Input part 3: Implementing Interaction Techniques
Interaction techniques

- A method for carrying out a specific interactive task
  - Example: enter a number in a range
    - could use… (simulated) slider
    - (simulated) knob
    - type in a number (text edit box)
  - Each is a different interaction technique
Suppose we wanted to implement an interaction for specifying a line

- Could just specify two endpoints
  - click, click
  - not good: no affordance, no feedback
- Better feedback is to use “rubber banding”
  - stretch out the line as you drag
  - at all times, shows where you would end up if you “let go”
Aside

- Rubber banding provides good feedback
- How would we provide better affordance?
Aside

- Rubber banding provides good feedback
- How would we provide better affordance?
  - Changing cursor shape is about all we have to work with
Implementing rubber banding

Accept the press for endpoint p1;
P2 = P1;
Draw line P1–P2;
Repeat
   Erase line P1–P2;
P2 = current_position();
   Draw line P1–P2;
Until release event;
Act on line input;
Implementing rubber banding

- Need to get around this loop absolute min of 5 times / sec
  - 10 times better
  - more would be better
- Notice we need “undraw” here
What’s wrong with this code?

Accept the press for endpoint p1;
P2 = P1;
Draw line P1-P2;
Repeat
   Erase line P1-P2;
   P2 = current_position();
   Draw line P1-P2;
Until release event;
Act on line input;
Not event driven

- Not in the basic event / redraw cycle form
  - don’t want to mix event and sampled
  - in many systems, can’t ignore events for arbitrary lengths of time
- How do we do this in a normal event / redraw loop?
You don’t get to write control flow anymore

- Basically have to chop up the actions in the code above and redistribute them in event driven form
  - “event driven control flow”
  - need to maintain “state” (where you are) between events and start up “in the state” you were in when you left off
Finite state machine controllers

- One good way to maintain “state” is to use a state machine
  - (deterministic) finite state machine
  - FSM
FSM notation

- Circles represent states
  - arrow for start state
  - double circles for "final states"
- notion of final state is a little off for user interfaces (don’t ever end)
- but still use this for completed actions
- generally reset to the start state
FSM notation

- Transitions represented as arcs
  - Labeled with a “symbol”
    - for us an event (can vary)
  - Also optionally labeled with an action

Mouse_Dn / Draw_Line()
Means: when you are in state A and you see a mouse down, do the action (call draw_line), and go to state B
FSM Notation

- Sometimes also put actions on states
  - same as action on all incoming transitions
Rubber banding again 
(cutting up the code)

Accept the press for endpoint p1;

A: $\begin{align*}
    & P2 = P1; \\
    & \text{Draw line } P1-P2; \\
    & \text{Repeat} \\
\end{align*}$

B: $\begin{align*}
    & \text{Erase line } P1-P2; \\
    & P2 = \text{current_position}(); \\
    & \text{Draw line } P1-P2; \\
    & \text{Until release event;} \\
\end{align*}$

C: $\begin{align*}
    & \text{Act on line input;} \\
\end{align*}$
FSM control for rubber banding

A: $\text{P2} = \text{P1};$
   Draw line $\text{P1}-\text{P2};$

B: Erase line $\text{P1}-\text{P2};$
   $\text{P2} = \text{current\_position}();$
   Draw line $\text{P1}-\text{P2};$

C: Act on line input;
Second example: button

- Press inside: highlight
- Move in/out: change highlight
- Release inside: act
- Release outside: do nothing
FSM for a button?
FSM for a button

Press-inside / A

Enter / C

Leave / B

Release / D

Release / E
FSM for a button

A: highlight button
B: unhighlight button
C: highlight button
D: <do nothing>
E: do button action
In general...

- Machine states represent context of interaction
  - “where you are” in control flow
- Transitions indicate how to respond to various events
  - what to do in each context
“Events” in FSMs

- What constitutes an “event” varies
  - may be just low level events, or
  - higher level (synthesized) events
    - e.g. region-enter, press-inside

- Example: Swing ActionEvents
  - Generated from a range of *different* low-level events
    - Completion of button activation FSM
    - Hitting *enter* in a text field
Guards on transitions

- Sometimes also use “guards”
  - predicate (bool expr) before event
  - adds extra conditions req to fire
  - typical notation: pred: event / action
    - e.g. button.enabled: press-inside / A

- Note: FSM augmented with guards is Turing complete
FSM are a good way to do control flow in event driven systems

- Can do (formal or informal) analysis
  - are all possible inputs (e.g. errors) handled from each state
  - what are next legal inputs
    - can use to enable / disable
- Can be automated based on higher level specification
Implementing FSMs

```c
state = start_state;
for (;;) {
    raw_evt = wait_for_event();
    evt = transform_event(raw_evt);
    state = fsm_transition(state, evt);
}
```

- Note that this is basically the normal event loop
Implementing FSMs

```cpp
fsm_transition(state, evt)
    switch (state)
    {
        case 0:    // case for each state
            case 1:    // case for next state
                return state;
    }
```
Implementing FSMs

```c
fsm_transition(state, evt)
    switch (state)
        case 0:  // case for each state
            switch (evt.kind)
                case loc_move:  // trans evt
                    ... action ...  // trans action
                    state = 42;    // trans target
                case loc_dn:
                    ...
            case 1:  // case for next state
                switch (evt.kind) ...
        return state;
```
Implementing FSMs

```c
fsm_transition(state, evt)
    switch (state)
        case 0:  // case for each state
            switch (evt.kind)
                case loc_move:  // trans evt
                    ... action ...  // trans action
                    state = 42;  // trans target
                case loc_dn:
                    ...
                case 1:  // case for next state
                    switch (evt.kind) ...
    return state;
```
Table driven implementation

- Very stylized code
- Can be replaced with fixed code + table that represents FSM
  - only have to write the fixed code once
  - can have a tool that generates table from something else
Table driven implementation

- Table consists of array of states
- Each state has list of transitions
- Each transition has
  - event match method
  - list of actions (or action method)
  - target state
Table driven implementation

```python
fsm_transition(state, evt)
    for each transition TR in table[state]
        if TR.match(evt)
            TR.action()
            state = TR.to_state()
            break;
    return state
```

- Simpler: now just fill in table