CSCI 1106
Lecture 17

Using State Transition Diagrams

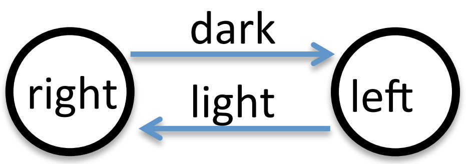
Announcements

- Today's Topics
  - Implementing State Transitions
  - Mapping state transition diagrams to programs
  - When to use `when`

Recall

States and Transitions

- State
  - Unique set of conditions
  - Describes a step of a task
  - Represented by a circle and a label
- Transition
  - Change of one or more conditions
  - Describes a change from one state to another
  - Represented by a labeled arc



Program Code

```
var state = STOPPED
motor.left.target = 0
motor.right.target = 0

onevent button.forward
  state = RIGHT

onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0

onevent prox
  if state != STOPPED then
    when prox.ground.delta[0] >= THRESHOLD do
      state = RIGHT
      motor.left.target = TARGET
      motor.right.target = 0
    end

    when prox.ground.delta[0] < THRESHOLD do
      state = LEFT
      motor.left.target = 0
      motor.right.target = TARGET
    end
  end
```

Translating State Transition Diagrams

- Problem:
  - We design our solution by creating a state transition diagram (STD)
  - We need to translate the STD into a program
- Idea: Use a standard process
  - Use a variable to encode the current state
  - Enumerate all states as constants
  - Identify events associated with each transition
  - Gather transition information
  - Implement event handlers to perform the transitions

Tracking and Enumerating States

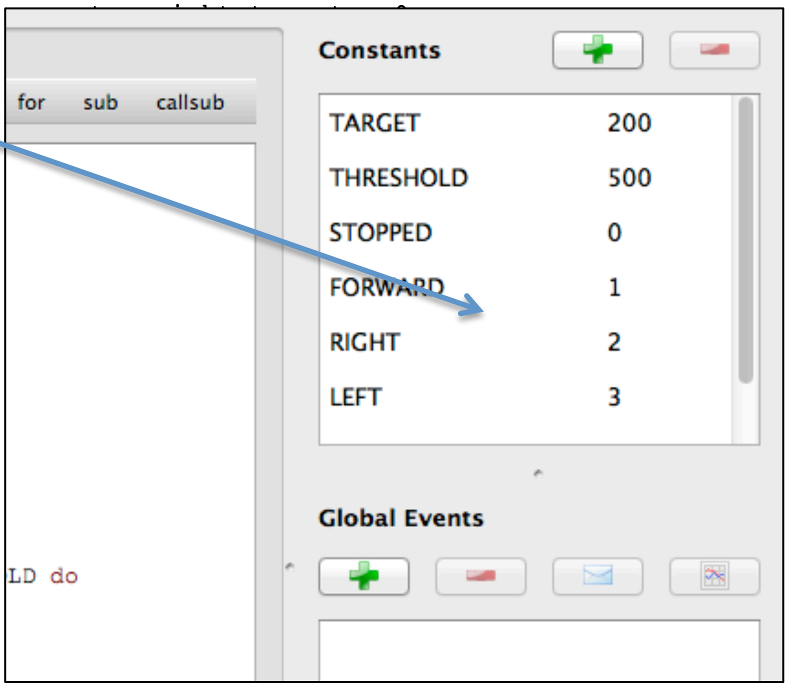
- Use a *state* variable
  - Stores the current state
  - Set to an initial state,
    e.g., STOPPED
- Enumerate all states
  - Select state names
    e.g., STOPPED, RIGHT, LEFT
  - Number consecutively
  - Add states as constants
- Can be done automatically

```
var state = STOPPED

motor.left.target = 0
motor.right.target = 0

onevent button.forward
  state = RIGHT

onevent button.backward
  state = STOPPED
  motor.left.target = 0
```



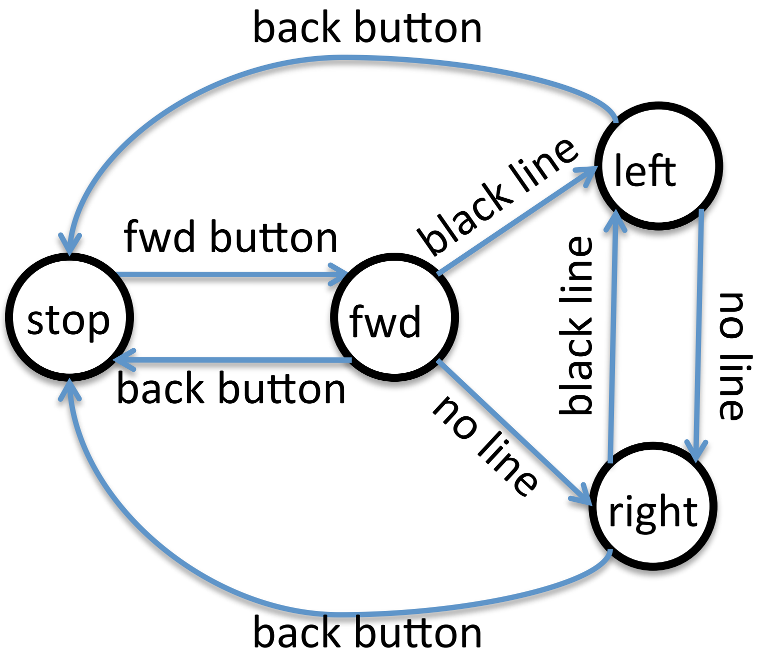
Constants

TARGET	200
THRESHOLD	500
STOPPED	0
FORWARD	1
RIGHT	2
LEFT	3

Identify Events

- Identify the events associated with each transition
  - `button.forward`: Forward Button pressed
  - `prox`: horizontal proximity or ground proximity sensors
  - `timer0` or `timer1`: timer has expired
  - `tap`: robot tapped
  - etc
- Add an event handler for each event
  - `onevent button.forward`
  - `onevent prox`
  - `onevent timer0`
- In each handler implement all the transitions associated with the event

Example: Identify Events



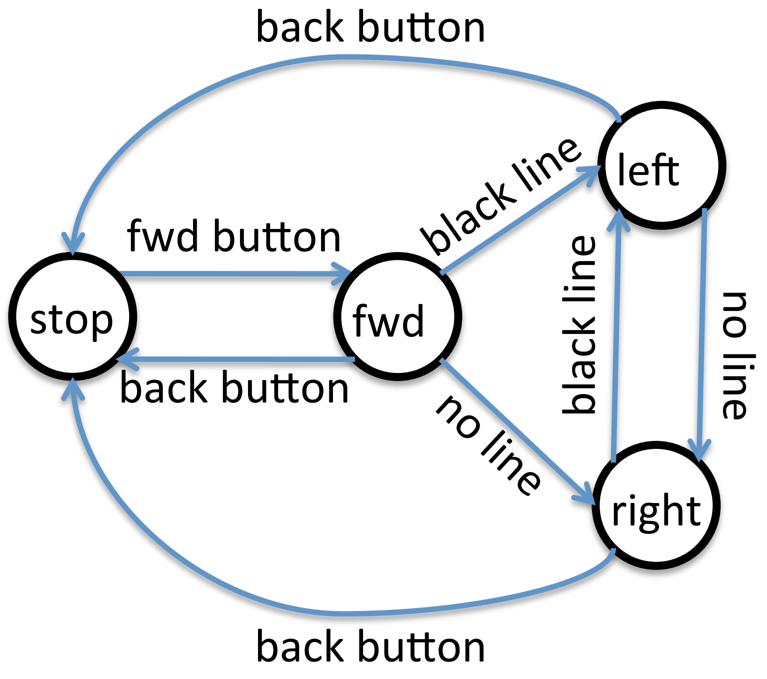
Events

- button.forward
- button.backward
- prox

```
onevent button.forward
   ...
onevent button.backward
   ...
onevent prox
   ...
```

Gather Transition Information

- For each transition, identify
  - States (CONSTANTS)
  - Event (handler)
  - Sensor/device
  - Change in sensor/device
  - Thresholds (if any)
  - Action to perform
- E.g., transition: fwd ➔ left
  - States:
    - From: fwd (`FORWARD`)
    - To: left (`LEFT`)
  - Event (Handler): `prox`
  - Sensor: `prox.ground.delta[0]`
  - Change in sensor: response decreases (dark)
  - Threshold: < 500 means dark
  - Turn left
    ```
    motor.left.target = 0
    Motor.right.target = 200
    ```
- Implement the transitions in their event handlers



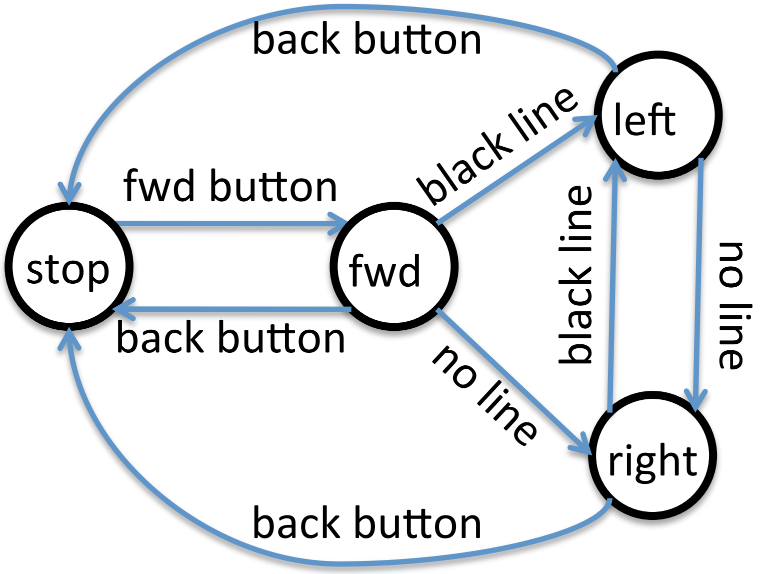
Implement the Transitions

- Inside the handler use template:

```
if state == FROM_STATE and sensor has changed then
  state = TO_STATE
  perform action
end
```

- E.g., transition: fwd ➔ left

```
onevent prox
  if state == FORWARD and prox.ground.delta[0] < 500 then
    state = LEFT
    motor.left.target = 0
    motor.right.target = 200
  end
```



Optimizations

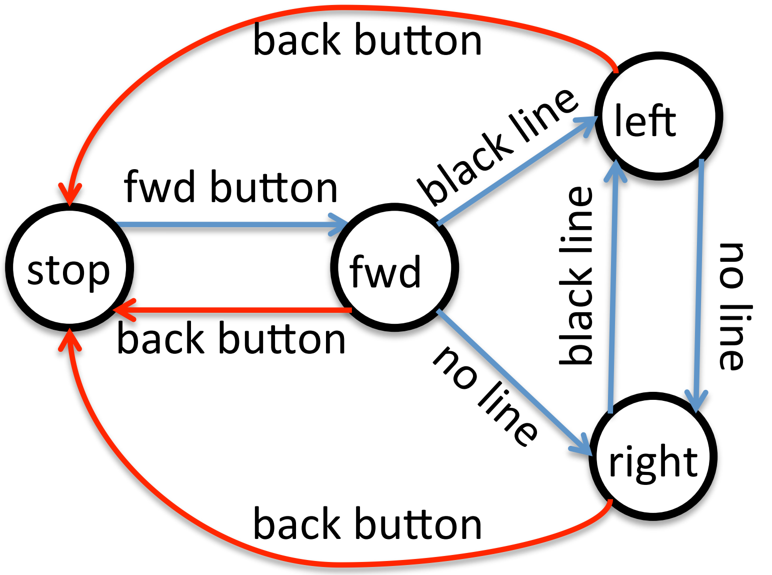
- Consider the handler for the "back button" transitions:

```
onevent button.backward
  if state == FORWARD then
    state = STOPPED
    motor.left.target = 0
    motor.right.target = 0
  elseif state == LEFT then
    state = STOPPED
    motor.left.target = 0
    motor.right.target = 0
  elseif state == RIGHT then
    state = STOPPED
    motor.left.target = 0
    motor.right.target = 0
  end
```

- Why is there no AND part?
- Is this necessary?

```
onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0
```

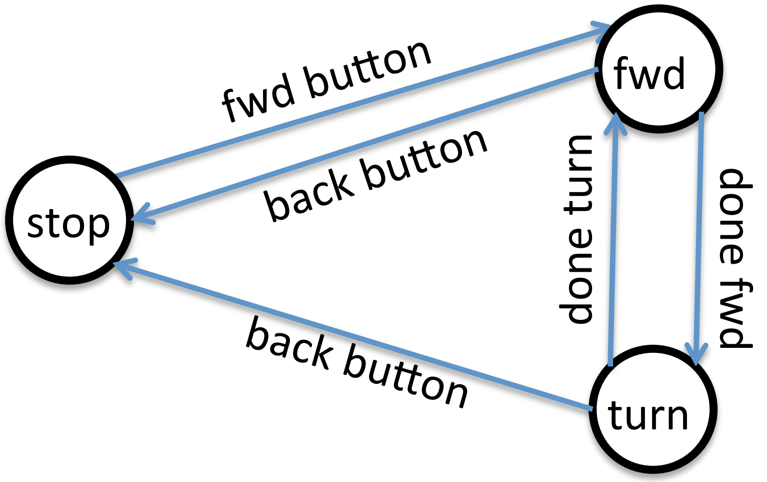
- In many cases code can be optimized!



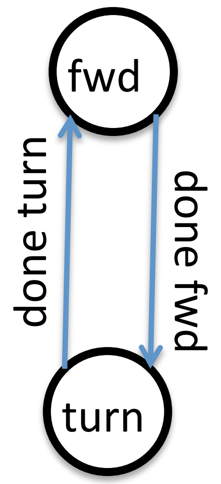
Another Example: Move in a Square

The Square STD

- States:
  - stop (STOPPED)
  - Fwd (FORWARD)
  - turn (TURN)
- Transitions:
  - stop ➔ fwd
  - fwd ➔ stop
  - turn ➔ stop
  - fwd ➔ turn
  - turn ➔ fwd
- Events:
  - Forward Button
  - Backward Button
  - timer0



Timer based Transitions



Done Fwd

- States:
  - From: fwd (`FORWARD`)
  - To: turn (`TURN`)
- Event handler: `timer0`
- Device: `timer.period[0]`
- Thresholds: None
- Action:
  - Start turning

    ```
    motor.left.target = -200
    motor.right.target = 200
    ```
  - Set timer period

    ```
    timer.period[0] = 1000
    ```

Done Turn

- States:
  - From: turn (`TURN`)
  - To: fwd (`FORWARD`)
- Event handler: `timer0`
- Device: `timer.period[0]`
- Thresholds: None
- Action:
  - Start moving straight

    ```
    motor.left.target = 200
    motor.right.target = 200
    ```
  - Set timer period

    ```
    timer.period[0] = 2000
    ```

The `timer0` Event Handler

The timer0 Event Handler

```
onevent timer0
  if state == FORWARD then
    state = TURN
    timer.period[0] = 1000
    motor.left.target = -200
    motor.right.target = 200
  elseif state == TURN then
    state = FORWARD
    timer.period[0] = 2000
    motor.left.target = 200
    motor.right.target = 200
  end
```

The Other Event Handlers

```
onevent button.forward
  state = FORWARD
  timer.period[0] = 2000
  motor.left.target = 200
  motor.right.target = 200

onevent button.backward
  state = STOPPED
  timer.period[0] = 0
  motor.left.target = 0
  motor.right.target = 0
```

Using elseif

What happens if state == FORWARD

Right

```
onevent timer0
  if state == FORWARD then
    state = TURN
    timer.period[0] = 1000
    motor.left.target = -200
    motor.right.target = 200
  elseif state == TURN then
    state = FORWARD
    timer.period[0] = 2000
    motor.left.target = 200
    motor.right.target = 200
  end
```

Wrong

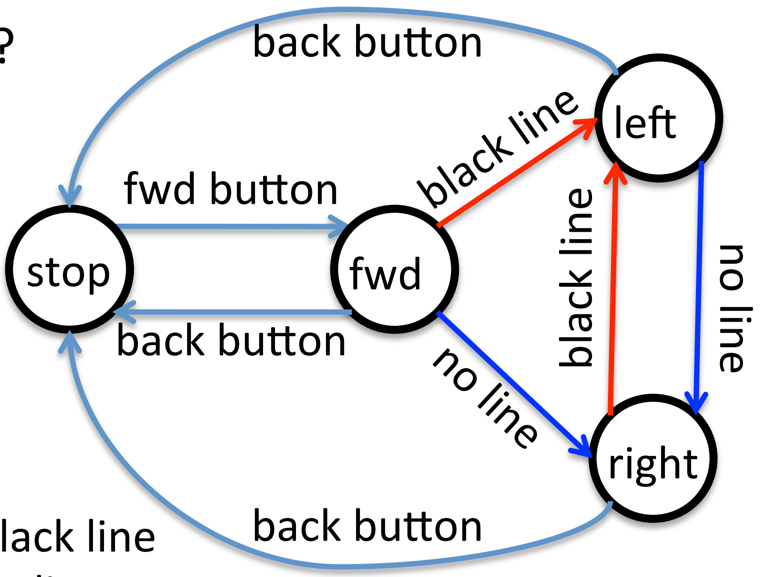
```
onevent timer0
  if state == FORWARD then
    state = TURN
    timer.period[0] = 1000
    motor.left.target = -200
    motor.right.target = 200
  end

  if state == TURN then
    state = FORWARD
    timer.period[0] = 2000
    motor.left.target = 200
    motor.right.target = 200
  end
```

Key Idea: Multiple transitions in one event handler should be linked with `elseif`

What is `when`?

- Consider our line follower (again)
- Which transitions occur on a `prox` event?
  - on black line
    - fwd ➔ left
    - right ➔ left
  - on no line
    - fwd ➔ right
    - left ➔ right
- Observation:
  - If we are not STOPPED
  - Transition to LEFT *when* we encounter a black line
  - Transition to RIGHT *when* we encounter no line
- Idea: Transitions occur *when* things change
- Analogy:
  - When we encounter a stop sign, we stop the car
  - We do not continue stopping the car once it has stopped



`if` vs `when`

`if`

- Form:

```
if condition then
  body
end
```

- If the condition is true the body is executed
- E.g., if we see a stop sign stop, regardless of whether we are already stopped

when

- Form:

```
when condition do
  body
end
```

- If the condition is true now and was not true before, the body is executed
- E.g., if we see a stop sign and we are not stopped, then stop

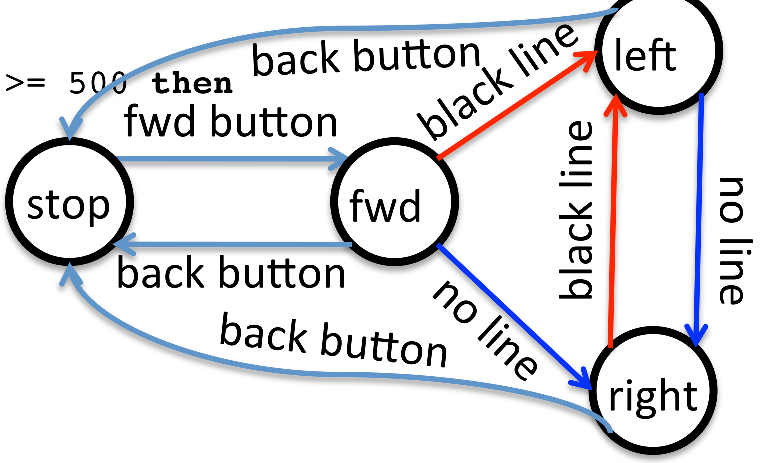
When to use `when`?

- Idea: Use `when` when the state of a sensor corresponds to a state
- Examples:
  - Line following:
    - Sensor registers dark means move left
    - Sensor registers light means move right
  - Wall avoidance:
    - Sensor registers an object ahead means turn
    - Sensor no registering an object means go forward

Example of when

Using `ifs`

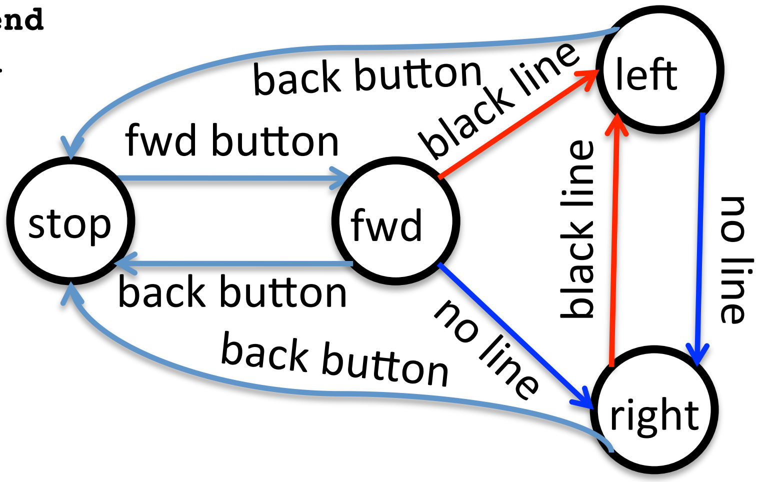
```
onevent prox
  if state == FORWARD and prox.ground.delta[0] < 500 then
    state = LEFT
    motor.left.target = 0
    motor.right.target = 200
  elseif state == RIGHT and prox.ground.delta[0] < 500 then
    state = LEFT
    motor.left.target = 0
    motor.right.target = 200
  elseif state == FORWARD and prox.ground.delta[0] >= 500 then
    state = RIGHT
    motor.left.target = 200
    motor.right.target = 0
  elseif state == LEFT and prox.ground.delta[0] >= 500 then
    state = RIGHT
    motor.left.target = 200
    motor.right.target = 0
  end
```



Example of when

Using whens

```
onevent prox
  if state != STOPPED then
    when prox.ground.delta[0] < 500 do
      state = LEFT
      motor.left.target = 0
      motor.right.target = 200
    end
    when prox.ground.delta[0] >= 500 do
      state = RIGHT
      motor.left.target = 200
      motor.right.target = 0
    end
  end
```



left
back button
black line
fwd button
stop
fwd
black line
no line
back button
no line
back button
right