Programming Languages and Techniques (CIS120)

Lecture 20

February 29th, 2016

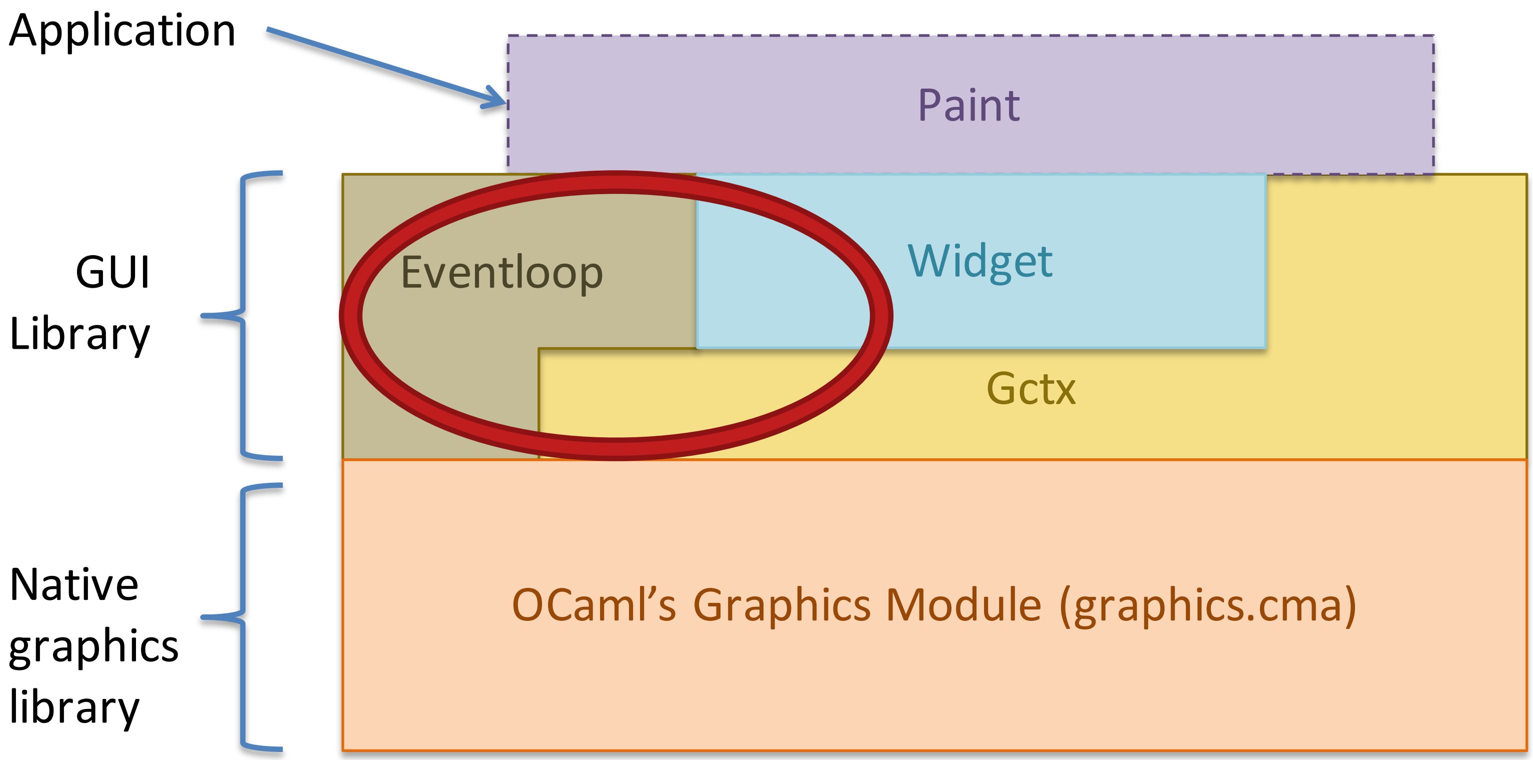
GUI library: events

How far are you on HW 5?

1. Haven’t started yet
2. Working on Tasks 1-4 (layout, drawing)
3. Working on Checkboxes
4. Working on Something Cool
5. I’m done!

Events and Event Handling

Project Architecture

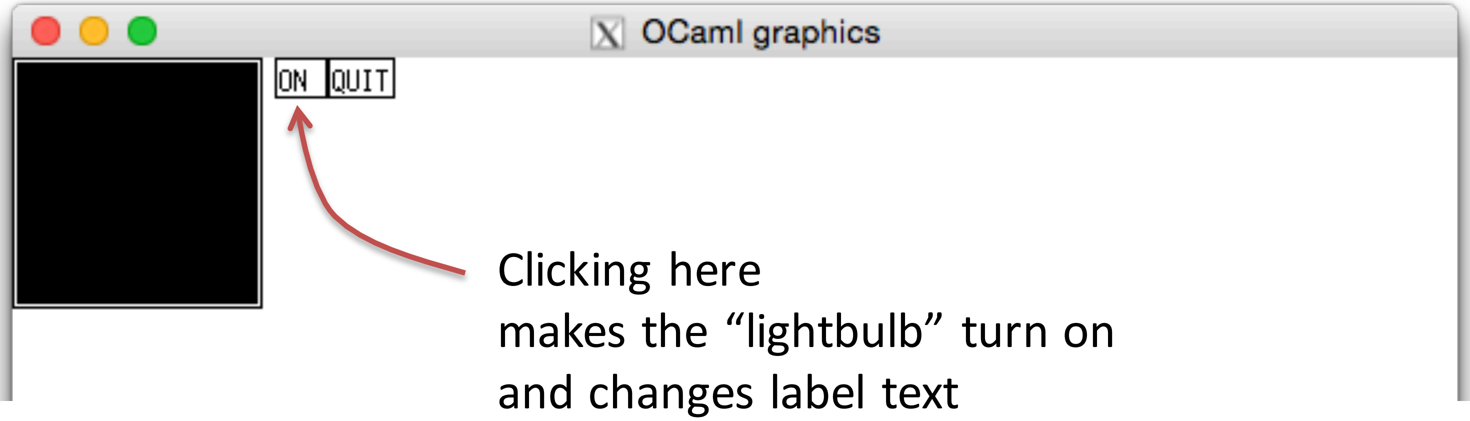


Goal of the GUI library: provide a consistent layer of abstraction *between* the application (Paint) and the Graphics module.

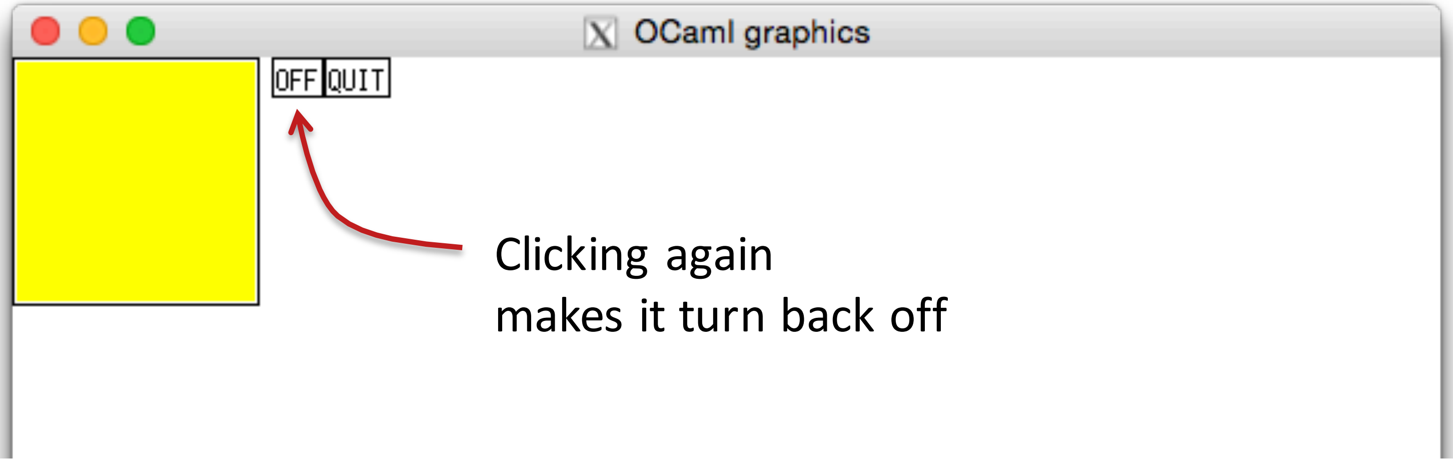
Demo: onoff.ml

Reacting to events

lightbulb demo

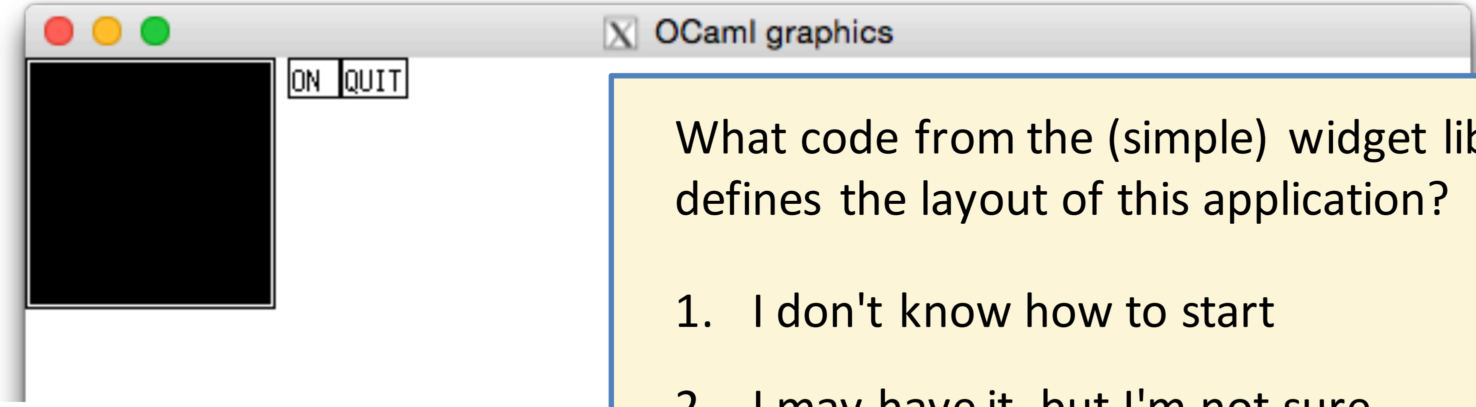


Clicking here
makes the "lightbulb" turn on
and changes label text



Clicking again
makes it turn back off

lightbulb demo

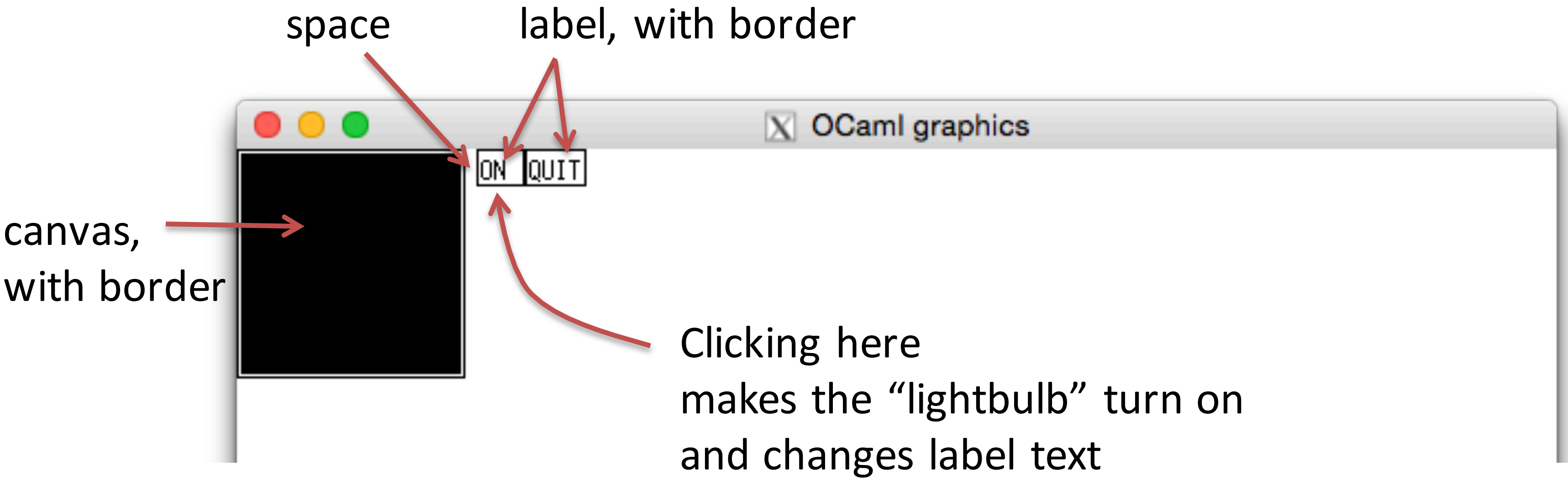


What code from the (simple) widget library defines the layout of this application?

1. I don't know how to start
2. I may have it, but I'm not sure
3. I'm sure I've got it

```
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
```

lightbulb demo

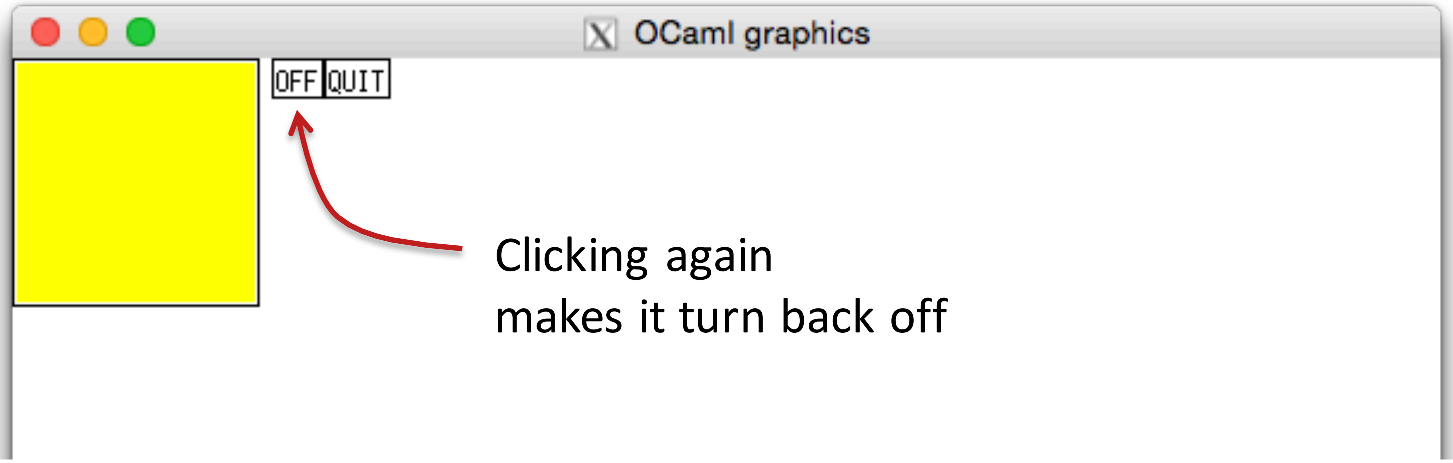


space

label, with border

canvas,
with border

Clicking here
makes the “lightbulb” turn on
and changes label text



Clicking again
makes it turn back off

User Interactions

- Problem: When a user moves the mouse, clicks the button, or presses a key, the application should react. How?

swdemo.ml

```
let run (w:widget) : unit =

  Gctx.open_graphics ();             (* open graphics window *)

  let g = Gctx.top_level in
  w.repaint g;                    (* repaint the widget once *)

  Graphics.synchronize ();            (* force window update *)
  ignore (Graphics.read_key ())       (* wait for a keypress *)
```

GUI terminology - Eventloop

```
let run (w:widget) : unit =
  Gctx.open_graphics ();
  let g = Gctx.top_level in

  let rec loop () : unit =
    Graphics.clear_graph ();

    w.repaint g;

    Graphics.synchronize ();          (* force window update *)

    wait for user input (mouse movement, key press)
    inform w about the input so widgets can react to it;

    loop ()                           (* tail recursion! *)
  in
    loop ()
```

Solution: The Event Loop

eventloop.ml

```
let run (w:Widget.t) : unit =
  Gctx.open_graphics ();
  let g = Gctx.top_level in


  let rec loop () =
    Graphics.clear_graph ();
    w.repaint g;
    Graphics.synchronize ();

    let e = Gctx.wait_for_event g in   (* wait for user input *)
      w.handle g e;                    (* react to event *)

    loop ()
  in
    loop ()
```

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
```

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

Reactive Widgets

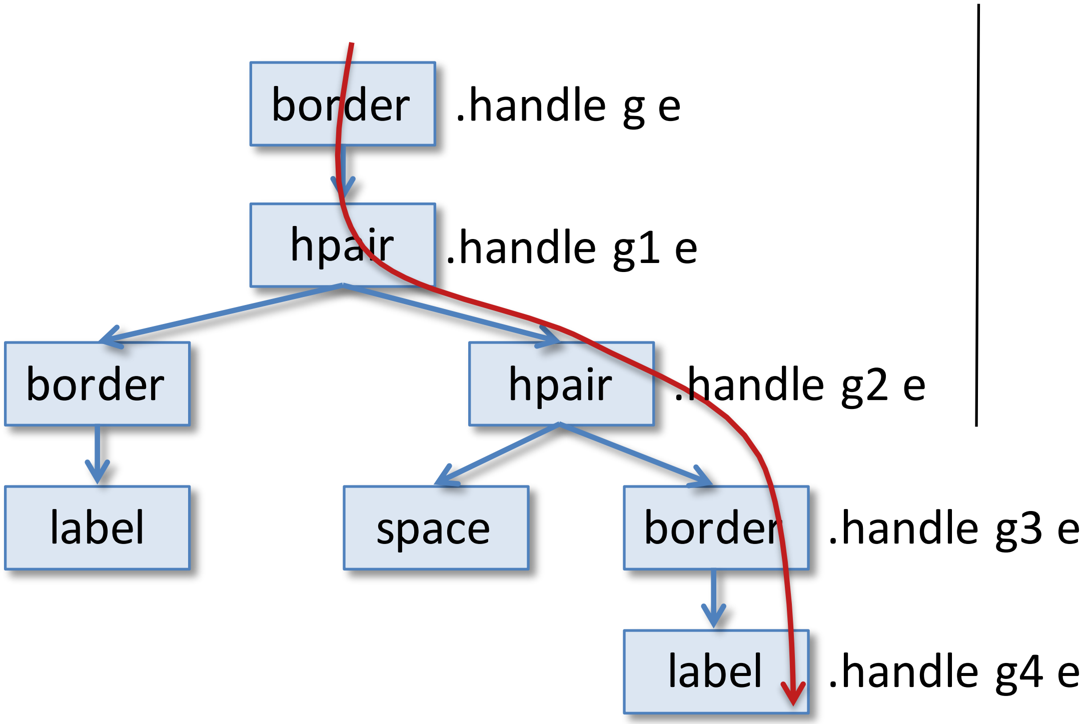
widget.mli

```
type t = {
  repaint : Gctx.gctx -> unit;
  size    : unit -> Gctx.dimension;
  handle  : Gctx.gctx -> Gctx.event -> unit  (* NEW! *)
}
```

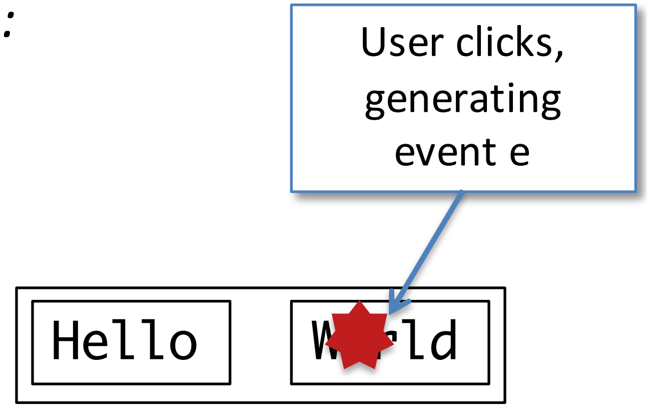
- Widgets have a “method” for handling events
  - The eventloop waits for an event and then gives it to the root widget
  - The widgets forward the event down the tree, according to the position of the event

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);
  }
```

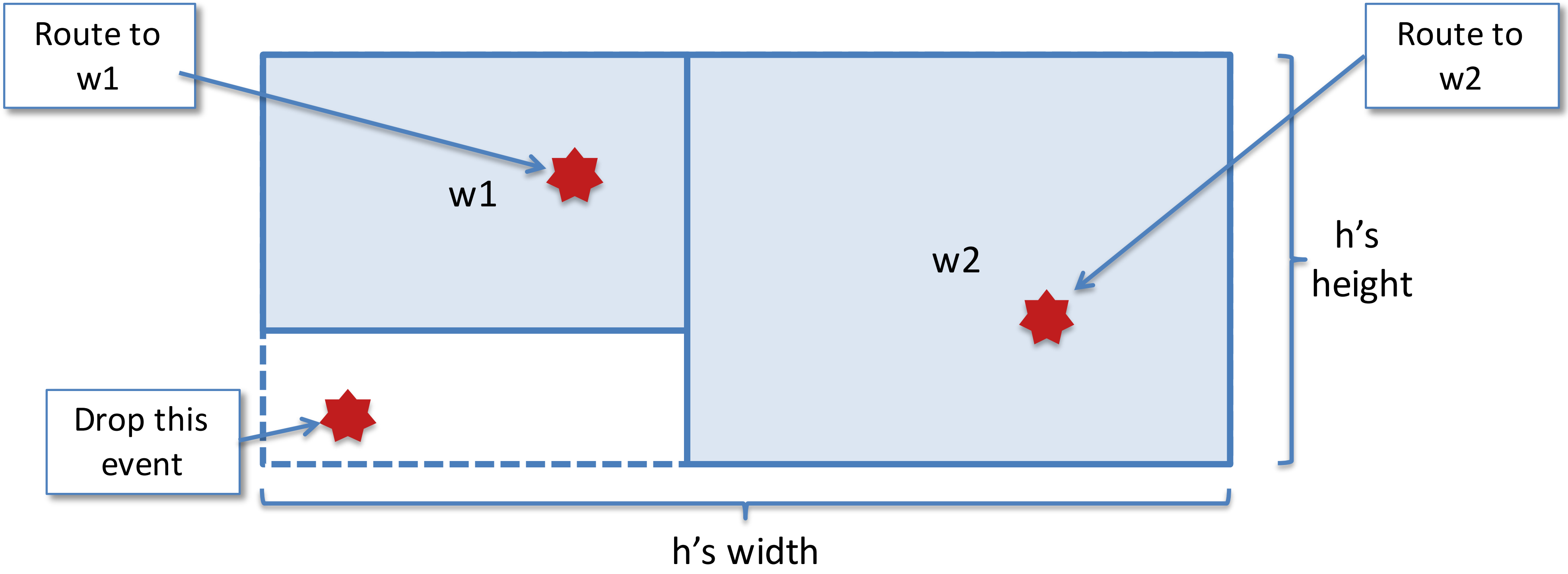
Consider routing an event through an hpair widget constructed by:

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

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

1. True
2. False

Dropping Events in an HPair



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

Stateful Widgets

How can widgets react to events?

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 encapsulate that string.
- But what if the application wants to 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.
  - e.g. the `label_controller` object provides a way to set the label

Demo: onnoff.ml

Changing the label on a button click

When a widget's handle function receives an event, it should also call functions from the Gctx library to update the view of the widget.

1. True
2. False
3. Not sure

Event Listeners

How to react to events in a modular way?

Event Listeners

- Widgets may want to react to many *different* sorts of events
- Example: Button
  - button click: changes the state of the paint program and button label
  - mouse movement: tooltip? highlight?
  - key press: provide keyboard access to the button functionality?
- These reactions should be independent
  - Each sort of event handled by a different *event listener* (i.e. a first-class function)
  - Reactive widgets may have *several* listeners to handle a triggered event
  - Listeners react in sequence, all have a chance to see the event
- A *notifier* is a container widget that adds event listeners to a node in the widget hierarchy
- Note: this way of structuring event listeners is based on Java's Swing Library design (we use Swing terminology).

Listeners

widget.ml

```
type event_listener = Gctx.gctx -> Gctx.event -> unit

(* Performs an action upon receiving a mouse click. *)
let mouseclick_listener (action: unit -> unit)
                       : event_listener =
  fun (g:Gctx.gctx) (e: Gctx.event) ->
    if Gctx.event_type e = Gctx.MouseDown
    then action ()
```

Notifiers

- A *notifier* is a container widget that adds event listeners to a node in the widget hierarchy.
- The *event listeners* “eavesdrop” on the events flowing through the node
  - The event listeners are stored in a list
  - They react in order, if one of them handles the event the later ones do not hear it
  - If none of the listeners handle the event, then the event continues to the child widget
- List of event listeners can be updated by using a notifier_controller

Notifiers and Notifier Controllers

widget.ml

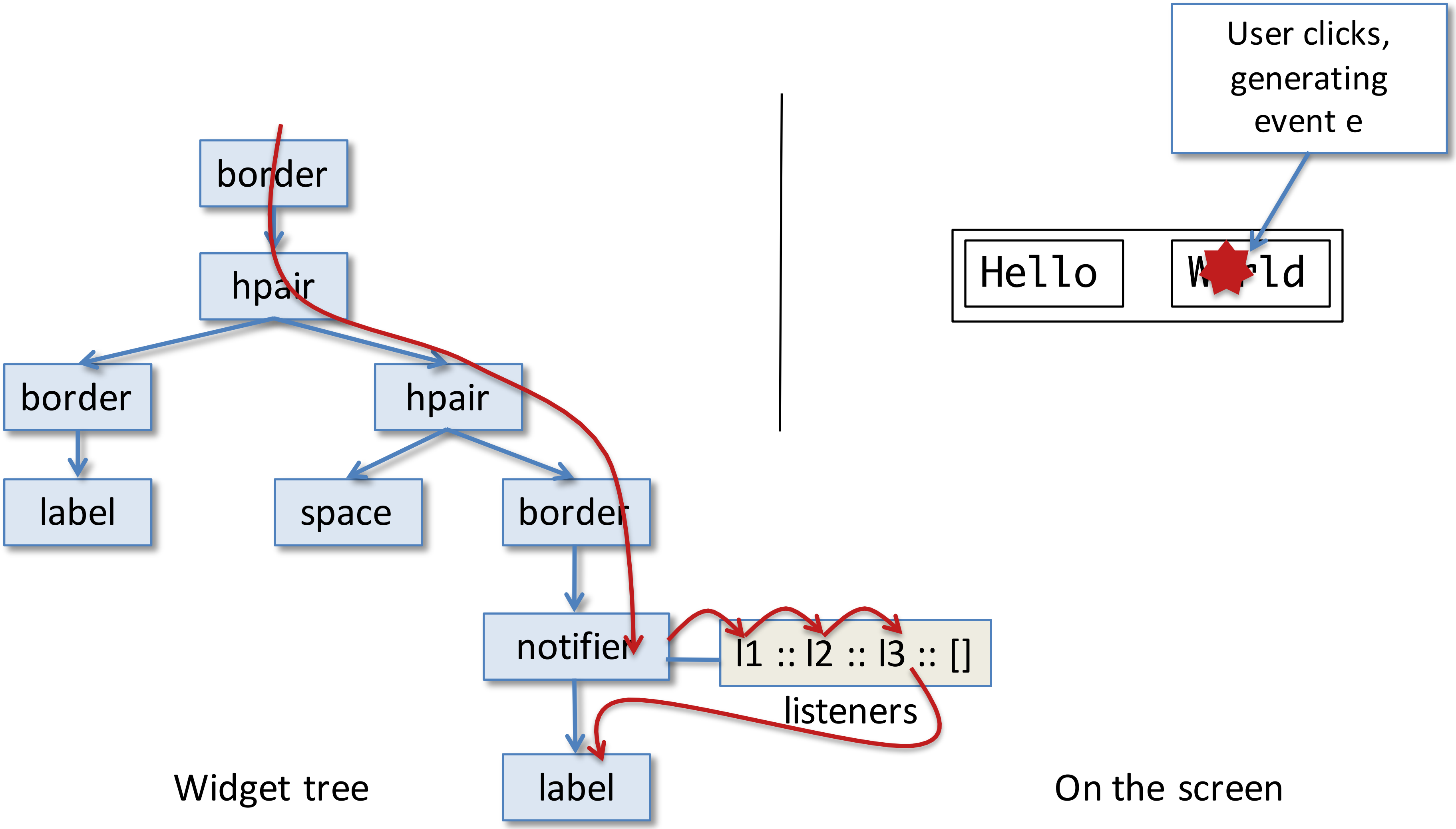
```
type notifier_controller =
     { add_listener : event_listener -> unit }

let notifier (w: widget) : widget * notifier_controller =
  let listeners = { contents = [] } in
  { repaint = w.repaint;
    handle =
      (fun (g: Gctx.gctx) (e: Gctx.event) ->
          List.iter (fun h -> h g e) listeners.contents;
          w.handle g e);
    size = w.size
  },
  { add_event_listener =
      fun (newl: event_listener) ->
          listeners.contents <-
                 newl :: listeners.contents
  }
```

Loop through the list of listeners, allowing each one to process the event. Then pass the event to the child.

The notifier_controller allows new listeners to be added to the list.

Listeners and Notifiers Pictorially



Buttons (at last!)

widget.ml

```
(* A text button *)
let button (s: string) : widget
                       * label_controller
                       * notifier_controller =
  let (w, lc)  = label s in
  let (w', nc) = notifier w in
    (w', lc, nc)
```

- A button widget is just a label wrapped in a notifier
- Add a mouseclick_listener to the button using the notifier_controller
- (For aesthetic purposes, you can but a border around the button widget.)