

Computer Labs: Event Driven Design

2º MIEIC

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Events and I/O

Event An **event** is a change in the state

- ▶ Virtually all I/O processing is driven by events
 - ▶ Whether events are detected by interrupts or by polling
 - ▶ Even video graphics output may depend on events (synchronization with the vertical “movement” to avoid visual artifacts)
- ▶ All labs so far, have been driven by I/O events
- ▶ Your project will also be event driven:
 - ▶ Its execution will depend on events generated by the I/O devices
 - ▶ Whether you use polling or interrupts for detecting these events.

Event Driven Design

- ▶ **Event** driven design is characterized by:
 - ▶ A **flow control** that is determined by the **environment** rather than the program itself
 - ▶ Code that is executed **reactively** in response to events that may occur **asynchronously** with program execution
- ▶ Event driven design is common in:
 - ▶ Graphical user interfaces (GUI)
 - ▶ Games
 - ▶ Communications/network software
 - ▶ Embedded systems

Simple Event Driven Design

Events The types of events that the different components of the system have to handle

Event Queues That provide the necessary buffering so that handling of an event may occur asynchronously to its occurrence

Event Handlers That process each type of event

Dispatchers That monitor the event queues and call the appropriate event handlers

- ▶ May be implemented as a simple loop that checks for events

Event Driven Design and Minix 3 DD Design

- We can find these elements of event driven design in the pattern used in the design of interrupt driven Minix 3 DDs

```
5: while( 1 ) { /* You may want to use a different condition */
6:     /* Get a request message. */
7:     if ( driver_receive(ANY, &msg, &ipc_status) != 0 ) {
8:         printf("driver_receive failed with: %d", r);
9:         continue;
10:    }
11:    if (is_ipc_notify(ipc_status)) { /* received notification
12:        switch (_ENDPOINT_P(msg.m_source)) {
13:            case HARDWARE: /* hardware interrupt notification */
14:                if (msg.m_notify.interrupts & irq_set) { /* subsc
15:                    ... /* process it */
16:                }
17:                break;
18:            default:
19:                break; /* no other notifications expected: do not
20:        }
21:    } else { /* received a standard message, not a notificati
```

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Event Driven Design and State Machines

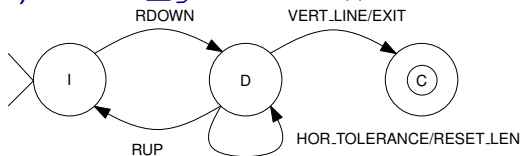
- ▶ For other than simple designs, it is very helpful to use state machines in combination with event driven design
 - ▶ A state machine is useful when event handling depends on the state of a process
- ▶ A state machine is itself event driven
 - ▶ The transition from one state to another depends on the occurrence of an input event

Lab 4: `test_gesture()` (2015/2016 version)

- ▶ The program should exit when the user "draws" a vertical line , while pressing down the right button
 - ▶ Need some "tolerance" to make it easy to test
- ▶ You can ignore some events, namely those related to other buttons.
- ▶ This year the gesture to detect will be different:



Lab 4 (15/16): `test_gesture()` State Machine (1/2)



Cur. State	Input	Next State	Output
I (nitial)	RDOWN	D (rawing)	
D (rawing)	VERT_LINE	C (omplete)	Exit
D (rawing)	RUP	I (nitial)	
D (rawing)	HOR_TOLERANCE	D (rawing)	Reset length

RDOWN Right button has been pressed

RUP Right button has been released

VERT_LINE Vertical line with desired length drawn

HOR_TOLERANCE Horizontal tolerance exceeded

- ▶ This is somewhat high-level
 - ▶ You need to detect the events from the packets received from the mouse
 - ▶ You can use other state machines

Lab 4 (15/16) test_gesture() - State Machine (2/2)

```
typedef enum {INIT, DRAW, COMP} state_t;
typedef enum {RDOW, RUP, MOVE} ev_type_t;
void check_hor_line(event_t *evt) {
    static state_t st = INIT; // initial state; keep state
    switch (st) {
        case INIT:
            if( evt->type == RDOWN )
                state = DRAW;
            break;
        case DRAW:
            if( evt->type == MOVE ) {
                [...] // need to check if events VERT_LINE or HOR_TOLERANCE
            } else if( evt->type == RUP )
                state = INIT;
            break;
        default:
            break;
    }
}
```

- ▶ This is rather high-level
 - ▶ You need to add code to detect the events
 - ▶ This can be done with other state machines

(State Machines)

- ▶ This state machine is an example of a **Mealy Machine**, drawn “à la DFA”:
 - ▶ A state machine where the output depends **not only** on the state **but also** on the input event
- ▶ An alternative state machine is the **Moore Machine**:
 - ▶ A state machine where the output depends **only** on the state.
 - ▶ This usually leads to extra states
 - ▶ In this (simple) case the two machines are structurally equal
- ▶ They are essentially equivalent, but in an event-driven design the implementation of a Mealy machine is more straightforward:
 - ▶ For each state, when a **relevant event** occurs, just produce the output (if any) and change the state (this is a special output)
 - ▶ A **relevant event** may not be a raw event generated by an input device:
 - ▶ “Raw” events generated by mice are the reception of packet bytes, not the change in the state of mouse buttons
 - ▶ This is the opposite of digital circuit design:
 - ▶ In HW, it is easier to implement Moore machines than Mealy machines

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Event Processing

- ▶ I/O devices' events are processed by the corresponding interrupt handlers

- ▶ The IHs may be

Application Dependent For example, the mouse IH not only receives the mouse packets, but also detects the exit sequence

Application Independent The mouse IH just receives the mouse packets. The exit sequence is detected by application dependent code.

- ▶ Need to define an application dependent event handler
- ▶ Need to specify how the IH “communicates” with this event handler
 - ▶ How the data received from the mouse is passed to the event handler?
 - ▶ When is the event handler executed?

Application Independent vs Application Dependent IH

In General

- ▶ Can be reused
 - ▶ Operating systems IH is independent of applications
- ▶ Introduces a level of indirection
 - ▶ May add flexibility
 - ▶ May be more responsive (app. indep. IHs are shorter)
 - ▶ Requires more code (overall)
 - ▶ Has higher overhead

In Minix 3 Labs and Project

`driver_receive()` is a blocking call

- ▶ Application dependent processing must be done in the same iteration loop as application independent processing
 - ▶ It is not possible to delay application dependent processing until there are no interrupts to handle
- ▶ It does not afford as much flexibility as in the general case
 - ▶ This is **not** an issue for ordinary Minix 3 DDs

Minix 3 and Application Independent IHs

```
5: while( 1 ) { /* You may want to use a different condition */
6:     /* Get a request message. */
7:     if ( driver_receive(ANY, &msg, &ipc_status) != 0 ) {
8:         printf("driver_receive failed with: %d", r);
9:         continue;
10:    }
11:    if (is_ipc_notify(ipc_status)) { /* received notification
12:        switch (_ENDPOINT_P(msg.m_source)) {
13:            case HARDWARE: /* hardware interrupt notification */
14:                if (msg.NOTIFY_ARG & irq_set) { /* subscribed int
15:                    ... /* process it */
16:                }
17:                ...
18:            }
19:        } else { /* received a standard message, not a notificati
20:            ...
21:        }
22:        /* Now, do application dependent event handling */
23:        if ( event & MOUSE_EVT ) {
24:            handle_mouse();
25:        }
26:        if ( event &
```


Further Reading

- ▶ Máquinas de Estado em C