

# 29: Extended state machines, non-determinism and composition





# Formalizing FSMs

We handwaved some aspects of FSMs

- ✓ Role and behavior of inputs and outputs
- ✓ Presence/absence of self-loops

Distinction between FSMs and extended SMs

*Why non-determinism might be useful*

*How to compose systems*



## Keeping track of data

An FSM is a 5-tuple: (States, Inputs, Outputs, update, initialState)

How do we keep track of internal data?

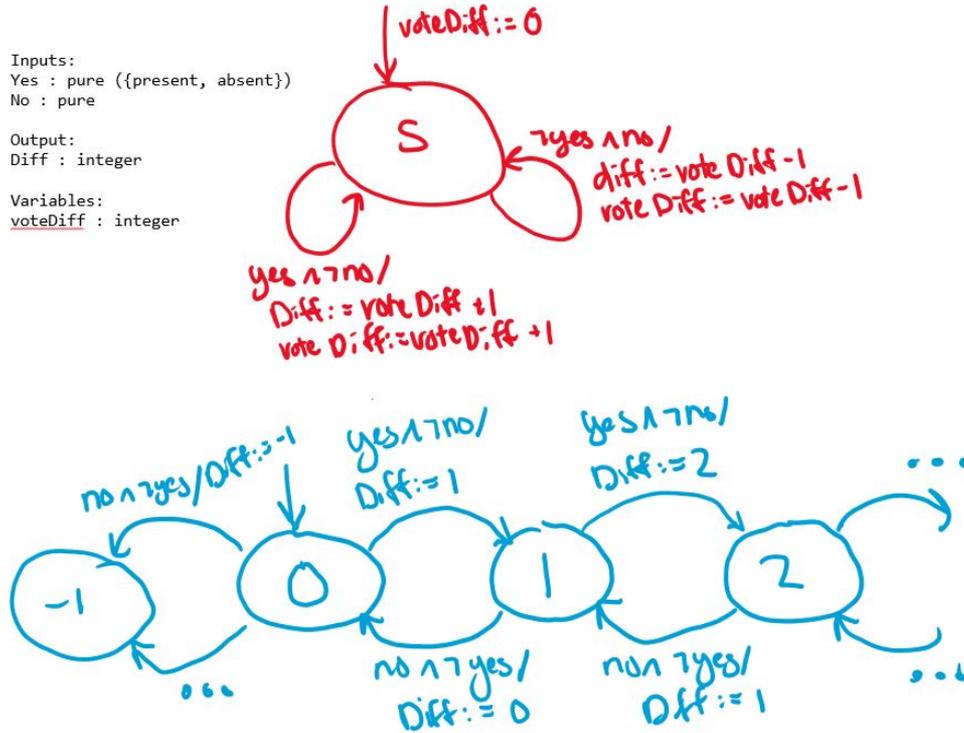
Example: system with yes/no vote buttons, keep track of difference in votes (board example)

# Vote counter

Inputs:  
Yes : pure ({present, absent})  
No : pure

Output:  
Diff : integer

Variables:  
voteDiff : integer



# FSM vs Extended SM

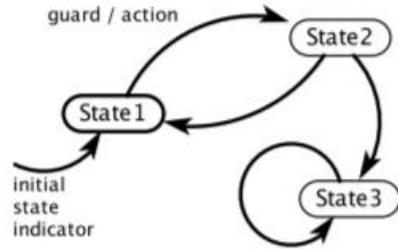


Figure 3.3: Visual notation for a finite state machine.

variable declaration(s)  
input declaration(s)  
output declaration(s)

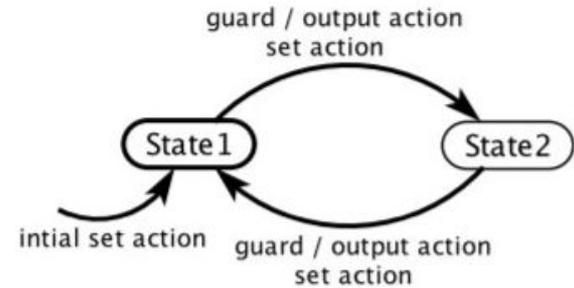
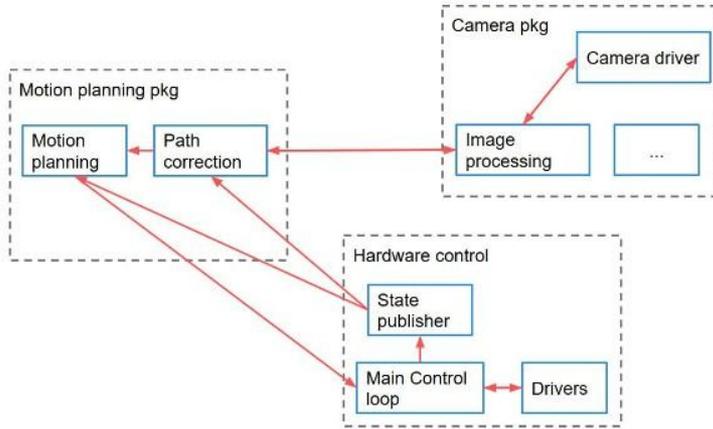


Figure 3.9: Notation for extended state machines.

# Review: Embedded systems as distributed systems



[image source](#)



[image source](#)

# Composition of automata

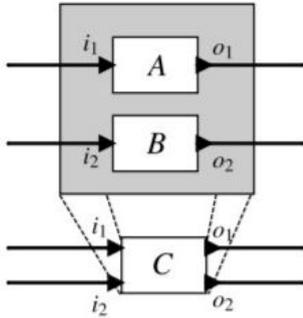


Figure 5.2: Side-by-side composition of two actors.

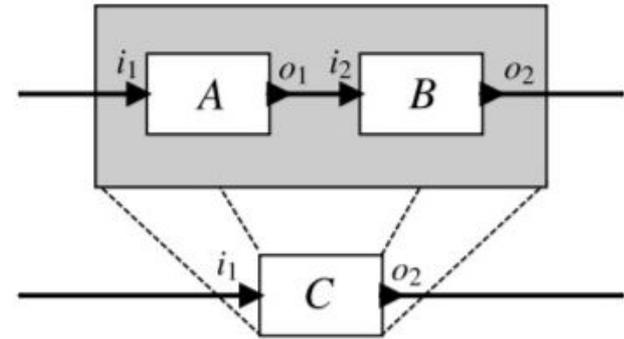


Figure 5.7: Cascade composition of two actors.

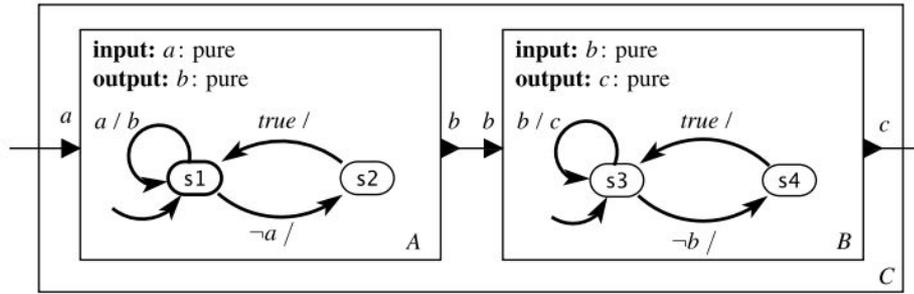


Figure 5.8: Example of a cascade composition of two FSMs.

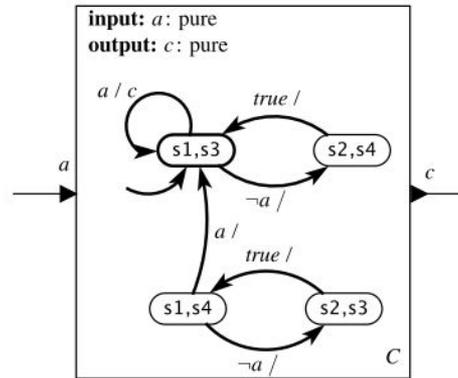


Figure 5.9: Semantics of the cascade composition of Figure 5.8, assuming synchronous composition.

# Feedback loops in automata

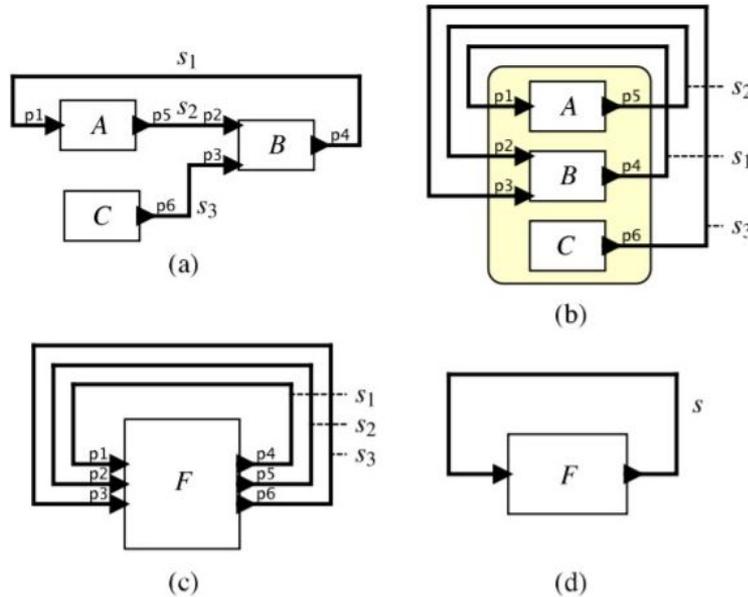


Figure 6.1: Any interconnection of actors can be modeled as a single (side-by-side composite) actor with feedback.

Lee/Seshia chapter 6

**Really powerful concept:** if we can model the environment and compose it with the model of the software, now we have a *closed system* and proofs about the system **only depend on transitions between states**

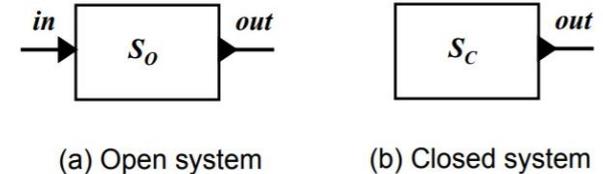
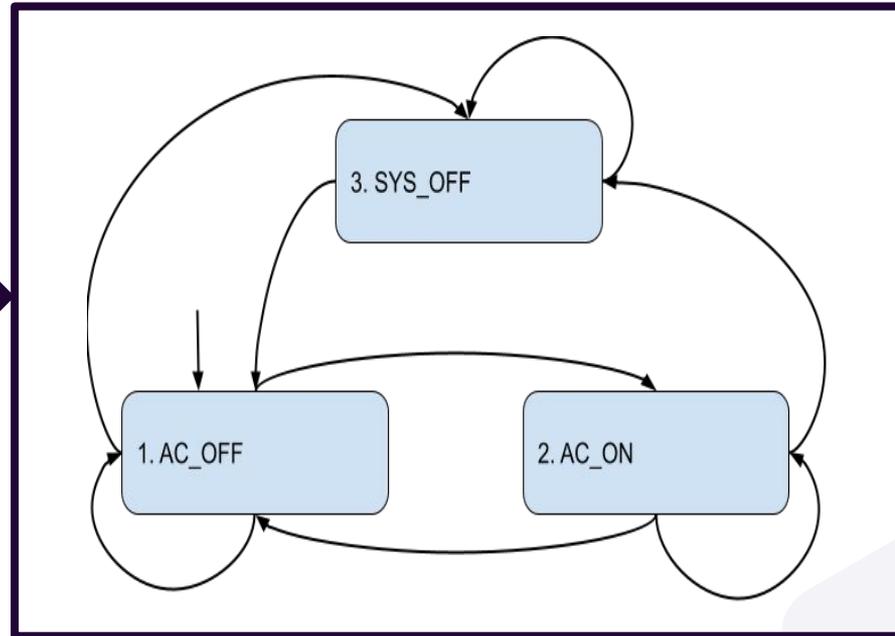


Figure 15.1: Open and closed systems.



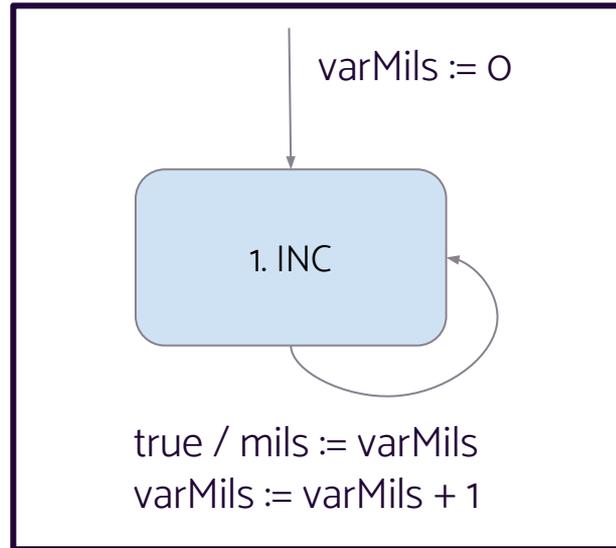
# AC model from prelab

on/off button  
currTemp  
desTemp  
mils





# Modeling mils



mils



“

*How do we model:*

- *Current temp*
- *Desired temp*
- *Button push*

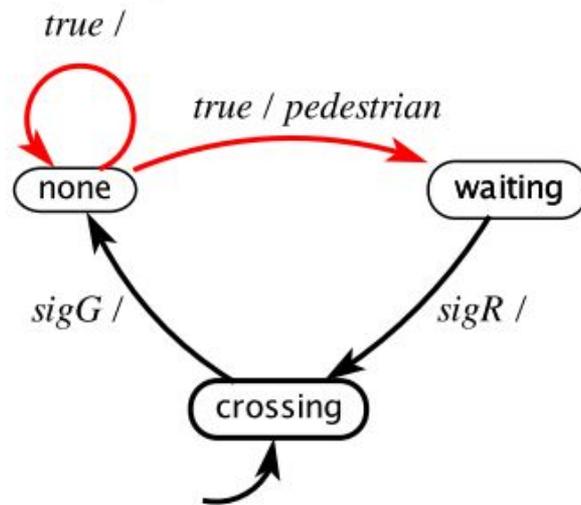
# Nondeterminism

Guards out of a state are not mutually exclusive

- Reason about the “possible set of states” a system can be in
- Useful for modeling environment

**inputs:**  $sigR, sigG, sigY$  : pure

**outputs:**  $pedestrian$  : pure



Lee/Seshia fig. 3.11