplay(display);
```

Selecting Events to "listen to"

- Don't always need all of the events. (Why?)

```
// Tell the BWS which input events you want.
XSelectInput( xinfo.display, xinfo.window,
        ButtonPressMask | KeyPressMask |
        ExposureMask | ButtonMotionMask );
```

- Defined masks: NoEventMask, KeyPressMask, KeyReleaseMask, ButtonPressMask, ButtonReleaseMask, EnterWindowMask, LeaveWindowMask, PointerMotionMask, PointerMotionHintMask, Button1MotionMask, Button2MotionMask, ..., ButtonMotionMask, KeymapStateMask, ExposureMask, VisibilityChangeMask, ...

- See
  - http://www.tronche.com/gui/x/xlib/events/types.html
  - http://www.tronche.com/gui/x/xlib/events/mask.html

Event Structure: Union

- X uses a C union

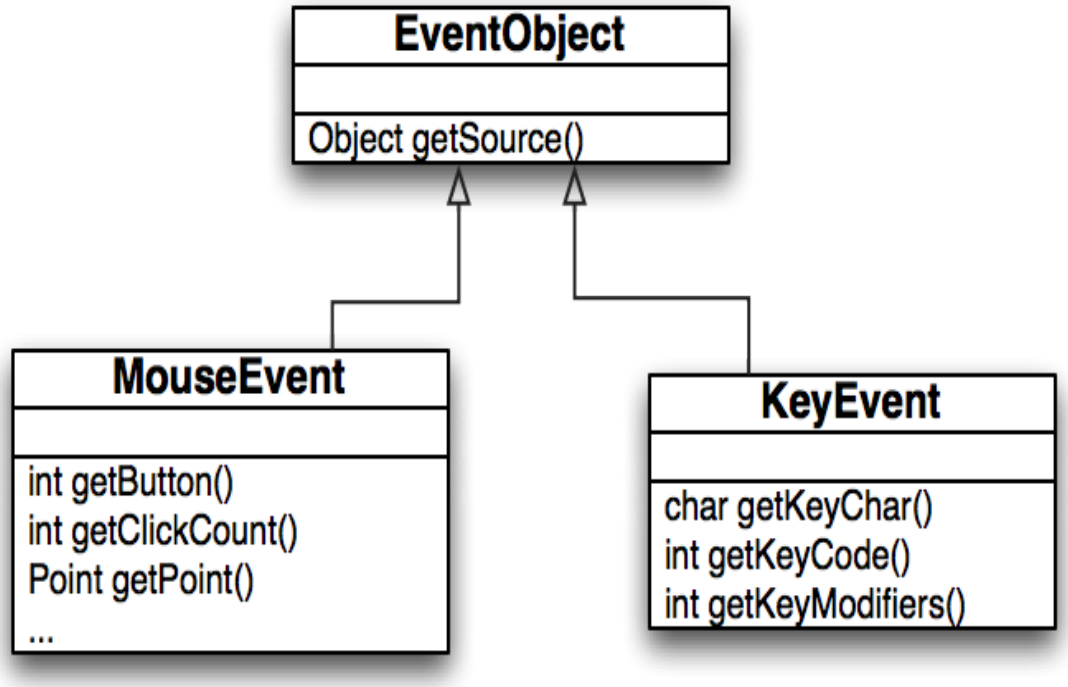
```
typedef union {
    int type;
    XKeyEvent xkey;
    XButtonEvent xbutton;
    XMotionEvent xmotion;
    // etc. ...
}
```

- Each structure contains at least the following

```
typedef struct {
    int type;
    unsigned long serial;  // sequential #
    Display* display;      // display event was read from
    Window window;         // window which event is relative to
} X___Event
```

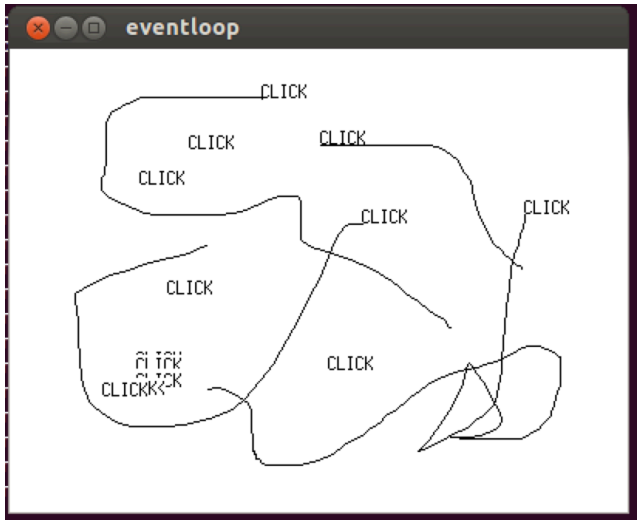
Java Event Structure: Inheritance

- Java (and C# and C++.NET and VB and Objective C and Swift and …) uses an inheritance hierarchy
- Each subclass contains additional information, as required (not shown)



Code Review: eventloop.cpp

- XSelectInput: defines events to process
- XNextEvent: used in event loop to get the next event to process
- Events
  - KeyPress and XLookupString
    - character vs. scan codes
  - Expose and resizing the window
  - MotionNotify on mouse move



Java Event Handling

- Java simplifies much of this
  - Events are transmitted to onscreen objects without programmer intervention
  - The event loop is hidden and managed by the JVM (i.e. you don't need to explicitly manage it)
  - To handle events, tell onscreen objects what you're interested in and what to do

Opening a Window in Java

```
import javax.swing.*;

public class TestWindow extends JFrame{

    public TestWindow(){
        this.setTitle("My Window");
        this.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    }

    public static void main (String args[]){
        TestWindow myWindow = new TestWindow();
        myWindow.setSize(400, 300);
        myWindow.setVisible(true);
    }
}
```

X Windows: Events + Drawing

Animation

Double Buffering

Animation

- A simulation of movement created by displaying a series of pictures, or frames.
  - Animation: *drawing frames at a consistent rate*.
- Goals:
  - Move things around on the screen
  - Repaint 24 - 60 times per second (frames-per-second, frame rate, or “FPS”)
  - Make sure events are handled on timely basis
  - Don’t use more CPU than necessary
  - Easily understood code

Respond to Events (non-blocking)

```
while( true ) {
   if (XPending(display) > 0) {      // pending events?
      XNextEvent(display, &event );  // yes, process them
      switch( event.type ) {
        // handle event cases here ...
      }
   }
   handleAnimation(xinfo);    // update animation objects
   repaint(xinfo);            // repaint the frame
}
```

This doesn't block, but it doesn't work very well either…

Key to animation: managing time

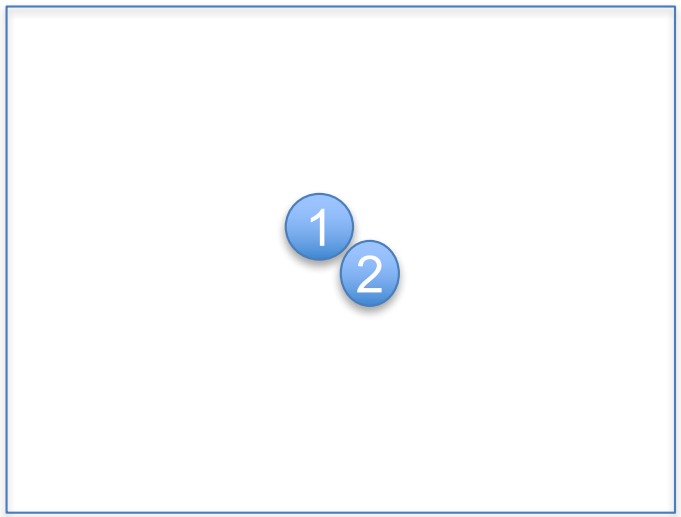
```
while( true ) {
   if (XPending(display) > 0) {      // pending events?
      XNextEvent(display, &event );  // yes, process them
      switch( event.type ) {
        // handle event cases here ...
      }
   }
   handleAnimation(xinfo);    // update animation objects
   repaint(xinfo);            // repaint the frame

    // sleep for about 1/30 second
    const int FPS = 30;
    usleep(1000000/FPS);
}
```

Much better, but still not great… can overwhelm CPU.

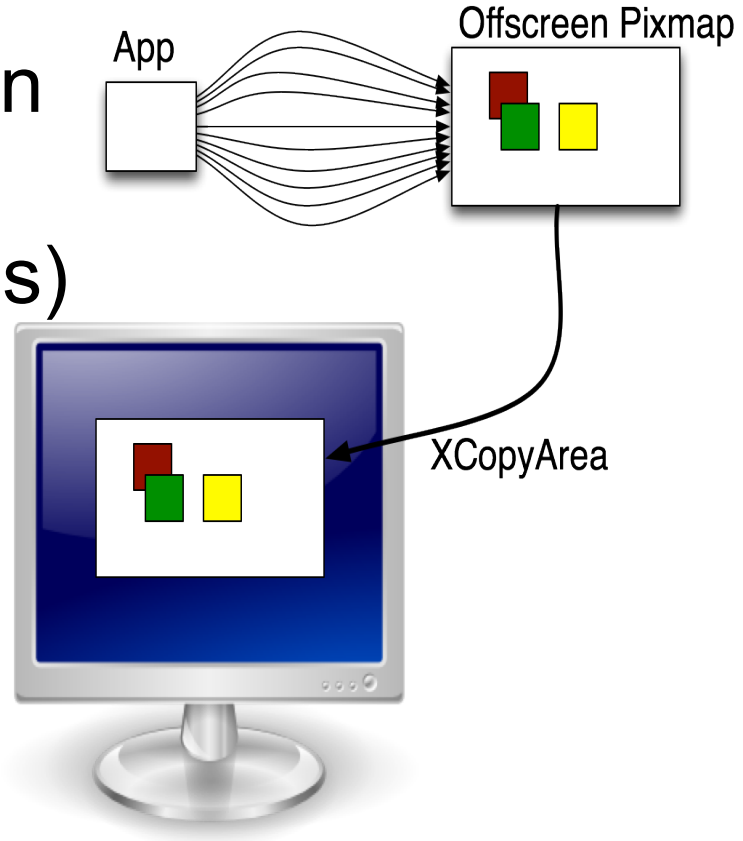
Screen Flicker During Drawing

- Imagine you are animating two balls on the display in a game of breakout
- As the balls get close to each other, you notice that one seems to flicker
  - Why?
- If you paint the balls sequentially, then you might clear a rectangle of the first ball's position, paint the first ball in the new position, then clear rect for the second ball and paint the second ball
- Ball 1 has a bite out of it
  - Or may even vanish …
  - Until next update



Fix: Double Buffering

- Flickering: when an intermediate image is on the display
  - e.g.: Clear, then redraw strategies
- Solution:
  - Create an off screen image buffer
  - Draw to the buffer
  - Copy the buffer to the screen as quickly as possible (hopefully between refreshes)
- In X manual
- In … MOST … other situations, it is done for you



Double Buffering

```
// create off screen buffer
xinfo.pixmap = XCreatePixmap(xinfo.display,
xinfo.window,
    width, height, depth); // size and *depth* of pixmap

// draw into the buffer
// note that a window and a pixmap are “drawables”
XFillRectangle(xinfo.display, xinfo.pixmap,
    xinfo.gc[0], 0, 0, width, height);

// copy buffer to window
XCopyArea(xinfo.display, xinfo.pixmap, xinfo.window,
xinfo.gc[0],
    0, 0, width, height,  // pixmap region to copy
    0, 0); // top left corner of pixmap in window

XFlush( xinfo.display );
```

Java Code: set Double Buffering

- In java swing, double buffering is built into the JComponent class (which is a base class for all Swing components, so they inherit this functionality)
- Two methods:
  - public boolean isDoubleBuffered();
  - public void setDoubleBuffered(boolean o);
- Double-buffering enabled by default !
  - If set in top-level container, all subcomponents will be double buffered regardless of individual settings
  - Why?

Understanding Modern GUI Toolkits

Widgets

- GUI Toolkits contain sets of widgets that you can use to build applications, and enable event delivery to widgets
- So … what is a widget?
- A widget (also graphical control element or control) is an element of interaction in a graphical user interface (GUI), such as a button or a scroll bar. Controls are software components that a computer user interacts with through direct manipulation to read or edit information about an application. User interface libraries contain a collection of widgets and the logic to render these.
  - Wikipedia (AKA the font of all knowledge)

Nesting Windows: Child vs. Sibling Window

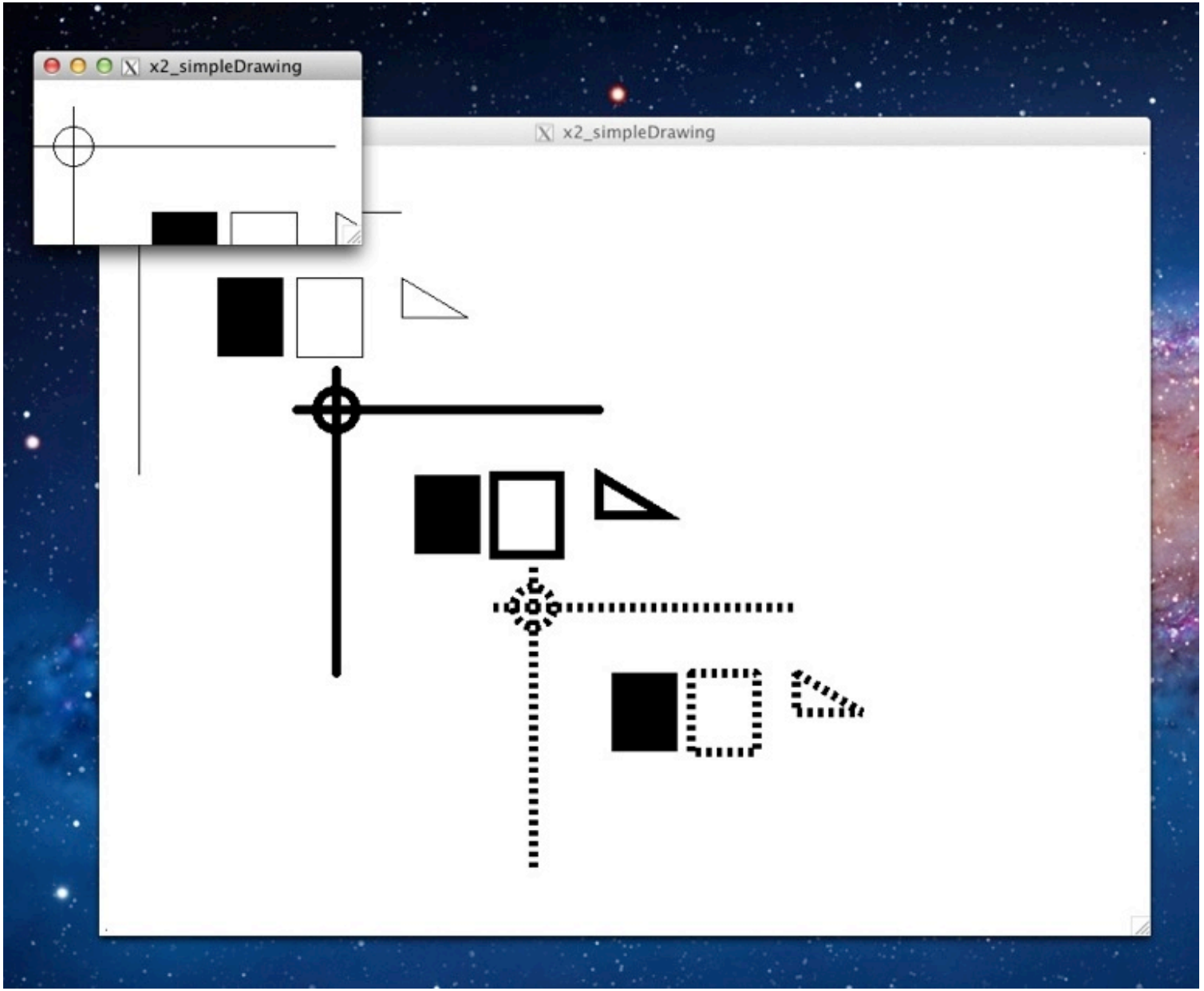
```
    xInfo1.display = display;
    xInfo1.screen = screen;
    initX(argc, argv, xInfo1, DefaultRootWindow( display ),
              100, 100, 800, 600);

    xInfo2.display = display;
    xInfo2.screen = screen;
    initX(argc, argv, xInfo2, DefaultRootWindow( display ),
              50, 50, 300, 200);
```

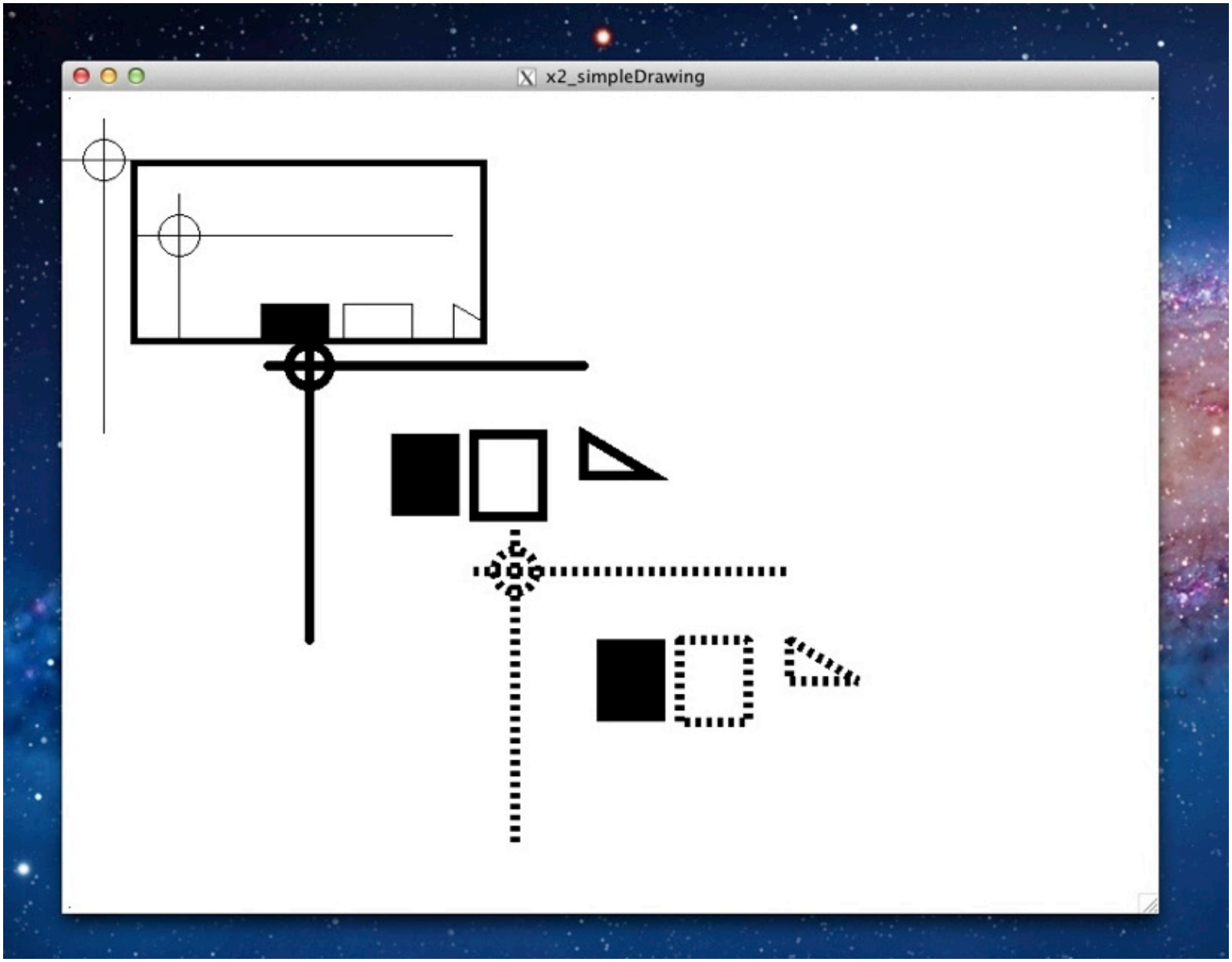
```
    xInfo1.display = display;
    xInfo1.screen = screen;
    initX(argc, argv, xInfo1, DefaultRootWindow( display ),
              100, 100, 800, 600);

    xInfo2.display = display;
    xInfo2.screen = screen;
    initX(argc, argv, xInfo2, xInfo1.window,  // Change
“root” window
              50, 50, 300, 200);
```

multiwindow.cpp: Sibling Window

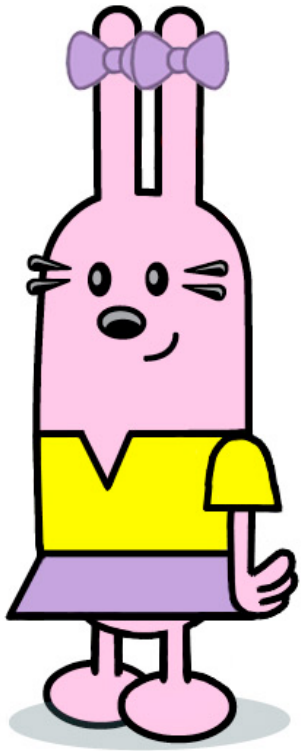


multiwindow.cpp: Child Window



Widget

- Child windows are essentially widgets
  - Widget is a generic name for parts of an interface that have their own behavior: buttons, progress bars, sliders, drop-down menus, spinners, file dialog boxes, …
  - widgets also called “components”, “controls”
  - Can have their own appearance
  - Receive and interpret their own events
  - Put into libraries (toolkits) for reuse



Widget from ***Wow Wow Wubbzy***

Java AWT, Java SWT, Java Swing

- Each operating system implements a set of native widgets
  - What you would expect: buttons, checkboxes, combo boxes, etc., etc.
  - But each OS's native widget set had idiosyncrasies
- Java's cross-platform goal required a decision:
  - AWT, lowest common denominator
  - Swing, roll your own for the JVM.
  - SWT, platform specific
- Pluses and minuses to each approach.
  - What are they?

Pop Quiz

- Why Java?
- Why did we talk about XWindows at all?

Summary

- Events (structure, selecting)
- Event loops (timing)
- Animation
- Double Buffering