



Control System Training

MODULE 7 – Finite State Machines

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Finite State Machine - Definition

Definitions:

- **Finite State Machine** - A computational model consisting of a predefined number of states. Only one state can be active at a time. The active state performs some action, which could be nothing, then decides which state, including itself, becomes the next active state.
 - States cannot be dynamically added or removed
 - One state is defined as the starting state.
 - A state machine may have an end (exit) state or may be defined to execute perpetually.
 - Can be used to process Sequential Boolean Logic
 - There are many other uses such as language processing, and compilers.

How the machine works

■ The machine:

- Executes code for the initial state
- Loops forever executing the code for whatever state is designated to be next, or until a state requests it to stop

■ Recommendation for FRC robots:

- During each robot control system “scan” cycle, 20 milliseconds, a single “state” is executed.
- In some cases, this will mean that a 20 millisecond delay will be performed to get to the next state. Generally, 20 milliseconds is too small to be concerned with. If it is, then the state design should be reconsidered to avoid this delay.

What each “State” Does

■ Each state:

1) Performs some computation, or initiates some action. The action could be:

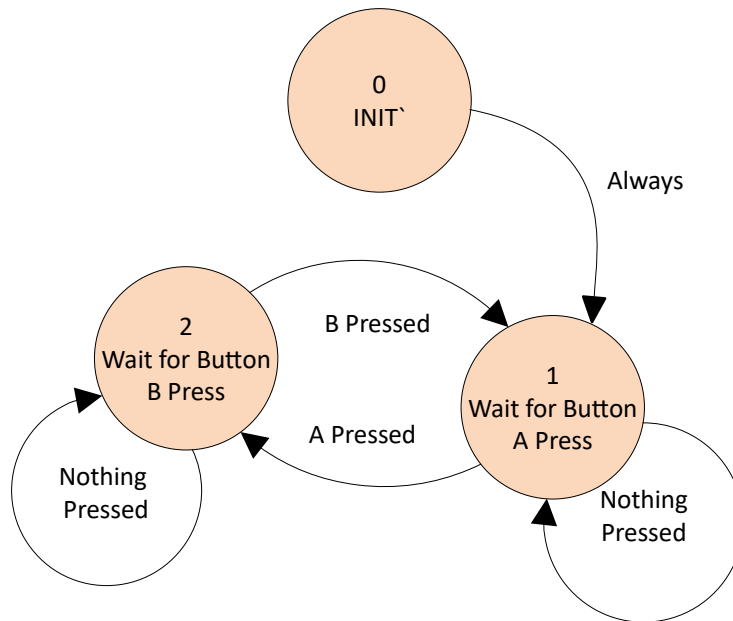
- Starting or stopping a motor
- Opening or closing a solenoid
- Setting a variable for another part of the code to use
- A combination of things

Doing nothing is a valid action.

2) Decides which state should execute next. The next state could be:

- The same state
- A known state determined during design
- One of several states determined by logic

Drawing State Machines



Actions:

0 – INIT

None

1 – Wait for button A press
Turn off light

2 – Wait for button B press
Turn on light

- **Each State is a circle. Define each state with a unique name and/or state number.**
- **Lines between states are transitions. Document the conditional causing each state transition.**
- **Document actions taken by each state. This can be done in the circle defining the state. However, a separate list allows for more detailed description of the actions.**

Defining States

- **Define a separate initialization state – State 0**
 - If somehow there is an error, and the state is set to zero, then this will cause initialization.
- **Include an error recovery state**
 - Recycle system, wait, and allow system to try again.
- **Keep states simple**
- **Keep states simple**
- **If possible, join common sequences of actions together to reduce the number of states**
- **Actions of states should not need to include conditionals.**

Designing Finite State Machine - 1/3

■ Sample Problem – Cube Capture

- Robot has a “hand” with positions:
 - Opened = false
 - Closed = true
- Robot has an “arm” with positions:
 - Retracted = false
 - Extended = true
- System is “ready” when “hand” is opened and “arm” is retracted
- User pushes button to initiate “capture cube”. Auto repeat of cube capture is not allowed. Ensure user pushed button for 60 milliseconds.
- Sequence of cube capture is:
 - Close “arm” extension solenoid. Wait 1 second for arm to extend.
 - Close “hand” solenoid. Wait 2.0 seconds for “hand” to settle.
 - Open “arm” extension solenoid. Wait 1.3 seconds for arm to retract.
 - Open “hand” solenoid to release potential cube into bin. Wait 1.5 seconds for cube to drop before allowing next “grab” action.

Designing Finite State Machine 2/3

■ List:

- Inputs
- Outputs
- Individual actions, and sequence of actions

■ Optionally, draw a Logic Diagram Graph similar to sequential logic.

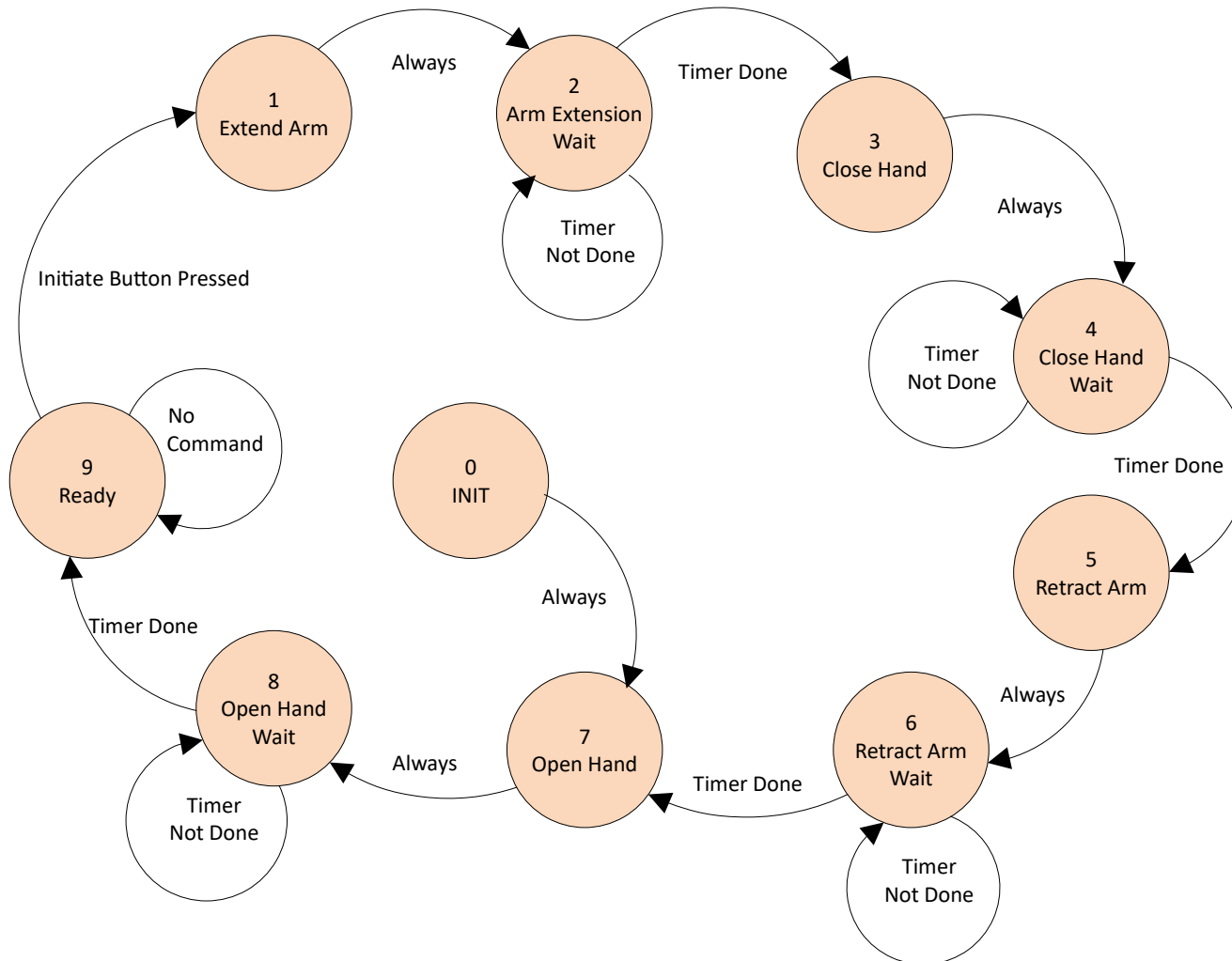
■ Draw the state diagram:

- Start with an “initialization” state
- Add states waiting for events that start sequences of actions – sensor inputs, user button press, autonomous request.
- Add states for sequences of actions. Often this occur in pairs – 1) take action, start timer, 2) wait for timer to expire before selecting next action.

■ Define for each state:

- Actions performed, if any
- Tests used to determine next state

Designing Finite State Machine 3/3



Actions:

0 – INIT

Open Hand
Retract Arm

1 – Extend Arm

Extend Arm
Initiate 1.0 Second Timer

2 – Arm Extension Wait

None

3 – Close Hand

Close Hand
Initiate 2.0 second timer

4 – Close Hand Wait

None

5 – Retract Arm

Retract Arm
Initiate 1.3 second timer

6 – Retract Arm Wait

None

7 – Open Hand

Open Hand
Initiate 1.5 second timer

8 – Open Hand Wait

None

9 – Ready

None

Notes:

1) Initiate button on-delay, permissive checking, and edge triggering done outside of finite state machine. (This could be done either way.)

2) Cancel button would transition to 0-INIT state.

Sequential Logic or State Machine

- **Many problems can be solved either by sequential logic or state machines. How to choose between them:**
 - Simple machines are probably implemented more easily using sequential logic.
 - More complex machines are probably easier to implement using a finite state machine.

Exercise 7.2 – Shoot Flying Disc

- User pushes a button to shoot Flying Disc.
- Ensure user meant to push button. Button must be pressed for three cycles before initiating action. (Cycle time is 0.020 seconds).
- Can only shoot a frisbee if we have one. A limit switch indicates this. Also battery voltage must be > 11.5 volts. Can only shoot one frisbee at a time.
- Motors take 3 seconds to spin up to speed.
- Engage solenoid for 2 second to push frisbee into shooting wheel.
- Allow 2 more seconds for shooting to occur.
- After shooting is done, stop motor. (For now, don't allow continuous shooting.)
- Allow user to press a Cancel button. The cancel button must be pressed for at least 3 cycles before becoming active. After the Cancel, force a 5 second reset before allowing a new shot.
- It takes 5 seconds after shooting for a new frisbee to be in place ready to shoot.
- Design shooting logic. Also provide “ready to shoot” digital for dashboard display. Use ONLY a finite state machine, combined with combinatorial logic from Module 4 if needed. (It is possible to include Sequential Logic inside a Finite State Machine. For this exercise, don't do this.)

Exercise 7.1 – Shoot Flying Disc

- **Flying Disc shooter system has two outputs:**
 - Shooting motor (on/off)
 - Solenoid to push flying disc into shooter wheel.
- **Flying Disc shooter system has one sensor:**
 - Limit switch indicating shooting system contains a flying disc.
- **User pushes a button to shoot flying disc. Ensure user meant to push button. Button must be pressed for 0.060 seconds before initiating action. (Robot cycle time is 0.020 seconds).**
- **Only shoot a flying disc if system contains a disc. Also battery voltage must be > 11.5 volts. Only one disc can be shot at a time.**
- **Shooting motor takes 3 seconds to spin up to speed. Engage solenoid for 2 second to push flying disc into shooting wheel. Allow 2 more seconds for shooting to complete. After shooting is complete, stop motor. (For now, don't allow continuous shooting.) It takes 5 seconds after shooting for the next flying disc to be in place ready to shoot.**
- **Allow user to press a Cancel button. The cancel button must be pressed for at least 0.060 seconds before becoming active. After the Cancel, force a 5 second reset before allowing a new shot.**
- **Design shooting logic. Also provide “ready to shoot” digital for dashboard display. Use a finite state machine and perhaps combinatorial logic from module 4.**