Finite State Machine Notes

A finte state machine (FSM) is a "gadget" or circuit that takes in various inputs and produces various outputs. It is a sequential circuit, i.e., the circuit also has a state. To keep this discussion simple, let's assume that the FSM is driven by a clock – at the start of every clock cycle, the circuit examines its state and inputs, and produces a new output/state. For most of this discussion, we'll assume that the output and next state are equivalent.

When given a problem, there are 3 major questions you should ask yourself.

1. What is my circuit trying to control? What values can I assign to the entity that I'm trying to control? Each such value would be a **STATE**. In a finite state diagram, you would draw a bubble for each STATE.

2. What are the different sensors/inputs that my circuit can look at? What are the different values for my inputs?

3. For each STATE, what happens for a certain input? Draw an arc to show how your machine would react to that input, i.e., how it moves from one state to the next.

Let's walk through this process with an example. Construct the state transition table and the finite state machine diagram for the following sequential circuit in a residential thermostat. The circuit checks an internal and external thermometer. If the internal temperature is within 1 degree of the desired temperature, the thermostat does not change its setting. If the internal temperature is more than 1 degree higher than the desired temperature, the thermostat is set to COOL. If the internal temperature is more than 1 degree lower than the desired temperature, the thermostat is set to HEAT. If the external temperature is within 5 degrees of the desired temperature, the thermostat is set to OFF (over-riding all of the above considerations).

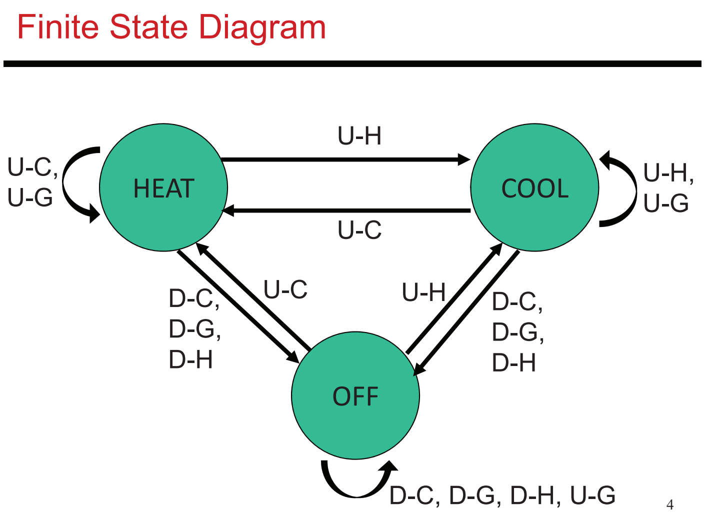
This is a fairly complex problem. What is my circuit trying to control? It is trying to control my AC and furnace, and the thermostat can be in one of three possible settings – HEAT, COOL, OFF. So my diagram will have 3 bubbles.

Now what are my inputs? I clearly have two independent thermometers that are providing inputs. I don't care about the exact temperature, but I care about the temperature "zone", so let's assume that the sensor is spitting out the "zone". The external thermometer only cares about 2 zones – you are either within 5 degrees of your desired temperature or you're not. Let's call this input E (external temperature) with values D (the desired zone) or U (the undesired zone). The internal thermometer has 3 zones – the internal temperature is either too cold, within 1 degree of desired, or too hot. Let's call this input I (internal temperature) with values C (too cold), G (Goldilocks zone), or H (too hot).

We now have our 3 states (HEAT, COOL, OFF). We have input E (can be D or U) and input I (can be C, G, or H). Since the two input thermometers are independent, my input can take one of 6 forms: D-C, D-G, D-H, U-C, U-G, U-H. So my state transition table will have 18 possible entries – for each of my 3 states, I have to show my next state for each of the 6 possible inputs. This is what the table will look like. See how I systematically laid out my current state, my input E, my input I, and my next state. Note that next state is computed based on all the instructions spelled out in the problem.

Current State	Input E	Input I	Output State
HEAT	D	C	OFF
HEAT	D	G	OFF
HEAT	D	H	OFF
HEAT	U	C	HEAT
HEAT	U	G	HEAT
HEAT	U	H	COOL
COOL	D	C	OFF
COOL	D	G	OFF
COOL	D	H	OFF
COOL	U	C	HEAT
COOL	U	G	COOL
COOL	U	H	COOL
OFF	D	C	OFF
OFF	D	G	OFF
OFF	D	H	OFF
OFF	U	C	HEAT
OFF	U	G	OFF
OFF	U	H	COOL

Now let's draw the diagram. Remember 3 bubbles for the 3 states. For each state, I could have 6 arcs coming out since I can have one of 6 possible inputs. But since I could only move to one of 3 states, I typically will have 3 arcs coming out. Each arc will list the inputs that cause that transition. See figure below. Confirm that every state is handling all 6 possible inputs.



Finite State Diagram

Frequently Asked Questions

1. In my thermostate example, I said that two inputs can produce six possible combinations. In some problems, not all of the input combinations may be possible. For example, only one of the input sensors may be allowed to interrupt your FSM at a time, i.e., one input sensor may flag 1 while all other input sensors flag 0. This is referred to as a 1-hot input; so if you have 4 sensors, you'd have only 4 possible inputs, not 16.

2. If my sensor is detecting the color of a stop light, do I have 1 input or 3 inputs? This sensor is providing 1 input, where the input can have values RED, GREEN, YELLOW. You could also assume that the sensor is providing 3 inputs – RED with values 0 or 1, GREEN with values 0 or 1, YELLOW with values 0 or 1. But this latter approach will make your table and diagram look a lot messier.