Event Driven UIs and Model-View-Controller

CS160: User Interfaces

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Includes slides based on those of James Landay & Jeffrey Heer

Reminder

Archos 5 hardware available in class this Weds – one per group.

Pls bring a check for $200 to UC Regents as a deposit.

You need the Archos for individual programming assignment 4 – no BT in emulator. OK to work in pairs. But still submit individually.

Anyone else need Wii remote?

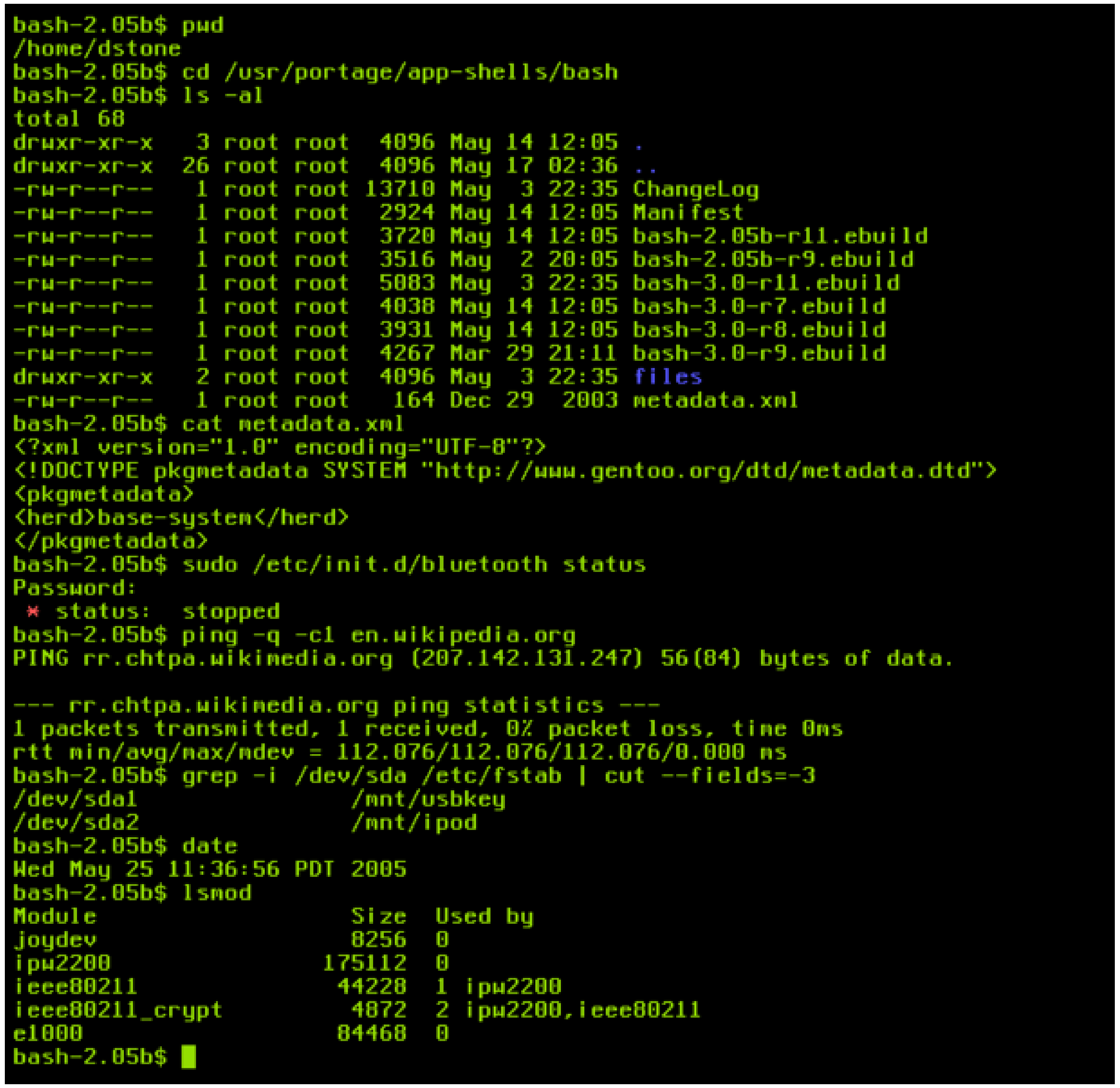
Topics

Interactive application programming

- Component Model
- Event-Driven User Interfaces
- Model-View Controller pattern

Interactive Application Programming

In the beginning...

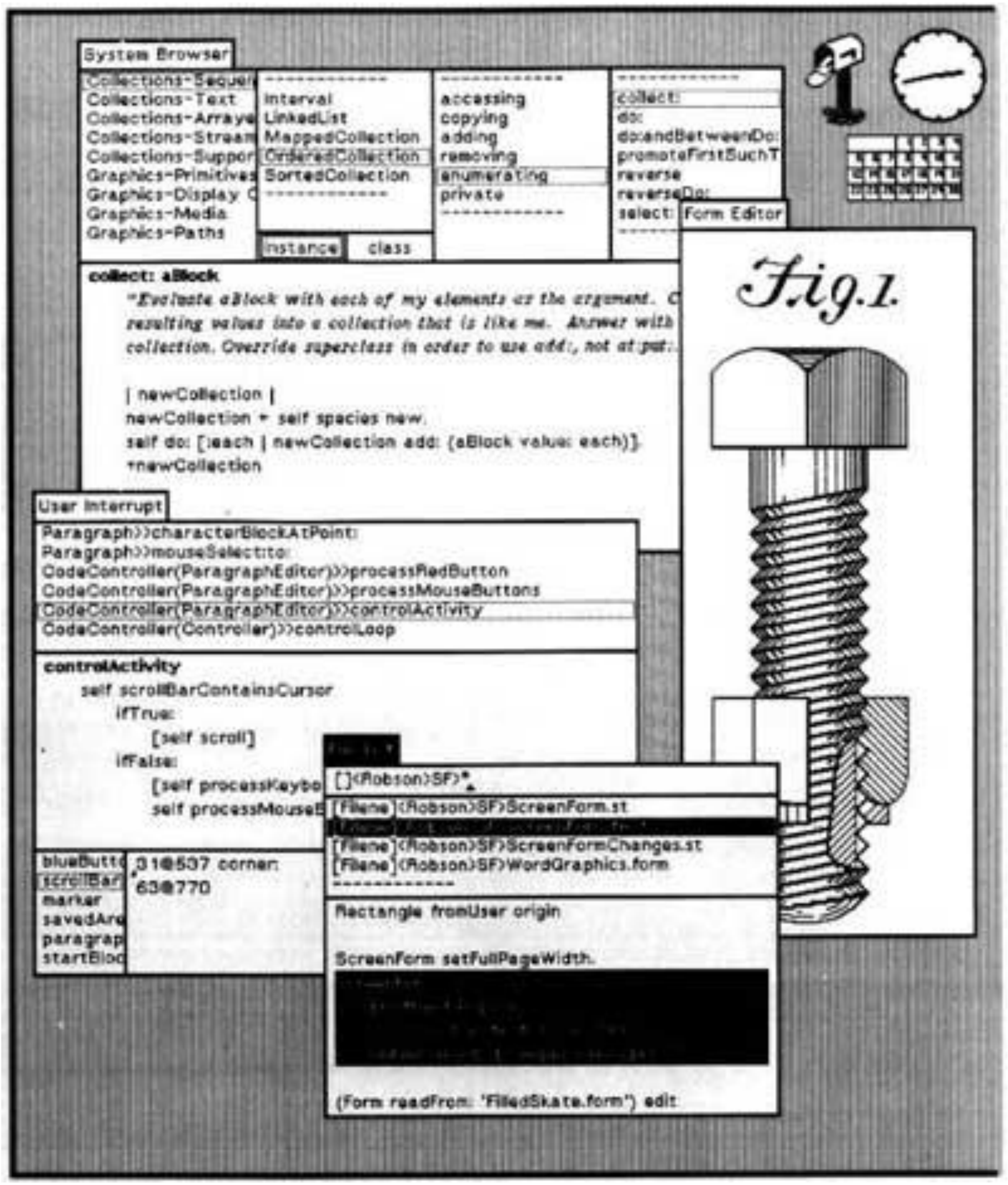


```
bash-2.05b$ pwd
/home/dstone
bash-2.05b$ cd /usr/portage/app-shells/bash
bash-2.05b$ ls -al
total 68
drwxr-xr-x   3 root root  4096 May 14 12:05 .
drwxr-xr-x  26 root root  4096 May 17 02:36 ..
-rw-r--r--   1 root root 13710 May  3 22:35 ChangeLog
-rw-r--r--   1 root root  2924 May 14 12:05 Manifest
-rw-r--r--   1 root root  3720 May 14 12:05 bash-2.05b-r11.ebuild
-rw-r--r--   1 root root  3516 May  2 20:05 bash-2.05b-r9.ebuild
-rw-r--r--   1 root root  5083 May  3 22:35 bash-3.0-r11.ebuild
-rw-r--r--   1 root root  4038 May 14 12:05 bash-3.0-r7.ebuild
-rw-r--r--   1 root root  3931 May 14 12:05 bash-3.0-r8.ebuild
-rw-r--r--   1 root root  4267 Mar 29 21:11 bash-3.0-r9.ebuild
drwxr-xr-x   2 root root  4096 May  3 22:35 files
-rw-r--r--   1 root root   164 Dec 29  2003 metadata.xml
bash-2.05b$ cat metadata.xml
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE pkgmetadata SYSTEM "http://www.gentoo.org/dtd/metadata.dtd">
<pkgmetadata>
<herd>base-system</herd>
</pkgmetadata>
bash-2.05b$ sudo /etc/init.d/bluetooth status
Password:
 * status:  stopped
bash-2.05b$ ping -q -c1 en.wikipedia.org
PING rr.chtpa.wikimedia.org (207.142.131.247) 56(84) bytes of data.

--- rr.chtpa.wikimedia.org ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 112.076/112.076/112.076/0.000 ms
bash-2.05b$ grep -i /dev/sda /etc/fstab | cut --fields=-3
/dev/sda1               /mnt/usbkey
/dev/sda2               /mnt/ipod
bash-2.05b$ date
Wed May 25 11:36:56 PDT 2005
bash-2.05b$ lsmod
Module                  Size  Used by
joydev                  8256  0
ipw2200               175112  0
ieee80211              44228  1 ipw2200
ieee80211_crypt         4872  2 ipw2200,ieee80211
e1000                  84468  0
bash-2.05b$ █
```

http://www.cryptonomicon.com/beginning.html

The Xerox Alto (1973)



```
collect: aBlock
    "Evaluate aBlock with each of my elements as the argument. C
    resulting values into a collection that is like me. Answer with
    collection. Override superclass in order to use add:, not at:put:.

    | newCollection |
    newCollection ← self species new.
    self do: [:each | newCollection add: (aBlock value: each)].
    ↑newCollection
```

```
Paragraph>>characterBlockAtPoint:
Paragraph>>mouseSelect:to:
CodeController(ParagraphEditor)>>processRedButton
CodeController(ParagraphEditor)>>processMouseButtons
CodeController(ParagraphEditor)>>controlActivity
CodeController(Controller)>>controlLoop
```

```
controlActivity
    self scrollBarContainsCursor
        ifTrue:
            [self scroll]
        ifFalse:
            [self processKeybo
            self processMouseB
```

```
31@537 corner:
63@770
```

```
[]<Robson>SF>*
[Filene]<Robson>SF>ScreenForm.st
[Filene]<Robson>SF>ScreenFormChanges.st
[Filene]<Robson>SF>WordGraphics.form
------------
```

```
Rectangle fromUser origin

ScreenForm setFullPageWidth.

(Form readFrom: 'FilledSkate.form') edit
```

Event-Driven UIs

Old model (e.g., UNIX shell, DOS)

- Interaction controlled by system, user queried for input when needed by system

Event-Driven Interfaces (e.g., GUIs)

- Interaction controlled by user
- System waits for user actions and then reacts
- Complex, dynamic screen content requires a more complicated system.

Event-Driven UIs

i.e. A “console” program looks like this:

```
do some work…
prompt user for input
wait for user input
process it…
```

Event-Driven UIs

i.e. An “interactive” program does at least this:

```
Do until a quit command: {
        wait for user input
        process it…
        (optionally) update display
}
```

Event-Driven UIs

“Console”-style input processing:

```
Switch (input-cmd) {
   case insert: do-insert(…)
   case delete: do-delete(…)
   case backspace: …
```

Event-Driven UIs

Can't use this approach for window systems. The result of a user command depends on what is the **active window** - usually the one under the mouse.

There are too many possible combinations of input x target window, and the window structure is dynamic.

Instead, code and data associated with a an active screen element are packaged together in a "widget" or "component."

Component/Widget Model

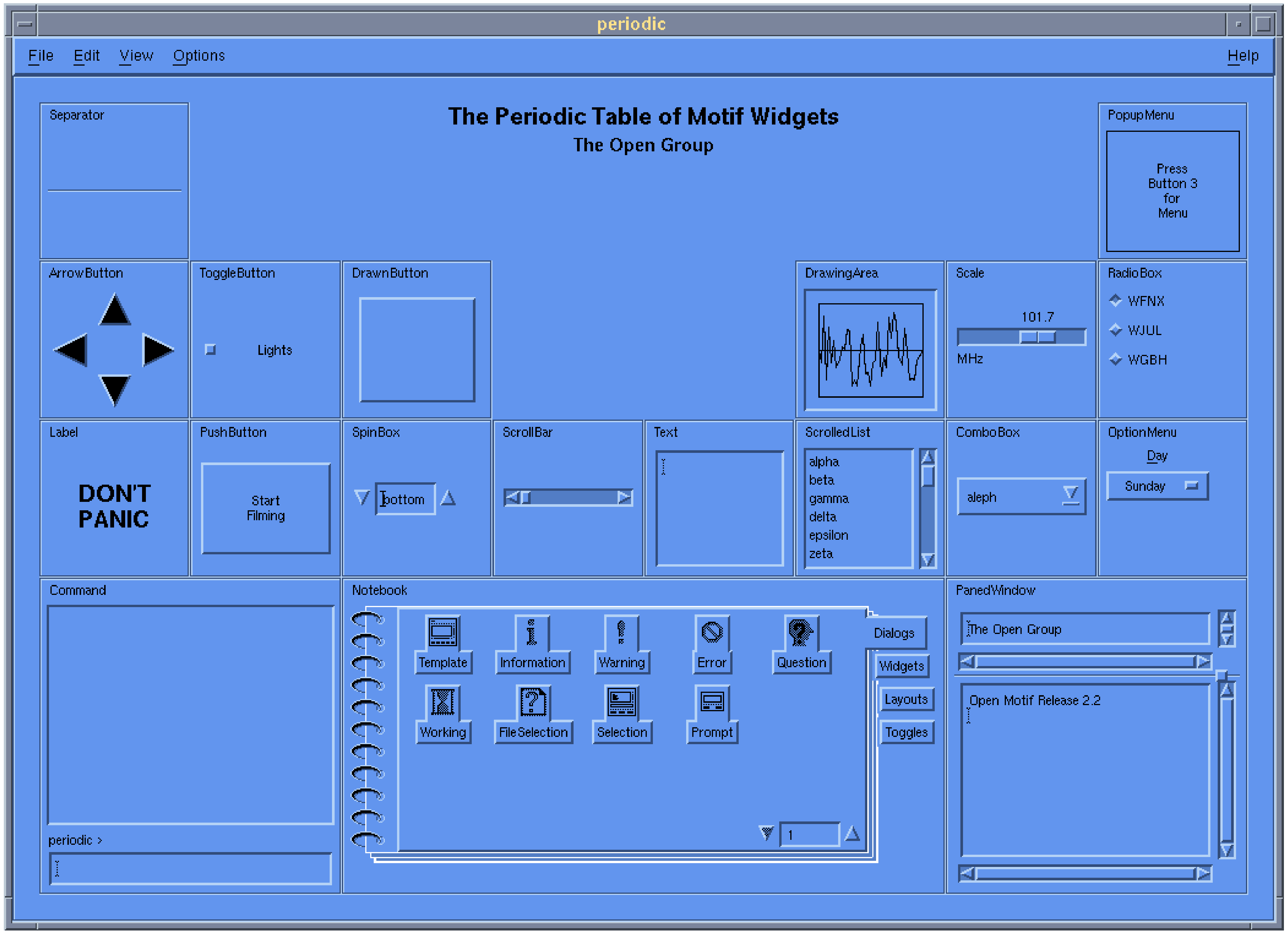
- Encapsulation and organization of interactive components ("widgets")
  - Typically using a class hierarchy with a top-level "Component" type implementing basic bounds management, and event processing
- Drawn using underlying 2D graphics library
- Input event processing and handling
  - Typically mouse and keyboard events
- Bounds management (damage/redraw)
  - Only redraw areas in need of updating

What are Some Examples of Components?

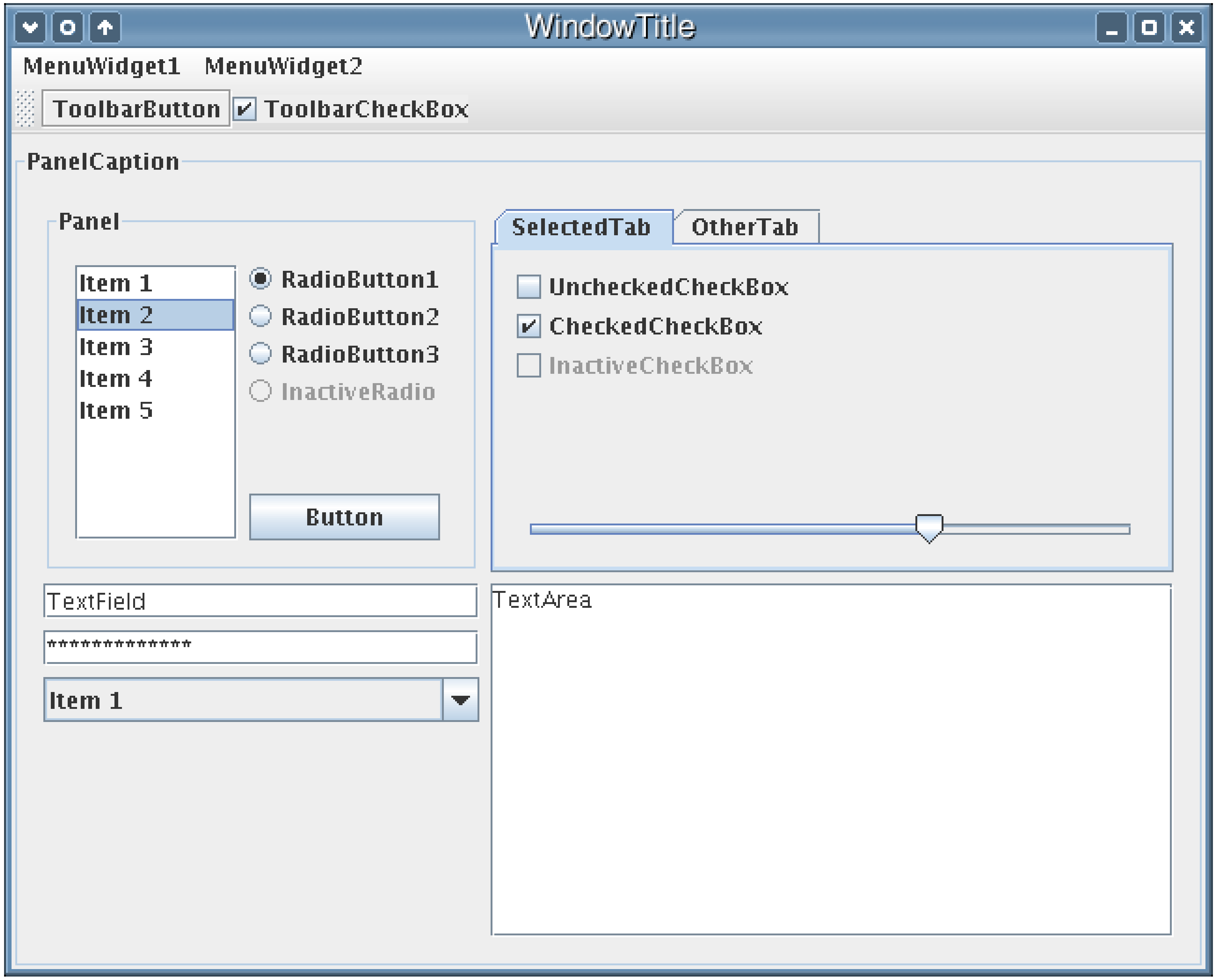
What are Some Examples of Components?

-Windows
-Layout panels
-Drawing panes
-Buttons
-Sliders
-Scrollbars
-Images
-Dropdown boxes
-Toolbars
-Menus
-Dialogue Boxes
-Progress indicators
-Video
-Icons
-Links
-Checkboxes
-Radio buttons
-Etc.

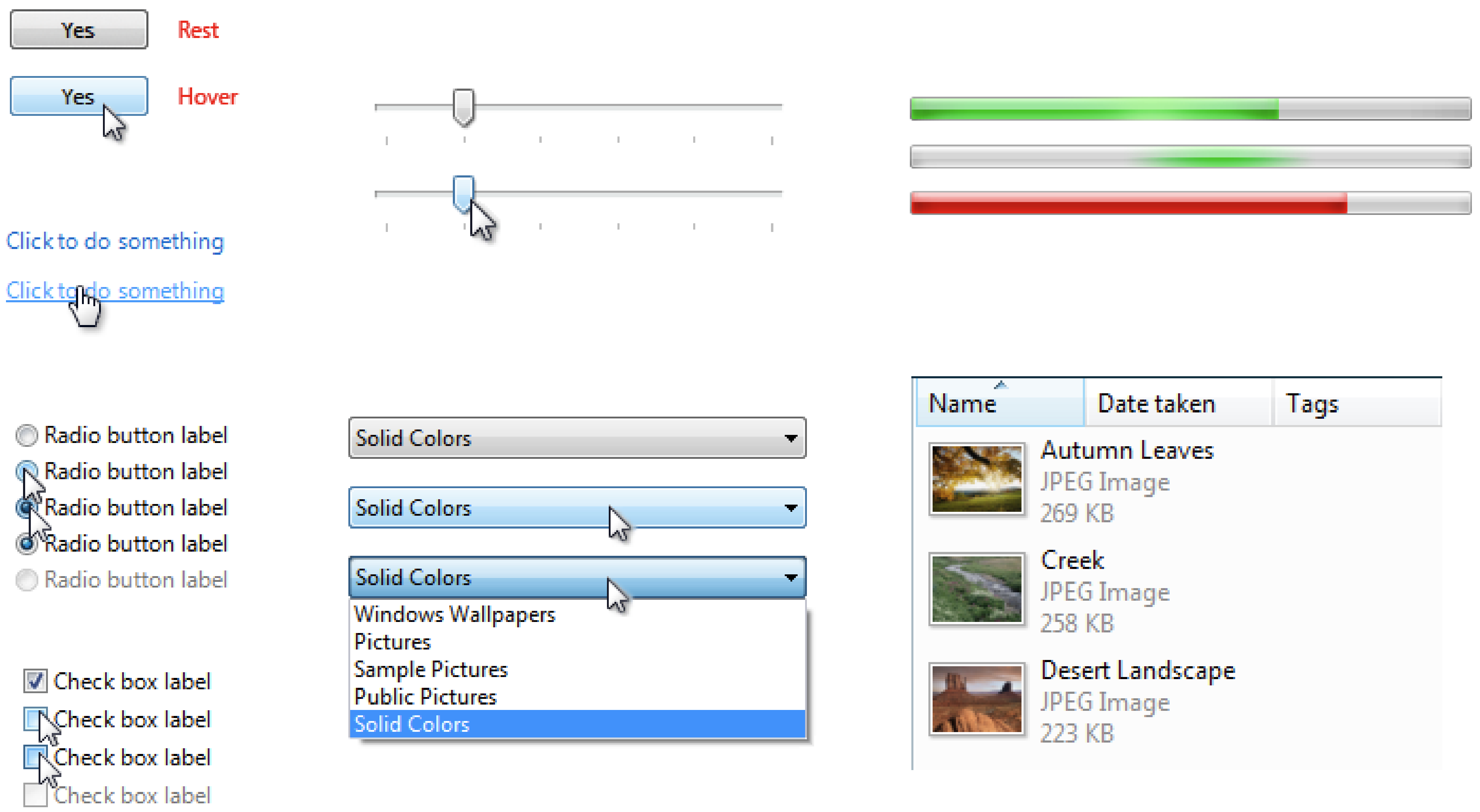
Periodic Table of Motif Widgets



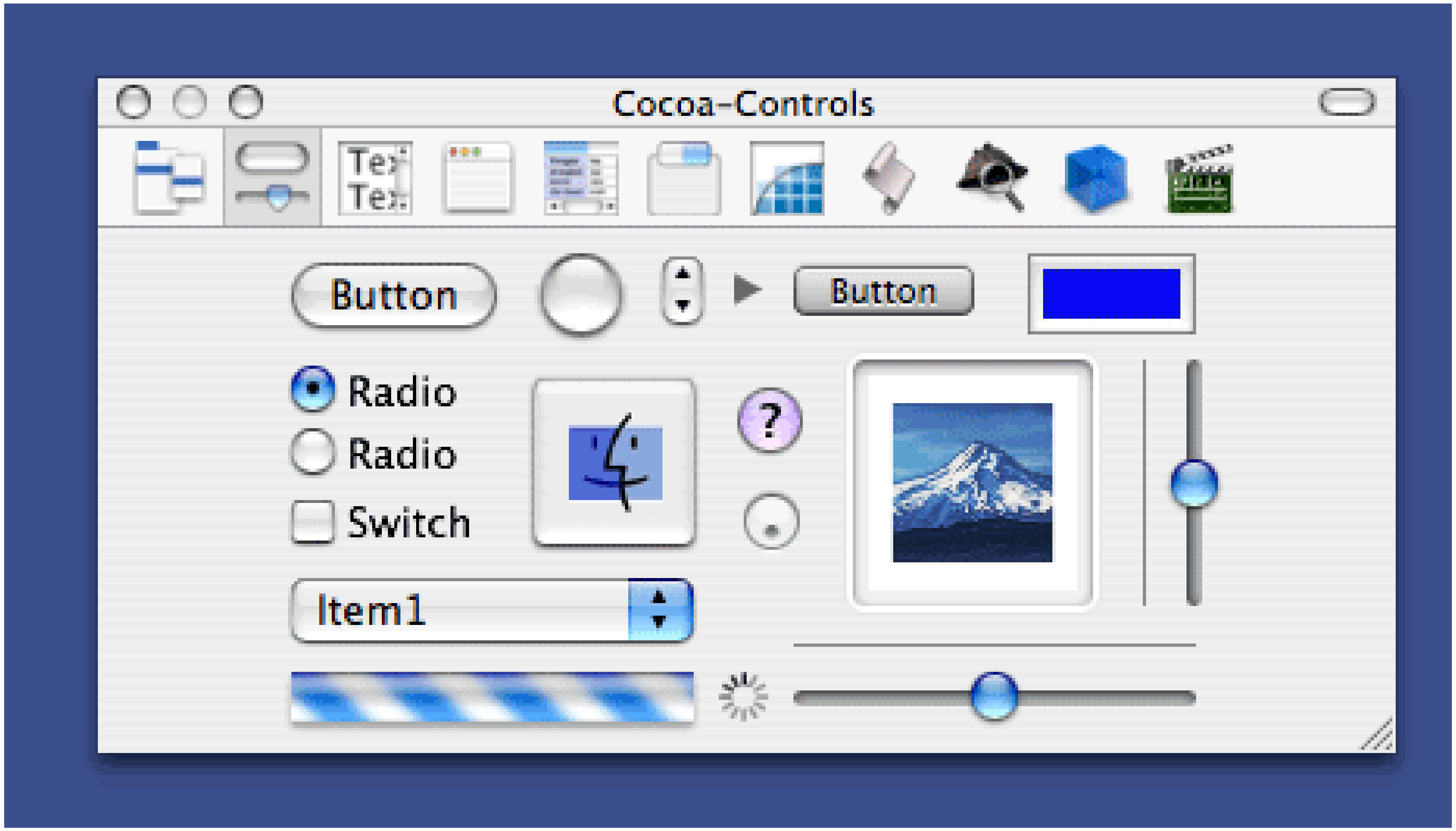
Java Swing Widgets



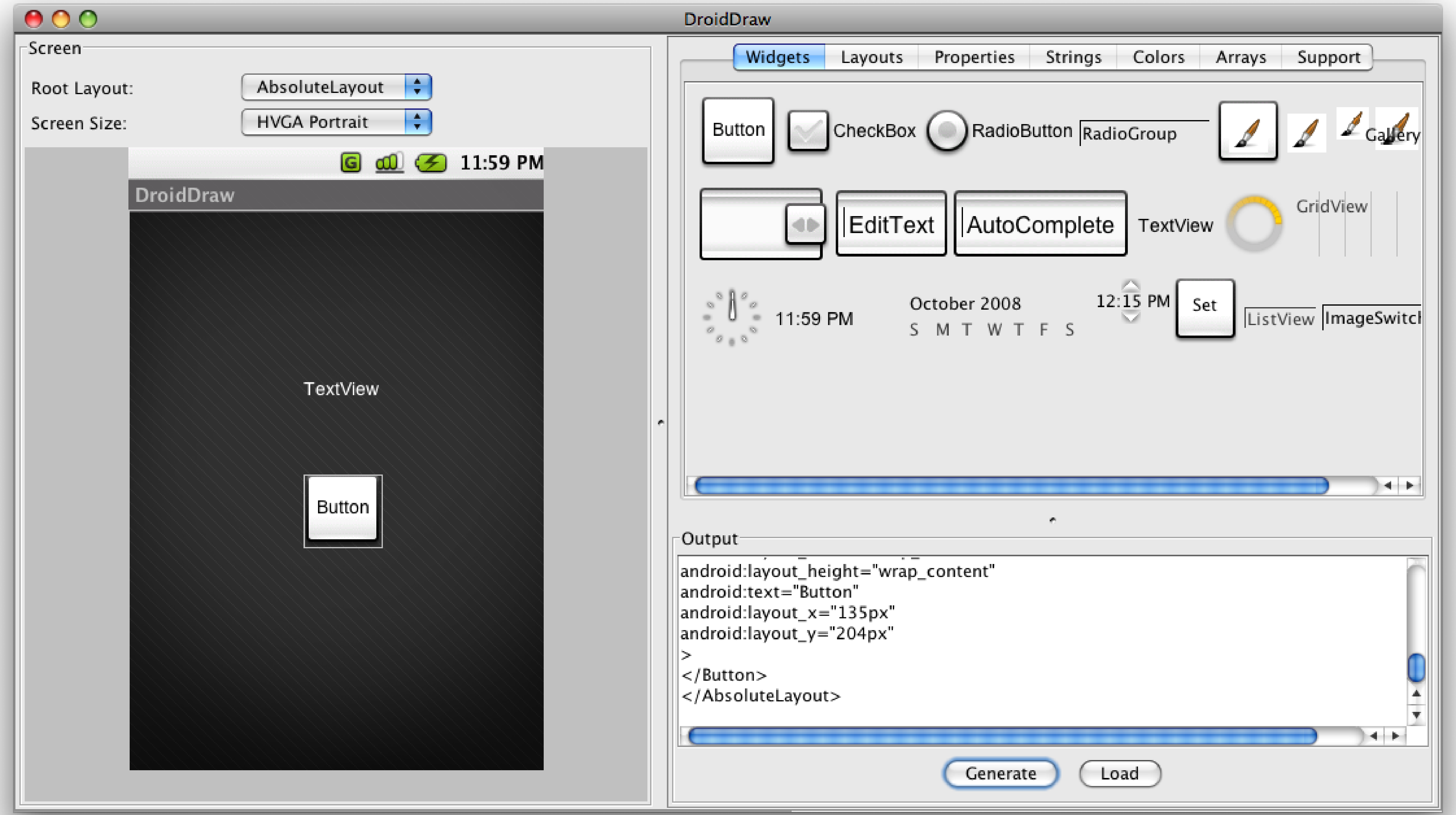
Windows Vista/.Net Widgets



Apple Cocoa Widgets



Android Widgets



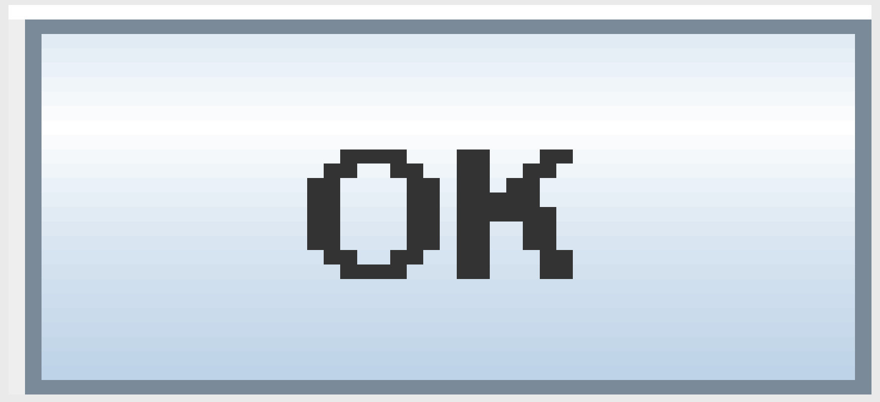
Root Layout: AbsoluteLayout
Screen Size: HVGA Portrait

```
android:layout_height="wrap_content"
android:text="Button"
android:layout_x="135px"
android:layout_y="204px"
>
</Button>
</AbsoluteLayout>
```

User Interface Components

Each component is an object with

- Bounding box
- Paint method for drawing itself
  - Drawn in the component's coordinate system
- Callbacks to process input events
  - Mouse clicks, typed keys

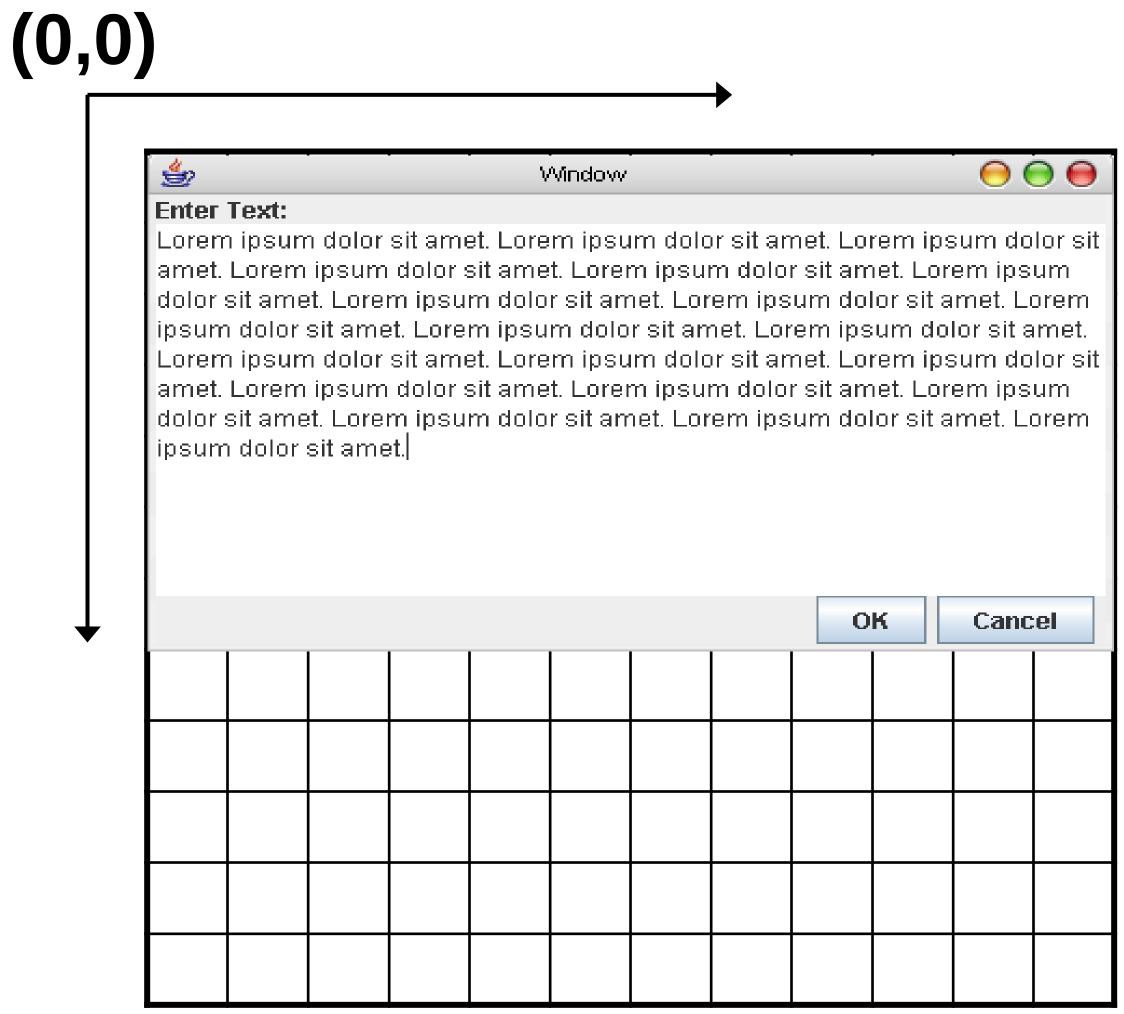


```
public void paint(Graphics g) {
   g.fillRect(…); // interior
   g.drawString(…); // label
   g.drawRect(…); // outline
}
```

2D Graphics Model

Every component is a clipped drawing canvas with a coordinate system

- Origin typically at top-left, increasing down and to the right
- Units depend on the output medium (e.g., pixels for screen)
- Rendering methods
  - Draw, fill shapes
  - Draw text strings
  - Draw images



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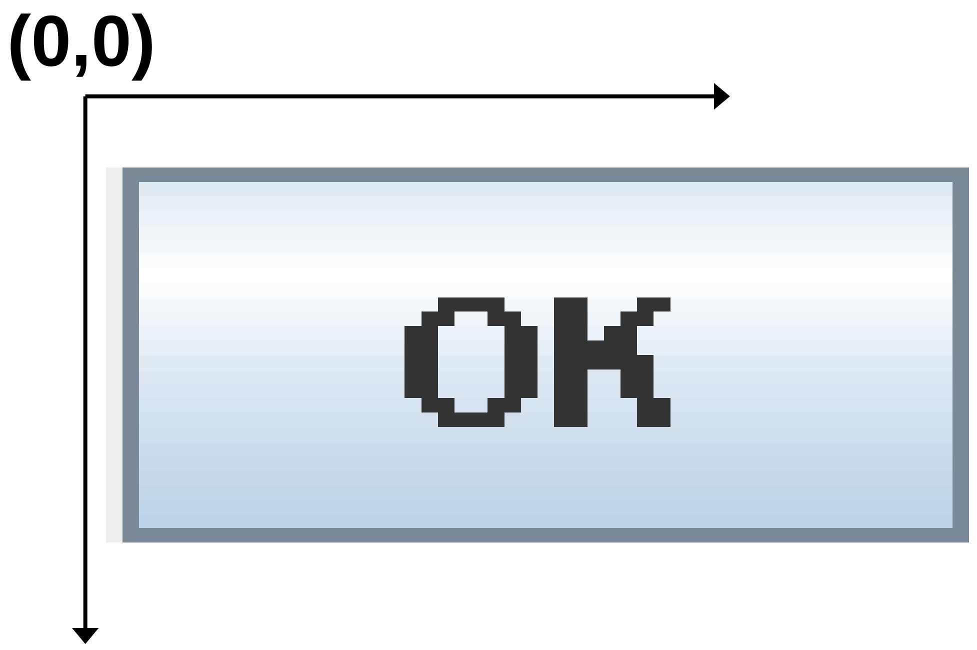
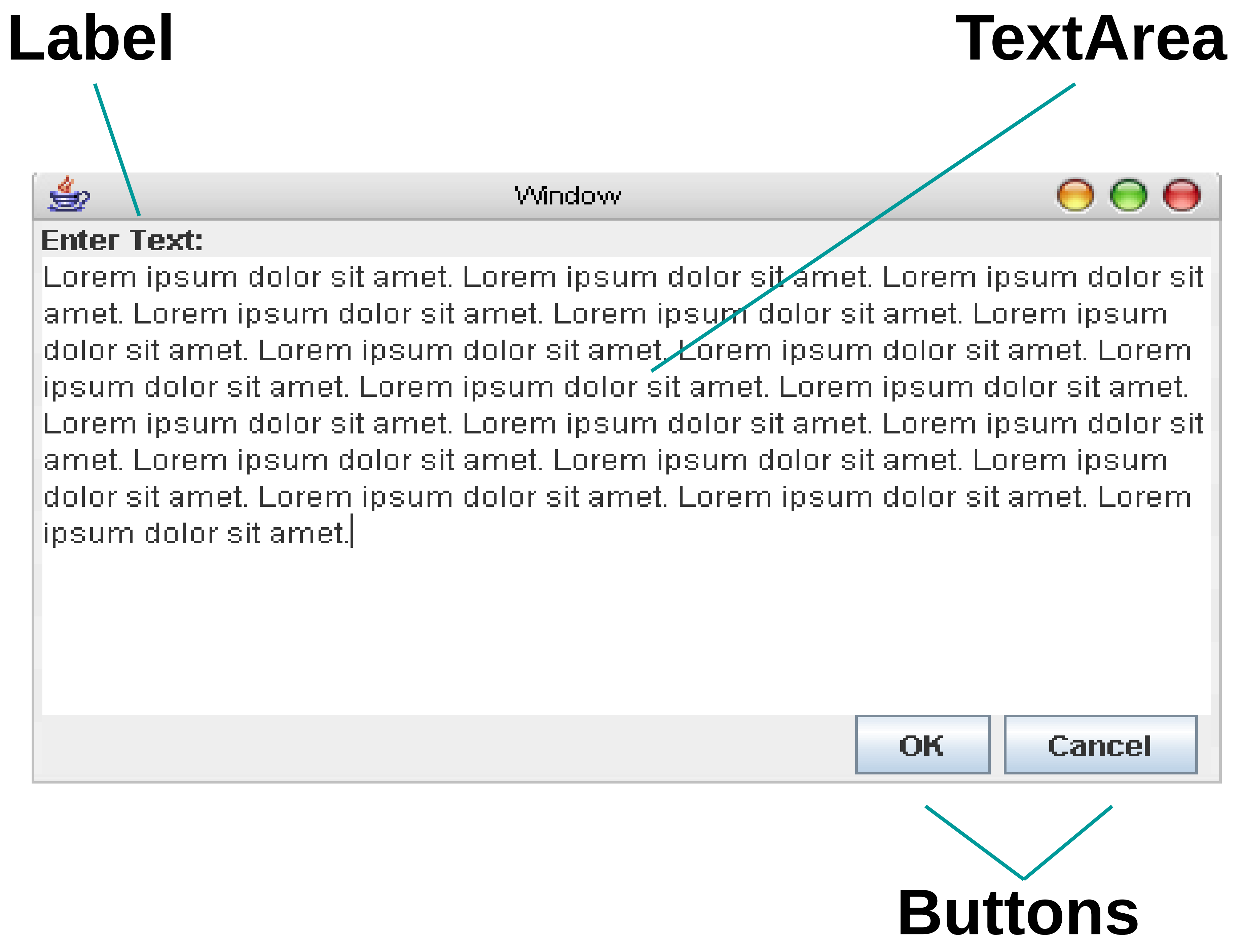


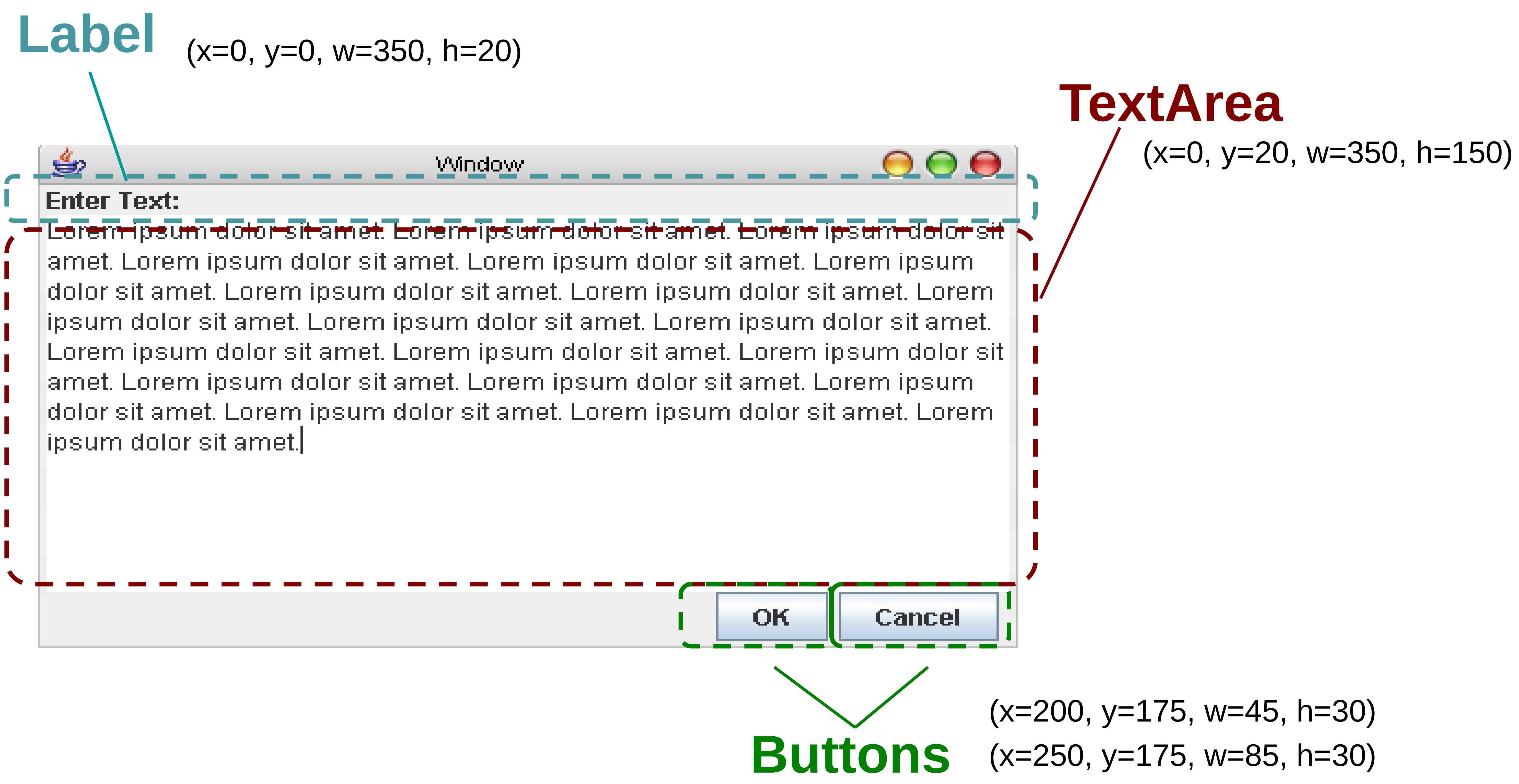
Composing a User Interface



Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet.

How might we instruct the computer to generate this layout?

Absolute Layout


Label
(x=0, y=0, w=350, h=20)
TextArea
(x=0, y=20, w=350, h=150)
Window
Enter Text:
OK
Cancel
Buttons
(x=200, y=175, w=45, h=30)
(x=250, y=175, w=85, h=30)

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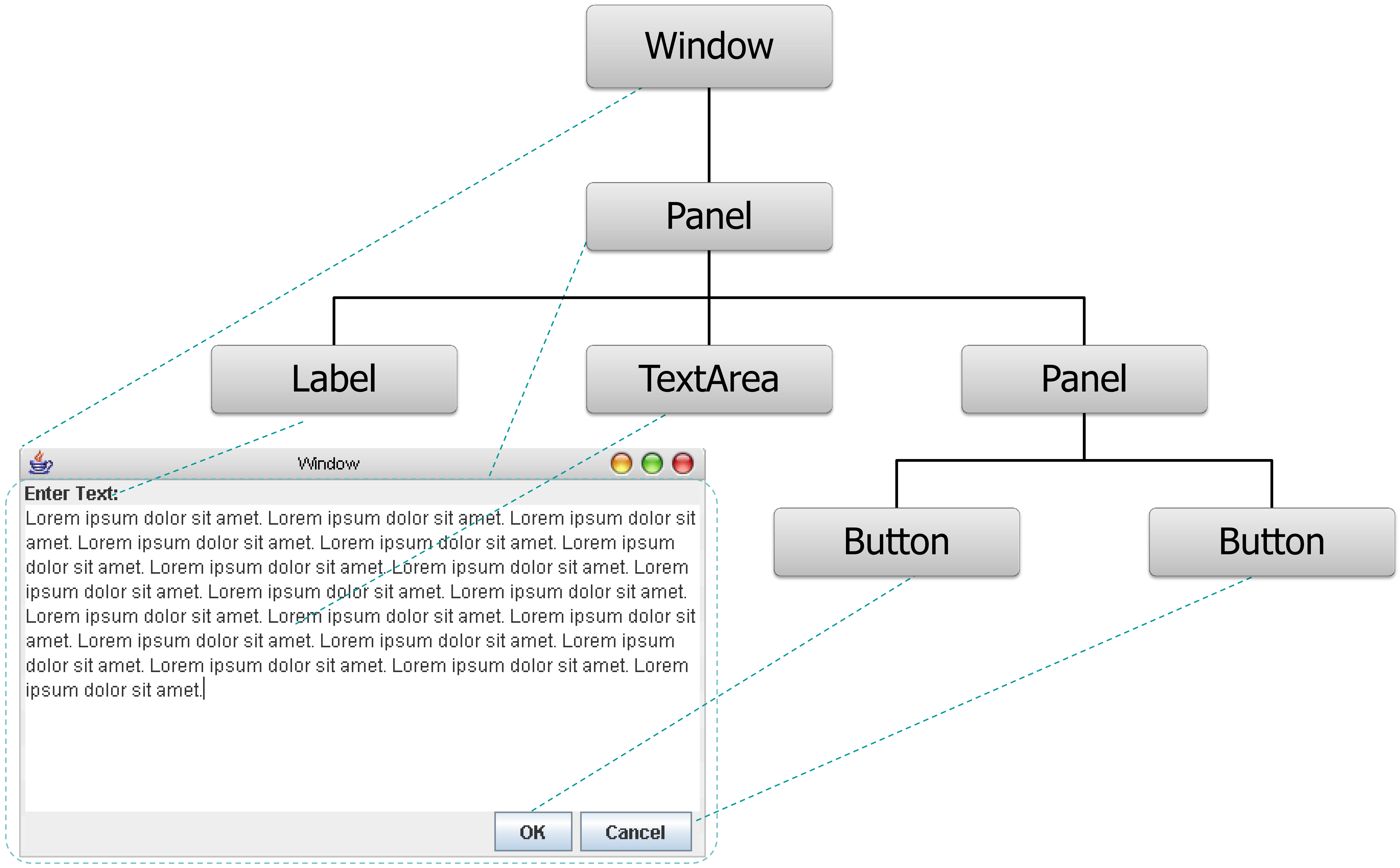
But this is inflexible and doesn't scale or resize well.

Containment Hierarchy



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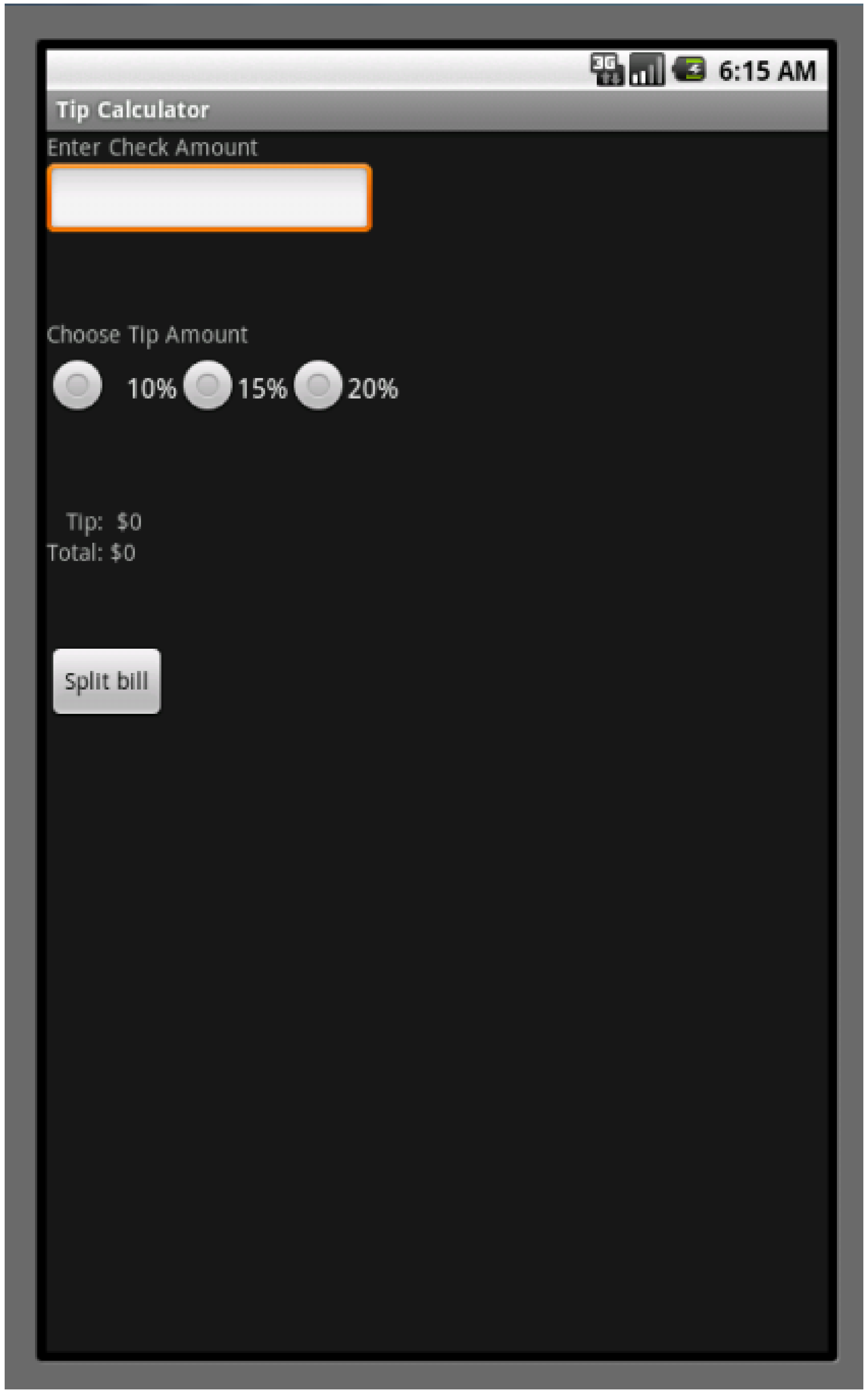
In Android

Declarative layout, main.xml:

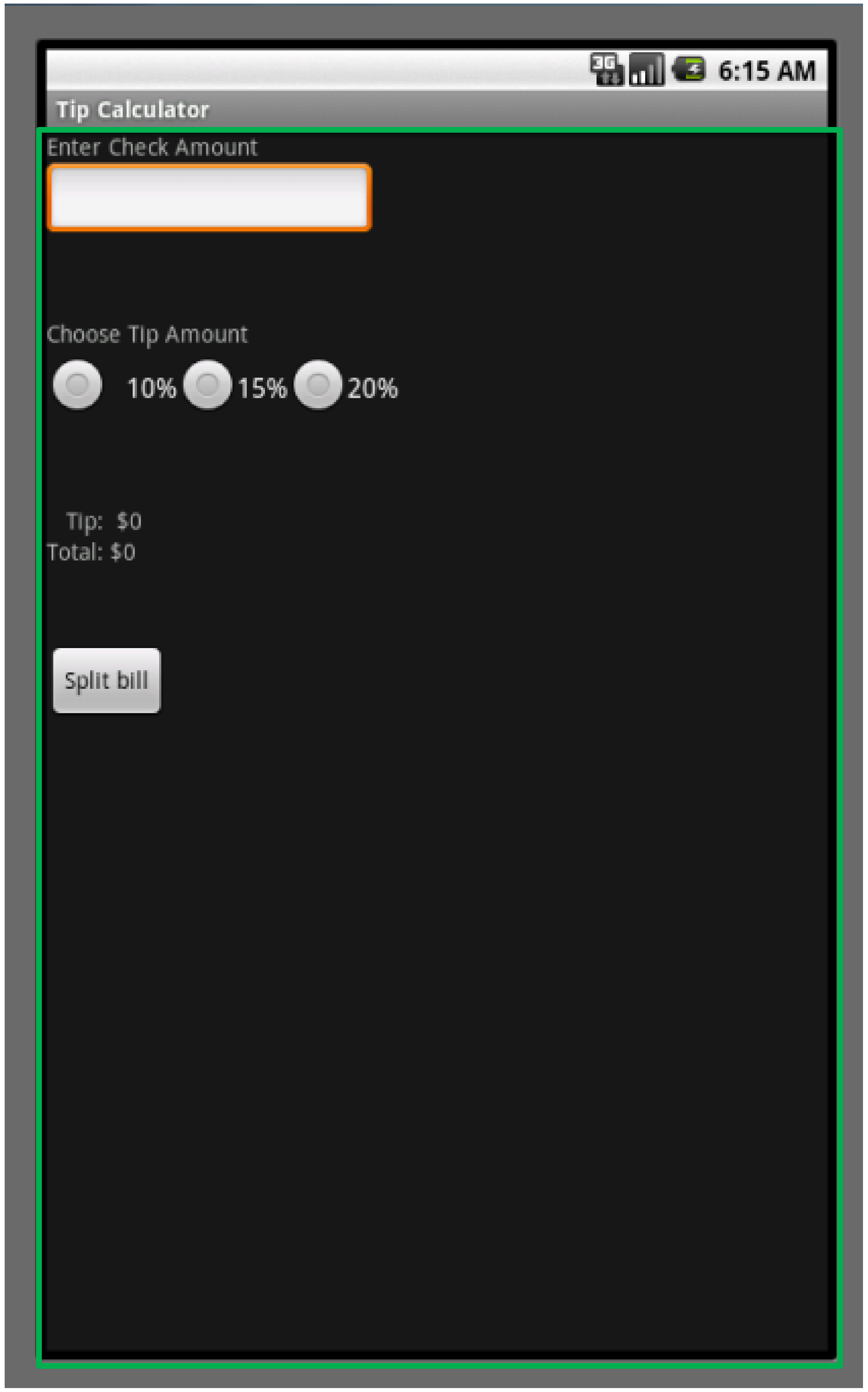
```
  <?xml version="1.0" encoding="utf-8" ?>
- <LinearLayout xmlns:android="http://schemas.android.com/apk/res/android" android:orientation="vertical" android:layout_width="fill_parent"
    android:layout_height="fill_parent" android:gravity="left">
    <TextView android:layout_width="wrap_content" android:layout_height="wrap_content" android:text="@string/enter_amt" />
    <EditText android:id="@+id/editText1" android:layout_width="200px" android:layout_height="wrap_content" android:numeric="decimal" />
    <FrameLayout android:layout_width="fill_parent" android:layout_height="0px" android:layout_weight="1" />
    <TextView android:layout_width="wrap_content" android:layout_height="wrap_content" android:text="@string/choose_tip" />
  - <RadioGroup android:layout_width="wrap_content" android:layout_height="wrap_content" android:orientation="horizontal" android:id="@+id/tipGroup1">
      <RadioButton android:checked="false" android:id="@+id/option1" android:text="10%" />
      <RadioButton android:checked="false" android:id="@+id/option2" android:text="15%" />
      <RadioButton android:checked="false" android:id="@+id/option3" android:text="20%" />
    </RadioGroup>
    <FrameLayout android:layout_width="fill_parent" android:layout_height="0px" android:layout_weight="1" />
    <TextView android:id="@+id/tipVal" android:layout_width="wrap_content" android:layout_height="wrap_content" android:text="Tip: $0" />
    <TextView android:id="@+id/totalVal" android:layout_width="wrap_content" android:layout_height="wrap_content" android:text="Total: $0" />
    <FrameLayout android:layout_width="fill_parent" android:layout_height="0px" android:layout_weight="1" />
    <Button android:id="@+id/splitButton" android:layout_width="wrap_content" android:layout_height="wrap_content" android:text="Split bill" />
    <FrameLayout android:layout_width="fill_parent" android:layout_height="0px" android:layout_weight="8" />
  </LinearLayout>
```

In Android

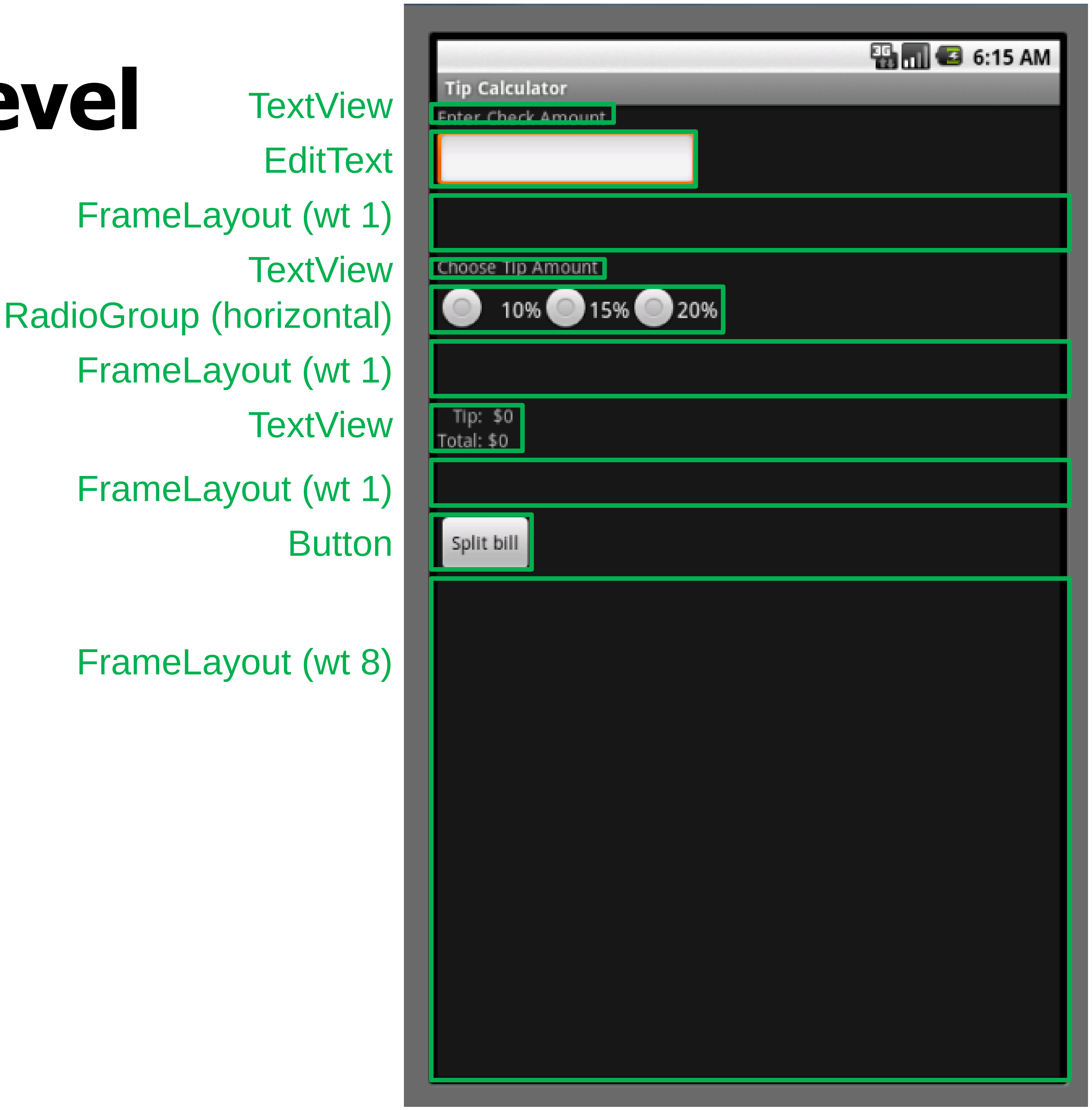

6:15 AM
Tip Calculator
Enter Check Amount
Choose Tip Amount
10%
15%
20%
Tip: $0
Total: $0
Split bill

Root View

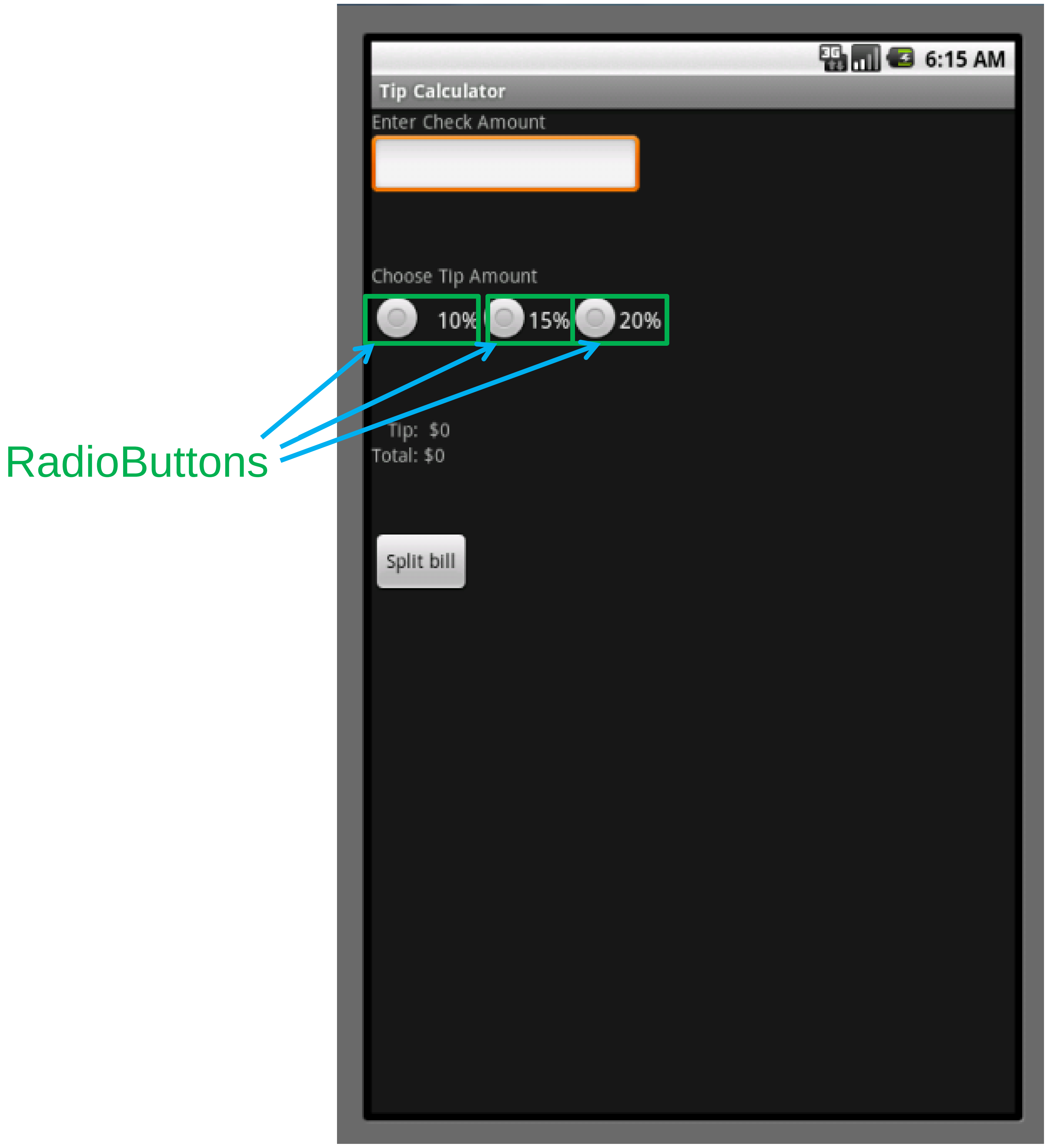
LinearLayout
(vertical)



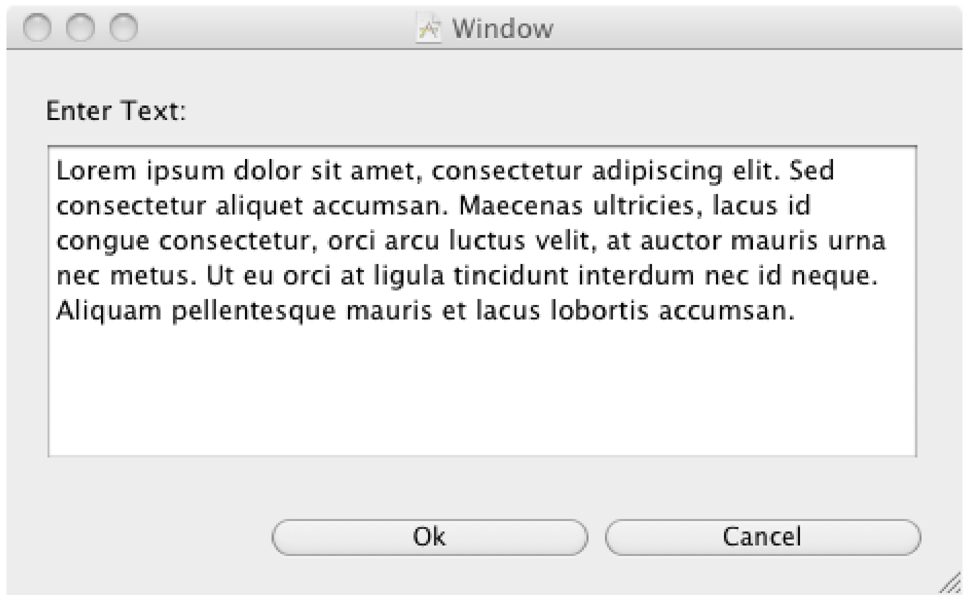
Next level


TextView
EditText
FrameLayout (wt 1)
TextView
RadioGroup (horizontal)
FrameLayout (wt 1)
TextView
FrameLayout (wt 1)
Button
FrameLayout (wt 8)
6:15 AM
Tip Calculator
Enter Check Amount
Choose Tip Amount
10%
15%
20%
Tip: $0
Total: $0
Split bill

Leaves


RadioButtons
6:15 AM
Tip Calculator
Enter Check Amount
Choose Tip Amount
10%
15%
20%
Tip: $0
Total: $0
Split bill

c.f. Layout in Cocoa: Springs + Struts



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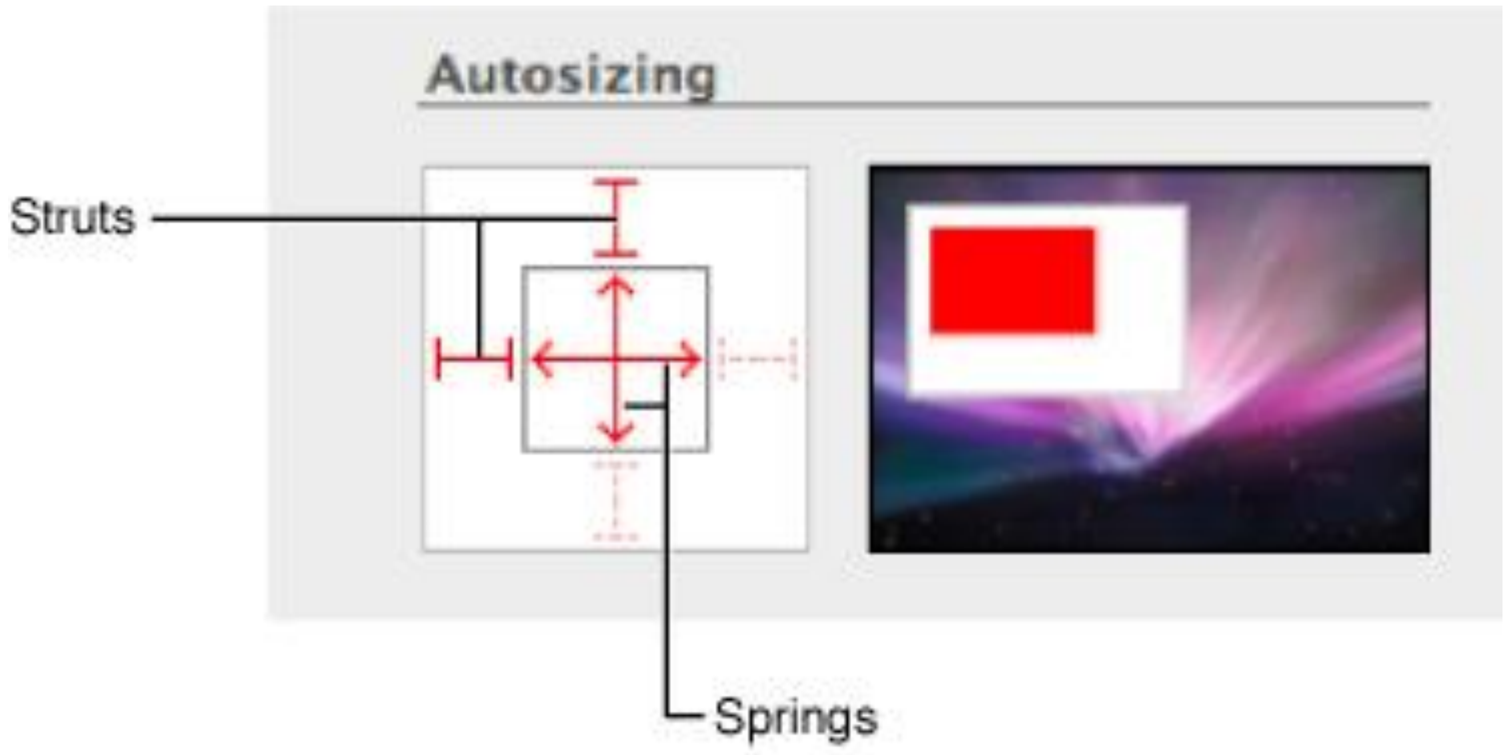


In Android

You can always use code for your layout (procedural layout):

```
lay1 = (LinearLayout)this.findViewById(R.id.mainFrame);
tv1 = new TextView(this);
lay1.add(tv1);      // Makes the textView a child of the LinearLayout View
fl1 = new FrameLayout(this);
fl1.LayoutParams(MATCH_PARENT, 0px, 1); // width, height, weight
lay1.add(fl1);
```

And create struct and spring space with variables. Then to update, override the **onLayout** method.

Events

Events

User input is modeled as events that must be handled by the system and applications.

- Mouse input (and touch, pen, etc.)
    - Mouse entered, exited, moved, clicked, dragged
    - **Inferred events**: double-clicks, gestures
- Keyboard (key down, key up)
- Sensor inputs
- Window movement, resizing

Anatomy of an Event

An event encapsulates the information needed for handlers to react to the input

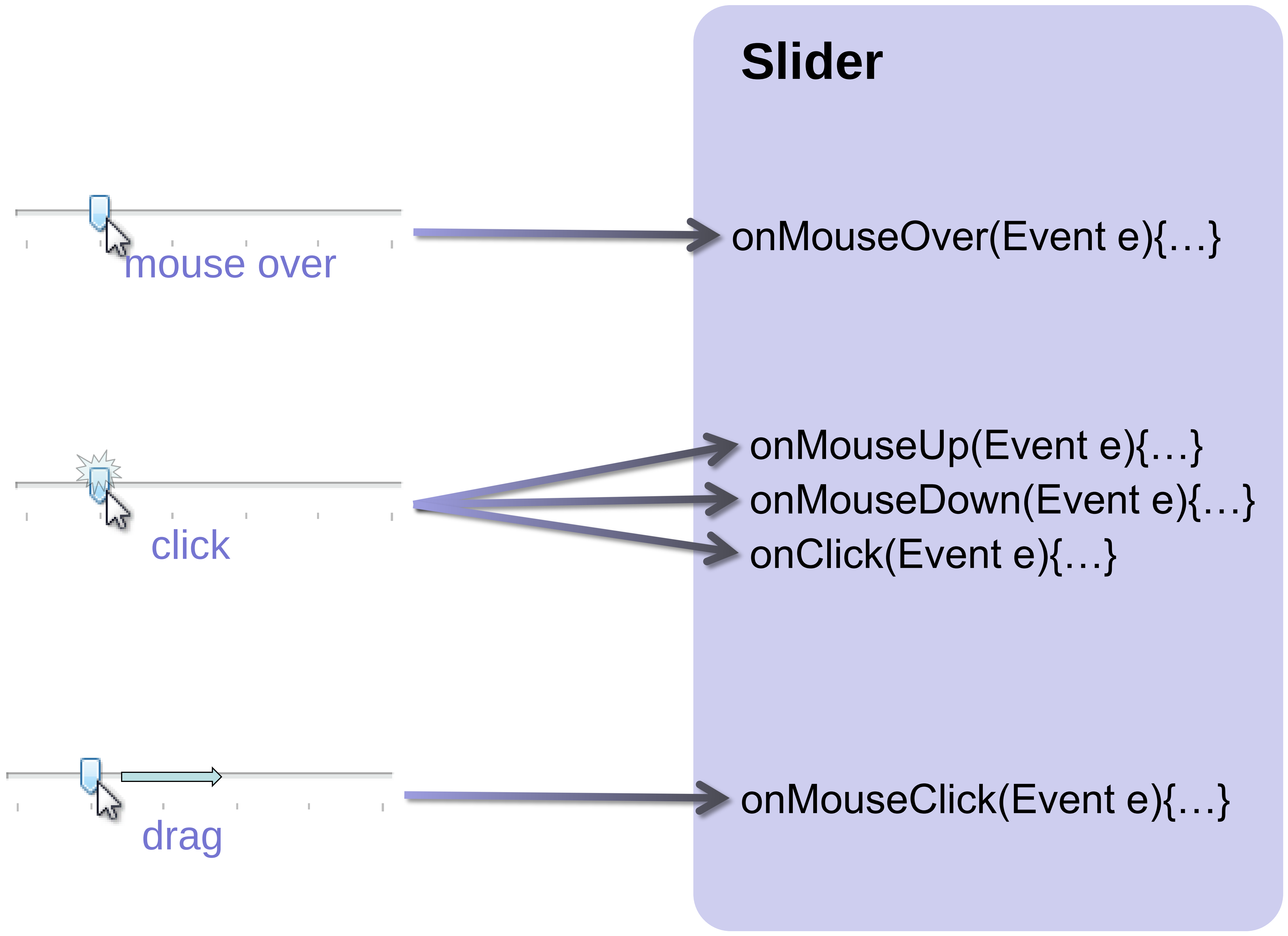
- Event Type (mouse moved, key down, etc)
- Event Source (the input component)
- Timestamp (when did event occur)
- Modifiers (Ctrl, Shift, Alt, etc)
- Event Content
  - Mouse: x,y coordinates, button pressed, # clicks
  - Keyboard: which key was pressed

Events

Level of abstraction may vary. Consider:

- **Mouse down** vs. **double click** vs. **drag**
- **Pen move** vs. **gesture**

Callbacks


Slider
mouse over
onMouseOver(Event e){…}
click
onMouseUp(Event e){…}
onMouseDown(Event e){…}
onClick(Event e){…}
drag
onMouseClick(Event e){…}

Event Dispatch Loop

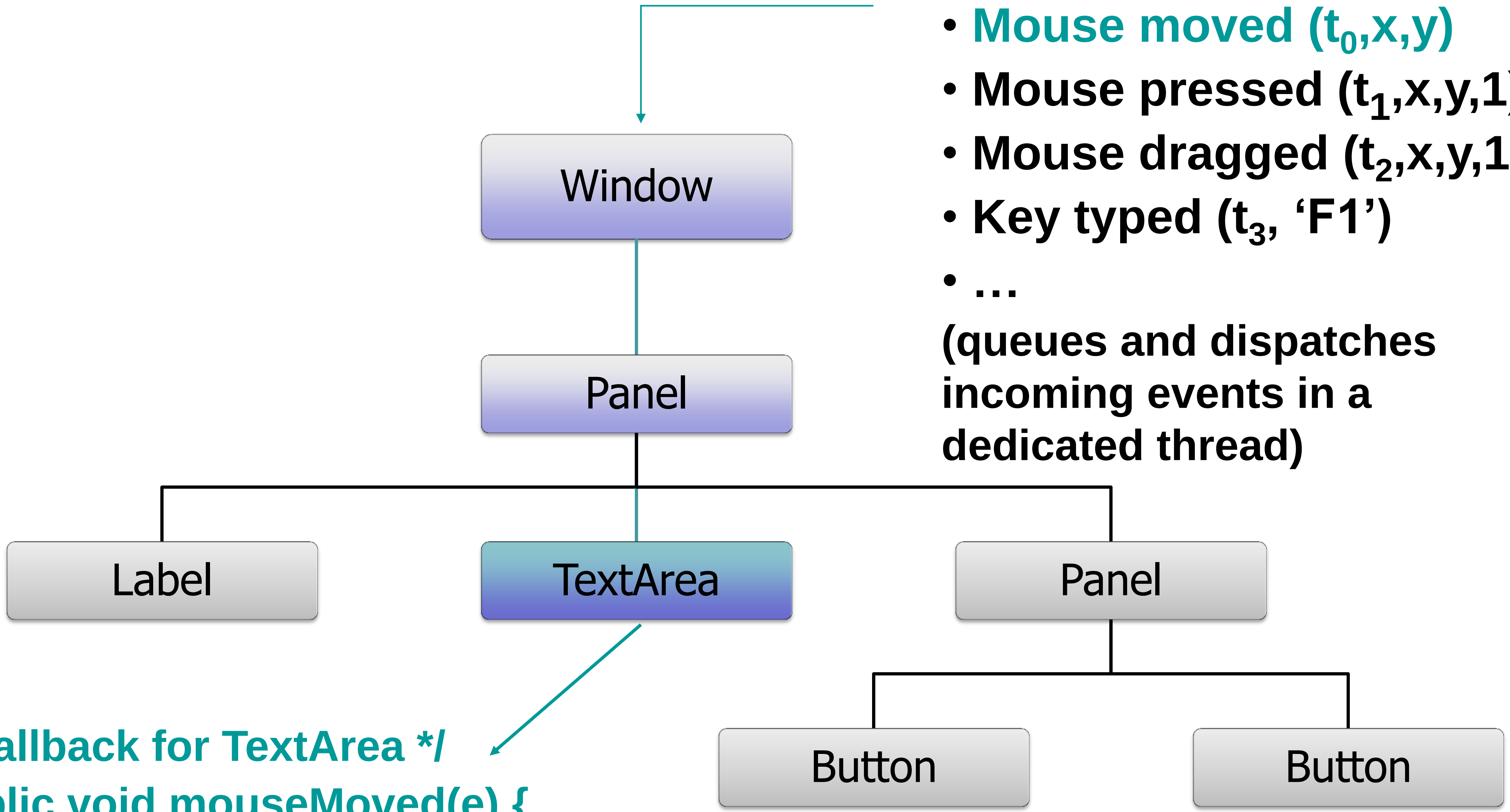
Mouse moved (t_0,x,y)

Event Queue
- Queue of input events

Event Loop (runs in dedicated thread)
- Remove next event from queue
- Determine event type
- Find proper component(s)
- Invoke callbacks on components
- Repeat, or wait until event arrives

Component
- Invoked callback method
- Update application state
- Request repaint, if needed

Event Dispatch



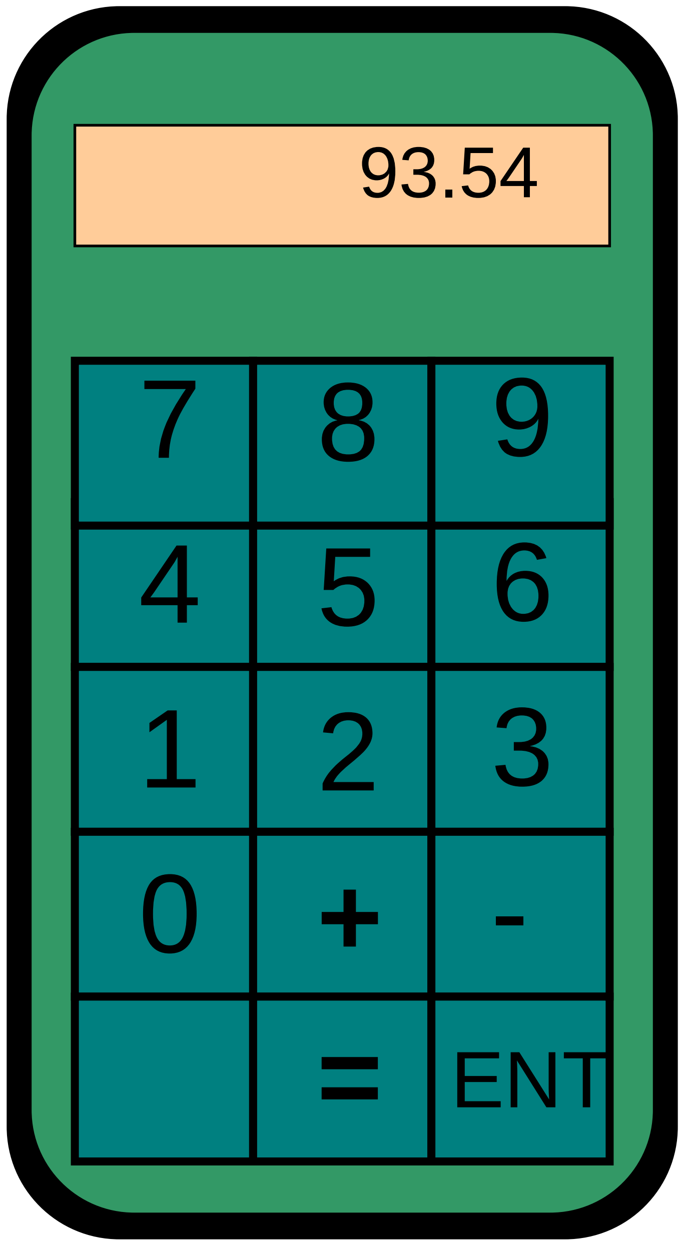
Event Queue

- **Mouse moved (t_0,x,y)**
- **Mouse pressed (t_1,x,y,1)**
- **Mouse dragged (t_2,x,y,1)**
- **Key typed (t_3, ‘F1’)**
- **…**

(queues and dispatches incoming events in a dedicated thread)

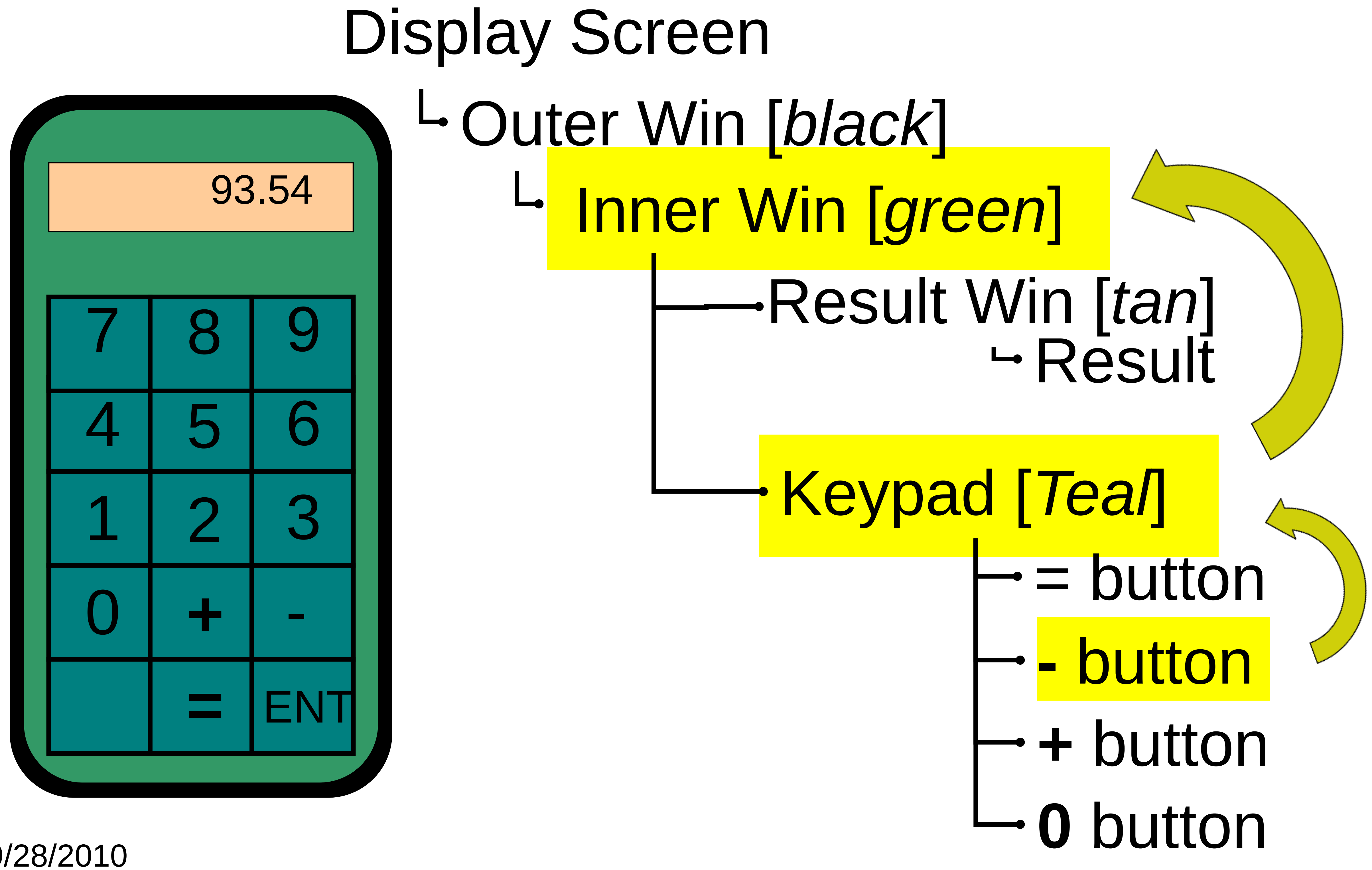
```
/* callback for TextArea */
public void mouseMoved(e) {
    // process mouse moved event
}
```

Interactor Tree



- Display Screen
  - Outer Win [*black*]
    - Inner Win [*green*]
      - Result Win [*tan*]
        - Result String
      - Keypad [*Teal*]
        - = button
        - **-** button
        - **+** button
        - **0** button

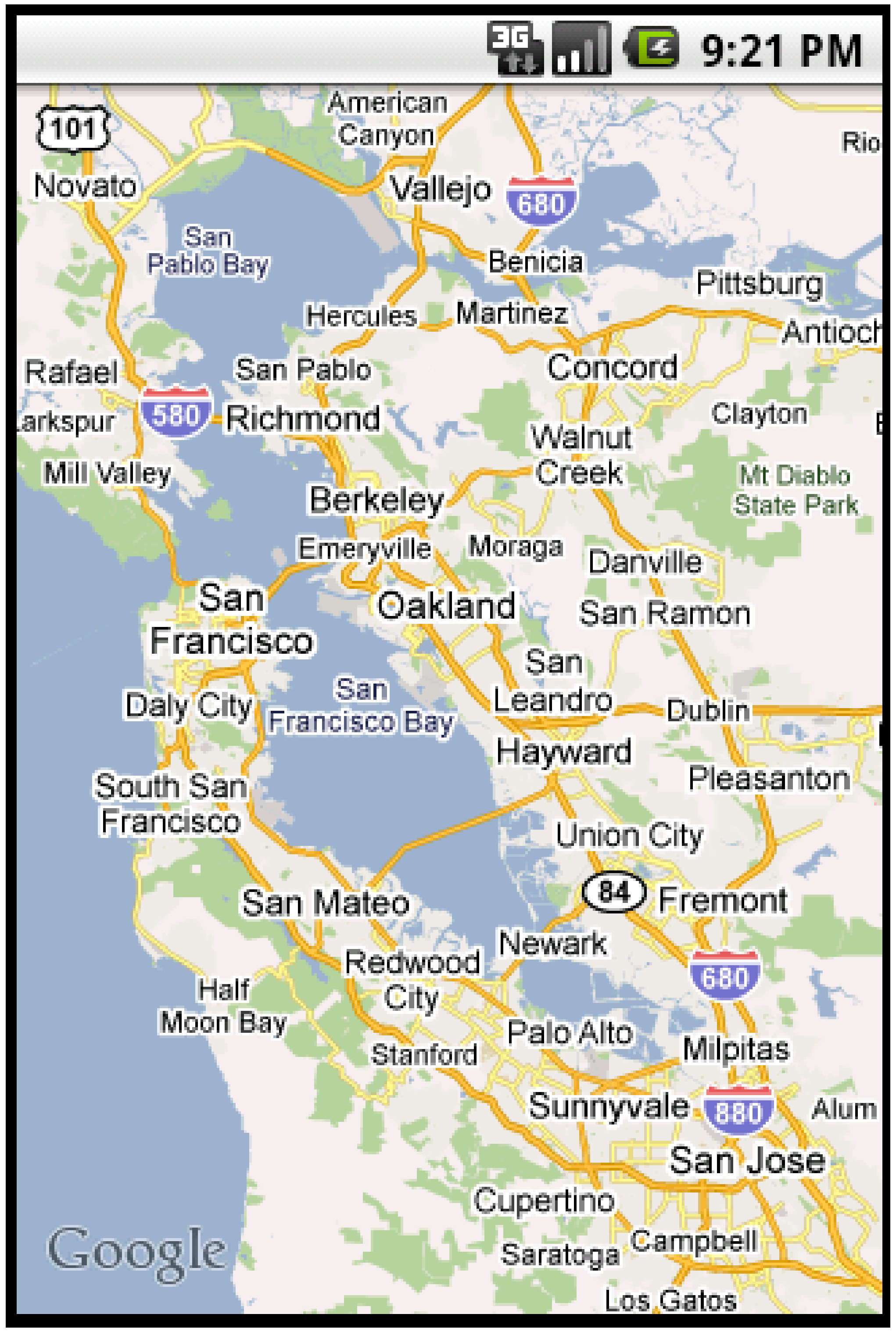
“Front” window gets event, decides whether to handle it.
- may decide to pass it on (by boolean return value).



Overlays

Sometimes the complexity in an existing widget makes it difficult to add event-handlers or draw methods to it

e.g. MapView



Overlays

An overlay sits "above" the other View and receives events first.

Handles onTouch() and onTap()

It should always forward events it doesn't want to deal with (return false in Android) so the main widget still works.

Code Style

There are several ways to use events:

```
Public class myApp extends Activity
        implements View.onClickListener, View.someOtherListener {

Public void onClick(View v)
        // figure out who handles the event

Public void onSomeOtherEvent(View v)
        // figure out who handles the event
```

Code Style

Or:

```
Public class myApp extends Activity {

  Public class myClickListener implements View.onClickListener {
     // handle the event for one widget
    Public void onClick(View w) {
         …
     }

  Public void onCreate(…) {
     myWidget.setOnClickListener(new myClickListener());
```

Code Style

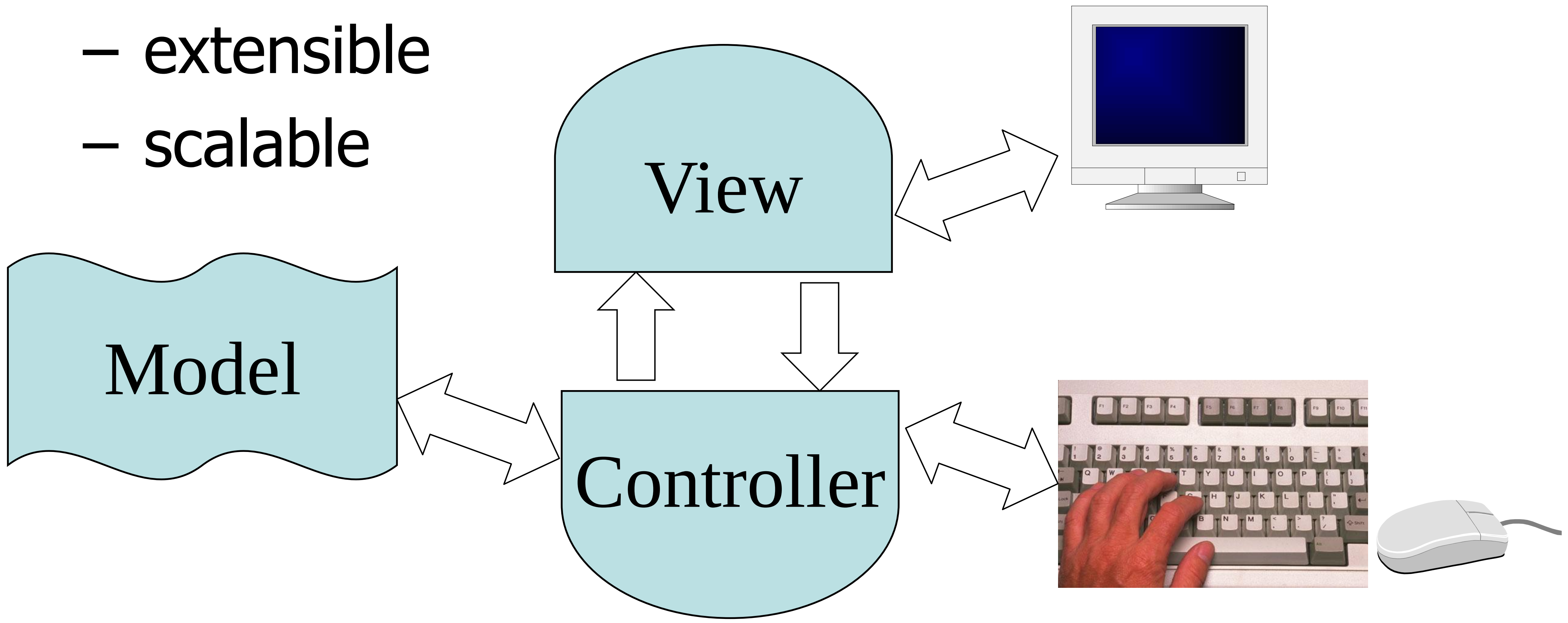
Tradeoffs:

- Activity-level:
  - Big switch statement to funnel event to right widget
  - Less modular
- Inner class:
  - Per-widget code only in onClick() methods
  - Much more modular
  - More memory to create classes? Perhaps – but they are very small objects.

Model-View-Controller Architecture

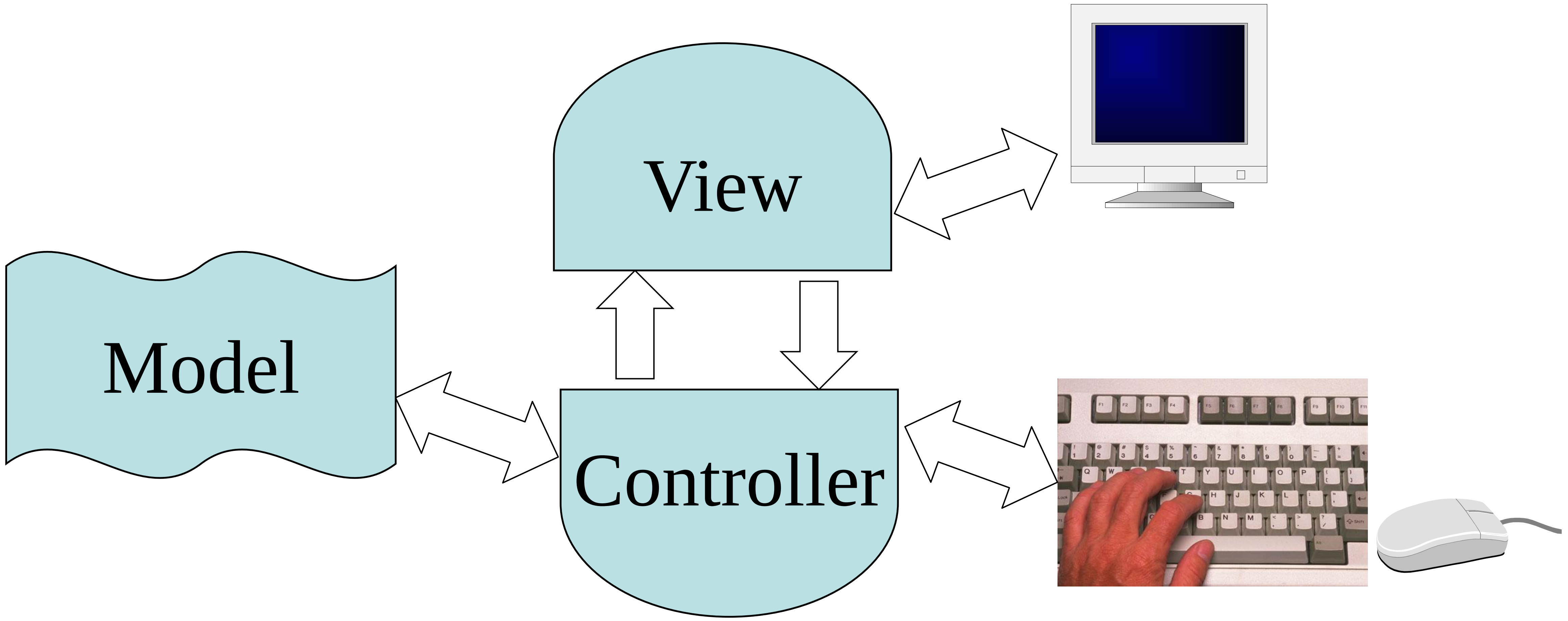
Model-View-Controller

- Architecture for interactive apps
  - introduced by Smalltalk developers at PARC
- Partitions application in a way that is
  - maintainable
  - extensible
  - scalable



Model-View-Controller

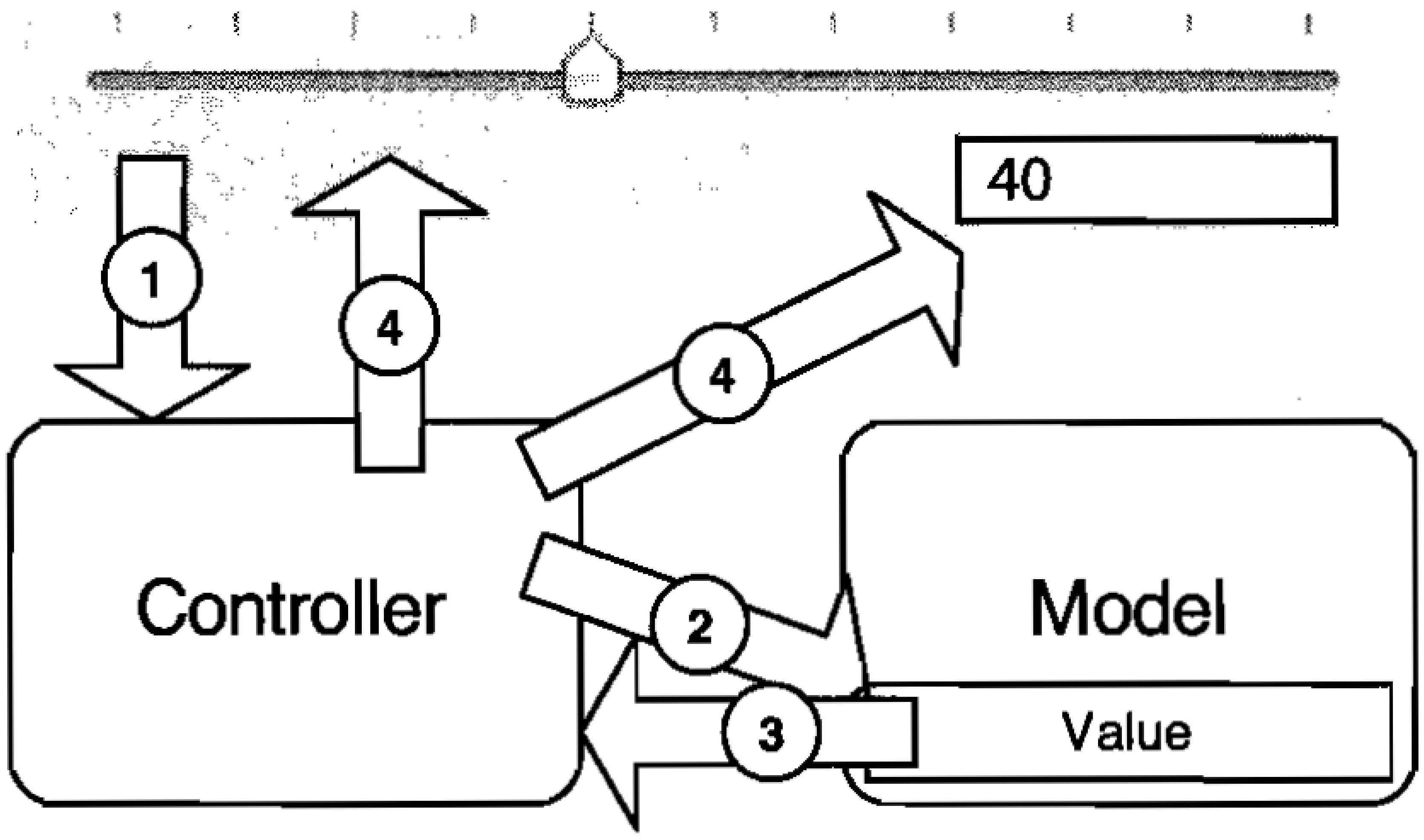
Idea is that the controller **mediates** between views (different representations of data) and the data itself, which is in the model.



Model-View-Controller

Is a general software design pattern

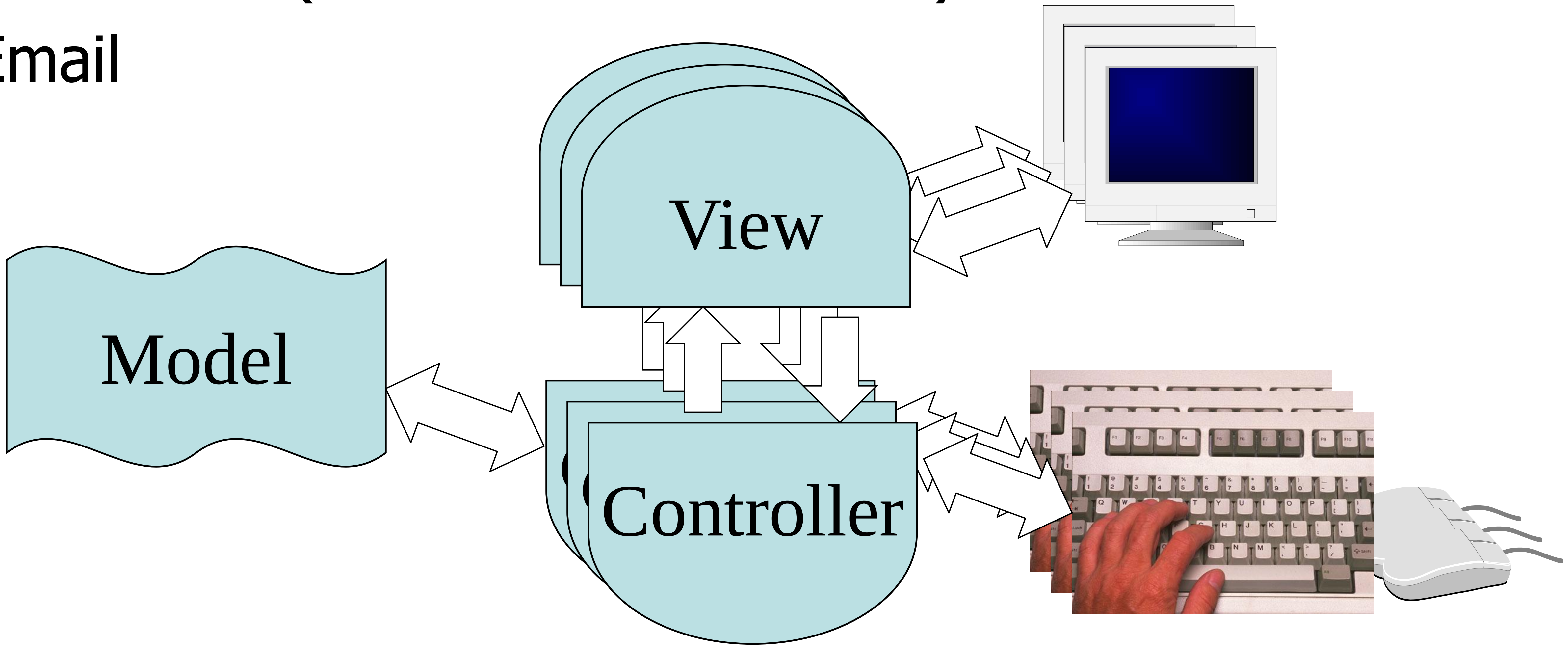
Very explicit in the Cocoa Framework



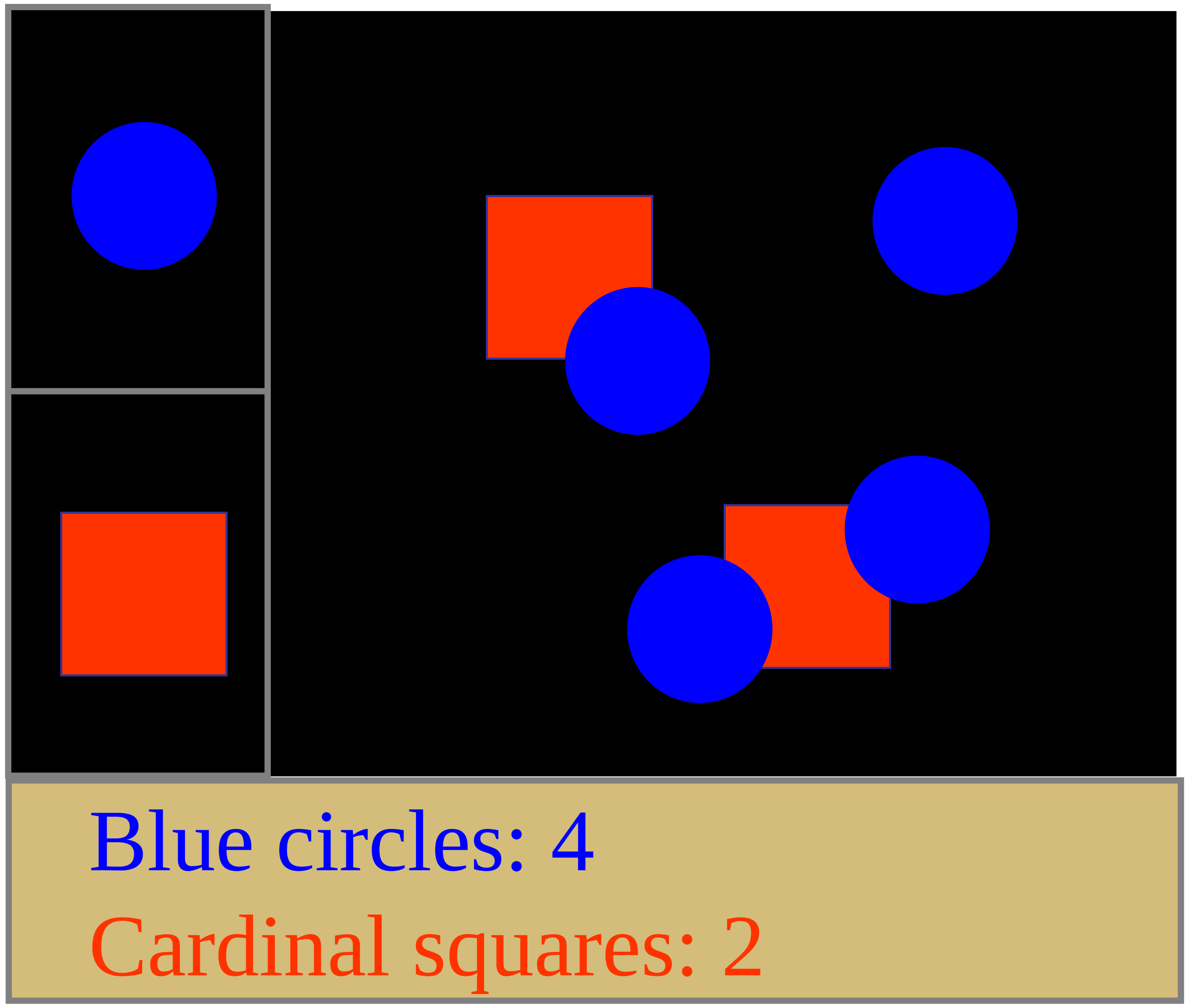
Model-View-Controller

Similar to the architecture of client-server systems:

- Amazon
- Spreadsheet views of DBs
- MMORPG's (World of Warcraft etc.)
- Email



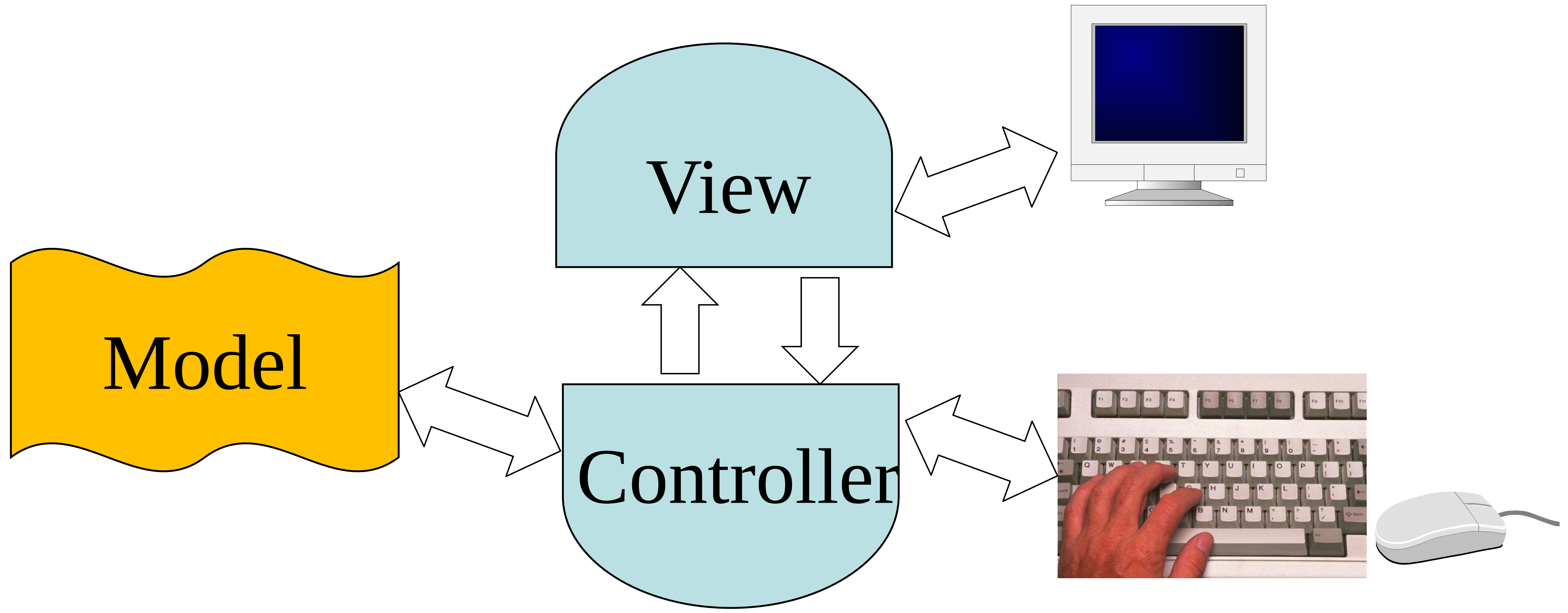
Example Application



Blue circles: 4

Cardinal squares: 2

Model

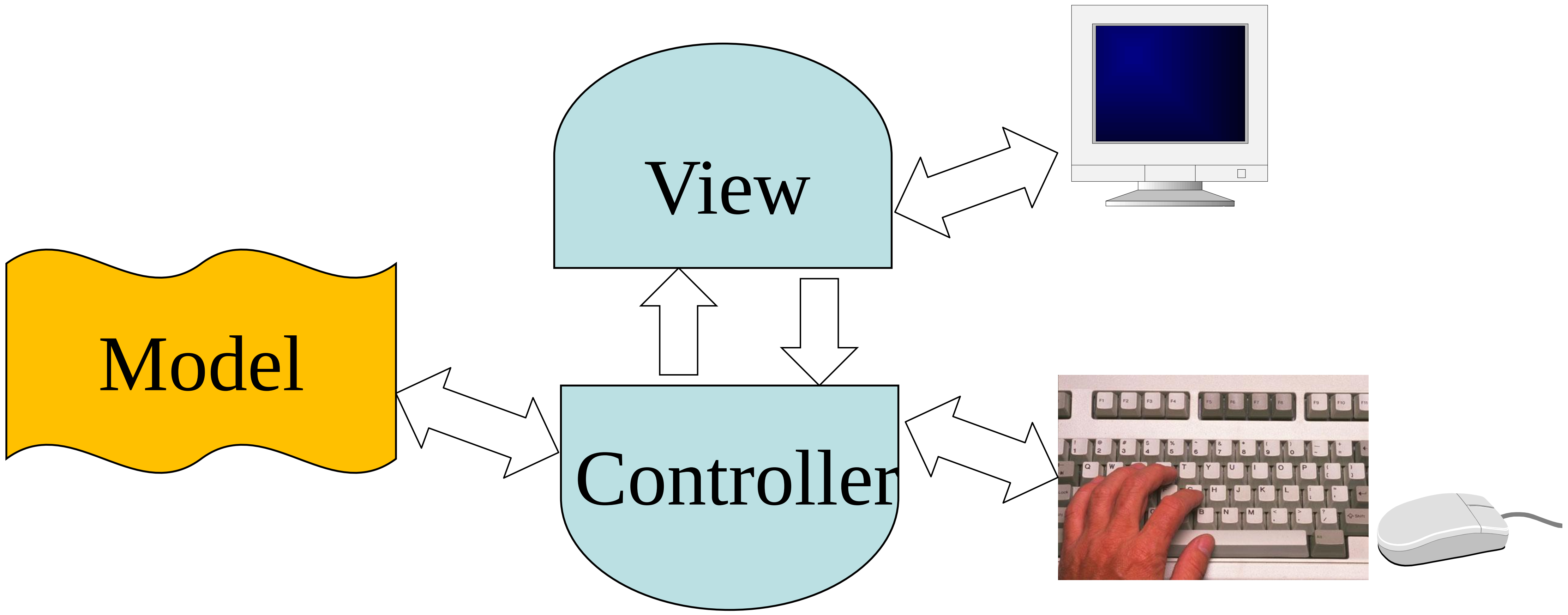


Information the app is trying to manipulate

Representation of real world state

- shapes in a drawing program
- document contents
- game state: players plus world
- email DB

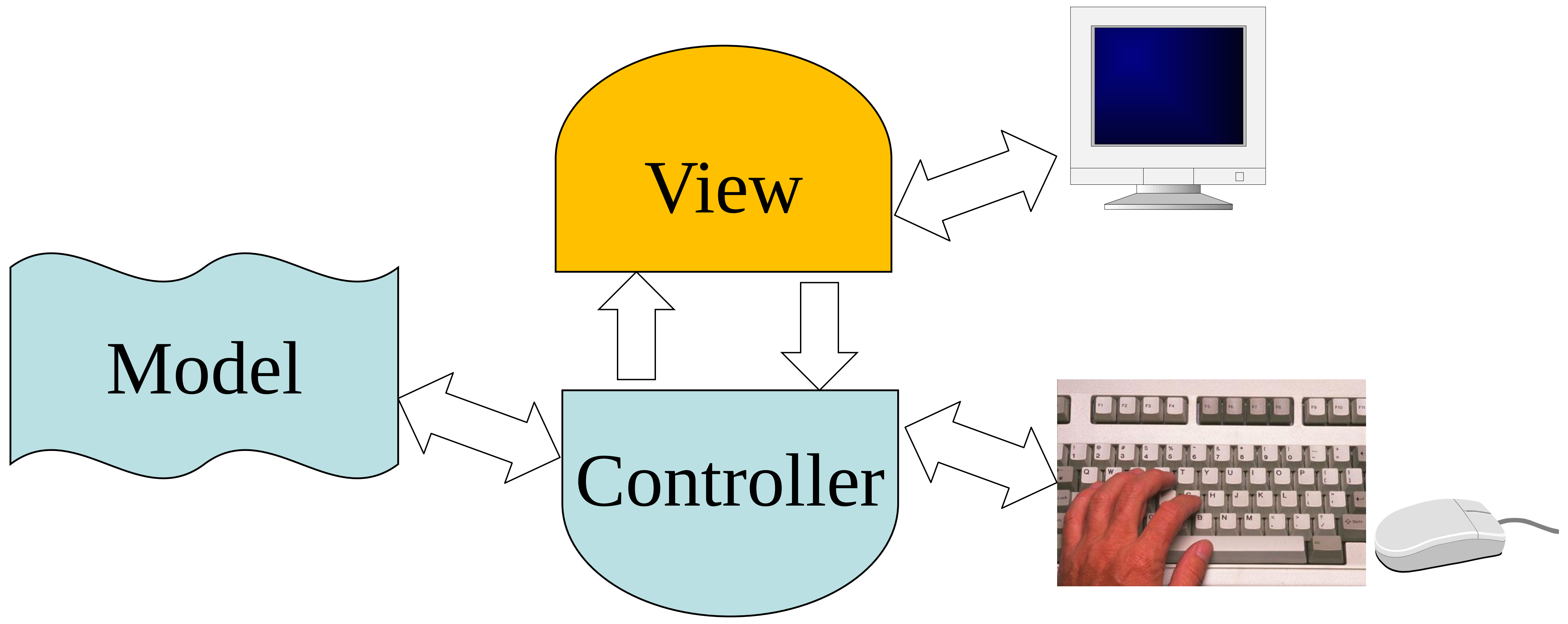
Model



The model should be **standalone**. i.e. it shouldn’t depend on the view or controller logic.

Ideally, its schema should be fixed since the logic of several controllers may depend on it.

View

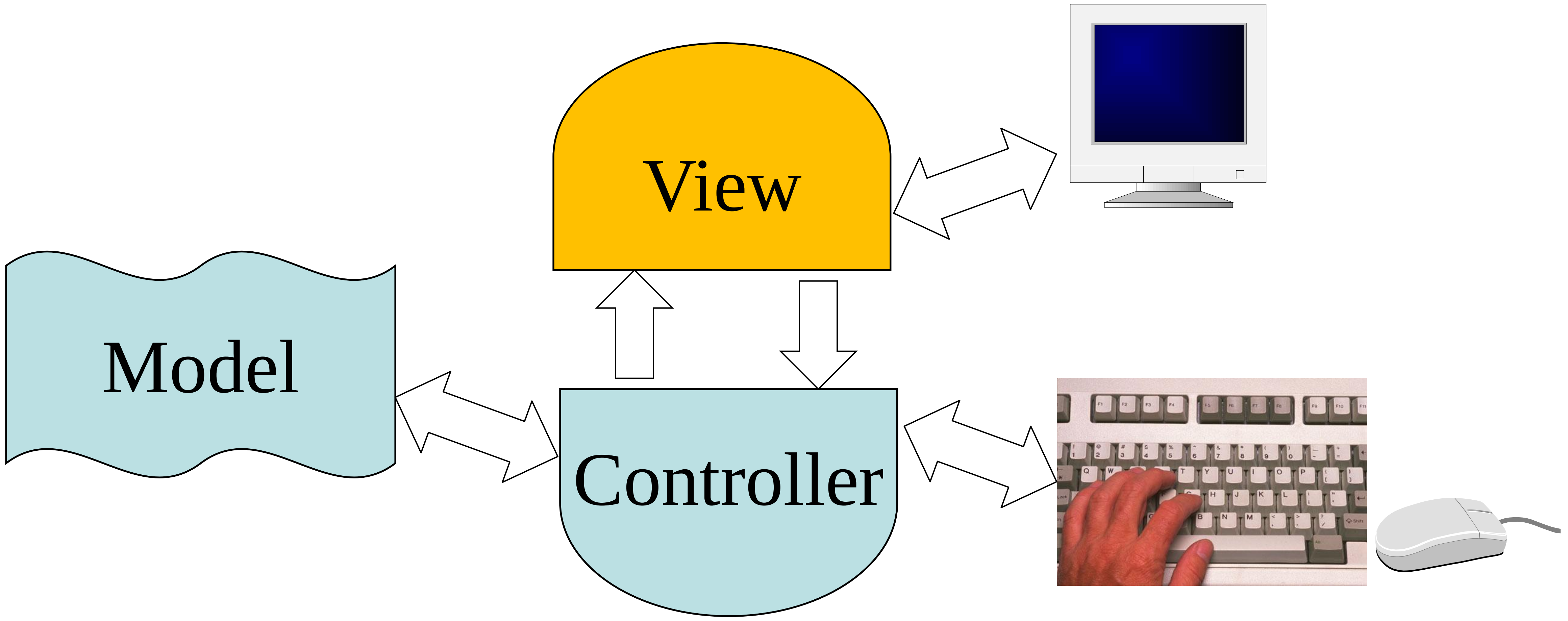


Implements a visual display of (part of) the model data.

May have multiple views

- e.g., board view and schematic for CAD tool
- Outline and page view for Powerpoint

View

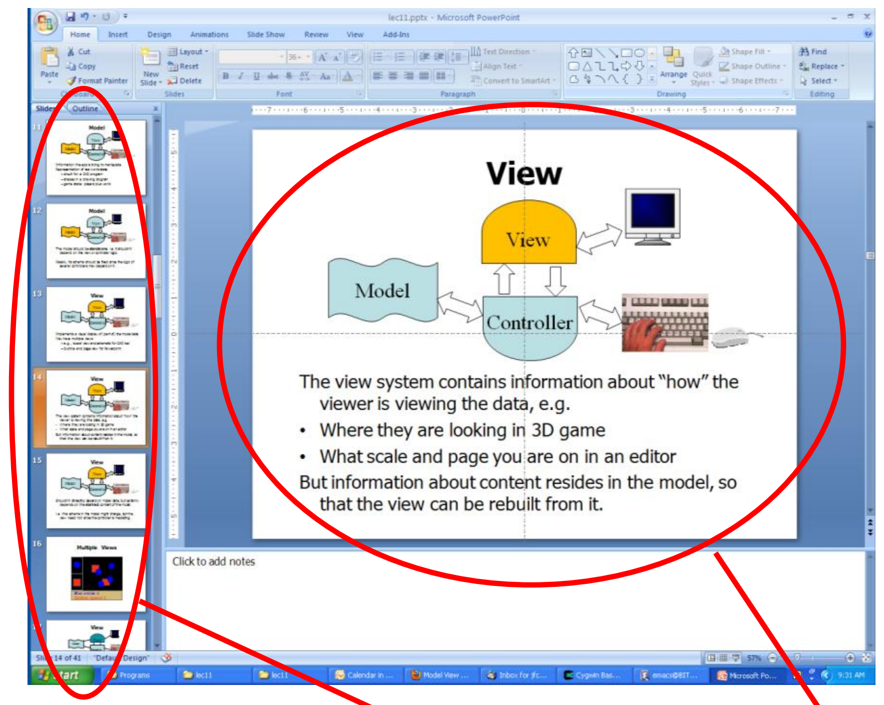


The view system contains information about "how" the viewer is viewing the data, e.g.

- Where they are looking in 3D game
- What scale and page you are on in an editor

But information about content resides in the model, so that the view can be rebuilt from it.

Views



View

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- Where they are looking in 3D game
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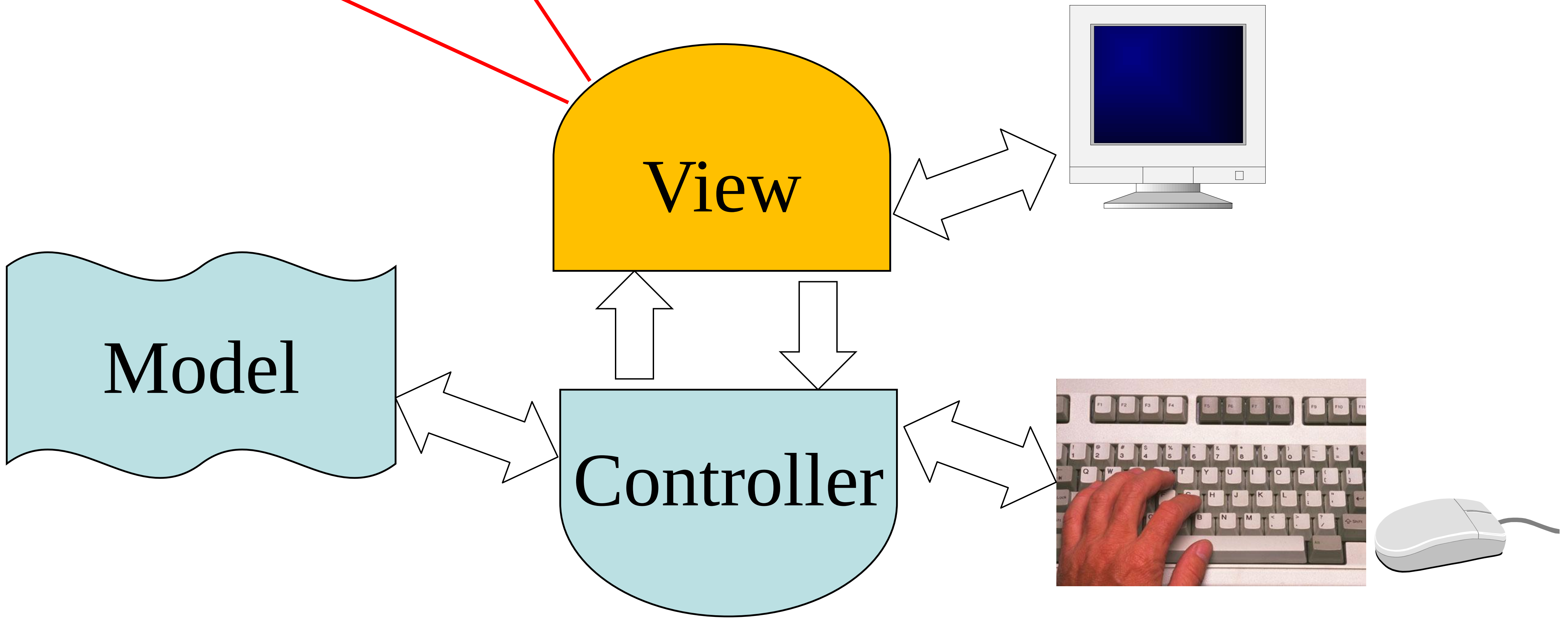
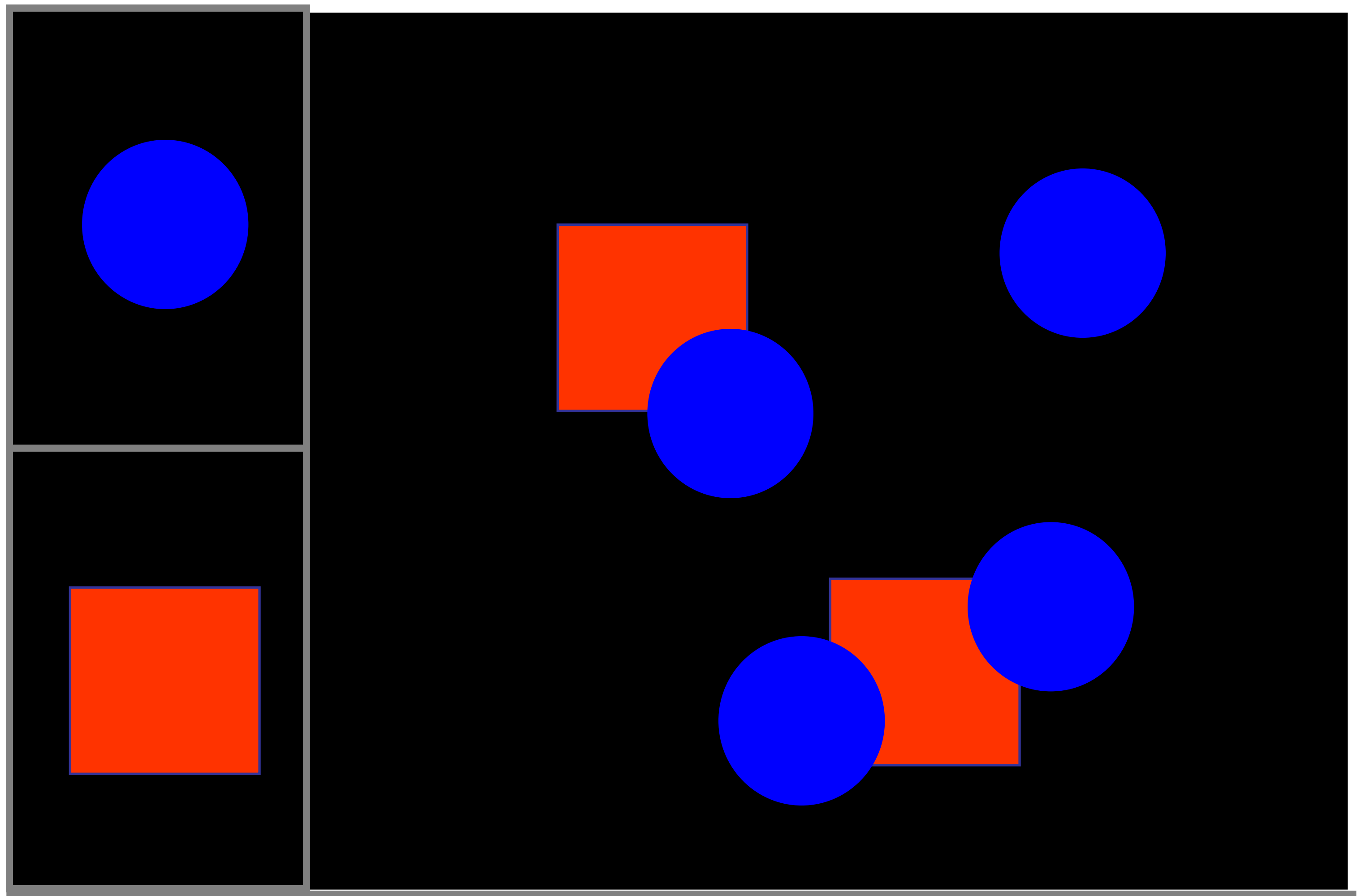
Click to add notes

View only needs to know current page number and scale and size of main view and context view.



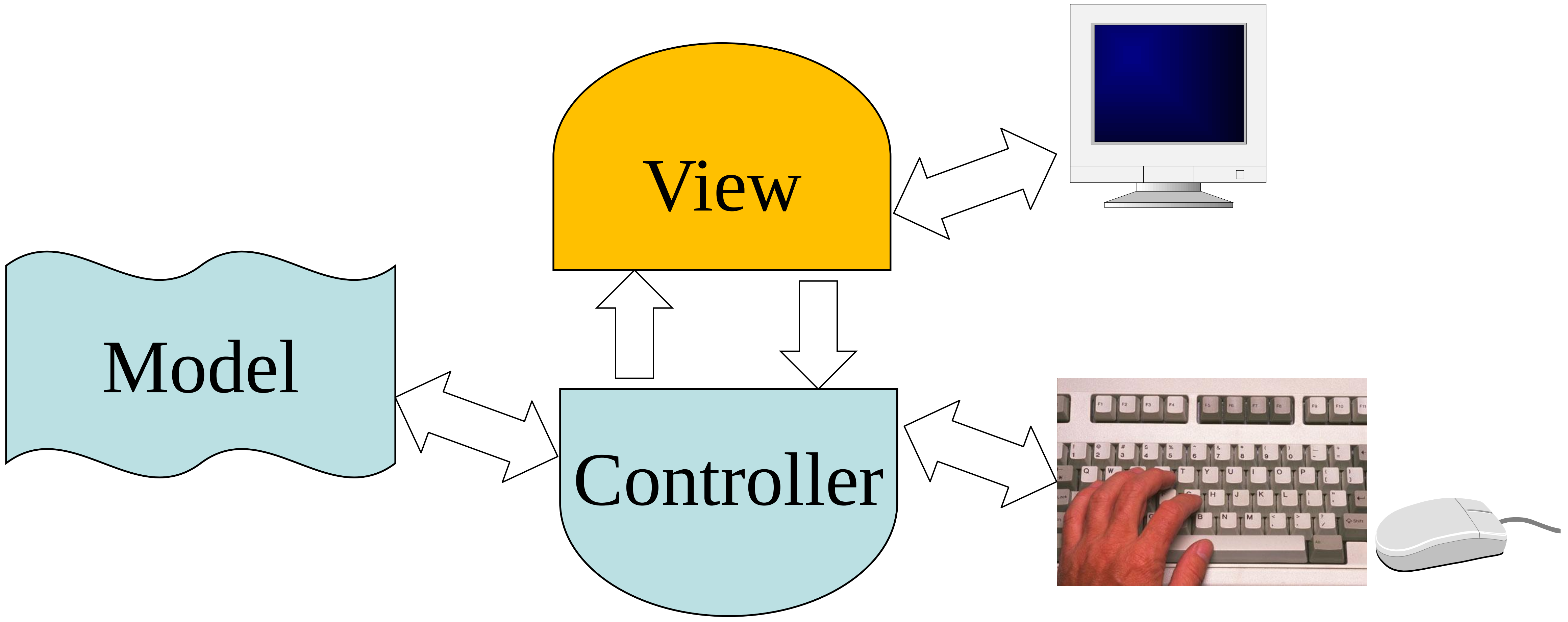
Multiple Views



Blue circles: 4

Cardinal squares: 2

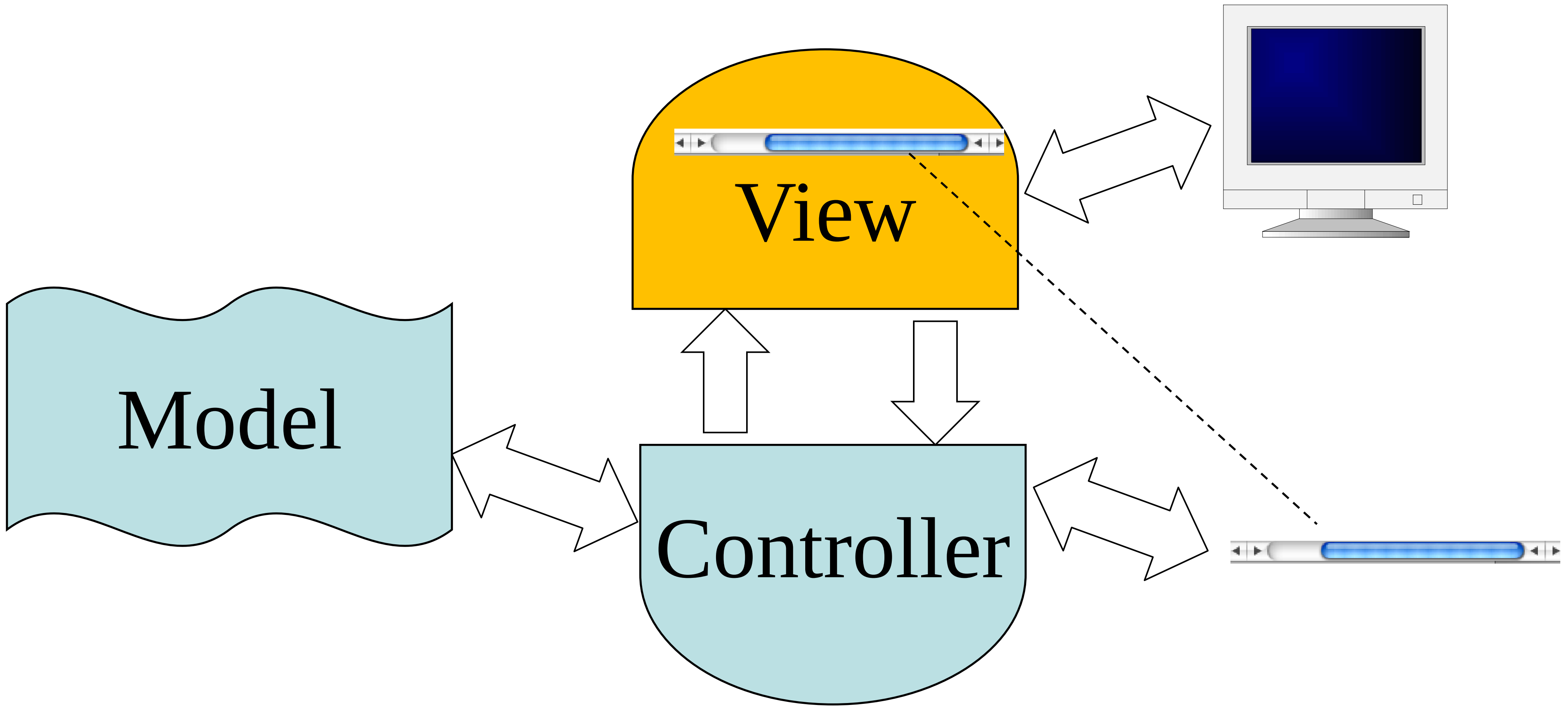
View



Shouldn't **directly** depend on model data, but certainly depends on the **abstract** content of the model.

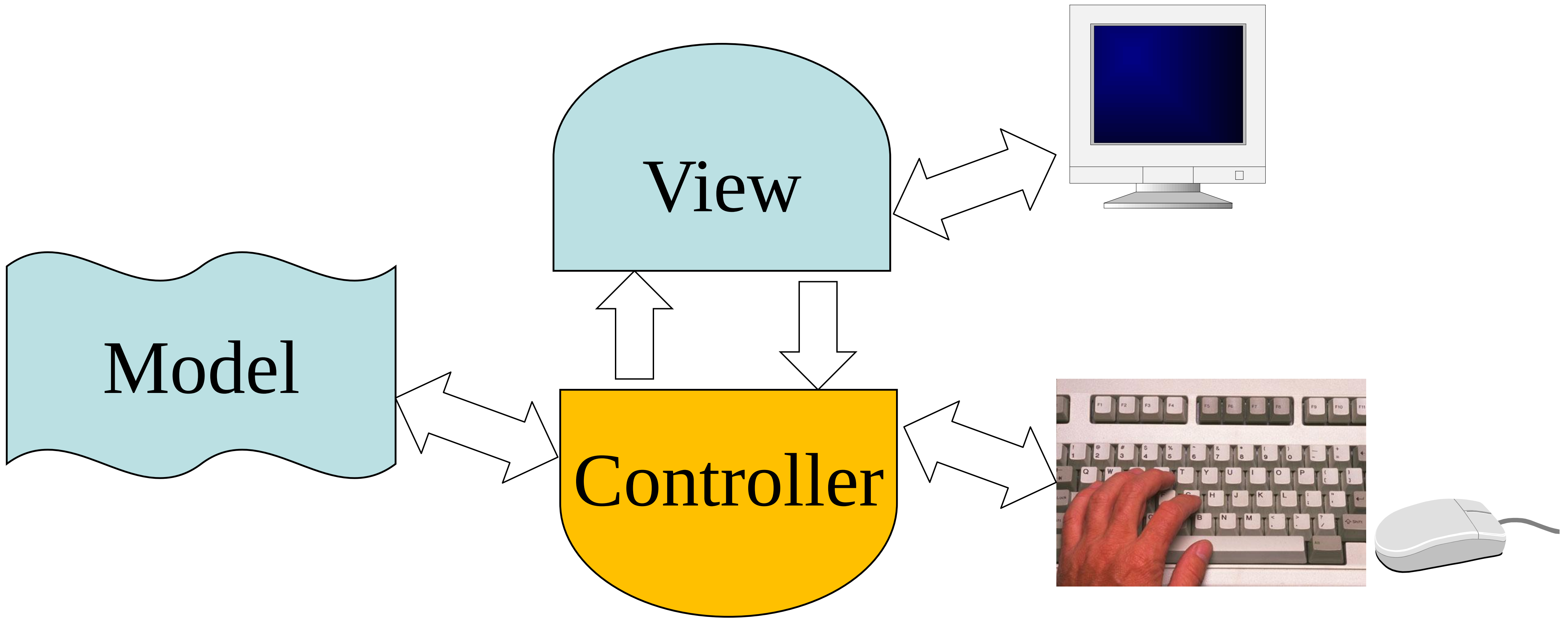
i.e. the schema in the model might change, but the view need not since the controller is mediating.

A Tweak



Since some view components are for input, the "input device" may really be a screen widget in the view.

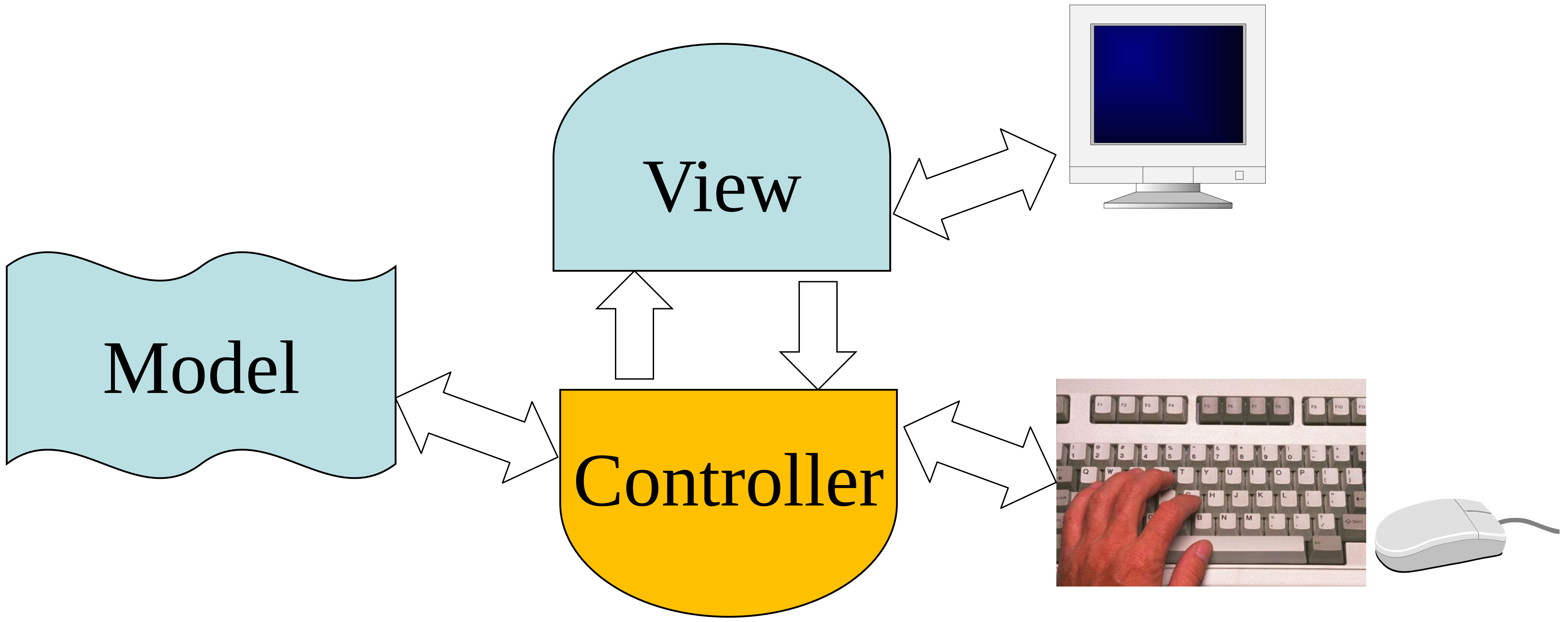
Controller



Mediating function:

- Converts information from model format to what the view needs.
- Interprets view state (e.g. the page you’re on) to make appropriate updates and queries from the model.

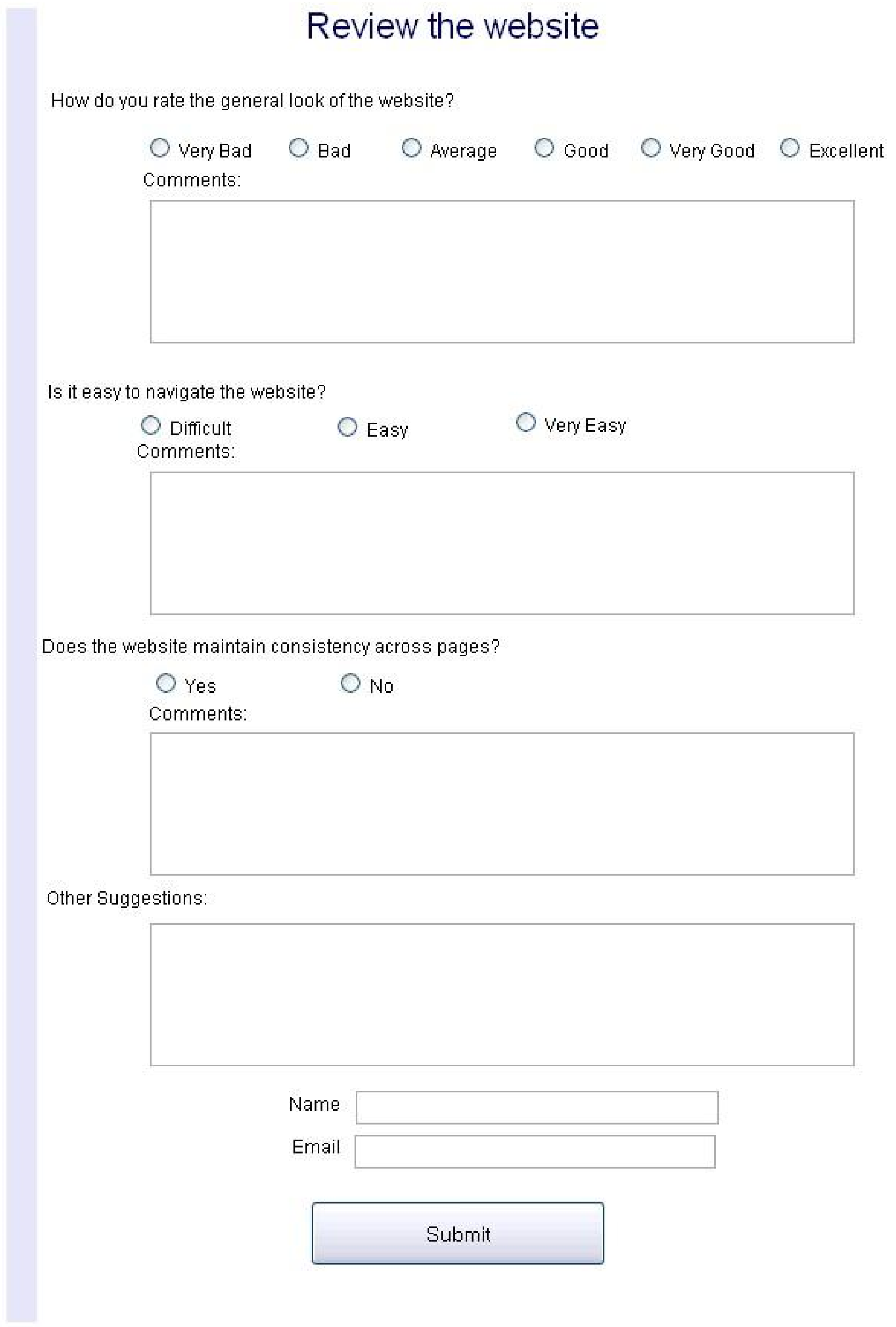
Controller



Control function:

- Makes things happen: processes events from input devices (or view widgets), and propagates changes by other apps from model to view.

Non-MVC design


Review the website

How do you rate the general look of the website?

○ Very Bad ○ Bad ○ Average ○ Good ○ Very Good ○ Excellent

Comments:

Is it easy to navigate the website?

○ Difficult ○ Easy ○ Very Easy

Comments:

Does the website maintain consistency across pages?

○ Yes ○ No

Comments:

Other Suggestions:

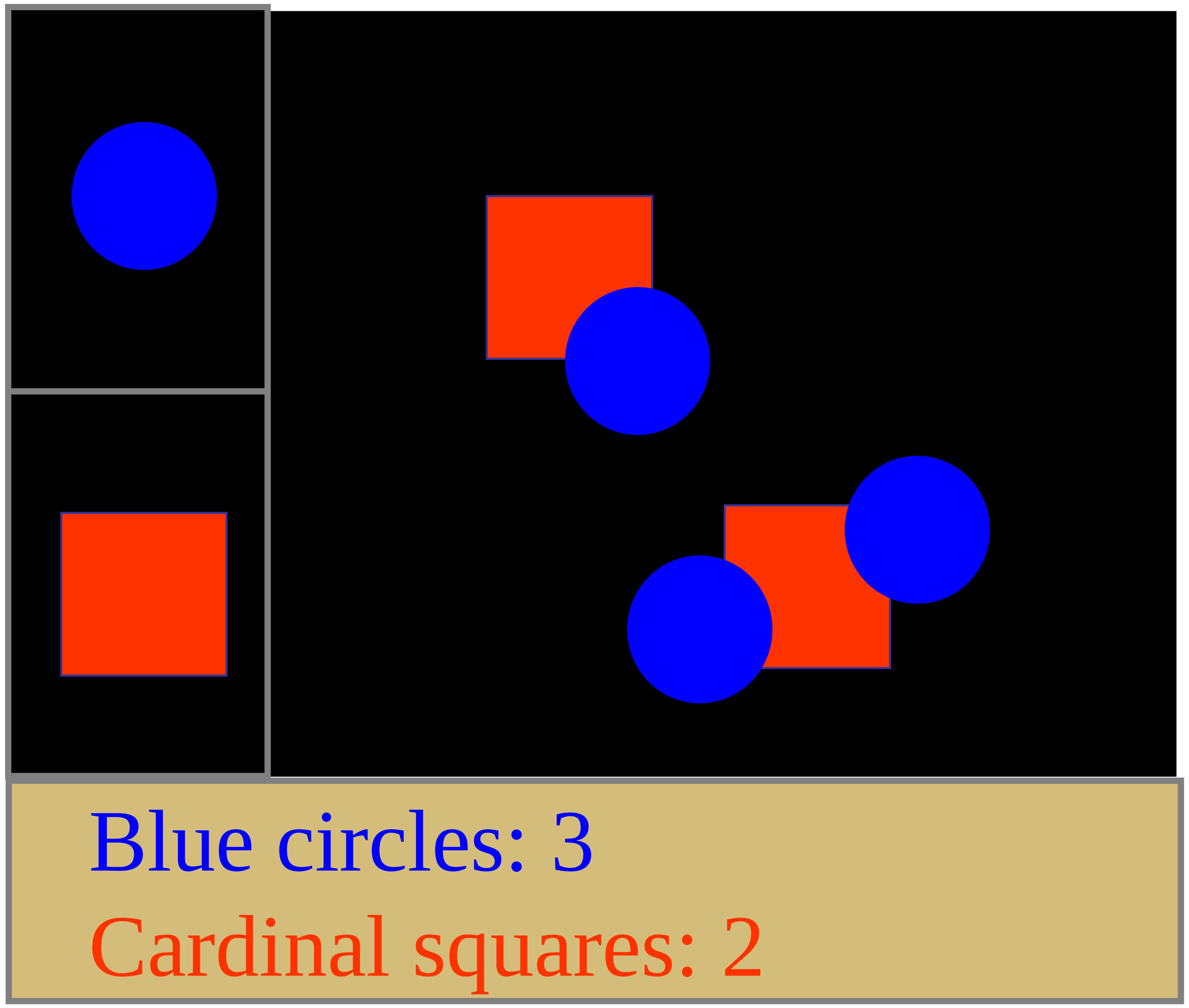
Name

Email

Submit

Avoid too much data stored in view.

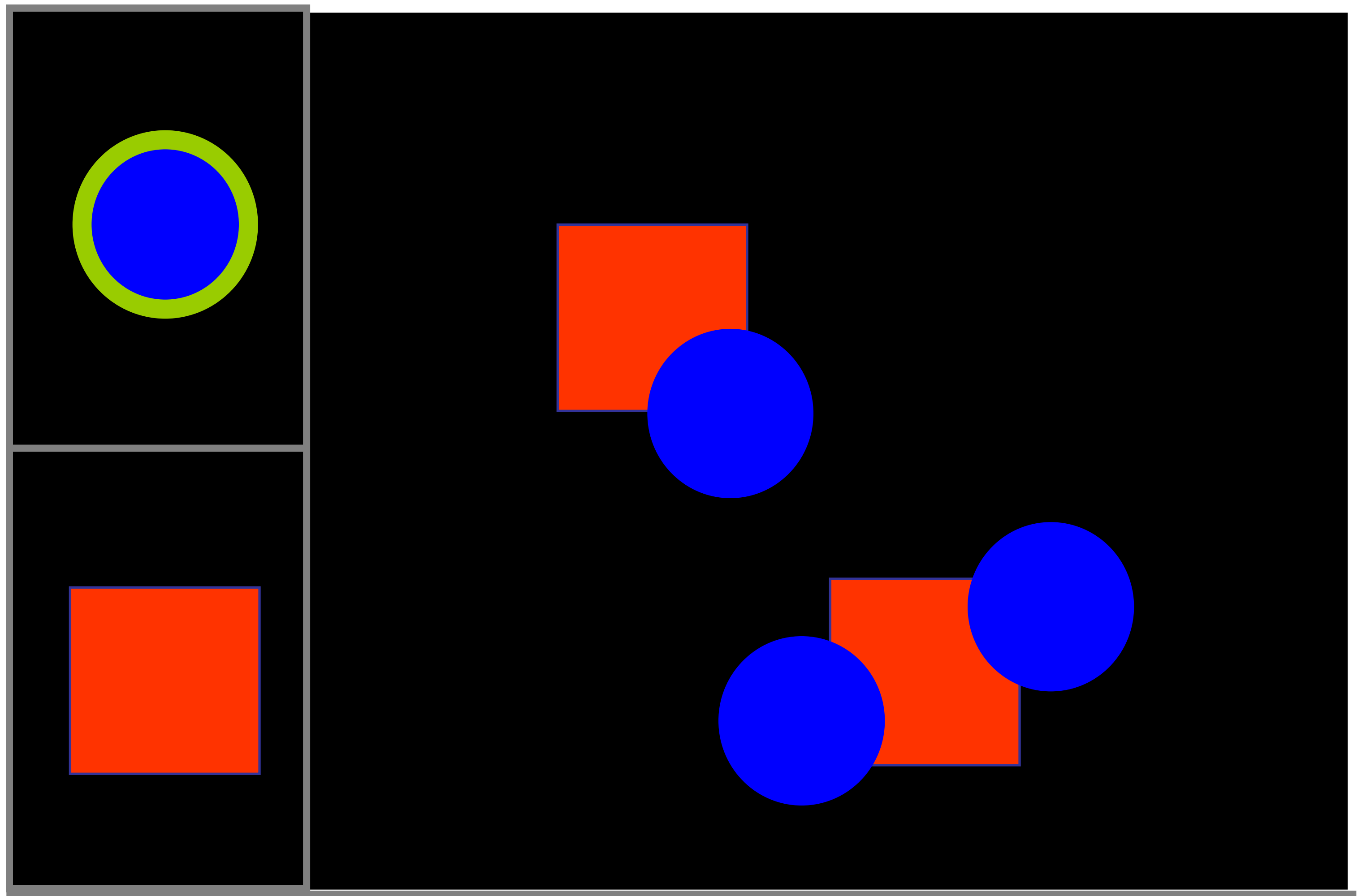
Adding a circle



Blue circles: 3

Cardinal squares: 2

Adding a circle



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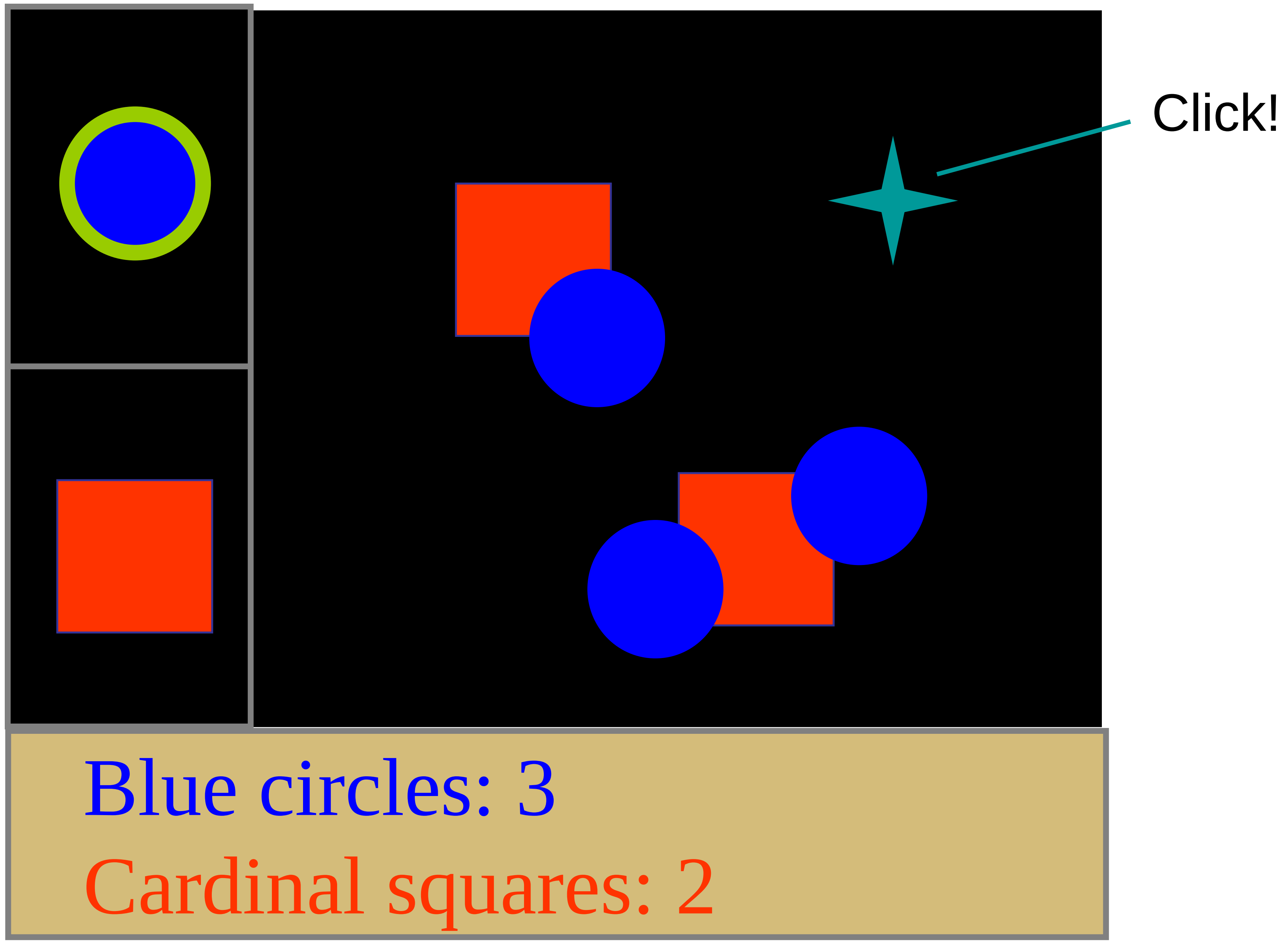
Adding a circle



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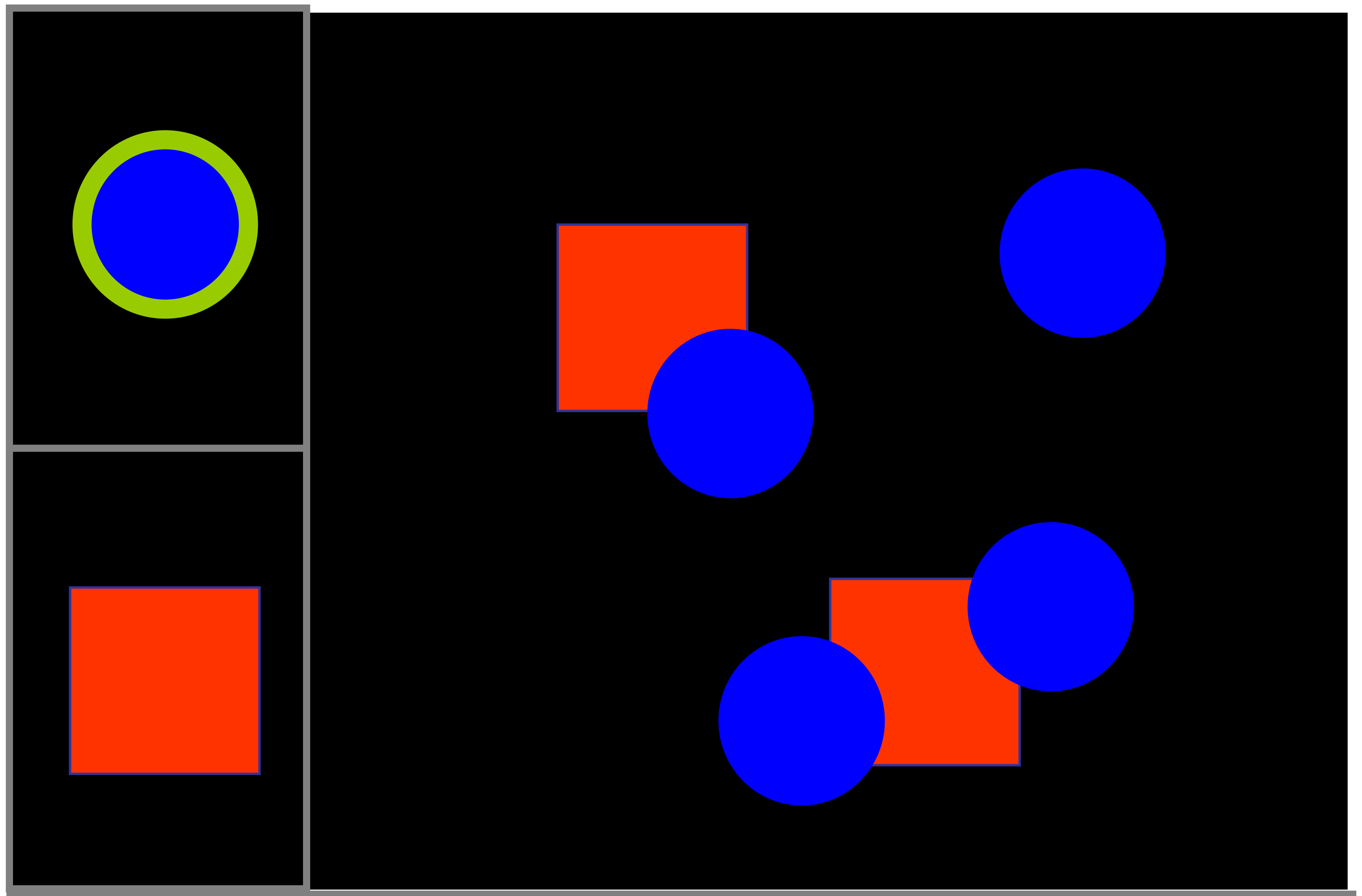

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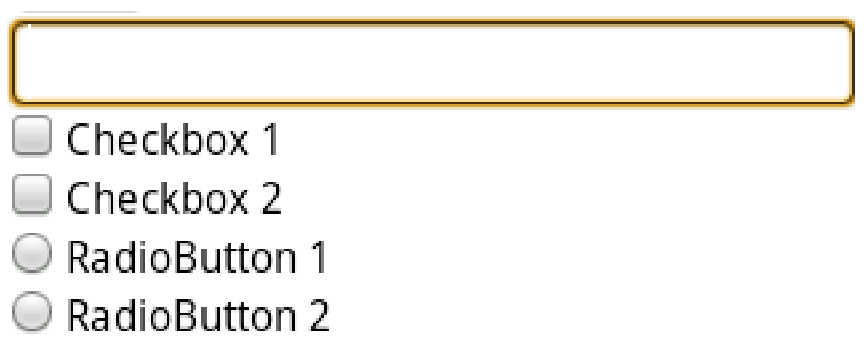
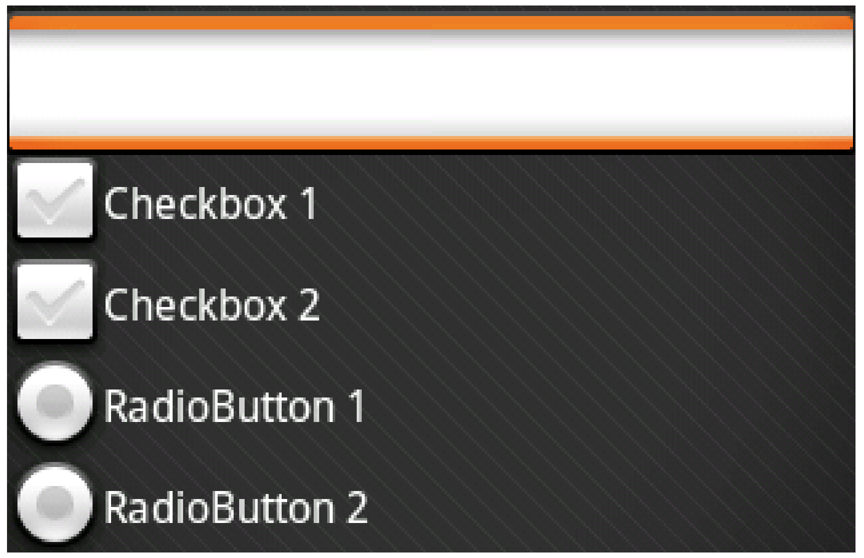
Relationship of View & Controller

"*pattern of behavior in response to user events (controller issues) is independent of visual geometry (view issues)" –Olsen, Chapter 5.2*

Relationship of View & Controller

"pattern of behavior in response to user events (controller issues) is independent of visual geometry (view issues)"





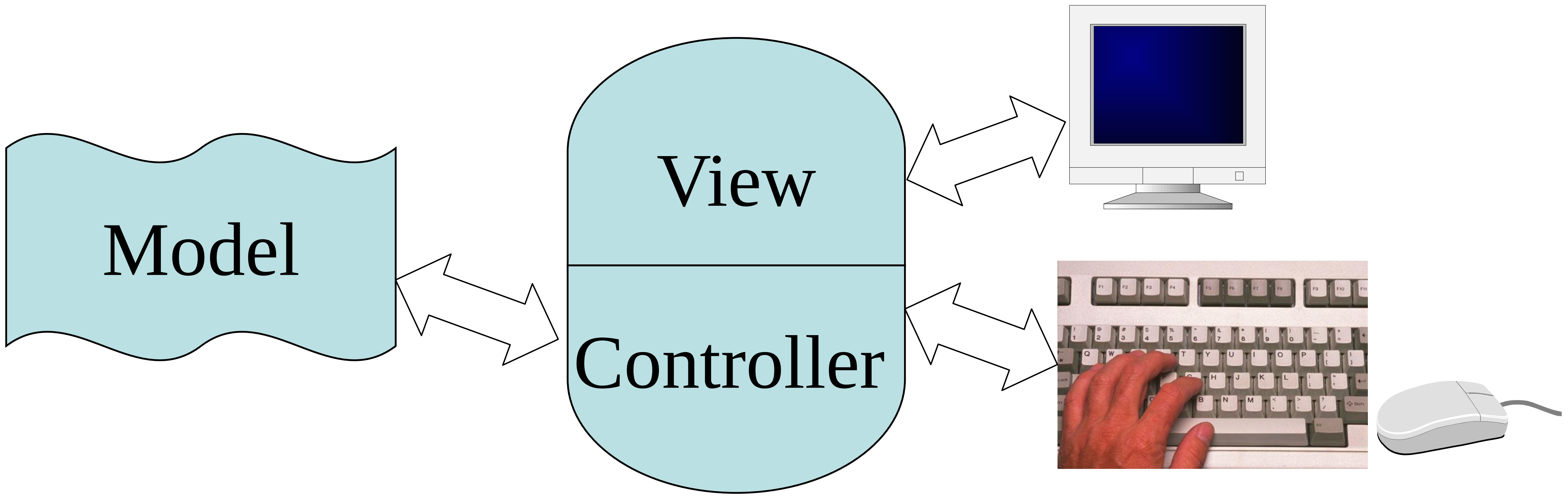
Controller must contact view to interpret what user events mean (e.g., selection)

Combining View & Controller

View and controller are tightly intertwined
- lots of communication between the two

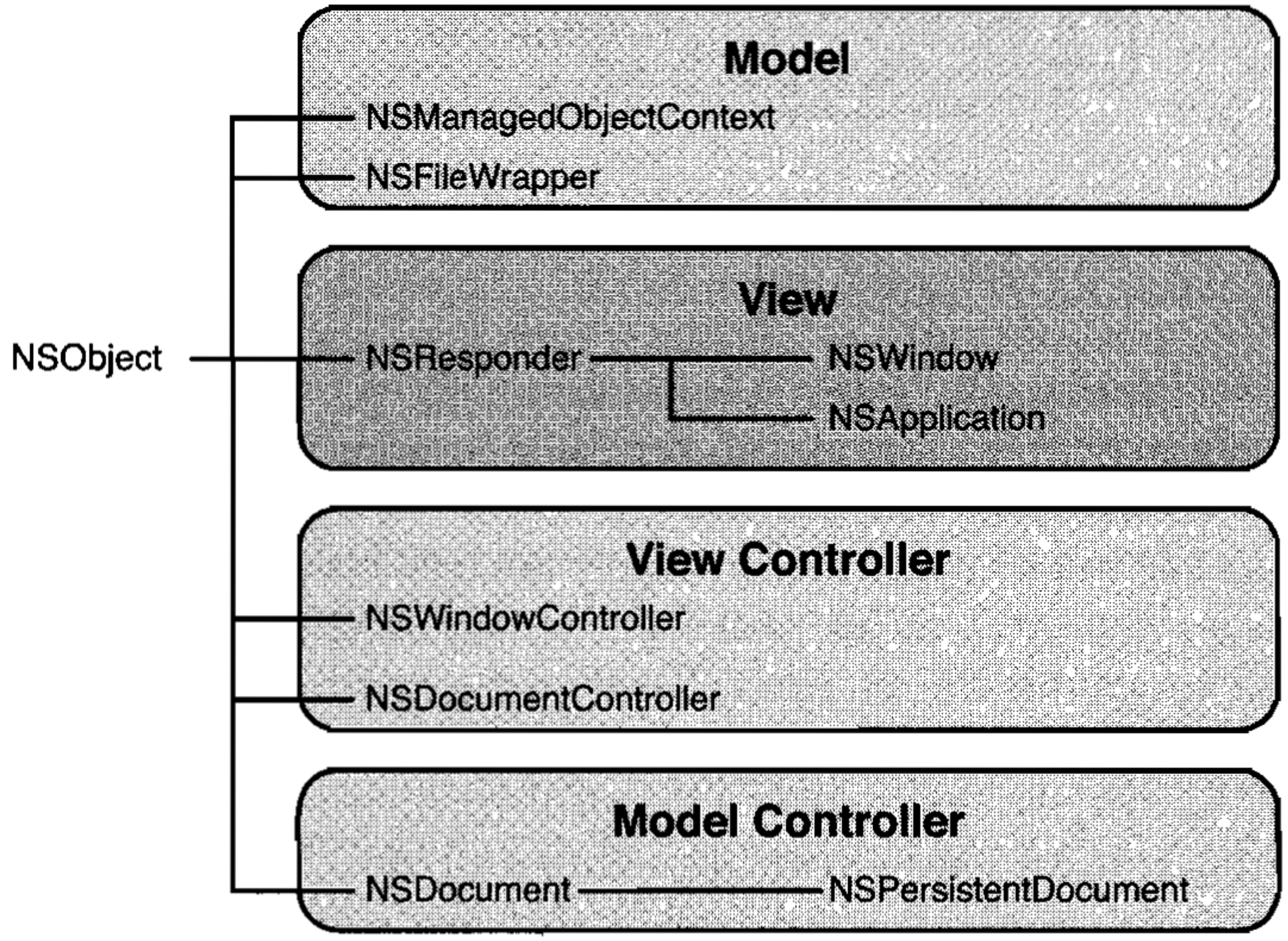
Almost always occur in pairs
- i.e., for each view, need a separate controller

Some apps combine into a single class



Apple's view

To more fully modularize, Cocoa separates some controllers into view-facing and model-facing subparts. Cocoa's document classes:



In Android

MVC architecture much less obvious, although it is claimed. Component control logic “internally MVC”.

One concrete example is **AdapterView**, which includes

- **ExpandableListView**
- **Gallery**
- **GridView**
- **ListView**
- **Spinner**

An Adapter class mediates between a View class and some data.

Why MVC?

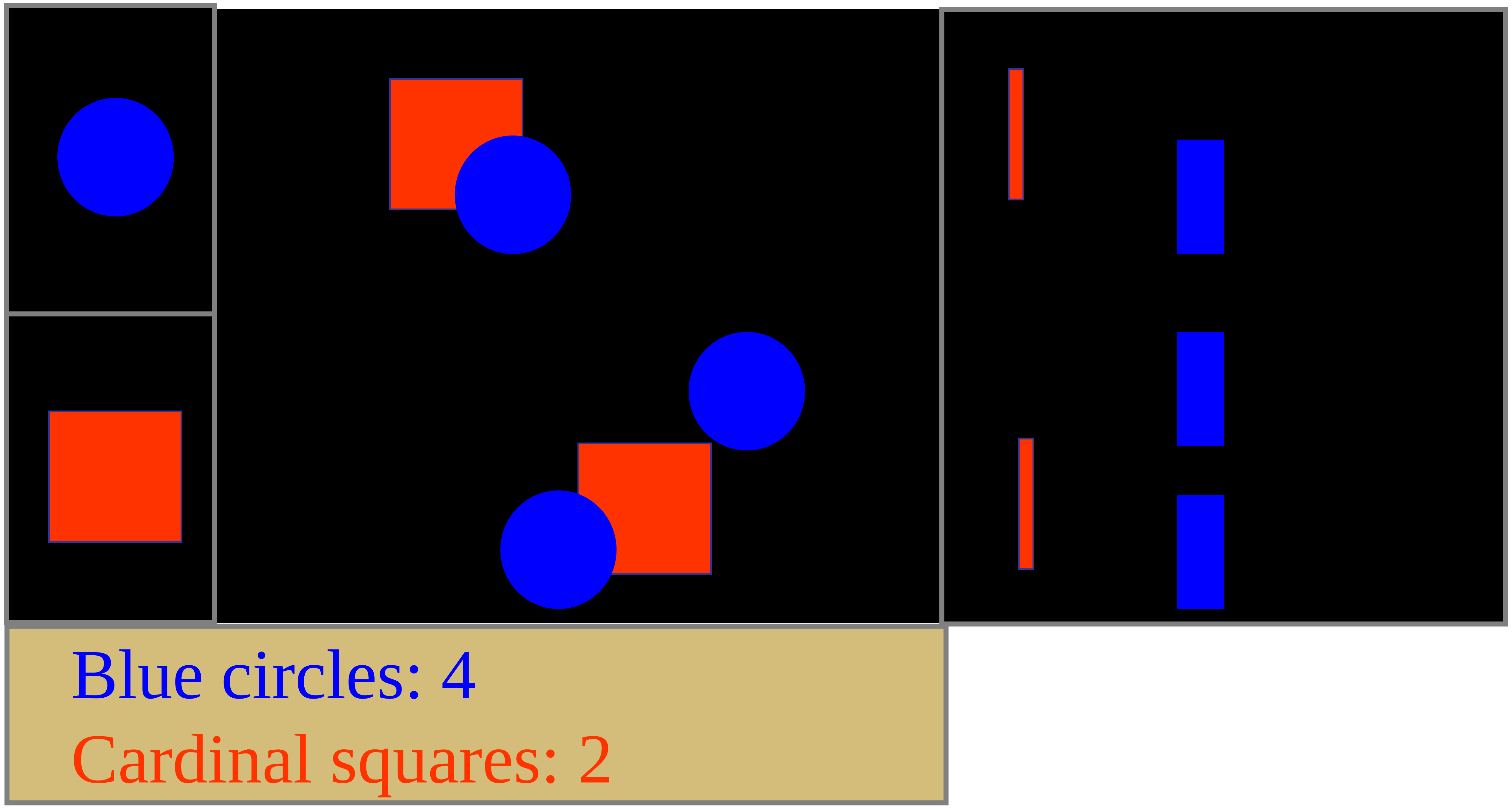
Combining MVC into one class will not scale

- model may have more than one view
- Each view is different and needs updating when model changes

Separation eases maintenance and extensibility

- easy to add a new view later
- model info can be extended, but old views still work
- can change a view later, e.g., draw shapes in 3-d (recall, view handles selection)
- flexibility of changing input handling when using separate controllers

Adding Views Later



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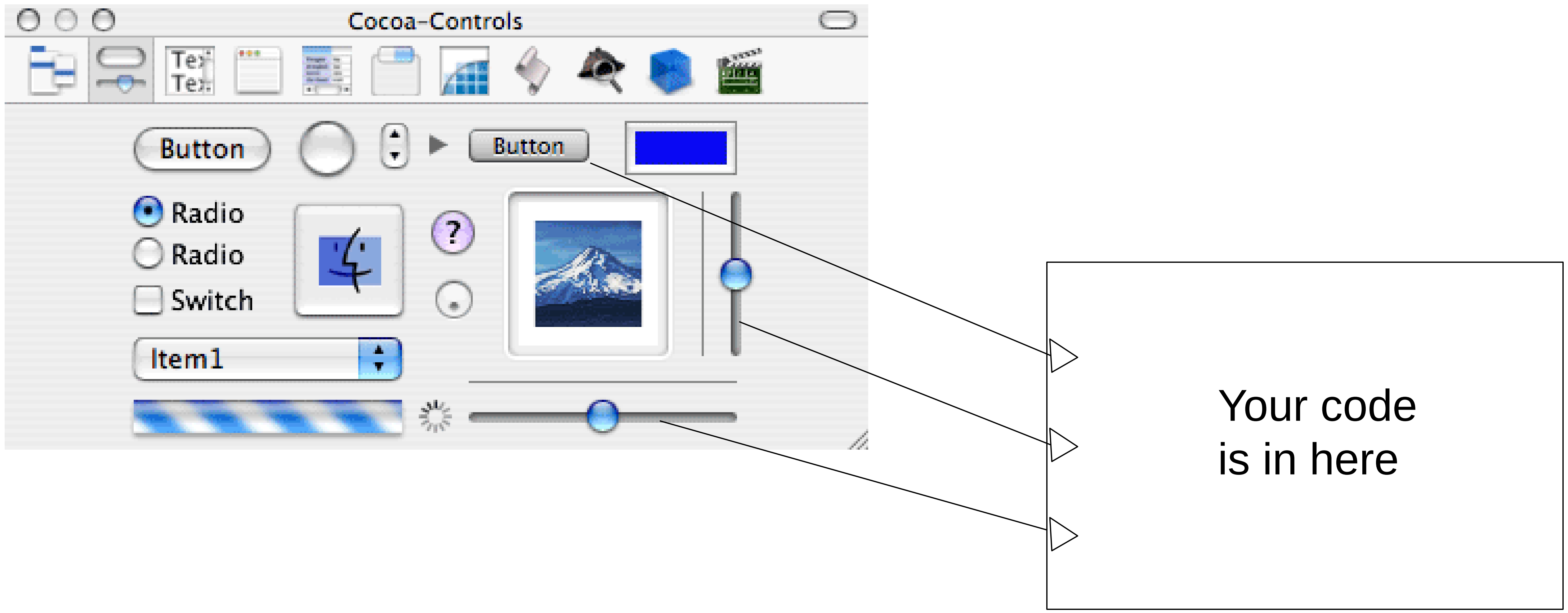
Cardinal squares: 2

MVC and connections

Cocoa and certain other systems (Nokia's Qt) support a dynamic connection model between widgets and code.

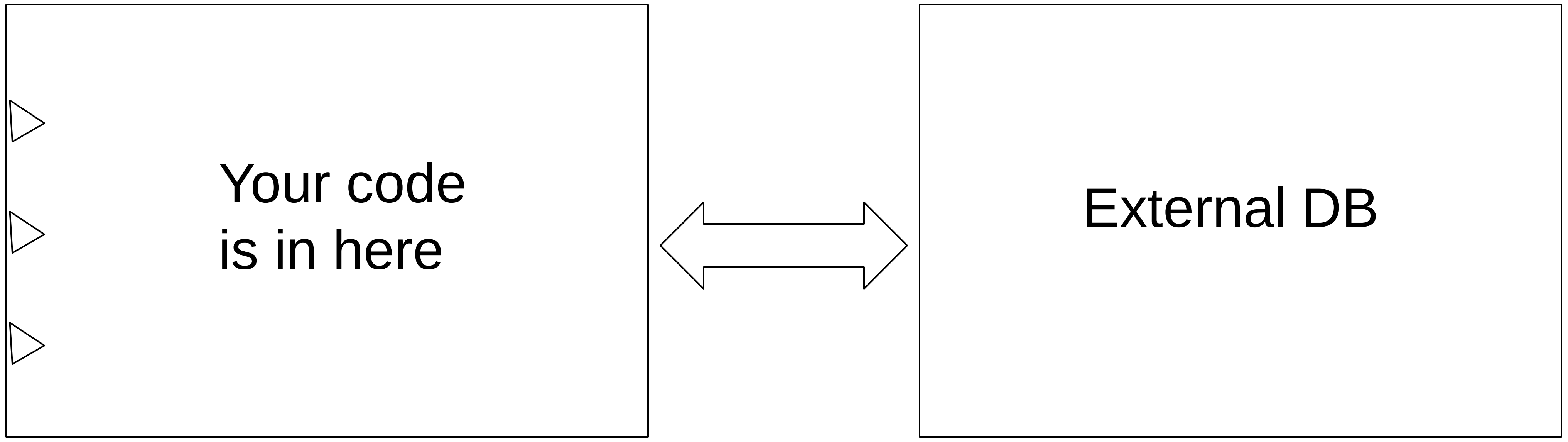
In Xcode, you edit these graphically with Interface Builder.



MVC and connections

This leads naturally to a clean view/controller boundary.

Similarly, Cocoa’s “core data” provides data encapsulation, creating a clean controller/model boundary.

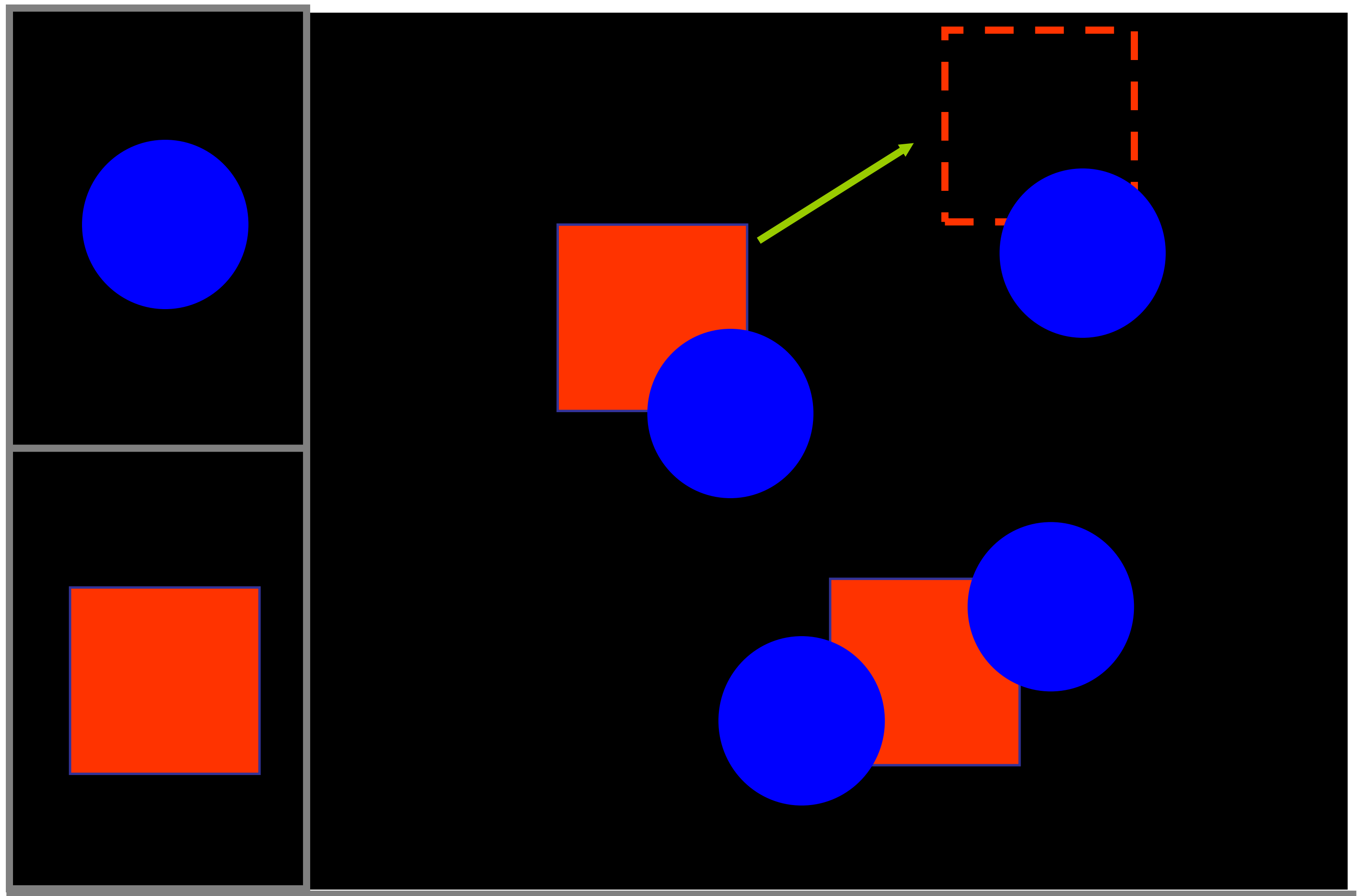


Changing the Display

How do we redraw when shape moves?

Widgets with an internal MVC structure make this easy because they have a model for the data to be drawn.

Moving Cardinal Square



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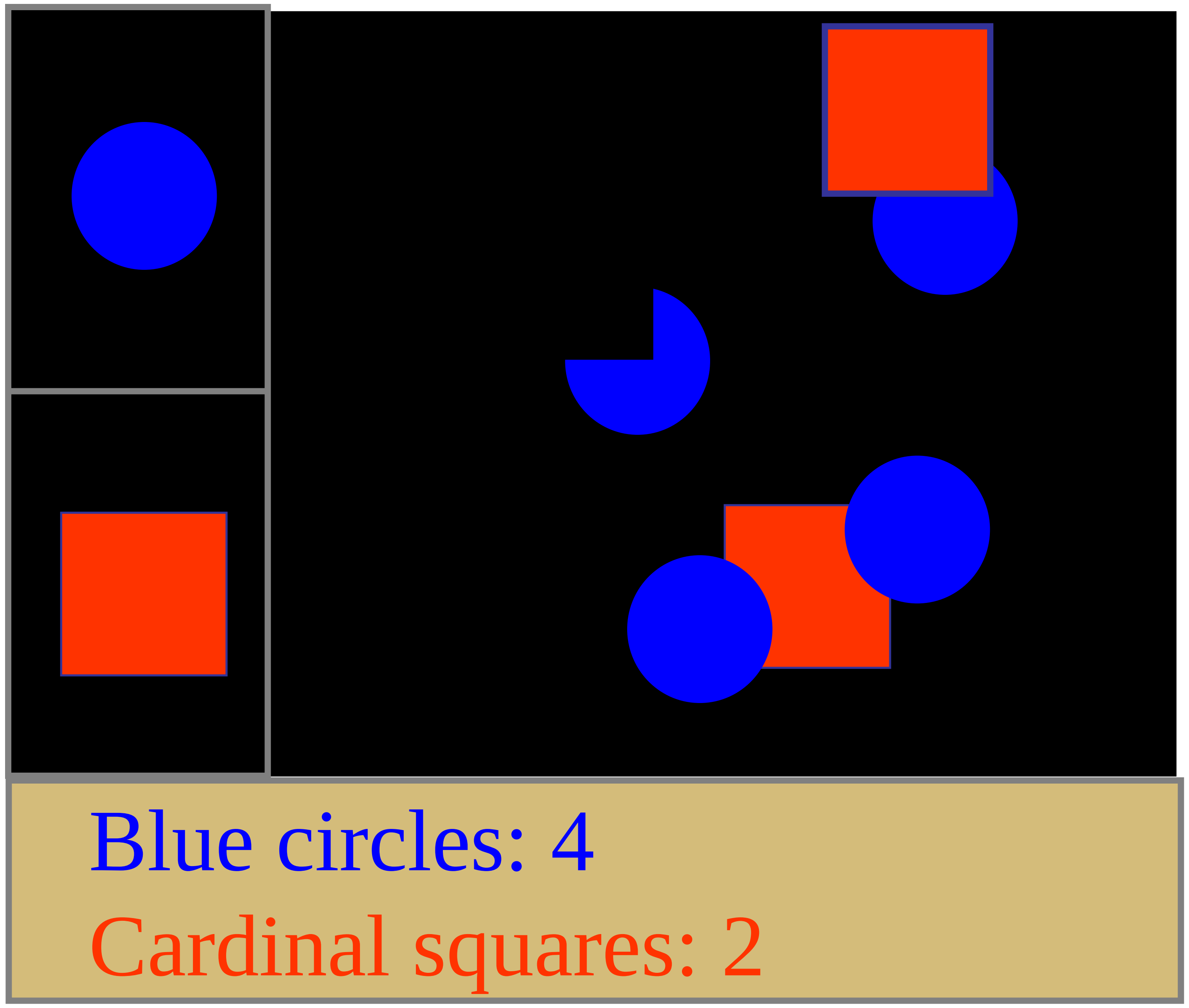
Erase w/ Background Color and Redraw



Changing the Display

Erase and redraw
- using background color to erase fails
- drawing shape in new position loses ordering

Move in model and then redraw view
- change position of shapes in model
- model keeps shapes in a desired order
- tell **all** views to redraw themselves in order
- slow for large / complex drawings

Damage / Redraw Method

View informs windowing system of areas that need to be updated (i.e., *damaged*) with **invalidate();**

- does not redraw them at this time…

Windowing system

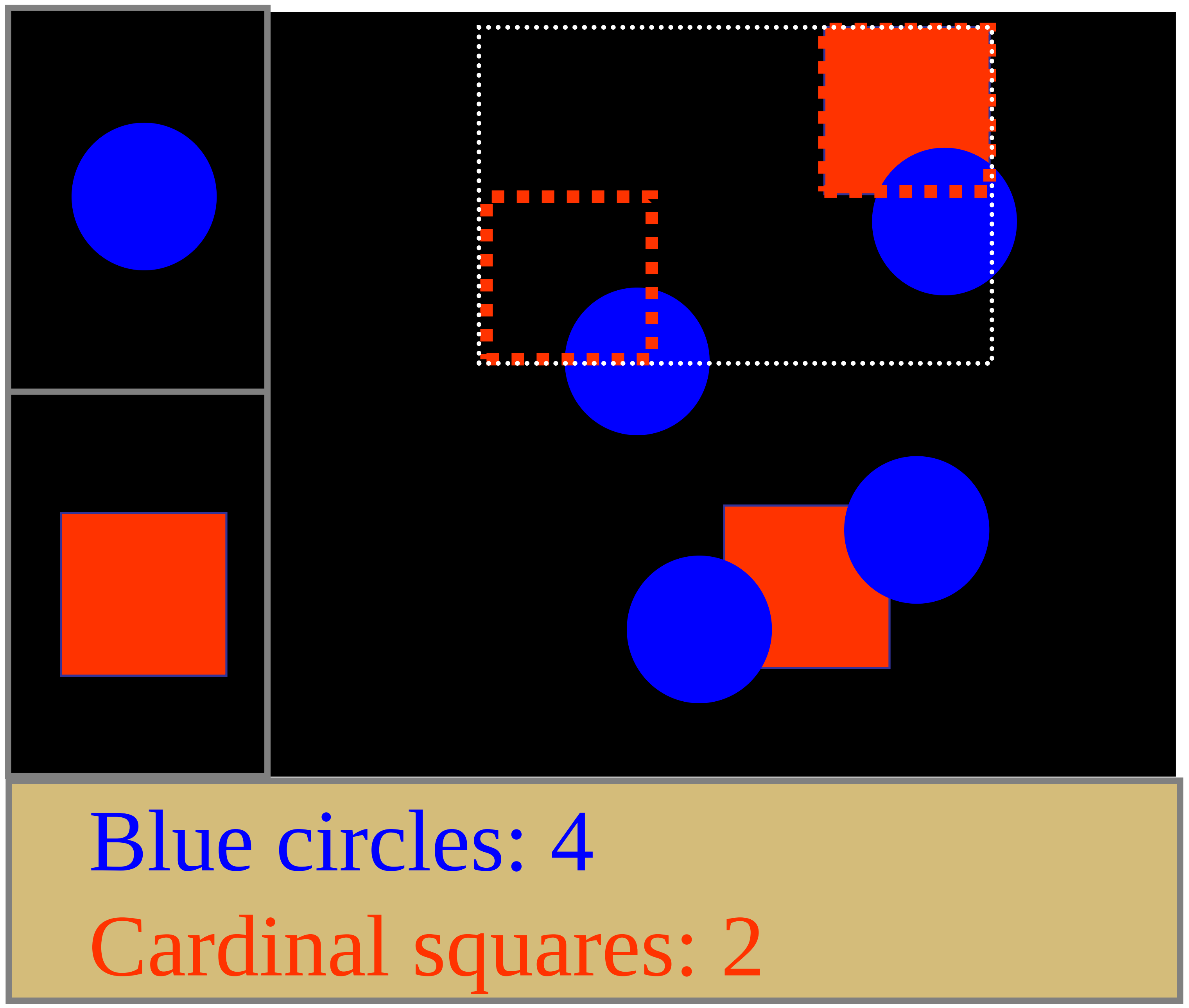
- batches updates
- clips them to *visible* portions of window

Next time waiting for input

- windowing system calls *draw* method

http://developer.android.com/guide/topics/ui/how-android-draws.html

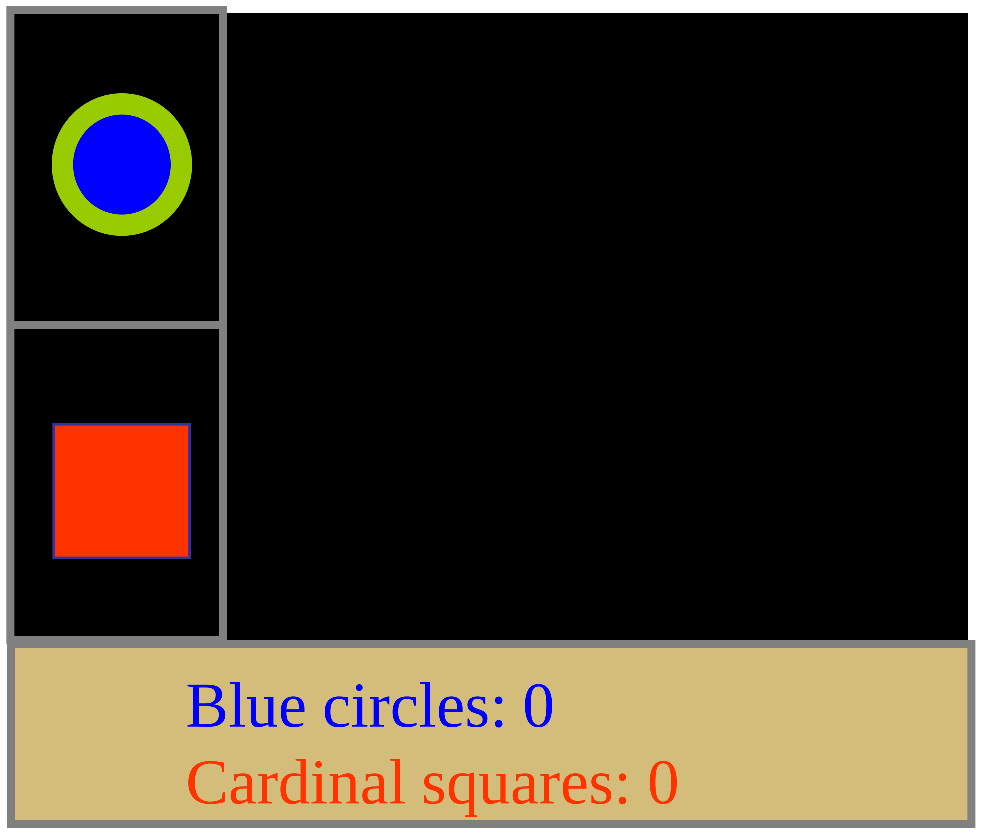
Damage old, Change position in model, Damage new



Example - Event Flow

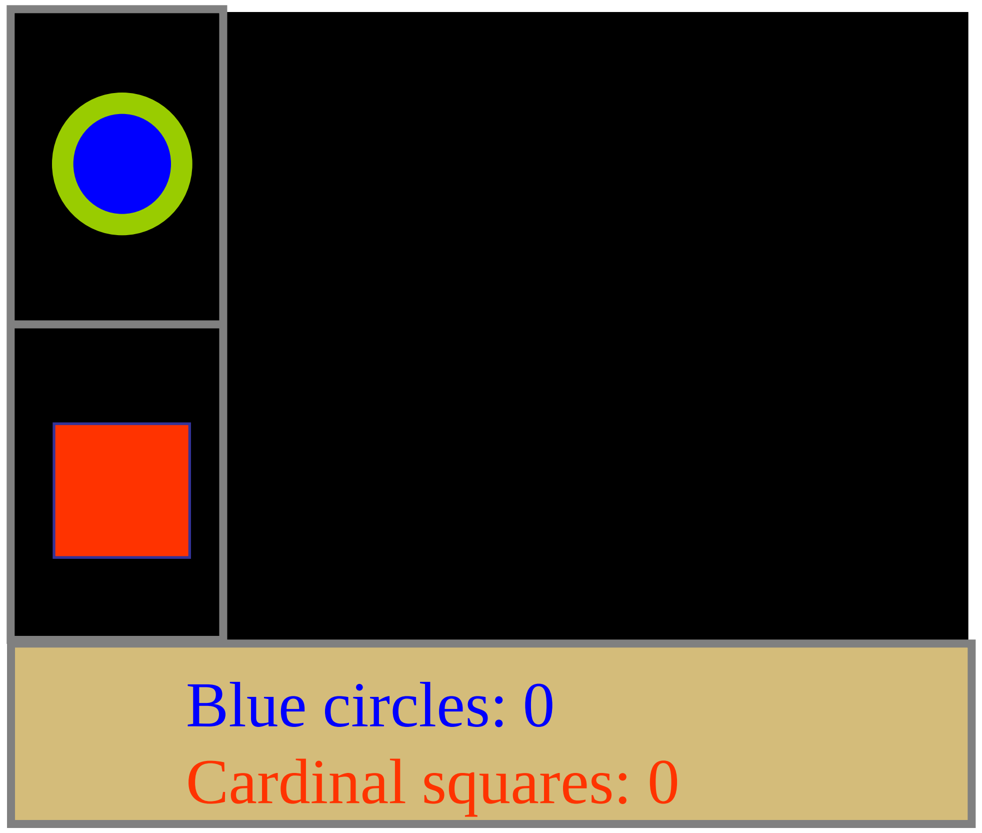
Creating a new shape

Event Flow (cont.)



Assume blue circle selected

Event Flow (cont.)



Press mouse over tentative position

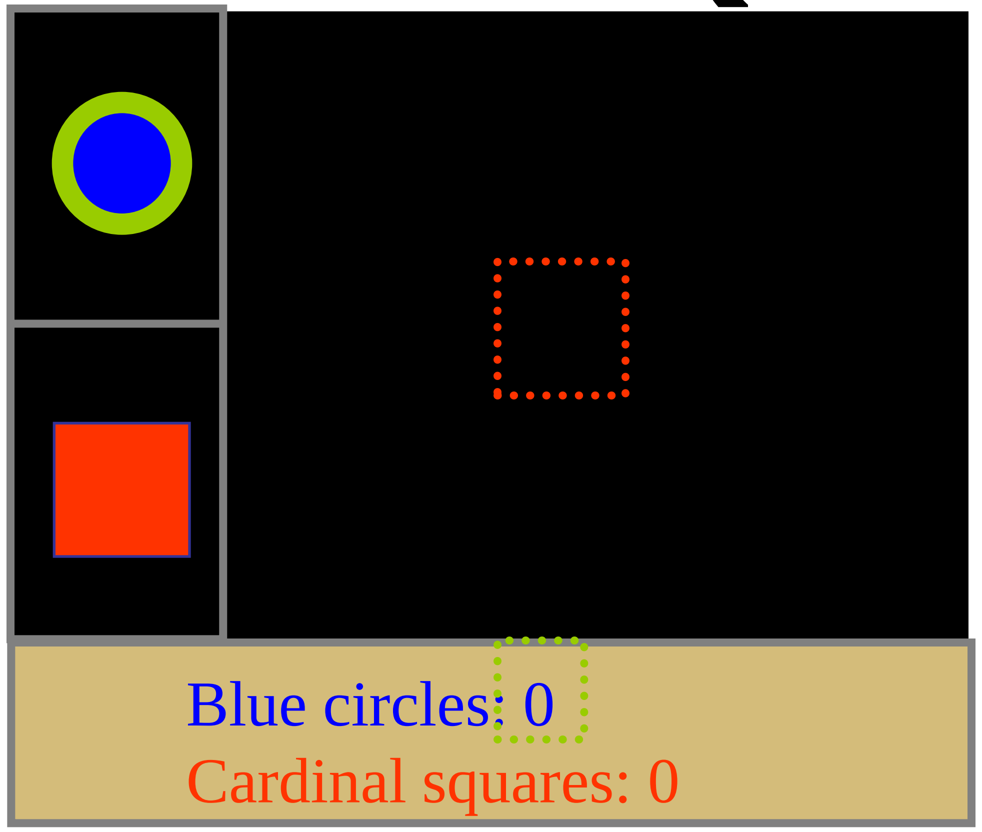
Windowing system identifies proper window for event

Controller for drawing area gets mouse click event

Checks mode and sees “circle”

Calls model’s AddCircle method with new position

Event Flow (cont.)



AddCircle adds new circle to model’s list of objects

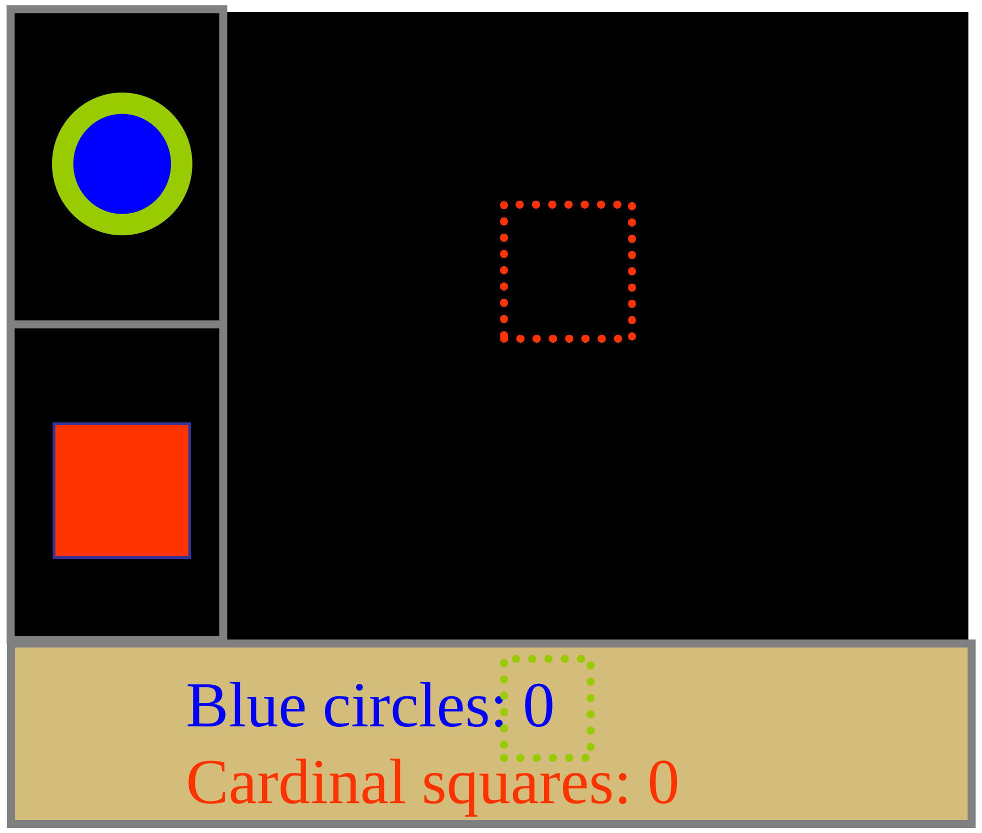
Model then notifies list of views of change

- drawing area view and text summary view

Views notifies windowing system of damage

- both views notify WS without making changes yet!

Event Flow (cont.)



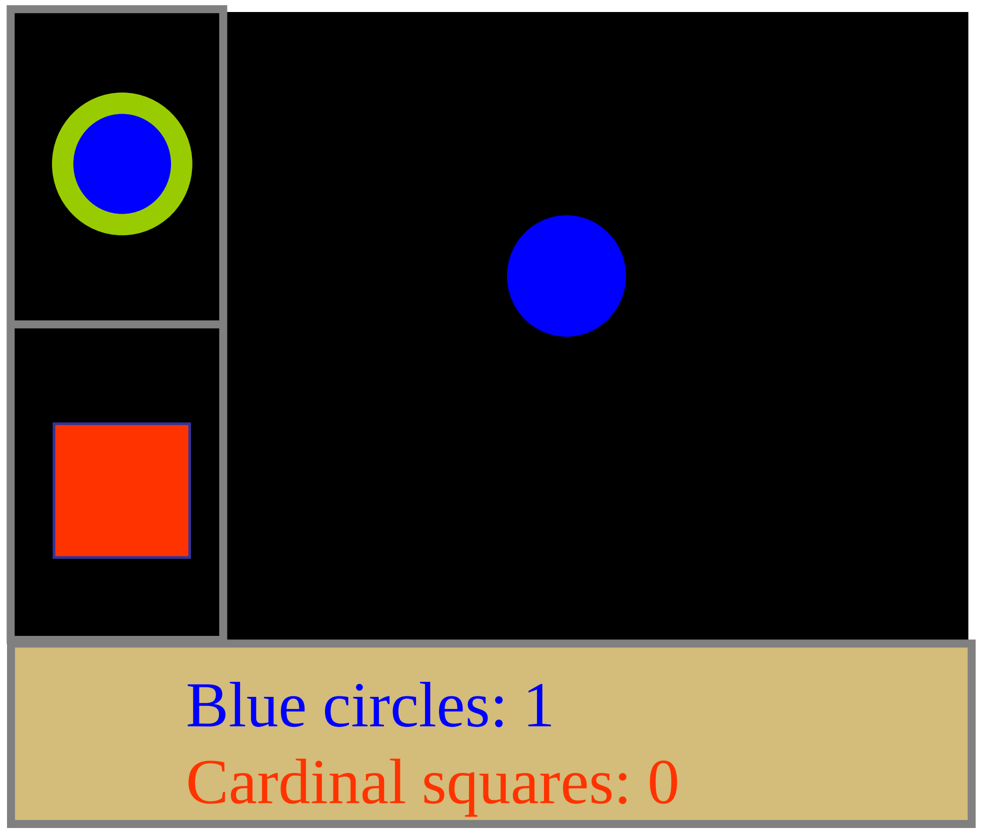
Views return to model, which returns to controller

Controller returns to event handler

Event handler notices damage requests pending and responds

If one of the views was obscured, it would be ignored

Event Flow (cont.)



Event handler calls views’ **draw()** methods with damaged areas

Views redraw all objects in model that are in damaged area

Review

Component Model

Event Handling

Model-View-Controller

- Break up a component into
  - **Model** of the data supporting the App
  - **View** determining the look of the application
  - **Controller** for mediating and event management
- Provides scalability and extensibility
- Damage-repair drawing

Reminder

Archos 5 hardware available in class this Weds – one per group.

Pls bring a check for $200 to UC Regents as a deposit.

You need the Archos for individual programming assignment 4 – no BT in emulator. OK to work in pairs. But still submit individually.