Finite State Machines (FSMs)

Pure FSM form is composed of:

- A set of states
- A set of possible inputs (or events)
- A set of possible outputs
- A transition function:
  - Given the current state and an input: defines the output and the next state

Finite State Machines (FSMs)

States:

- Represent all possible “situations” that must be distinguished
- At any given time, the system is in exactly one of the states
- There is a finite number of these states

FSMs and Control

How do we relate FSMs to Control?

- States are our memory of recent inputs

- Inputs are ?

FSMs and Control

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- Inputs are some processed representation of what the sensors are observing
- Outputs are ?

FSMs and Control

How do we relate FSMs to Control?

- States are our memory of recent inputs
- Inputs are some processed representation of what the sensors are observing
- Outputs are the control actions

FSMs: A Control Example

Suppose we have a vending machine:

- Accepts dimes and nickels
- Will dispense one of two things once $.20 has been entered: Jolt or Buzz Water
  - The “user” requests one of these by pressing a button
- Ignores select if < $.20 has been entered
- Immediately returns any coins above $.20

Vending Machine FSM

What are the states?

Vending Machine FSM

What are the states?

- $0
- $.05
- $.10
- $.15
- $.20

Vending Machine FSM

What are the inputs/events?

Vending Machine FSM

What are the inputs/events?

- Input nickel (N)
- Input dime (D)
- Select Jolt (J)
- Select Buzz Water (BW)

Vending Machine FSM

What are the outputs?

Vending Machine FSM

What are the outputs?

- Return nickel (RN)
- Return dime (RD)
- Dispense Jolt (DJ)
- Dispense Buzz Water (DBW)
- Nothing (Z)

Vending Machine Design

What is the initial state?

Vending Machine Design

What is the initial state?

- S = $0

Vending Machine Design

What can happen from S = $0?

Event	Next State	Output

Vending Machine Design

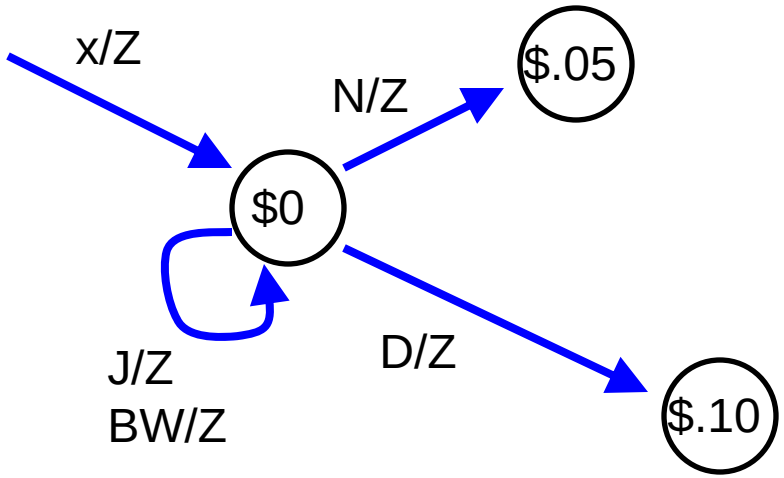
What can happen from S = $0?

What does this part of the diagram look like?

Event	Next State	Output
N	$.05	Z
D	$.10	Z
J	$0	Z
BW	$0	Z

Vending Machine Design

A piece of the state diagram:



Vending Machine Design

What can happen from S = $0.05?

Event	Next State	Output

Vending Machine Design

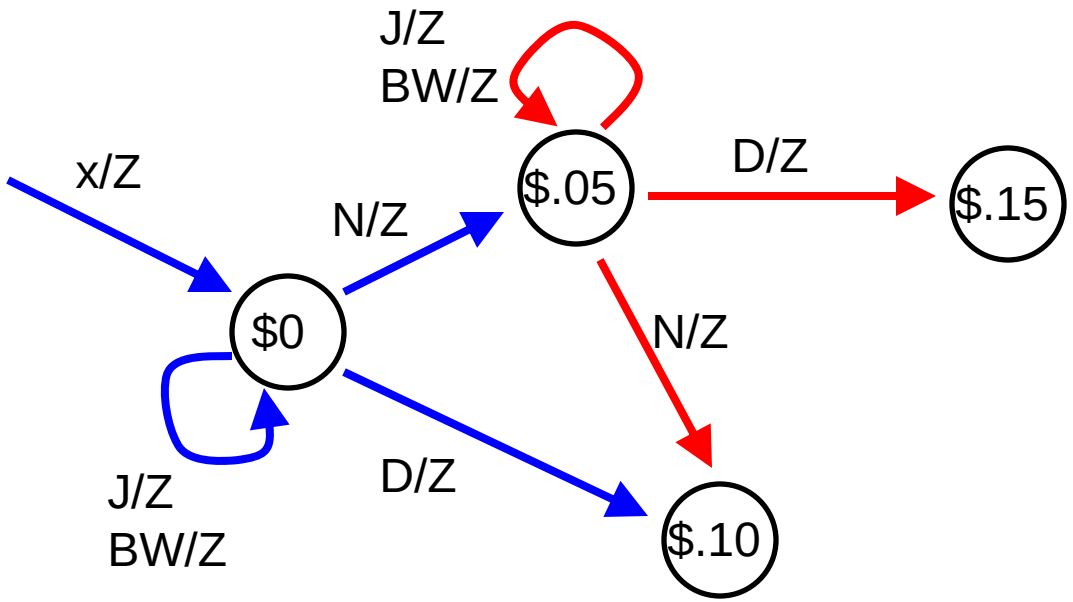
What can happen from S = $0.05?

What does the modified diagram look like?

Event	Next State	Output
N	$.10	Z
D	$.15	Z
J	$.05	Z
BW	$.05	Z

Vending Machine Design

A piece of the state diagram:



Vending Machine Design

What can happen from S = $0.10?

Event	Next State	Output

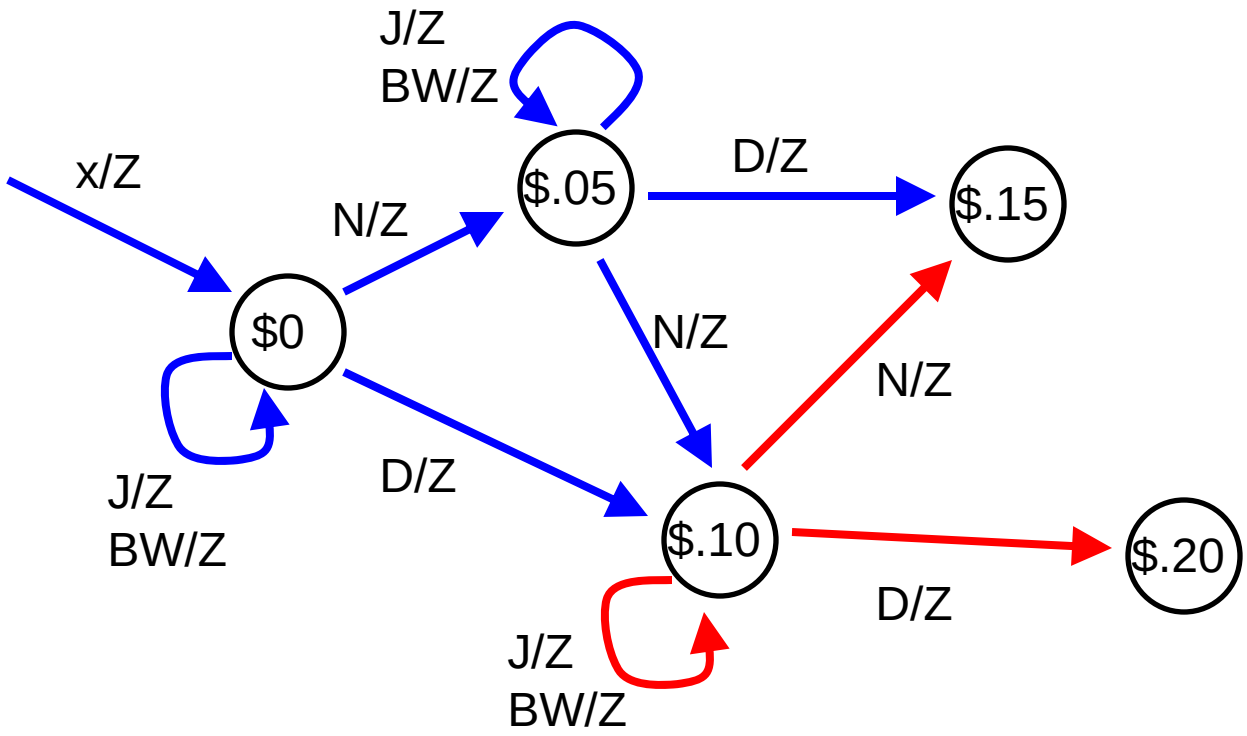
Vending Machine Design

What can happen from S = $0.10?

Event	Next State	Output
N	$.15	Z
D	$.20	Z
J	$.10	Z
BW	$.10	Z

Vending Machine Design

A piece of the state diagram:



Vending Machine Design

What can happen from S = $0.15?

Event	Next State	Output

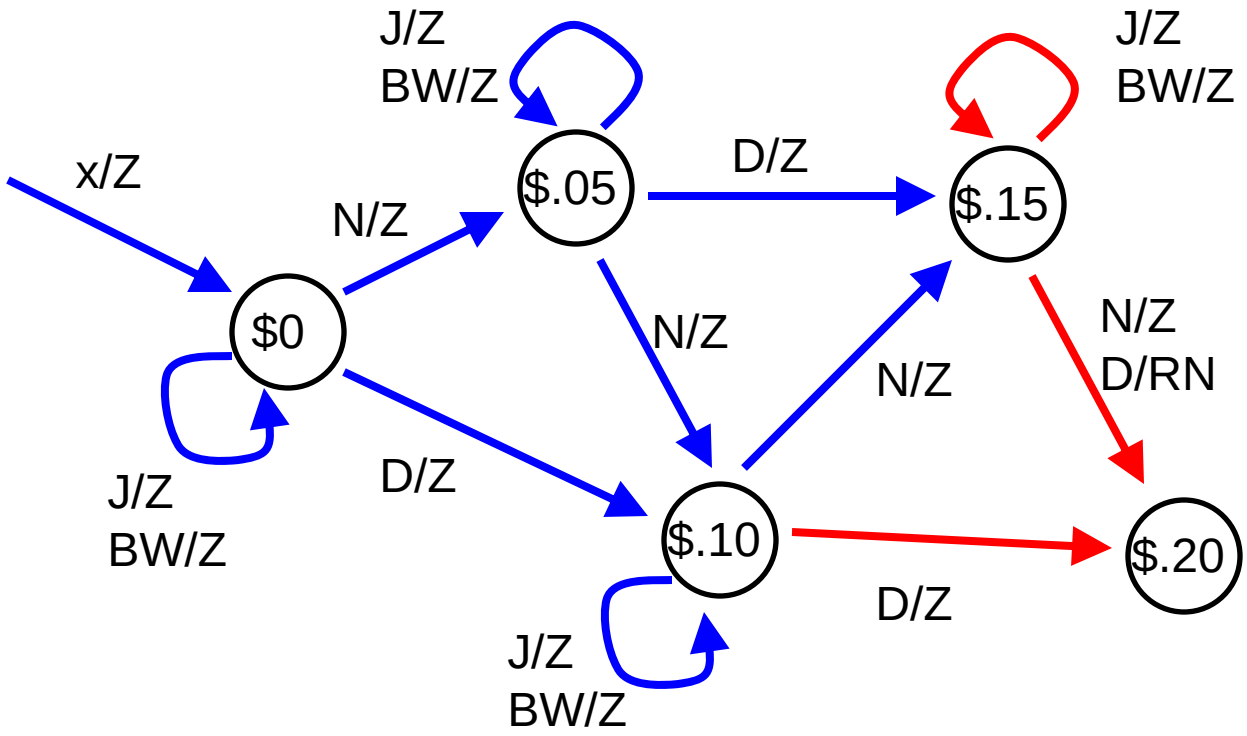
Vending Machine Design

What can happen from S = $0.15?

Event	Next State	Output
N	$.20	Z
D	$.20	RN
J	$.15	Z
BW	$.15	Z

Vending Machine Design

A piece of the state diagram:



Vending Machine Design

Finally: what can happen from S = $0.20?

Event	Next State	Output

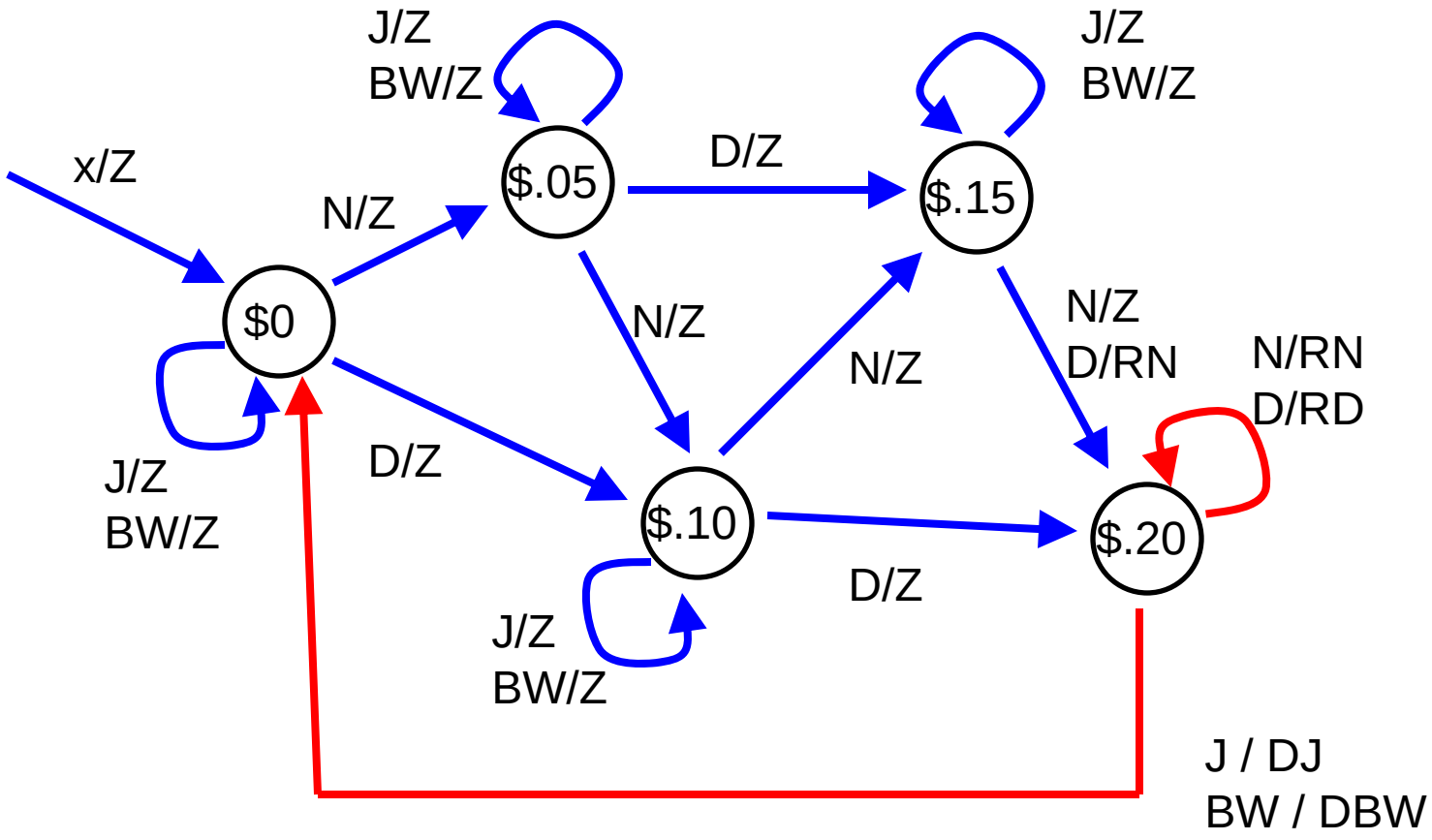
Vending Machine Design

Finally, what can happen from S = $0.20?

Event	Next State	Output
N	$.20	RN
D	$.20	RD
J	$0	DJ
BW	$0	DBW

Vending Machine Design

The complete state diagram:



FSMs in C

```
int state = 0;   // Initial state
while(1) {
  <do some processing of the sensory inputs>
  switch(state) {
      case 0:
            <handle state 0>
            break;
      case 1:
            <handle state 1>
            break;
      case 2: …
  }
}
```

Finite State Machines

- Very useful tool to describe sequential behavior.
- But – when used for control, we deviate from the theory in several key ways

FSMs As Controllers

- Need code that translates sensory inputs into FSM events
- An FSM output can require an arbitrary amount of time
  - We will often implement this control action as a separate function call
- Control actions will not necessarily be fixed (but could be a function of sensory input)

FSMs As Controllers (cont)

- We might choose to leave some events out of the implementation
  - Only some events may be relevant to certain states
- When in a state, the FSM may also issue control actions (even when a new event has not arrived)
  - Again, this may be implemented as a function call

FSMs in C

```
int state = 0;   // Initial state
while(1) {
  <do some processing of the sensory inputs>
  switch(state) {
      case 0:
            <handle state 0>
            break;
      case 1:
            <handle state 1>
            break;
      case 2: …
  }
}
```

FSMs in C (some other possibilities)

```
int state = 0;   // Initial state
while(1) {
  <do some processing of the sensory inputs>
  switch(state) {
      case 0:
            <handle state 0>
            break;
         :
      default:
            <handle default case>
            break;
  }
  <do some low-level control>
}
```

FSMs in C: Processing for Individual States

```
case STATE_10cents:
   // $.10 has already been deposited
   switch(event) {
        case EVENT_NICKEL:   // Nickel
                state = STATE_15cents;  // Transition to $.15
                break;
        case EVENT_DIME:   // Dime
                state = STATE_20cents;  // Transition to $.2
                break;
        case EVENT_JOLT:   // Select Jolt
        case EVENT_BUZZ:   // Select Buzzwater
                display_NOT_ENOUGH();
                break;

        case EVENT_NONE:   // No event
                break;            // Do nothing

   };
   break;
```

A Note on “Style” in C

- The numbers that we assigned to the different states are arbitrary (and at first glance, hard to interpret)
- Instead, we can define constant strings that have some meaning

- Replace: 0, 1, 2, 3, 4, 5
- With: STATE_00, STATE_05, STATE_10, STATE_15, STATE_20

A Note on “Style” in C

In C, this is done by adding some definitions to the beginning of your program (either in the .c file or the .h file):

```
#define STATE_00   0
#define STATE_05   1
#define STATE_10   2
#define STATE_15   3
#define STATE_20   4
```