Programming Languages and Techniques (CIS120)

Lecture 19

GUI library: Simple Widgets

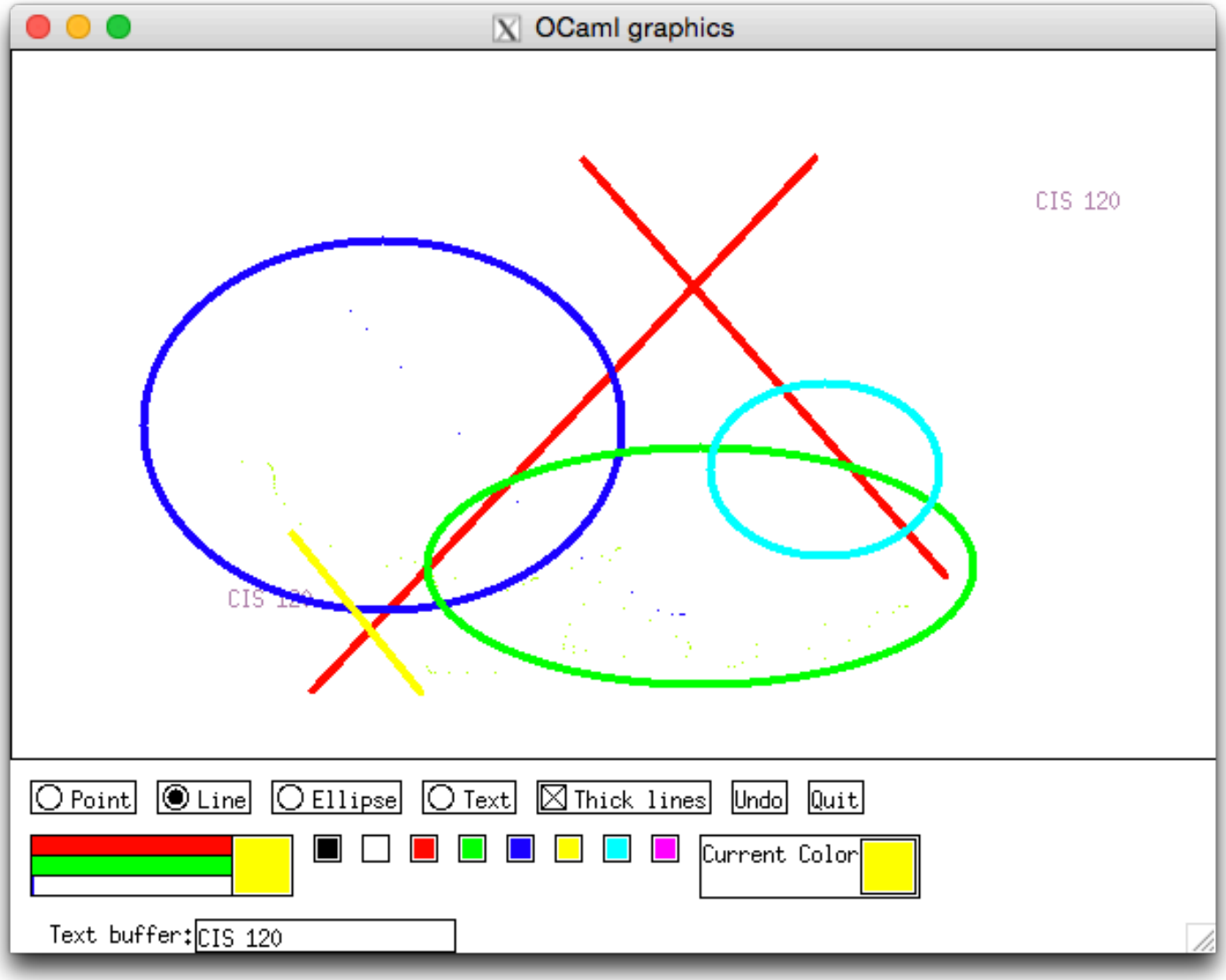
Chapter 18

Announcements

- HW5: GUI programming
  - Due: Tuesday, October 22nd at 11:59 pm
  - The project is structured as *tasks*, not *files* (one task may touch multiple files)

- Java Bootcamp
  - Wednesday, October 23rd 6:00-8:00PM
  - Towne 100
  - Java refresher / crash course: basic syntax, fields & methods, arrays, Eclipse setup, using the debugger
  - *Please respond to poll on Piazza if you plan to attend*

Building a GUI library & application



How far along are you in HW05: GUI Programming?

Not started yet

Task 0 finished

Working on tasks 1-4

Working on Task 5

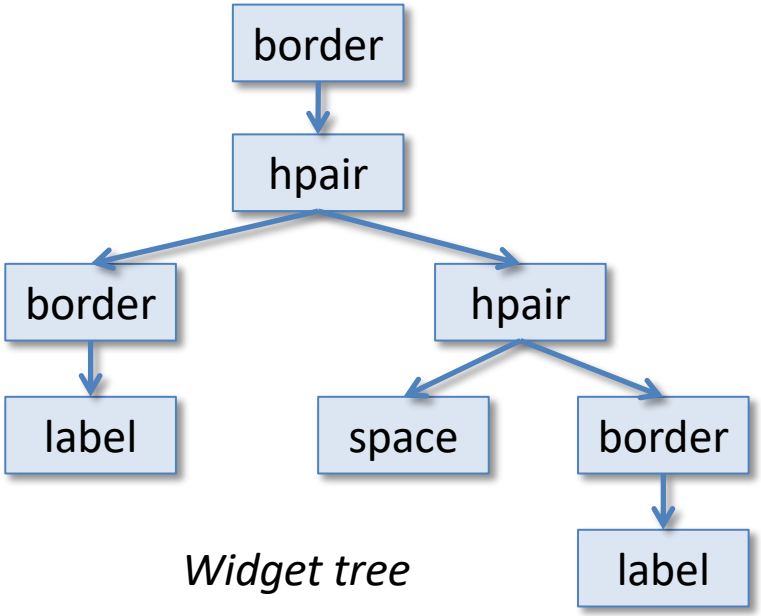
Working on Task 6

All done!

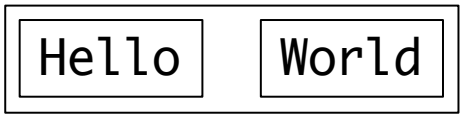
Review: A “Hello World” application

swdemo.ml

```
(* Create some simple label widgets *)
let l1 = label "Hello"
let l2 = label "World"
(* Compose them horizontally, adding some borders *)
let h =  border
           (hpair (border l1)
                  (hpair (space (10,10)) (border l2)))
```



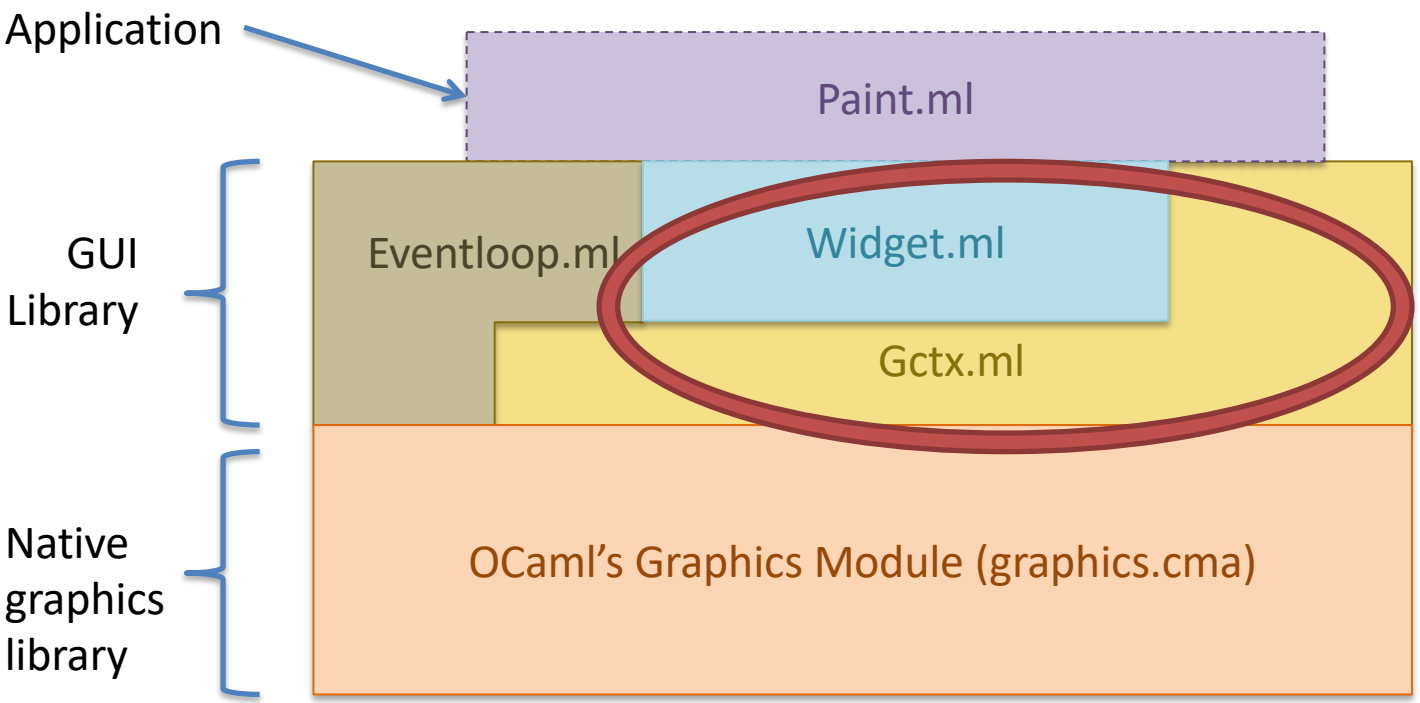
Widget tree



On the screen

Review: Widget Layout

- Widgets are “things drawn on the screen”. How to make them location independent?
- Idea: Use a *graphics context* to make drawing *relative* to the widget’s current position



The graphics context isolates the widgets from the Graphics module.

Simple Widgets

simpleWidget.mli

```
(* An interface for simple GUI widgets *)
type widget = {
   repaint : Gctx.gctx -> unit;
   size    : unit -> (int * int)
}
val label  : string -> widget
val space  : int * int -> widget
val border : widget -> widget
val hpair  : widget -> widget -> widget
val canvas : int * int -> (Gctx.gctx -> unit) -> widget
```

- You can ask a simple widget to repaint itself
- You can ask a simple widget to tell you its size

- Repainting is relative to a graphics context

Widget Examples

```
(* A simple widget that puts some text on the screen *)
let label (s:string) : widget =
{
  repaint = (fun (g:Gctx.gctx) -> Gctx.draw_string g (0,0) s);
  size = (fun () -> Gctx.text_size s)
}
```

simpleWidget.ml

```
(* A "blank" area widget -- it just takes up space *)
let space ((w,h):int*int) : widget =
{
  repaint = (fun (_:Gctx.gctx) -> ());
  size = (fun () -> (w,h))
}
```

simpleWidget.ml

The canvas Widget

- Region of the screen that can be drawn upon
- Has a fixed width and height
- Parameterized by a repaint method
  - …which will directly use the Gctx drawing routines to draw on the canvas

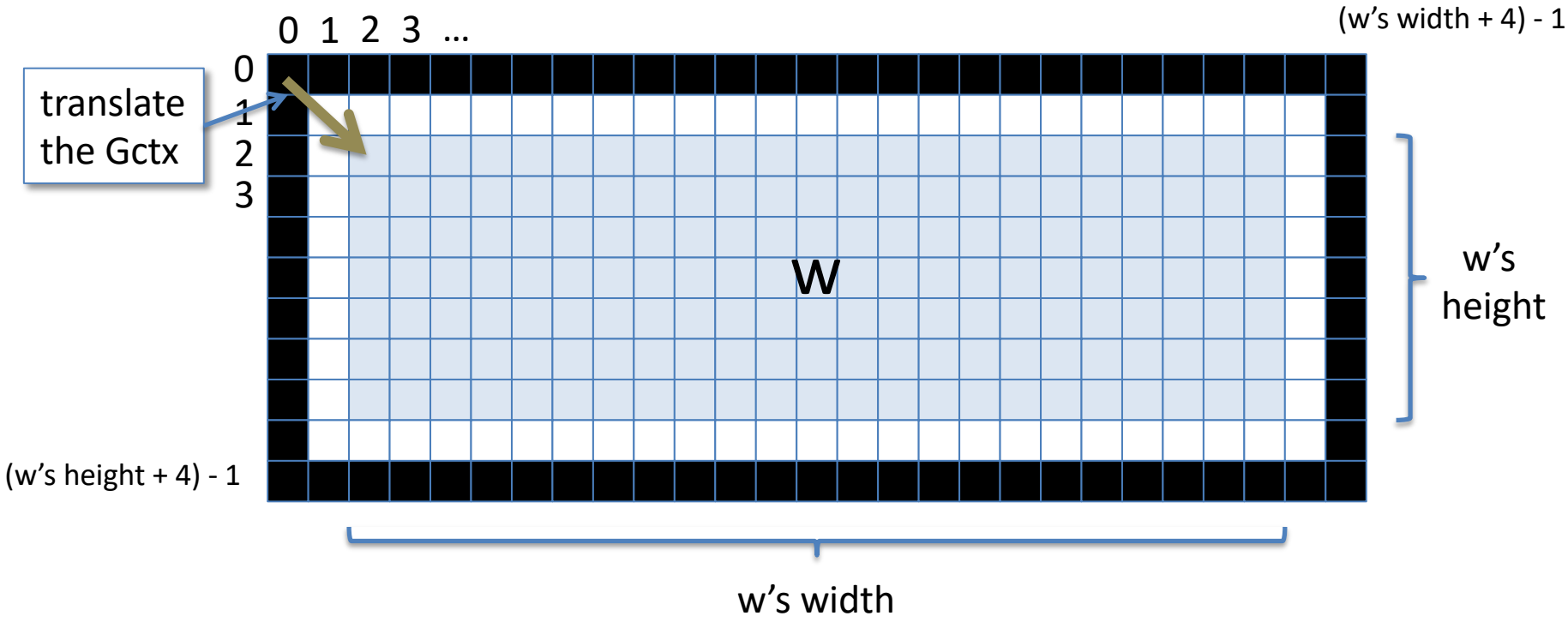
```
let canvas ((w,h):int*int) (r: Gctx.gctx -> unit) : widget =
{
  repaint = r;
  size = (fun () -> (w,h))
}
```

simpleWidget.ml

Nested Widgets

Containers and Composition

The Border Widget Container



- `let b = border w`
- Draws a one-pixel wide border around contained widget w
- b's size is slightly larger than w's (+4 pixels in each dimension)
- b's repaint method must call w's repaint method
- When b asks w to repaint, b must *translate* the Gctx.t to (2,2) to account for the displacement of w from b's origin

The Border Widget

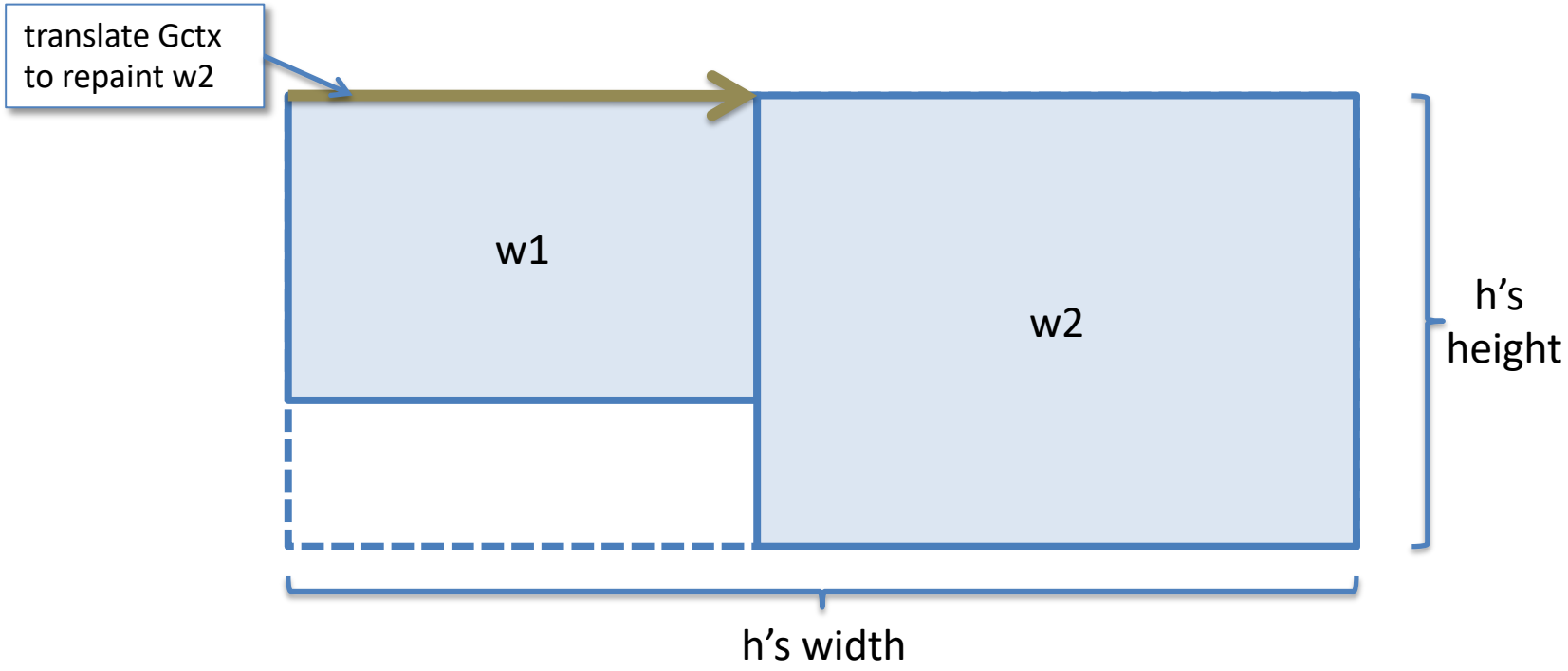
simpleWidget.ml

```
let border (w:widget):widget =
{
repaint = (fun (g:Gctx.gctx) ->
  let (width,height) = w.size () in
  let x = width + 3 in
  let y = height + 3 in
  Gctx.draw_line g (0,0) (x,0);
  Gctx.draw_line g (0,0) (0,y);
  Gctx.draw_line g (x,0) (x,y);
  Gctx.draw_line g (0,y) (x,y);
  let gw = Gctx.translate g (2,2) in
  w.repaint gw);

size = (fun () ->
  let (width,height) = w.size () in
  (width+4, height+4))
}
```

Draw the border

Display the interior

The hpair Widget Container



- `let h = hpair w1 w2`
- Creates a horizontally adjacent pair of widgets
- Aligns them by their top edges
  - Must translate the Gctx when repainting w2
- Size is the *sum* of their widths and *max* of their heights

The hpair Widget

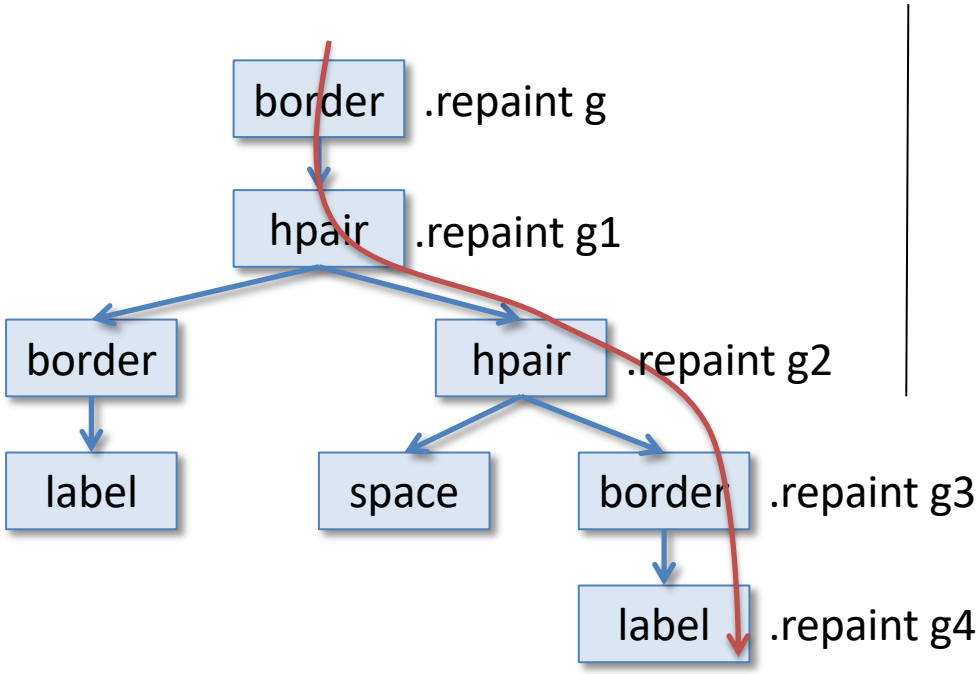
simpleWidget.ml

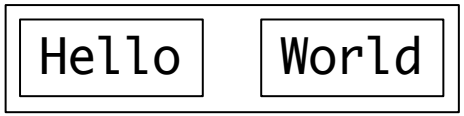
```
let hpair (w1: widget) (w2: widget) : widget =
  {
    repaint = (fun (g: Gctx.gctx) ->
            let (x1, _) = w1.size () in begin
              w1.repaint g;
              w2.repaint (Gctx.translate g (x1,0))
              (* Note translation of the Gctx *)
            end);

    size = (fun () ->
            let (x1, y1) = w1.size () in
            let (x2, y2) = w2.size () in
            (x1 + x2, max y1 y2))
  }
```

Translate the Gctx to shift w2's position relative to widget-local origin.

Drawing: Containers

Container widgets propagate repaint commands to their children:



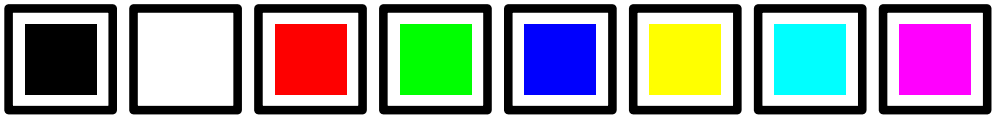


Widget tree

```
g1 = Gctx.translate g (2,2)
g2 = Gctx.translate g1 (hello_width,0)
g3 = Gctx.translate g2 (space_width,0)
g4 = Gctx.translate g3 (2,2)
```

On the screen

Container Widgets for layout

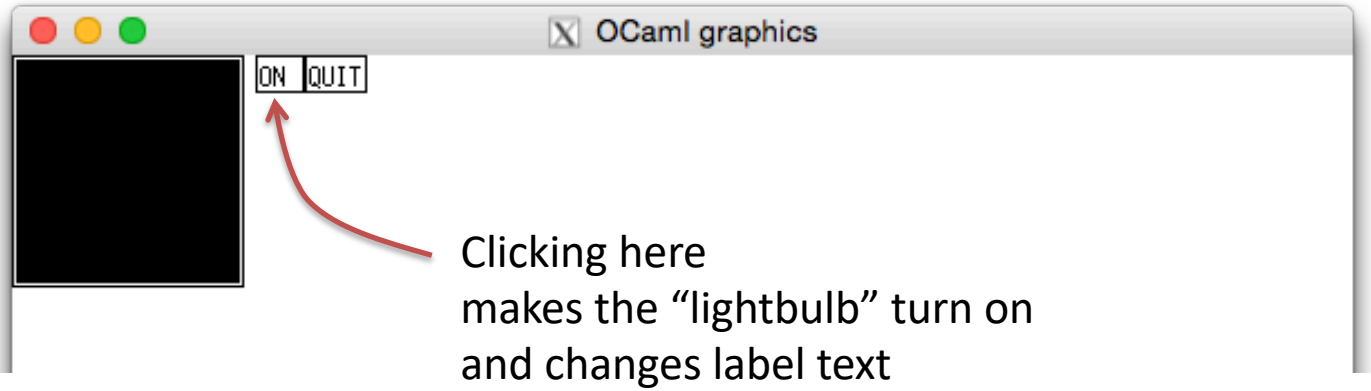


```
let color_toolbar : widget = hlist
   [ color_button black;  spacer;
     color_button white;  spacer;
     color_button red;    spacer;
     color_button green;  spacer;
     color_button blue;   spacer;
     color_button yellow; spacer;
     color_button cyan;   spacer;
     color_button magenta]
```

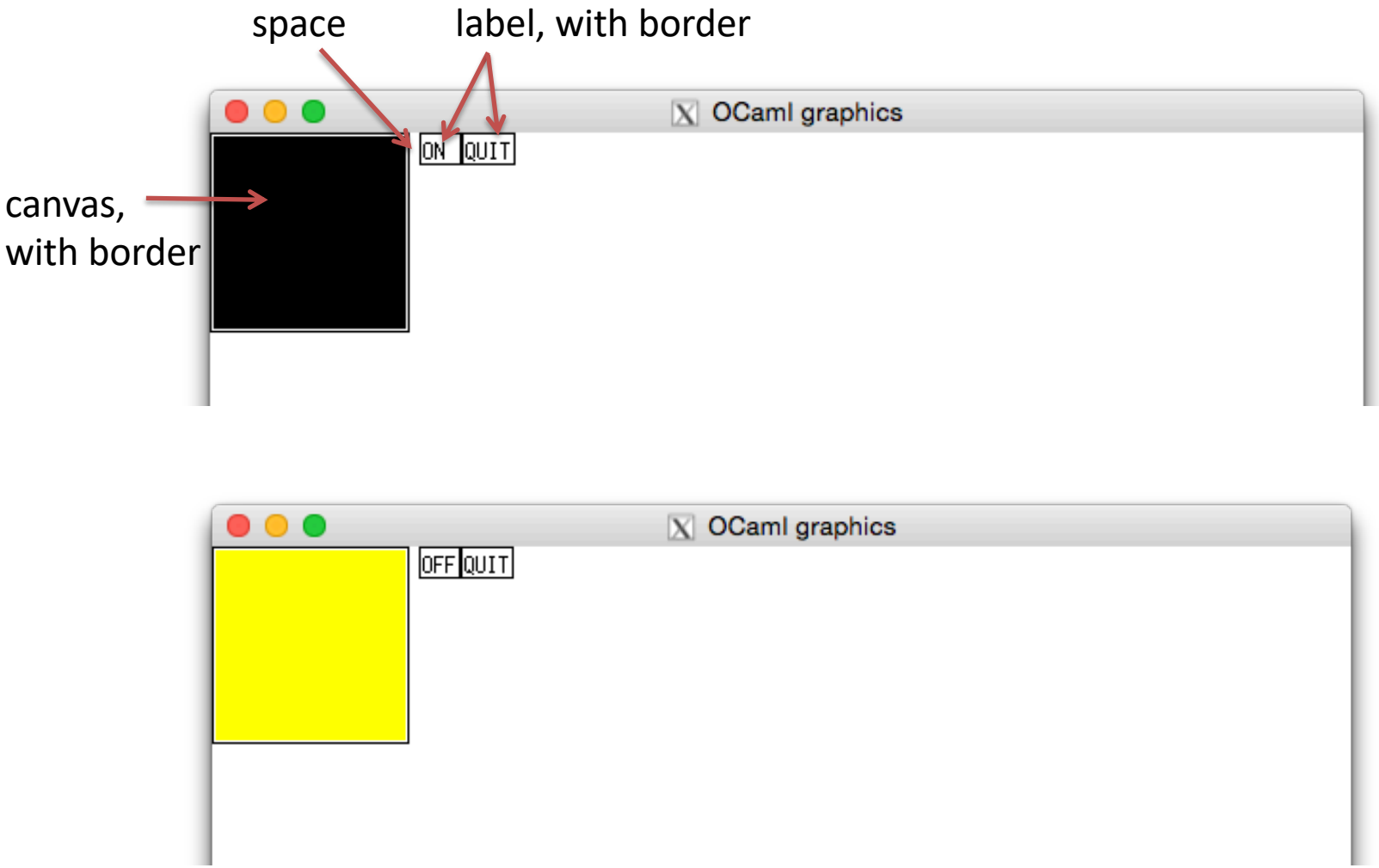
paint.ml

hlist is a container widget. It takes a list of widgets and turns them into a single one by laying them out horizontally (using hpair).

lightbulb demo



lightbulb demo



Do you know how you would use the (simple) widget library to define the layout of this application?


```
type widget = {
   repaint : Gctx.gctx -> unit;
   size    : unit -> (int * int)
}
val label  : string -> widget
val space  : int * int -> widget
val border : widget -> widget
val hpair  : widget -> widget -> widget
val canvas : int * int -> (Gctx.gctx -> unit) -> widget
```

I don't know how to start

I may have it, but I'm not sure

I'm sure I've got it

See: simpleWidget.ml and swdemo.ml

CODING WITH SIMPLE WIDGES

Events and Event Handling

Event loop with event handling

```
let run (w:widget) : unit =
  let g = Gctx.top_level  in      …create the initial gctx…
  Graphics.loop                   …wait for user input
    (fun e ->
       clear_graph ();
       w.handle g e;              …inform widget about the event…
       w.repaint g)               …update the widget's appearance…
```

Eventloop

```
let rec loop (f: event -> unit) : unit =
  let e = wait_next_event () in
  f e;
  loop f
```

Graphics

Events

gcxt.mli

```
type event

val wait_for_event : unit -> event

type event_type =
  | KeyPress of char  (* User pressed a key                    *)
  | MouseDown         (* Mouse Button pressed, no movement     *)
  | MouseUp           (* Mouse button released, no movement    *)
  | MouseMove         (* Mouse moved with button up            *)
  | MouseDrag         (* Mouse moved with button down          *)

val event_type : event -> event_type
val event_pos  : event -> gctx -> position
```

Remember:
The graphics context translates the location of the event to widget-local coordinates

Reactive Widgets

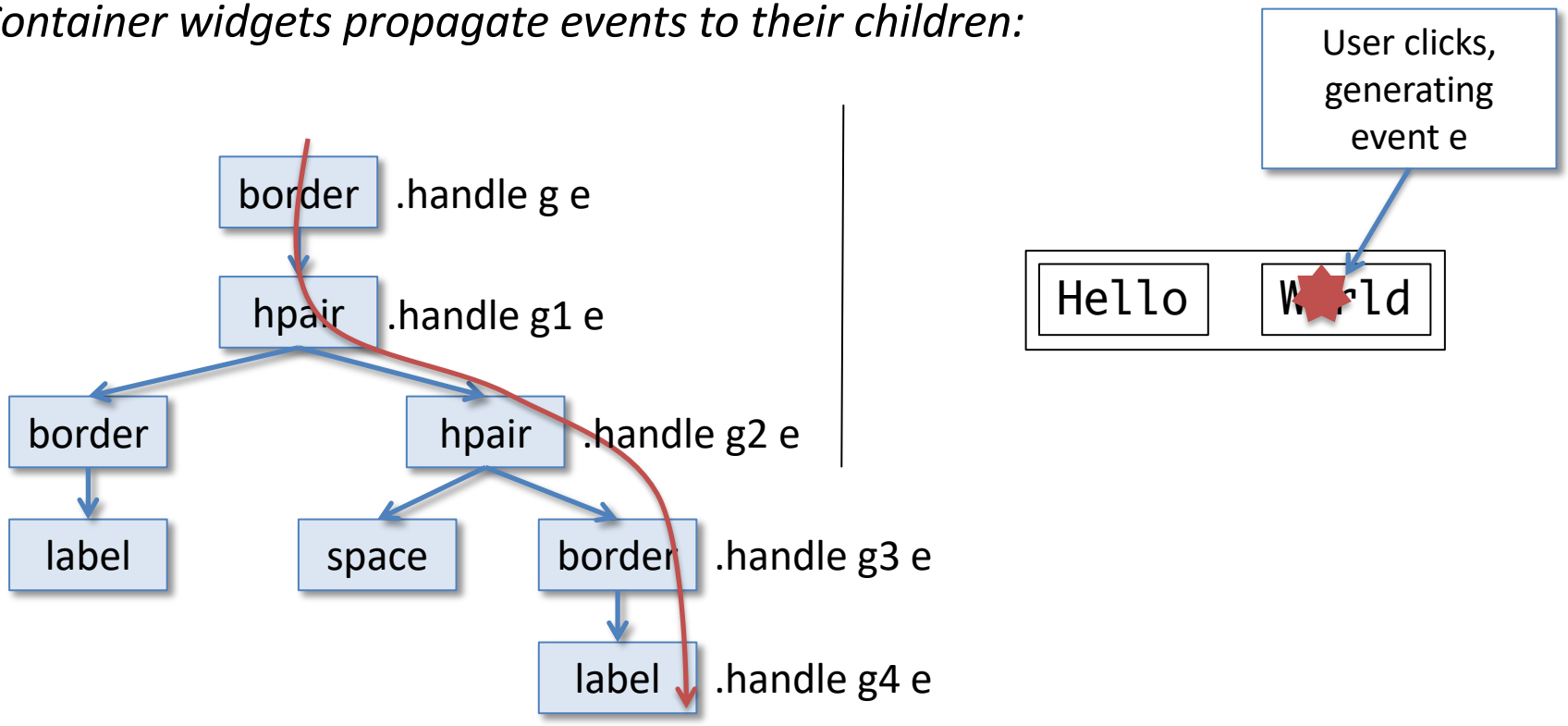
widget.mli

```
type widget = {
  repaint : Gctx.gctx -> unit;
  size    : unit -> Gctx.dimension;
  handle  : Gctx.gctx -> Gctx.event -> unit
}
```

- Widgets now have a “method” for handling events
  - The eventloop waits for an event and then gives it to the root widget
  - The widgets forward the event down the tree, according to the position of the event

Event-handling: Containers

Container widgets propagate events to their children:



Widget tree

On the screen

Routing events through container widgets

Event Handling: Routing

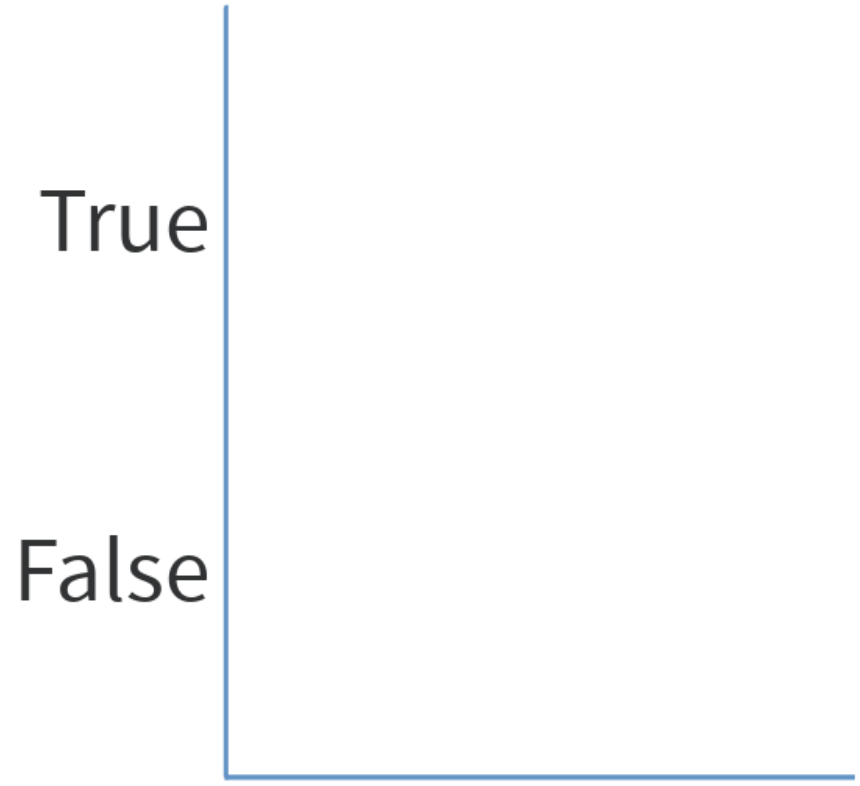
- When a container widget handles an event, it passes the event to the appropriate child
- The Gctx.gctx must be translated so that the child can interpret the event in its own local coordinates.

widget.ml

```
let border (w:widget):widget =
  { repaint = …;
    size = …;
    handle = (fun (g:Gctx.gctx) (e:Gctx.event) ->
       w.handle (Gctx.translate g (2,2)) e);
  }
```

Consider routing an event through an hpair widget constructed as shown. The event will always be propagated either to w1 or w2.

```
let hp = hpair w1 w2
```



Consider routing an event through an hpair widget constructed by:

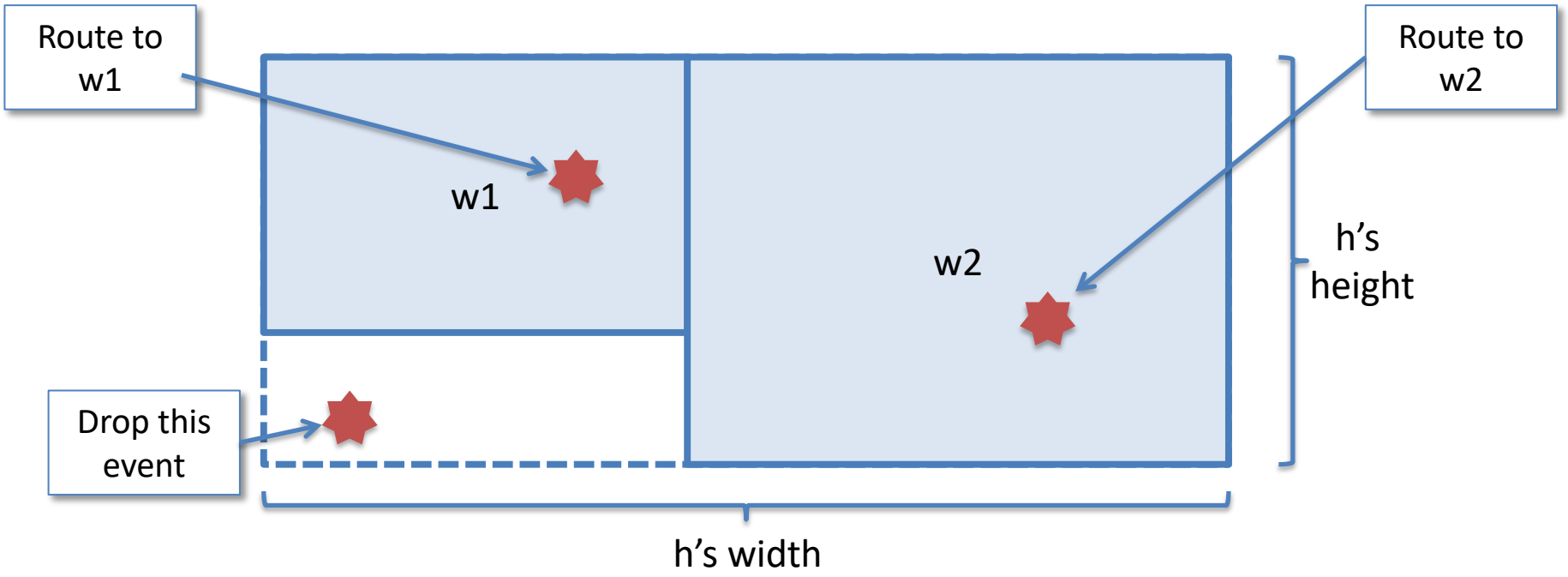
```
let hp = hpair w1 w2
```

The event will always be propagated either to w1 or w2.

1. True
2. False

Answer: False

Routing events through hpair widgets



- There are three cases for routing in an hpair.
- An event in the "empty area" should not be sent to either w1 or w2.

Routing events through hpair widgets

- The event handler of an hpair must check to see whether the event should be handled by the left or right widget.
  - Check the event's coordinates against the *size* of the left widget
  - If the event is within the left widget, let it handle the event
  - Otherwise check the event's coordinates against the right child's
  - If the right child gets the event, don't forget to translate its coordinates

```
handle =
 (fun (g:Gctx.gctx) (e:Gctx.event) ->
   if event_within g e (w1.size ())
   then w1.handle g e
   else
   let g = (Gctx.translate g (fst (w1.size ()), 0)) in
     if event_within g e (w2.size ())
     then w2.handle g e
     else ())
```

Stateful Widgets

How can widgets react to events?

(not very useful first stab at a)

A stateful `label` Widget

```
let label (s: string) : widget =
  let r = { contents = s } in
  { repaint = (fun (g: Gctx.gctx) ->
                 Gctx.draw_string g (0,0) r.contents);
    handle  = (fun _ _ -> ());
    size    = (fun () -> Gctx.text_size r.contents)
  }
```

- The label object can make its string mutable. The “methods” can refer to this mutable string.
- But how can we change this string in response to an event?

A stateful `label` Widget

widget.ml

```
type label_controller = { set_label: string -> unit }

let label (s: string) : widget * label_controller =
  let r = { contents = s } in
    ({ repaint = (fun (g: Gctx.gctx) ->
                  Gctx.draw_string g (0,0) r.contents);
      handle  = (fun _ _ -> ());
      size    = (fun () -> Gctx.text_size r.contents)
     }
    ,
    { set_label = fun (s: string) -> r.contents <- s })
```

- A *controller* gives access to the shared state.
  - Here, the `label_controller` object returned by `label` provides a way to set the label string