EVENT HANDLING

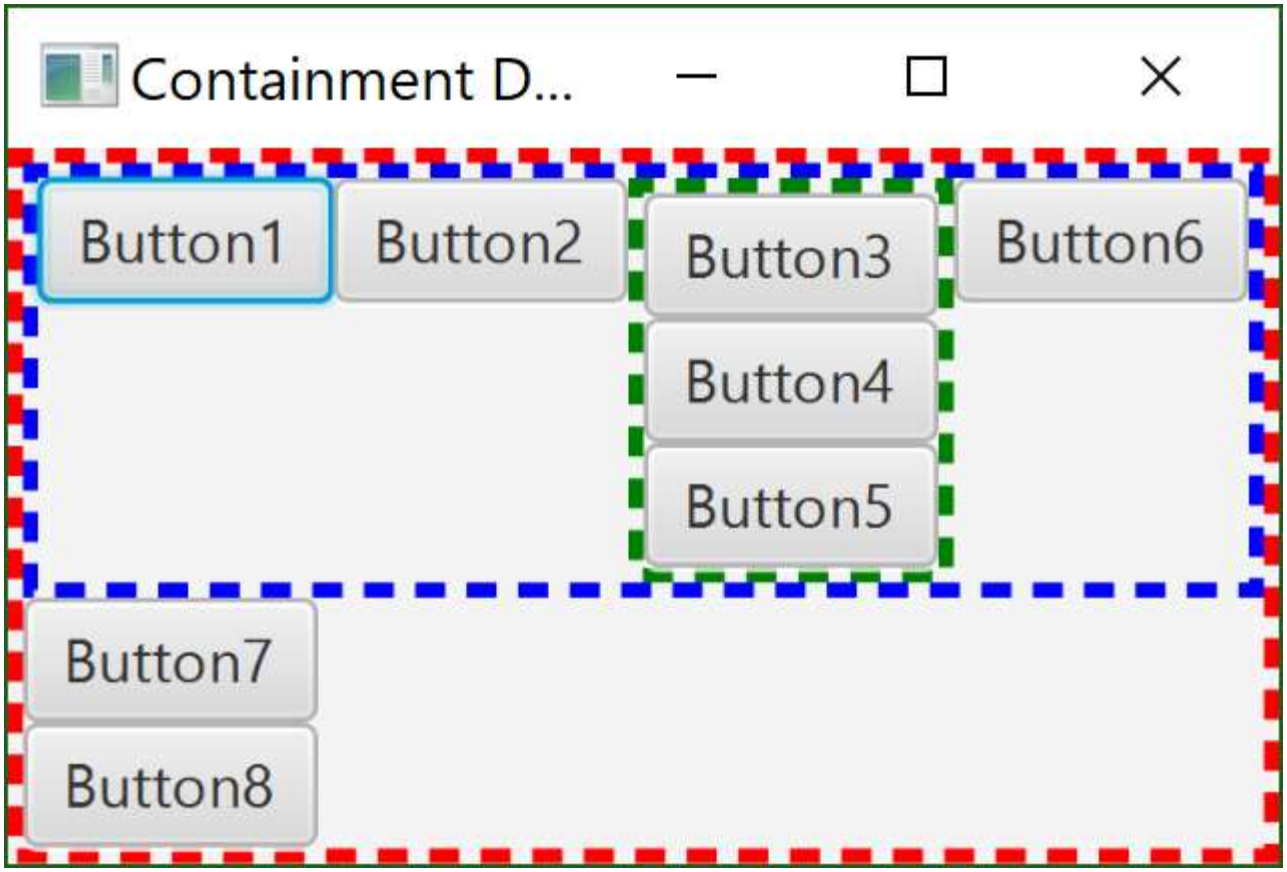
CMPT 381

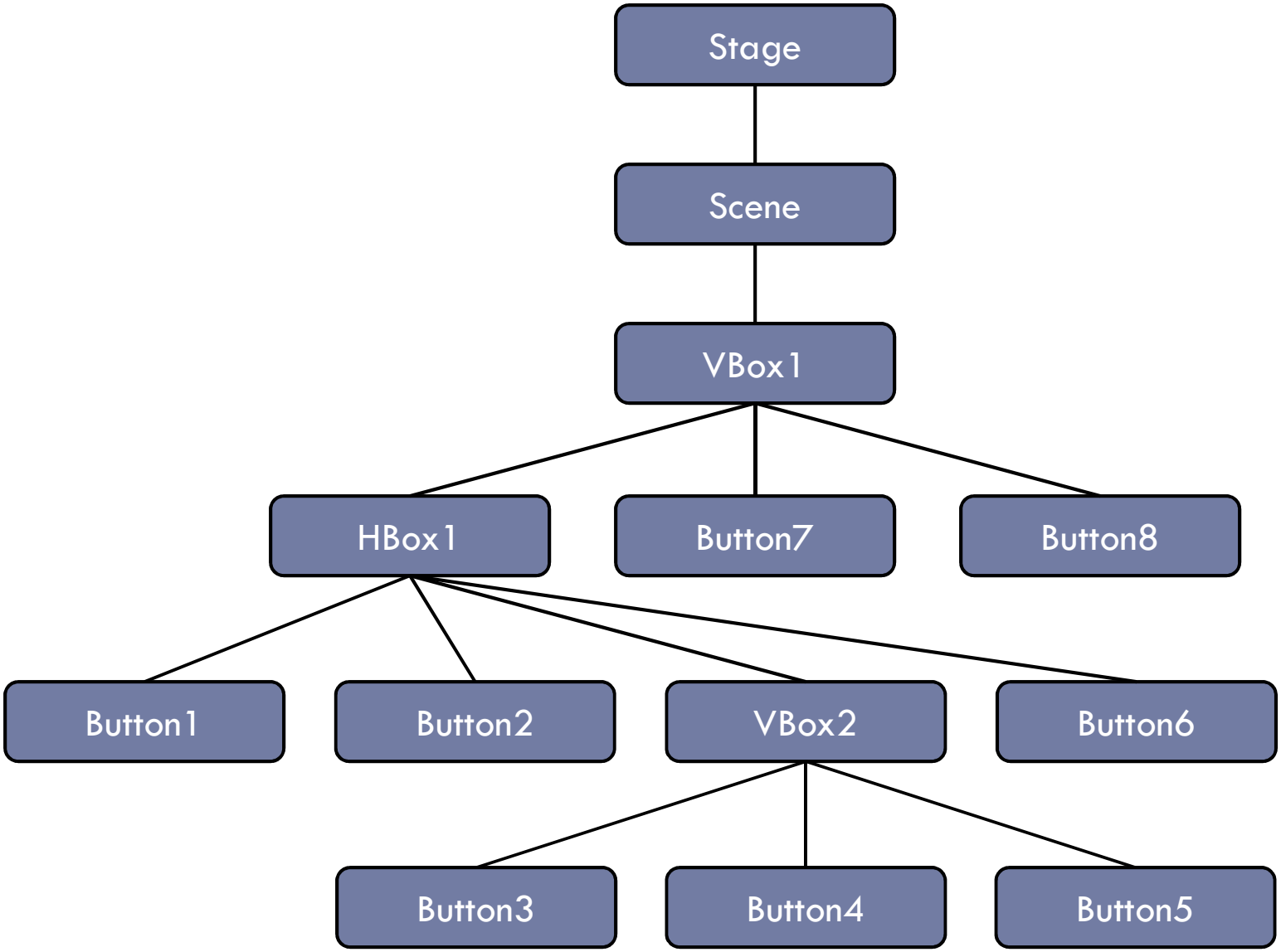
Overview

- Review of containment hierarchies
- Event handling
- Event responsibilities for window systems

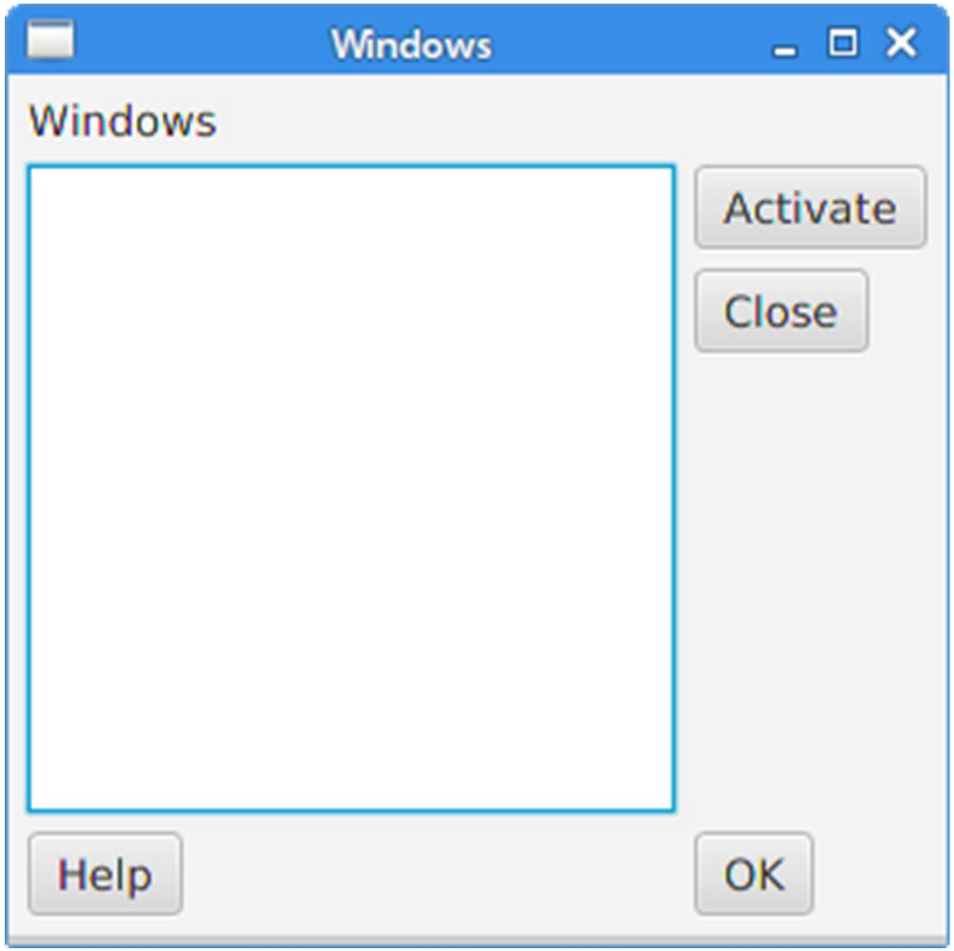
Containment Hierarchies

Draw the containment hierarchy:




Stage
Scene
VBox1
HBox1
Button7
Button8
Button1
Button2
VBox2
Button6
Button3
Button4
Button5

Draw the containment hierarchy:



Containment hierarchies

- Group widgets together (into container widgets)
- Control layout
- Control event routing

Event Handling

Event-Based GUI Programming

- Communication from user to computer via events
- An *input event* is something "interesting" that happens in an input channel
  - Mouse button down
  - Item dragged
  - Keyboard button pressed
  - Mouse wheel turned
  - Others for other types of input devices
- Also *pseudoevents* that are not direct input events

New devices mean new events

- Johnny Lee: Wiimote hacks
  - https://www.youtube.com/watch?v=QgKCrGvShZs
- Wiimote library for Java
  - http://motej.sourceforge.net/
- Kinect SDK for Java
  - http://research.dwi.ufl.edu/ufdw/j4k/

Input Event Architecture

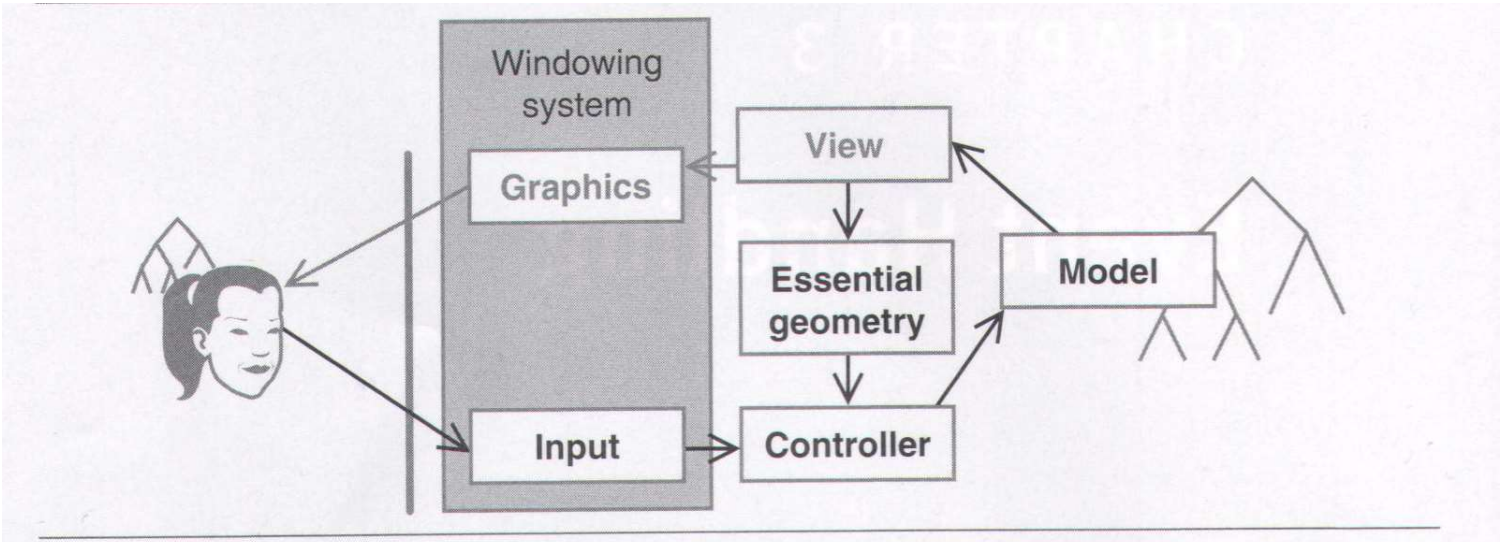


Figure 3.1 – Input event architecture

Types of events

- Device events
  - e.g. mouse button 1 down, wheel turned
- Filtered / high-level events
  - e.g. enter, leave, scroll
- Window events
  - e.g. resize window, close window
- Programmer-defined events
  - e.g. message arrived, calculation finished

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"Pseudoevents"

Three main issues

- Dispatching/receiving events
- Event must trigger code
- Notifying the view of any model changes

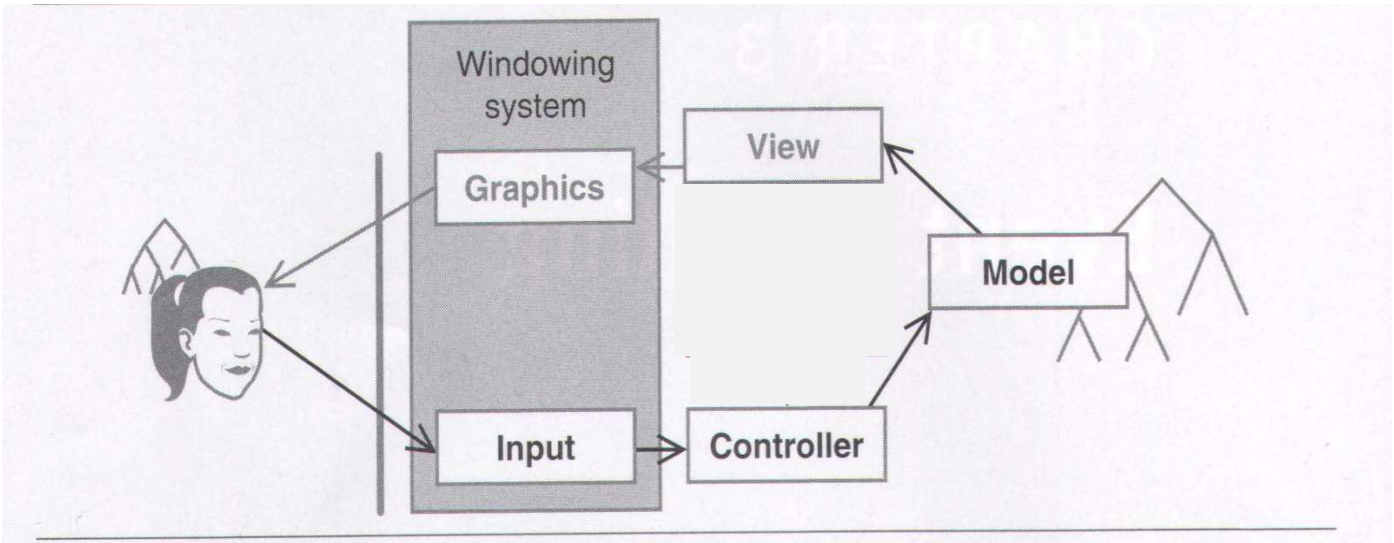


Figure 3.1 – Input event architecture

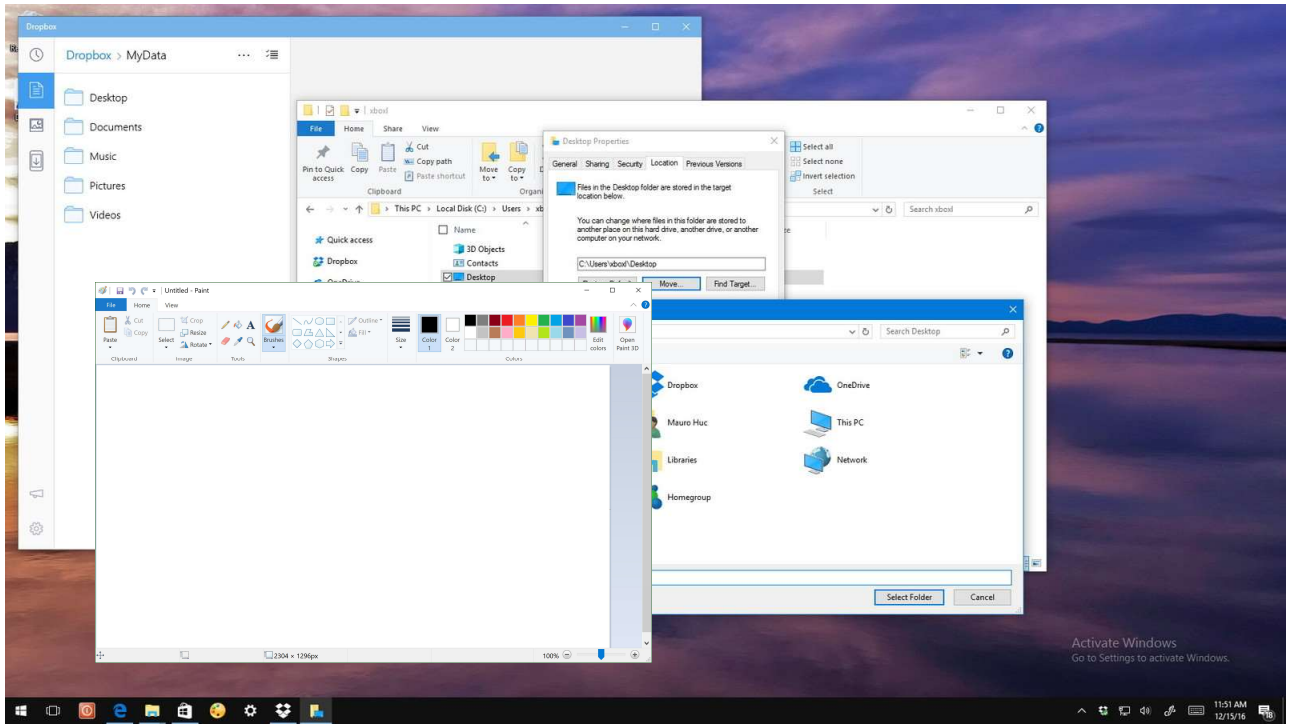
Dispatching Events

Window Trees

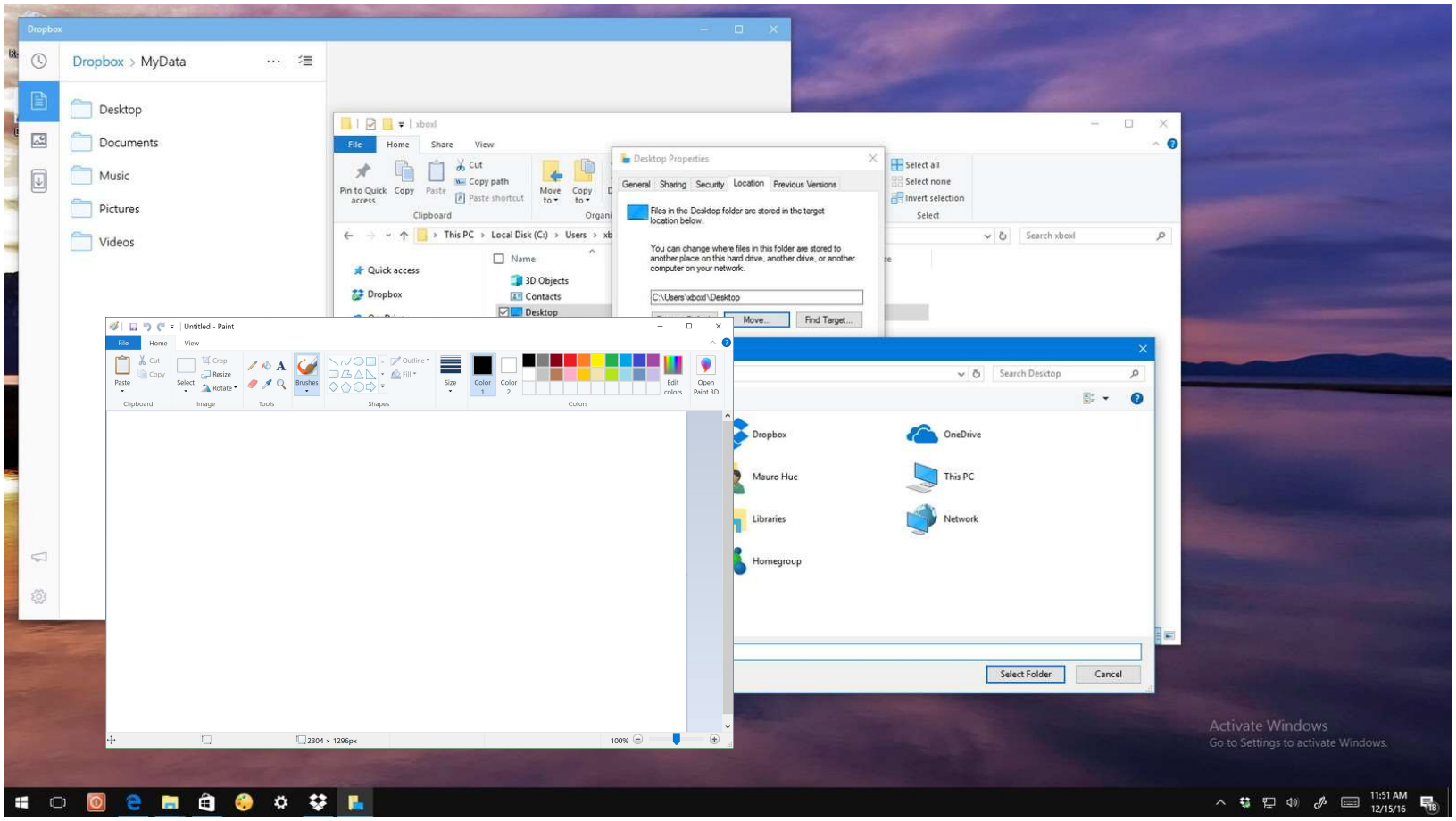
A colour box is clicked on the tool palette in the Paint application - where should the event go?

1. Window system decides which application

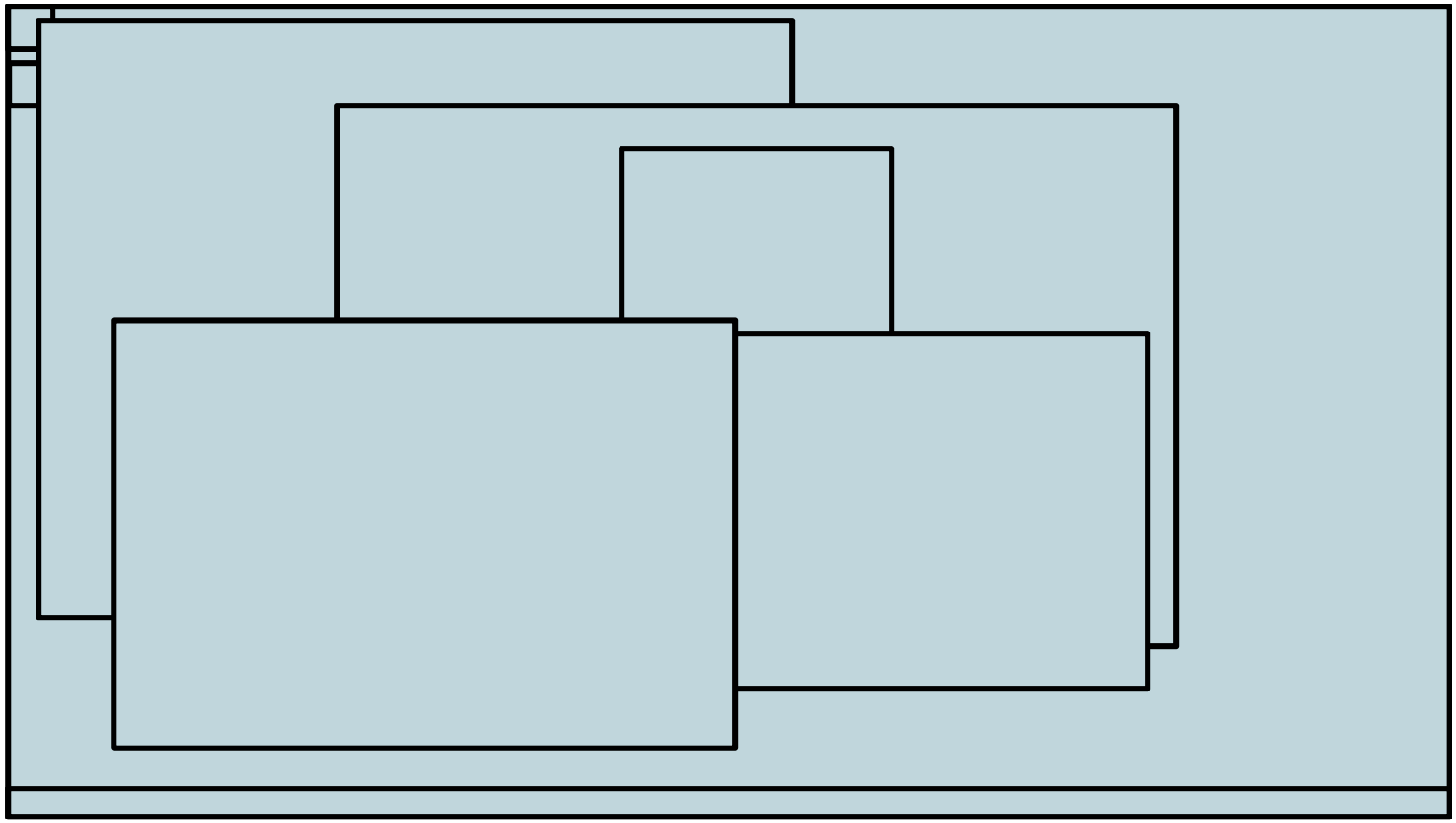
2. Application decides which widget



At the Window Manager level



WM: map of regions to applications



At the application level

Application window tree = containment hierarchy

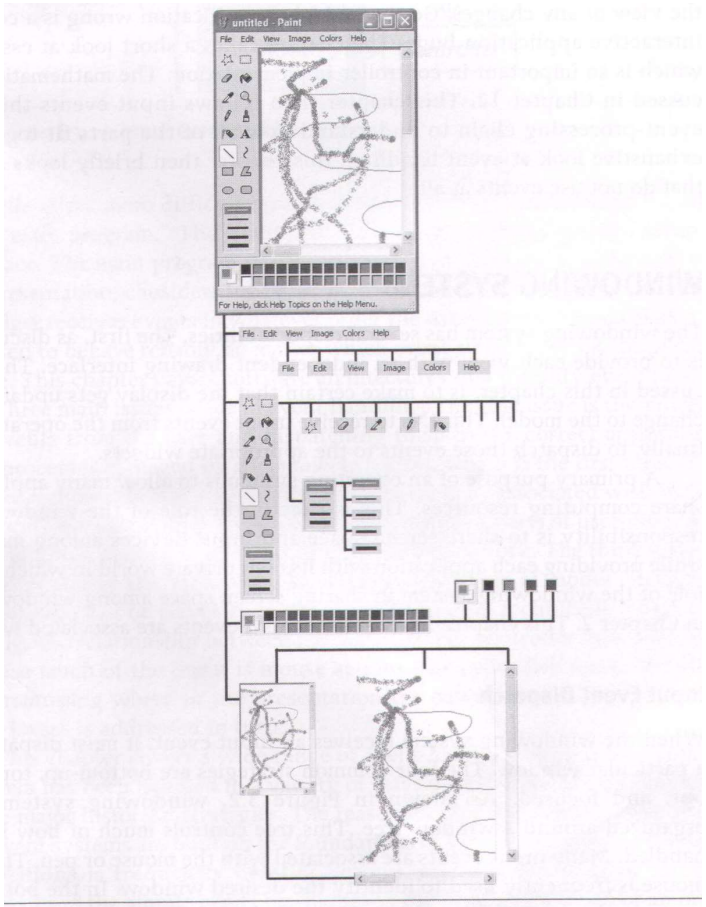


Figure 3.2 – Window tree

Approaches for Directing Events

- Bottom-up
- Top-down
- Bubble-out
- Focus-based

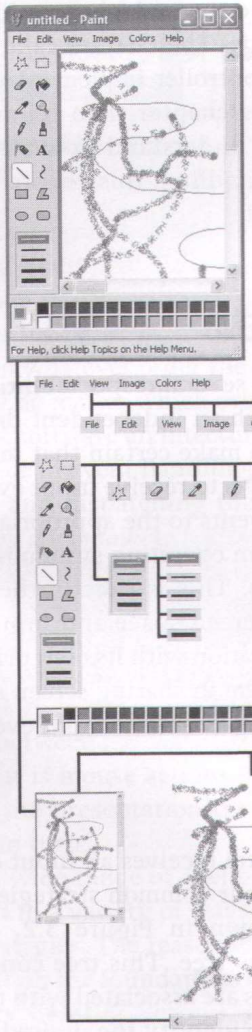


Figure 3.2 – Window tree

Bottom-up

- Event directed to lowest front-most window or widget in the tree
- If not needed, passed up

Top-down

- Event passed recursively down until a widget can use it
  - e.g., from top-level window, to container widget, to visible widget (e.g., a button)

Bubble-out

- Some systems don't have nested windows/ widgets
  - e.g., drawing shapes inside other shapes
- Bounding boxes are used to determine if an event has a 'hit'
- Then 'bubble out' passing the event to parents
  - Used in Flash and Javascript/HTML

Focus-based

- Windowing system keeps pointer to correct widget
- Key Focus – focus, unfocus events
  - Use mouse position
    - attach mouse position to all key events and dispatch events in the same way as mouse events
  - Remember a 'focus window'
    - send key events to last window to see mouse-down
    - click-to-type
  - Application control
    - explicitly set keyboard focus
- Mouse Focus
  - Allows us to be sloppy

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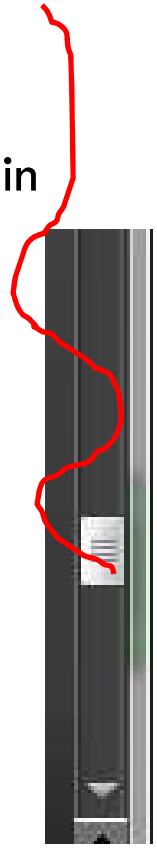


Device Events

- Most toolkits provide support for common types:
  - Button Events
  - Mouse Movement
  - Keyboard
  - Window Events
  - Other Inputs
    - Multi-user, touch, pressure, speech
    - New input device? Need to extend the UI toolkit
    - https://www.youtube.com/watch?v=PmgoxOHeQO0

Event/Code Binding

Main event loop

Event queues

Event dispatching

Main event loop

- Simple loop to get and dispatch events
- What layer implements it?

```
Initialization
While (not time to quit) {
    Get next event E
    Dispatch event E
}
```

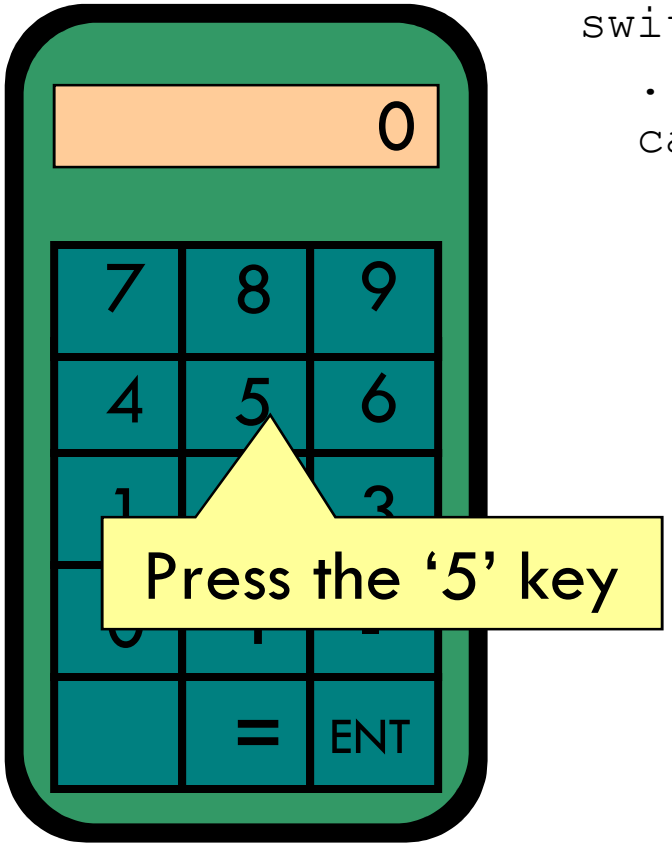
Event Queue

- OS receives device interrupts
- Places events on the queue
- Ensures that events are processed in order
- Different queues for different layers
- At application layer, the main event loop removes them from the queue

```
Mouse move (22,33)
Mouse move (40,30)
Mouse down left (45,34)
Mouse up left (46,35)
```

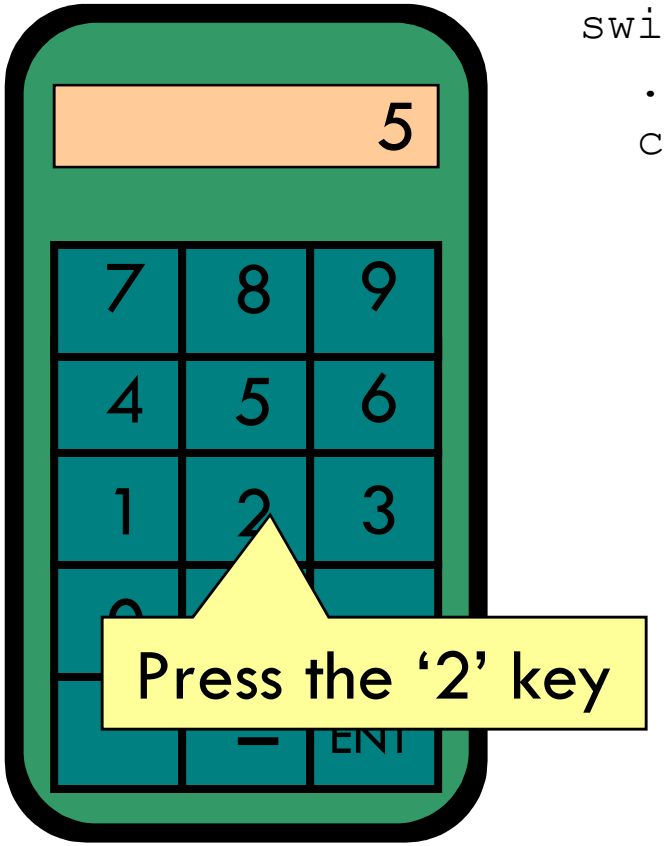
Basic event dispatch

- Application programmer writes dispatch code



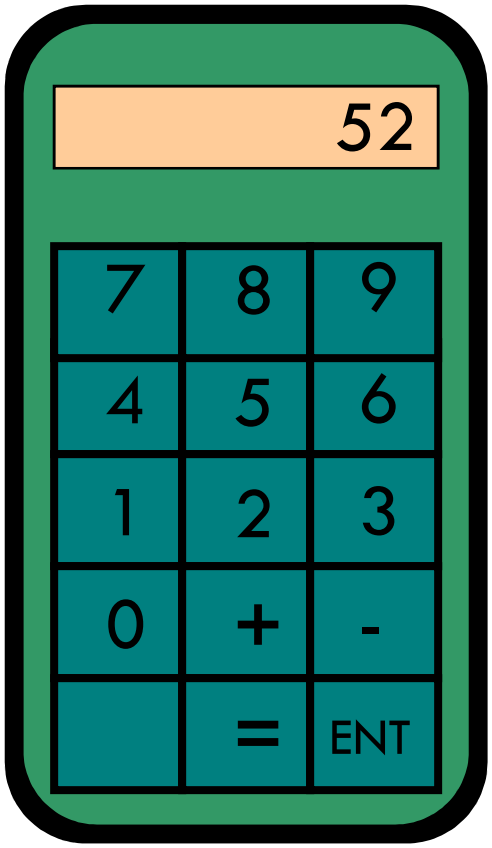

```
Dispatch (event E) {
  switch (E.window) {
    ...
    case FIVE-KEY:
        if (E.type == left-down){
          cur = 5 + 10*cur;
          display (cur);
          last-op = NUMBER;
        }
        ...
```

Basic event dispatch




```
Dispatch (event E) {
  switch (E.window) {
    ...
    case TWO-KEY:
        if (E.type == left-down) {
          cur = 2 + 10*cur;
          display (cur);
          last-op = NUMBER;
        }
        ...
```

Basic event dispatch



Event table dispatch

- Event tables (in the early days…)
  - indexed by event types (integer from 0 - 255)
  - holds pointers to functions that handle each event
  - one table per window

Callback Event Handlers

- Use named events instead of pointers
- Indicate specific code to run
- Tk: the bind command
  - bind associates events with commands
    - bind widget <event-type> command
    - `bind .myCanvas <Button-3> "showPopupMenu %x %y"`
- Tk: widget callbacks
  - certain widgets know they're going to be manipulated
  - they have built-in callbacks for particular actions
    - e.g. "-command" switch for buttons
    - `button .b -text "Test" -command "myProc"`

Object-Oriented Handling

- OO languages naturally handle message passing between independent objects
  - Application code for events can be moved to objects

```
dispatch (event e) {
    //handles the event or passes to child widget
    e.window.handleEvent(e);
}
```

Publish-subscribe dispatch

- Widgets register interest in certain events
  - Publish-subscribe design pattern
  - Publisher: the event producer
    - Note: the toolkit layer itself may be the publisher
  - Subscriber: the interested widget
- When an event occurs:
  - Publisher responsible for notifying all subscribers
- Java: listener interfaces
  - Objects implementing listener interfaces are automatically called when events occur
  - The listener object then calls application code

Swing events and listeners

User action	Listener type
User clicks a button, presses Return while typing in a text field, or chooses a menu item	ActionListener
User presses a mouse button over a component	MouseListener (MouseAdapter)
User moves the mouse over a component	MouseMotionListener (MouseMotionAdapter)
Table or list selection changes	ListSelectionListener
Component gets the keyboard focus	FocusListener
User closes a frame	WindowListener
Component becomes visible	ComponentListener

Swing example

```
JButton helloButton;
ButtonListener listen;  // a listener for button presses

helloButton = new JButton("Hello");
listen = new ButtonListener(); // create the button listener

// assign a command string to the button
helloButton.setActionCommand("hello");
// attach the button listener to the button
helloButton.addActionListener(listen);

class ButtonListener implements ActionListener {
    // actionPerformed is called automatically by the toolkit
    public void actionPerformed(ActionEvent e) {
      String action = e.getActionCommand();
      // handle the command for the hello button
      if (action.equals("hello")) {
           printMessage();
      } ...
```

JavaFX events and handlers

- Primary mechanism: EventHandlers
  - Implementations of the *EventHandler* interface
- Some Listeners still used (for properties e.g., Slider)
- Attaching EventHandlers:
  - Convenience methods (for Nodes with obvious events)
    - Node.setOn*EventType*(…)
    - e.g., myButton.setOnAction(…)
  - Node.addEventFilter(EventType, filter);
  - Node.addEventHandler(EventType, filter);

JavaFX events and handlers

- Node class convenience methods
  - Handle events that *all* Nodes can respond to
- setOnMouseMoved(…)
- setOnMousePressed(…)
- setOnTouchPressed(…)
- setOnZoom(…)
- setOnKeyPressed(…)
  - …and many more

- openjfx.io/javadoc/11/javafx.graphics/javafx/scene/Node.html

JavaFX events and handlers

- Specific Node classes have methods for their traditional events:
- Button, ComboBox, Menu, ContextMenu, TextField:
  - setOnAction(…)
- ListView, TableColumn, TreeView
  - setOnEditStart(…), setOnEditCommit(…)
- Window
  - setOnCloseRequest(…), setOnHidden(…)

JavaFX events and handlers

- Widgets with properties can attach change listeners
  - E.g., Slider valueProperty:

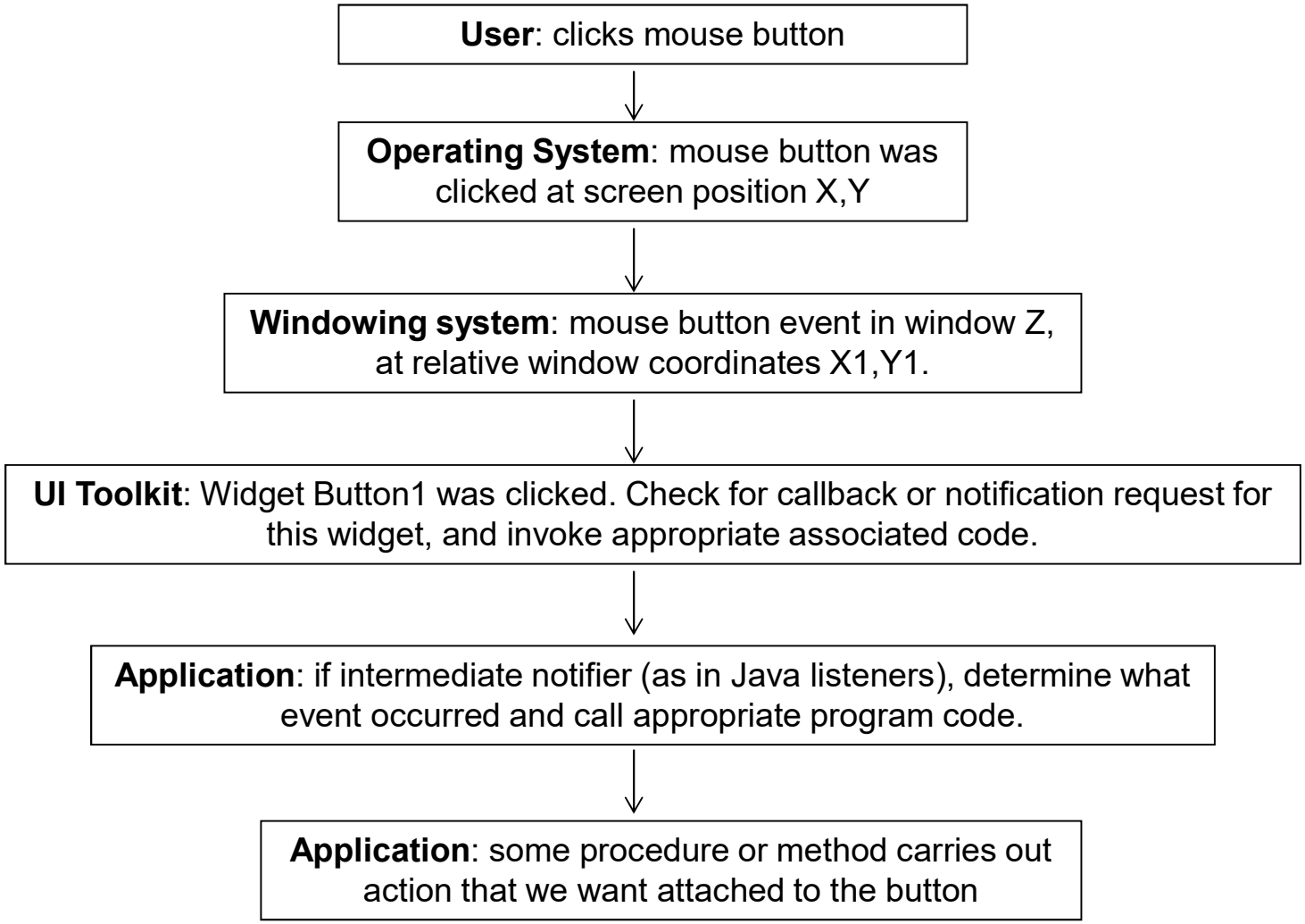
```
// Handle Slider value change events.
mySlider.valueProperty().addListener((observable, oldValue, newValue) -> {
    System.out.println("Slider Value Changed (newValue: " + newValue.intValue() + ")");
});
```

  - E.g., TextField textProperty:

```
// Handle TextField text changes.
myTextField.textProperty().addListener((observable, oldValue, newValue) -> {
    System.out.println("TextField Text Changed (newValue: " + newValue + ")");
});
```

  - note difference to TextField.setOnAction(…)

Life cycle of a mouse-click event



Connecting events in JavaFX (1)

- Instance of an EventHandler class

```
class ButtonHandler implements EventHandler {
    public void handle(Event event) {
        System.out.println("Hello");
    }
}
myHandler = new ButtonHandler;
btn.setOnAction(myHandler);
```

- Anonymous inner class

```
btn.setOnAction(new EventHandler<ActionEvent>() {
     public void handle(ActionEvent event) {
       System.out.println("Hello");
  }
});
```

Connecting events in JavaFX (2)

- Lambda expression

```
btn.setOnAction(e -> System.out.println("Hello"));
```

- Method reference

```
btn.setOnAction(this::handleButtonClick);
```

- Also through FXML (later)

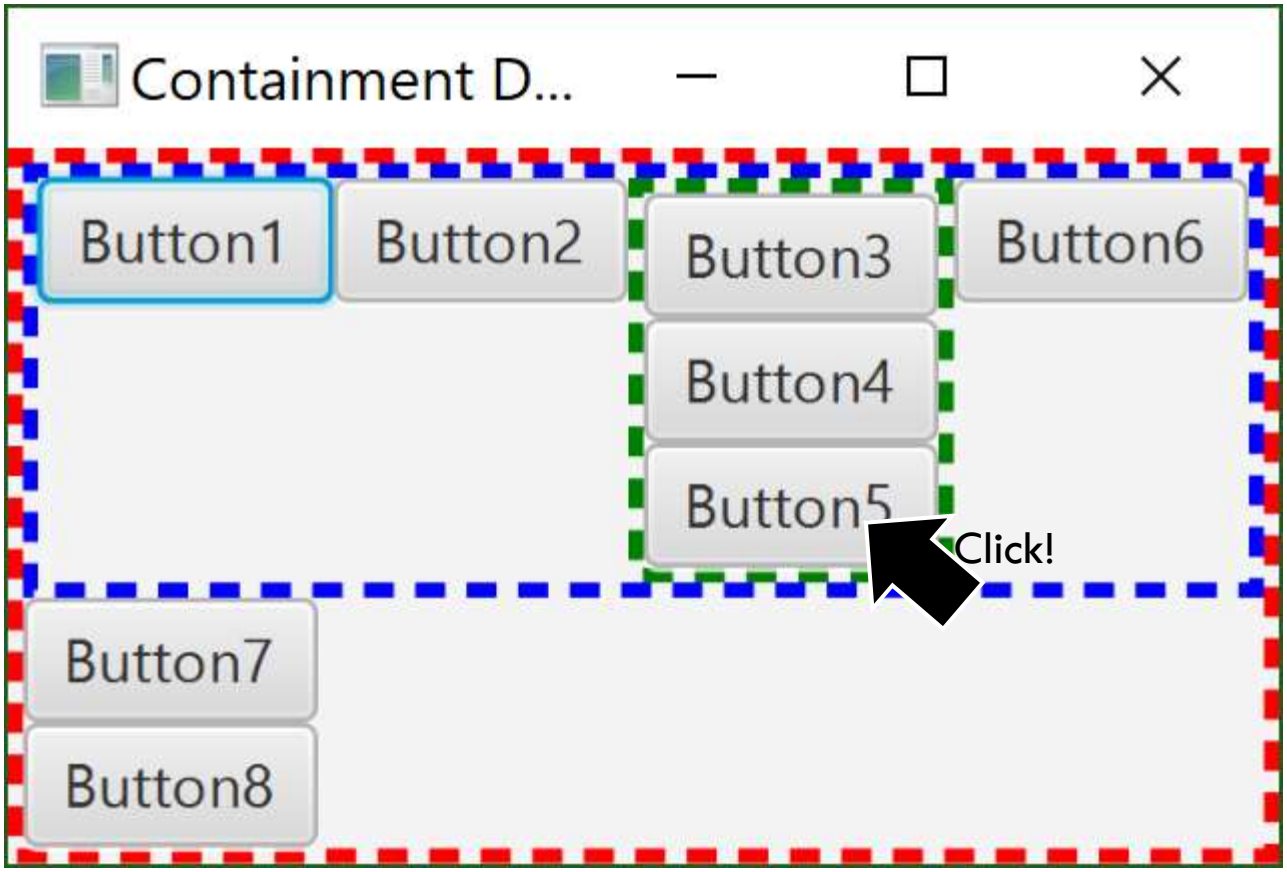
Method references ≈ C# Delegates

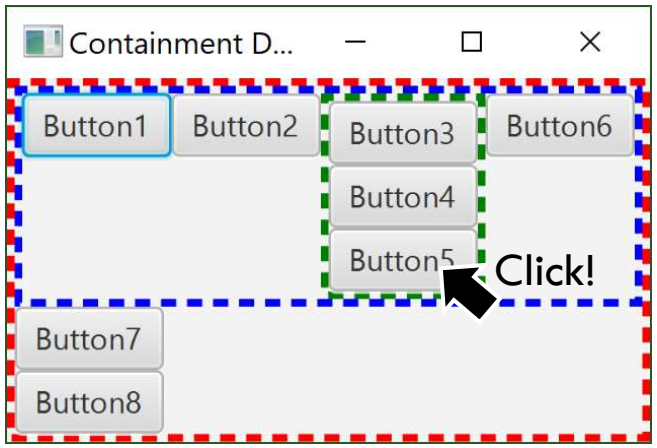
- Similar to callbacks / function pointers
- Assign a method to be called when event occurs
- += and -= operators to add/remove delegates

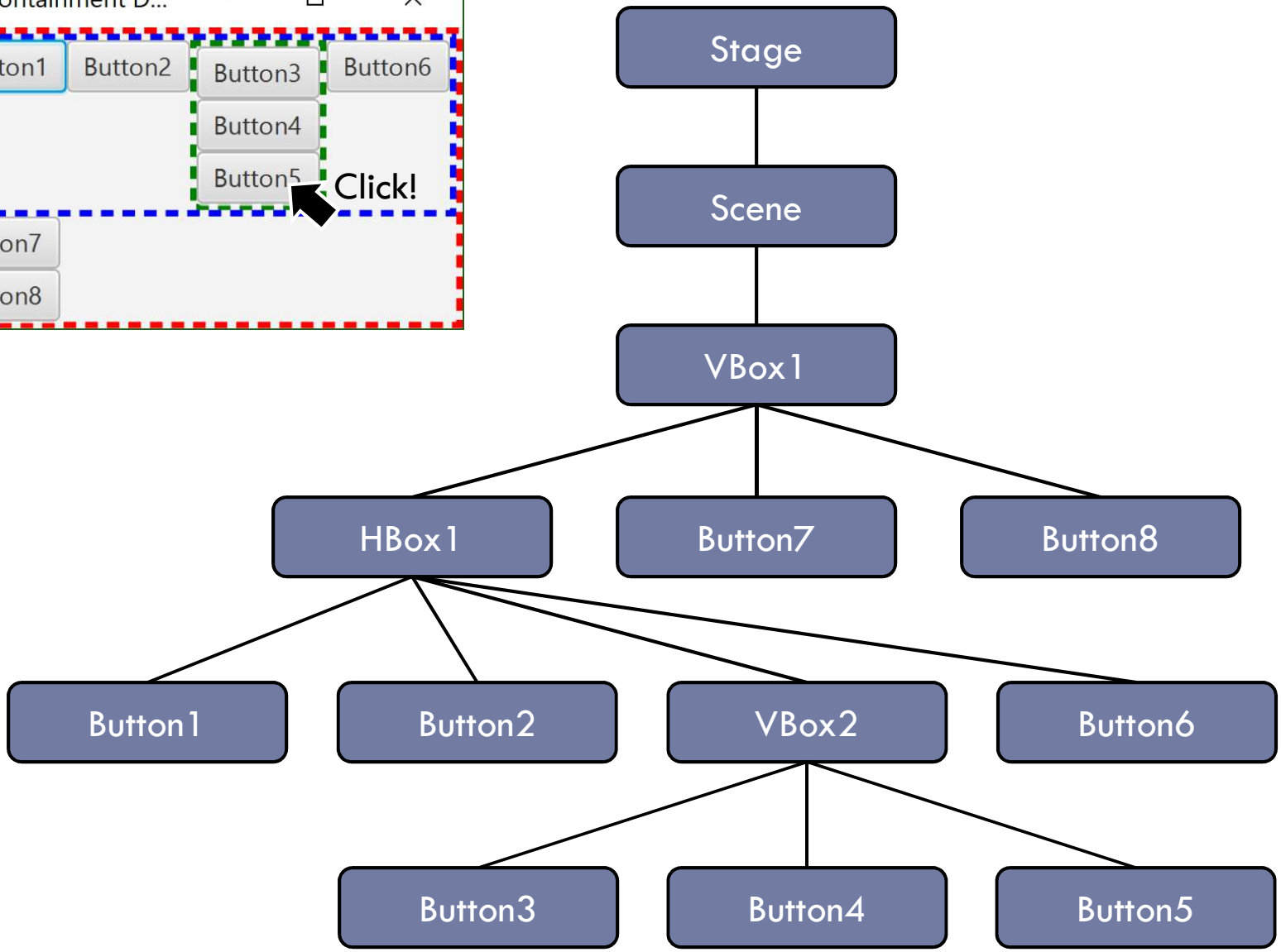
JavaFX event dispatching

- Two phases: top-down then bottom-up
- Top-down ("event capture")
  - Event *filters*
- Bottom-up ("event bubbling")
  - (note this is different from "bubble-out" in the text)
  - Event *handlers*
- Filters and Handlers use the same EventHandler interface – they are just called at different times

Where are events handled?




Containment D...
Button1
Button2
Button3
Button6
Button4
Button5
Click!
Button7
Button8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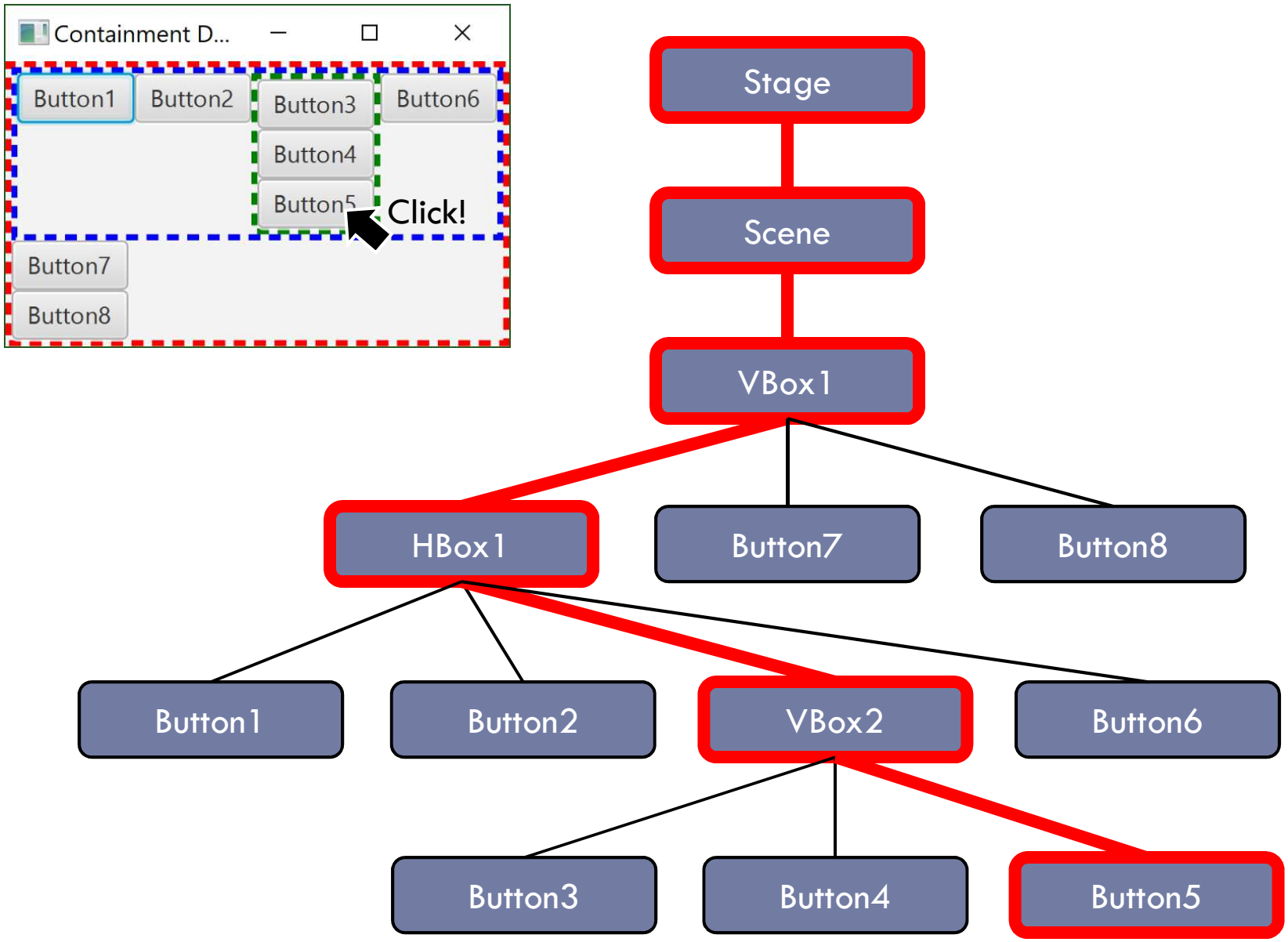
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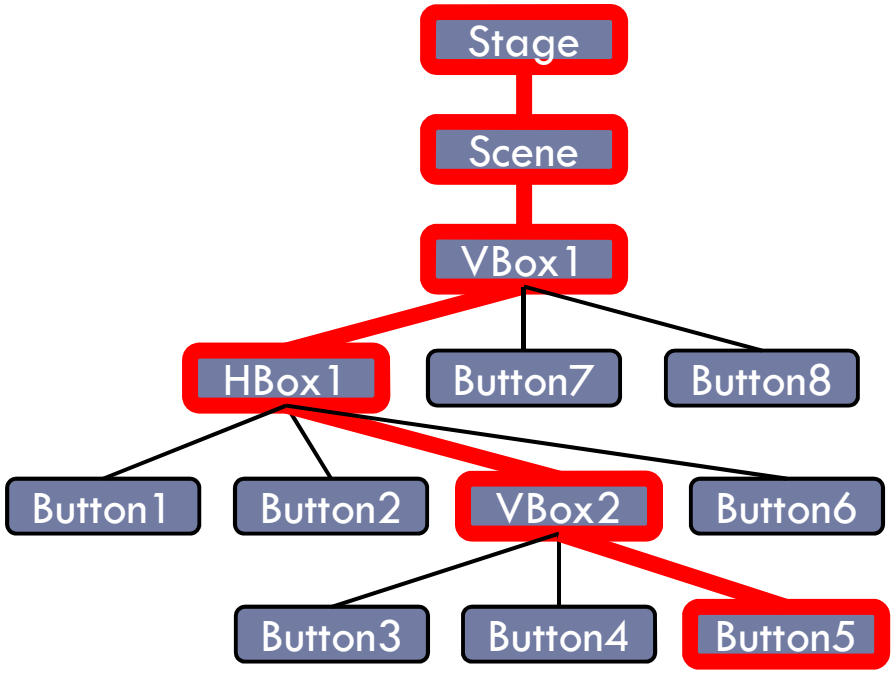
Where are events processed?

- At any or all Nodes
- Going downwards, with event filters
- Going back up, with event handlers
- In this UI the event could be handled 12 times
- How to stop further processing?
  - event.consume();



Node.addEventFilter(EventType, filter);
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