SE 2AA4, CS 2ME3 (Introduction to Software Development)

Winter 2018

23 Finite State Machines (Ch. 5)
DRAFT

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- Administrative details
- Classification of specification styles
- Continuation on specification qualities
- Homework exercise
- How to verify a specification
- Finite state machines

Administrative Details

TBD

Same Symbol/Term Different Meaning

- Can you think of some symbols/terms that have different meanings depending on the context?
- Homonyms
  - Homograph - same spelling different meaning, maybe different pronunciation (ex. bank, bow, biweekly, ...)
  - Homophone - same pronunciation, but different meaning, origin or spelling (ex. new/knew, to/too/two, ...)

Consistent

- Language and terminology must be consistent within the specification
- Potential problem with homonyms, for instance consider the symbol σ
  - Represents standard deviation
  - Represents stress
  - Represents the Stefan-Boltzmann constant (for radiative heat transfer)
- Changing the symbol may be necessary for consistency, but it could adversely effect understandability
- Potential problem with synonyms
  - Externally funded graduate students, versus eligible graduate students, versus non-VISA students
  - Enter key versus Return key
  - Other examples?

Complete

- Internal completeness
  - The specification must define any new concept or terminology that it uses
    - A glossary is helpful for this purpose
- External completeness
  - The specification must document all the needed requirements
    - Difficulty: when should one stop?

Incremental

- Referring to the specification process
  - Start from a sketchy document and progressively add details
  - A document template can help with this
- Referring to the specification document
  - Document is structured and can be understood in increments
  - Again a document template can help with this

Another Example

- Operational specification
  - "Let a be an array of n elements. The result of its sorting is an array b of n elements such that the first element of b is the minimum of a (if several elements of a have the same value, any one of them is acceptable); the second element of b is the minimum of the array of $n-1$ elements obtained from a by removing its minimum element; and so on until all n elements of a have been removed."
- Descriptive specification
  - "The result of sorting array a is an array b which is a permutation of a and is sorted."
  - How can we further specify (formalize) the notion of sorted?

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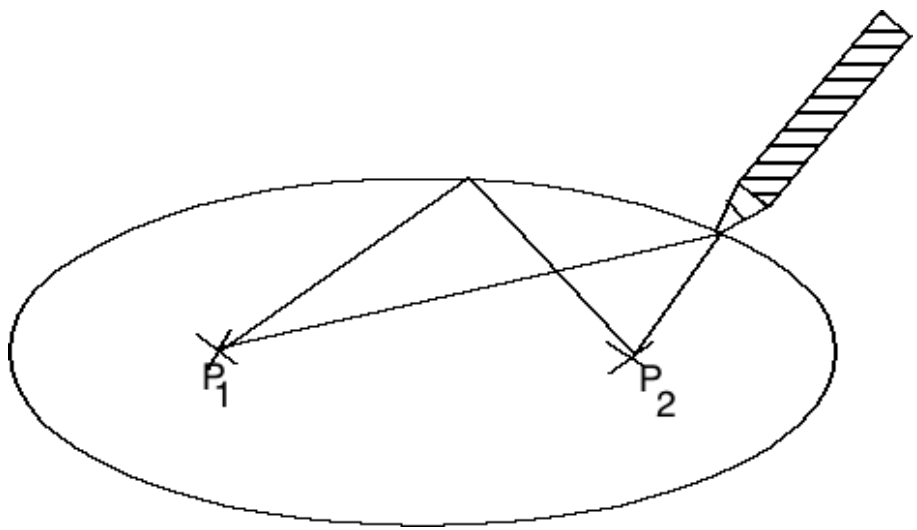
- Descriptive specification
  - "The result of sorting array a is an array b which is a permutation of a and is sorted."
  - How can we further specify (formalize) the notion of sorted?
  - $\text{sorted}(A) \equiv \forall(i : \mathbb{N} | 0 \leq i \leq (|A| - 2) : A[i] \leq A[i+1])$

Classification of Specification Styles

- Informal, semi-formal, formal
- Operational
  - Behaviour specification in terms of some abstract machine
- Descriptive
  - Behaviour described in terms of properties
- The module state machine specification that we use is a mix of operational and descriptive specification - Why?

Example Operational Specification

- Specification of a geometric figure E
- E can be drawn as follows
  1. Select two points P_1 and P_2 on a plane
  2. Get a string of a certain length and fix its ends to P_1 and P_2
  3. Position a pencil as shown in the next figure
  4. Move the pen clockwise, keeping the string tightly stretched, until you reach the point where you started drawing



Example Descriptive Specification

Geometric figure E is described by the following equation

$$ax^2 + by^2 + c = 0$$

where a, b and c are suitable constants

Homework Exercise

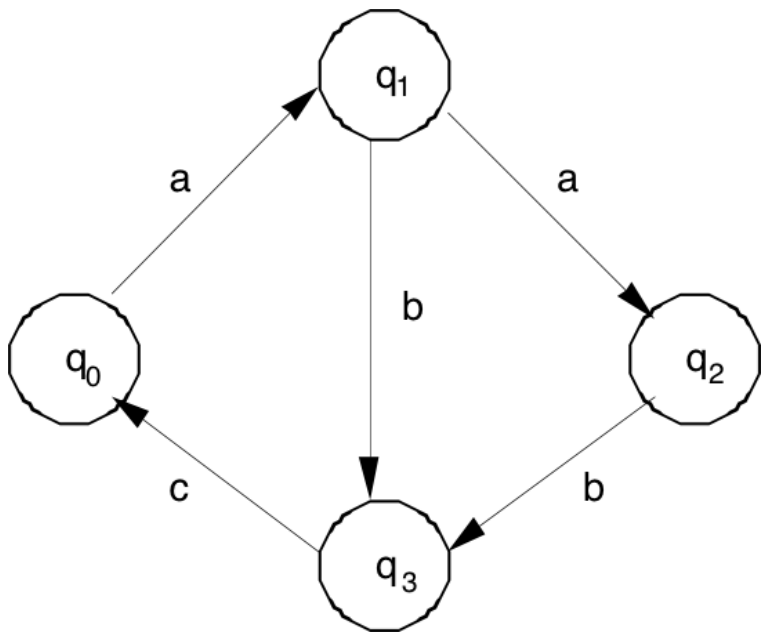
- Consider the **line formatter** specification and
  1. How well does the specification do with respect to the following qualities: abstract, correct, unambiguous, complete, consistent and verifiable?
  2. For a requirement specification like that given, what are the advantages and disadvantages of maintaining both a formal specification and a natural language specification?
- Even spending 5 minutes thinking about will help when we discuss next week
- In repo
  - The line formatter specification
  - Meyer (1985) "On Formalism in Specification"
- Will discuss next day

How to Verify a Specification

- Observe dynamic behaviour of the specified system
  - Simulation
  - Prototyping
  - "testing" the specification
- Analyze properties of the specified system
- Analogy with traditional engineering
  - Physical model of a bridge (prototype)
  - Mathematical model of a bridge
- We will return to this topic when we cover verification (Chapter 6)

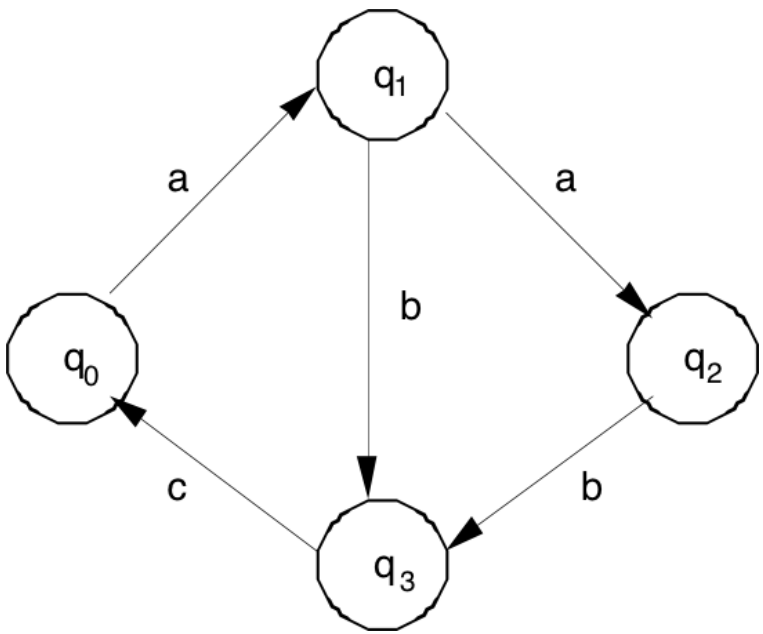
Finite State Machines (FSMs)

- Can specify control flow aspects
- Defined as
  - A finite set of states Q
  - A finite set of inputs I
  - A transition function $\delta : Q \times I \rightarrow Q$ (δ can be a partial function)



FSMs Continued

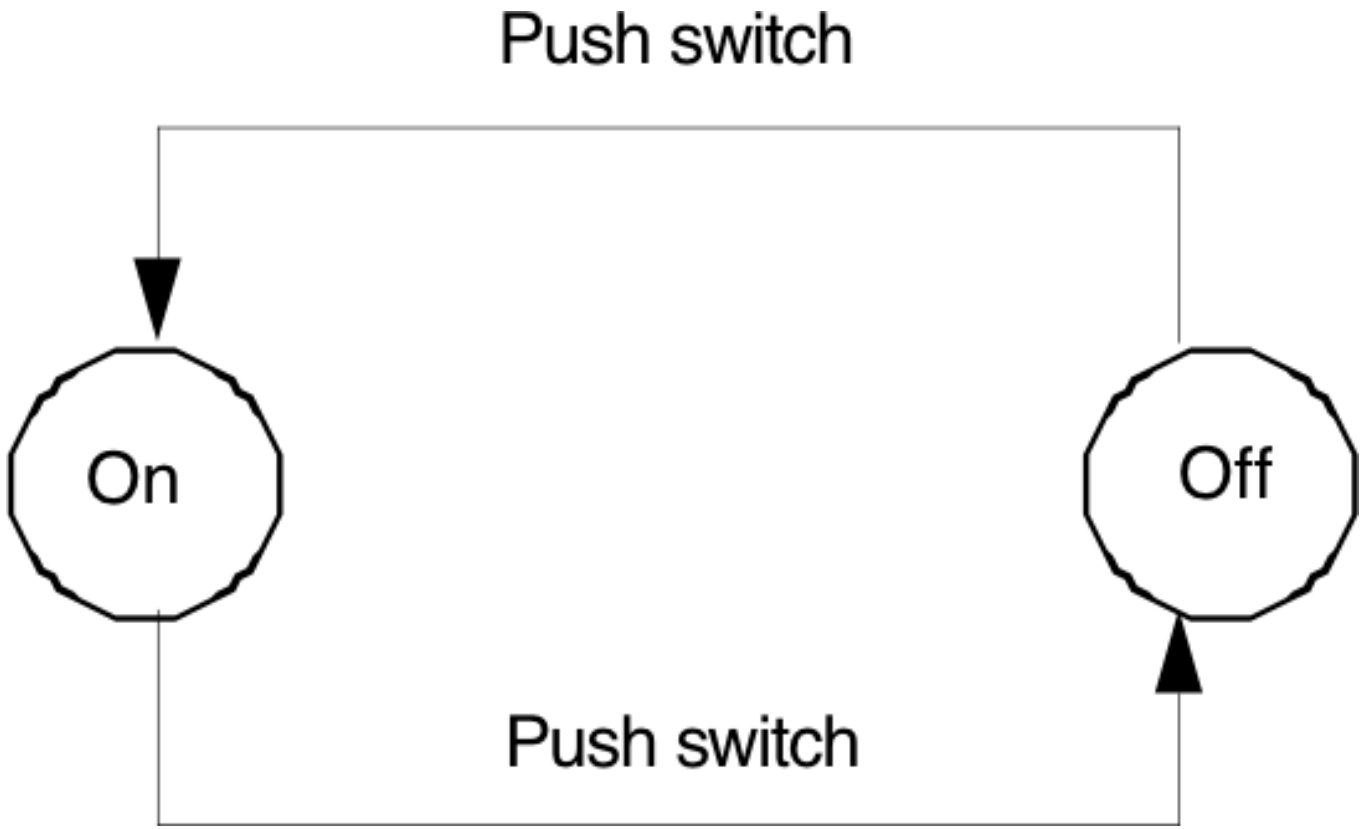
	$\mathbf{q_0}$	$\mathbf{q_1}$	$\mathbf{q_2}$	$\mathbf{q_3}$
a	q_1	q_2	-	-
b	-	q_3	q_3	-
c	-	-	-	q_0



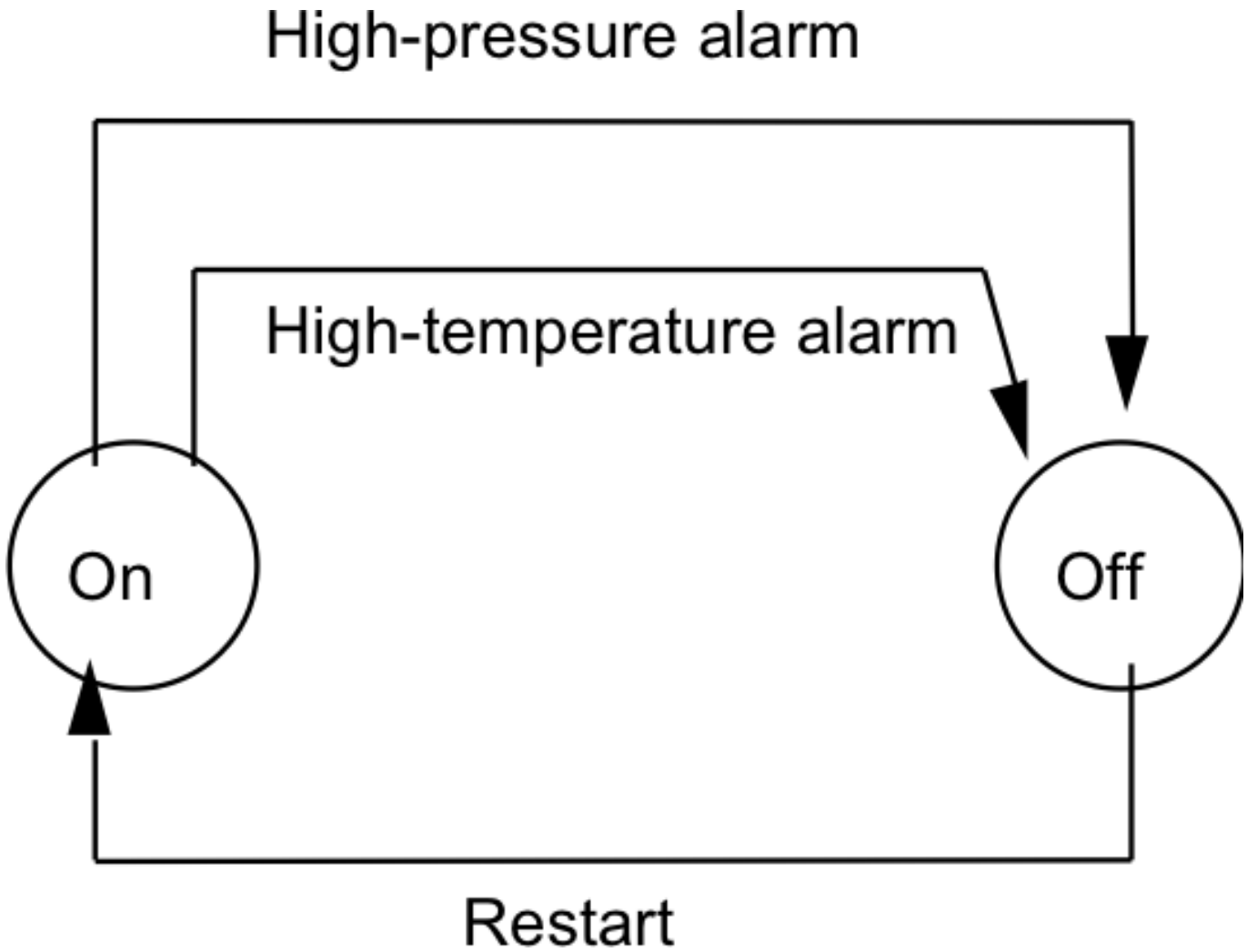
Example: A Lamp

- What are the states Q for a typical lamp?
- What are the set of inputs I
- What is the transition function δ?

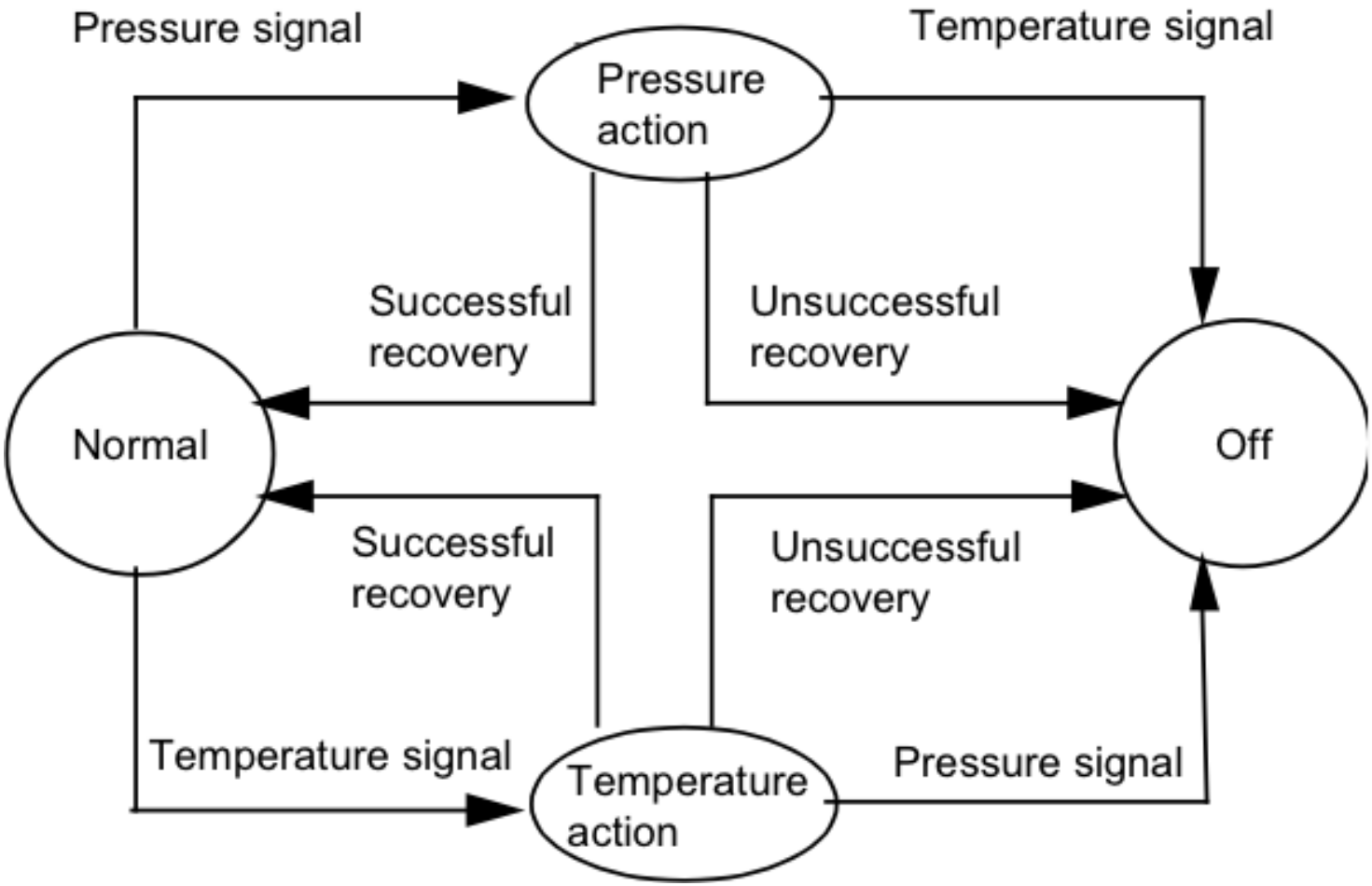
Example: A Lamp



Example: A Plant Control System



A Refinement



When to use FSMs for Specification?

- When is an FSM a good choice for specification?
- What are some examples of things we would specify using an FSM?

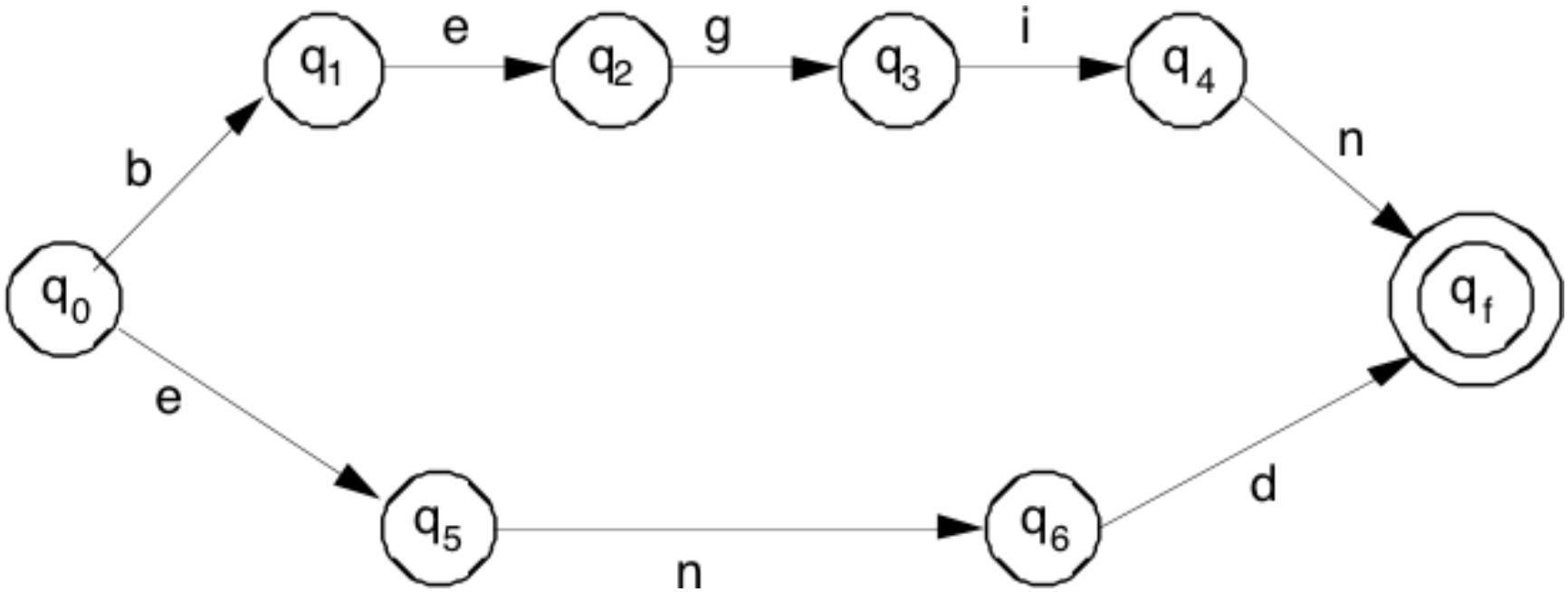
When to Potentially use FSMs

- Describing control flow
- Clear finite set of states (or modes)
- Specify acceptable strings for a parser
- Specifying hardware design
- For synchronous models (at any time a global state must be defined and a single transition must occur)

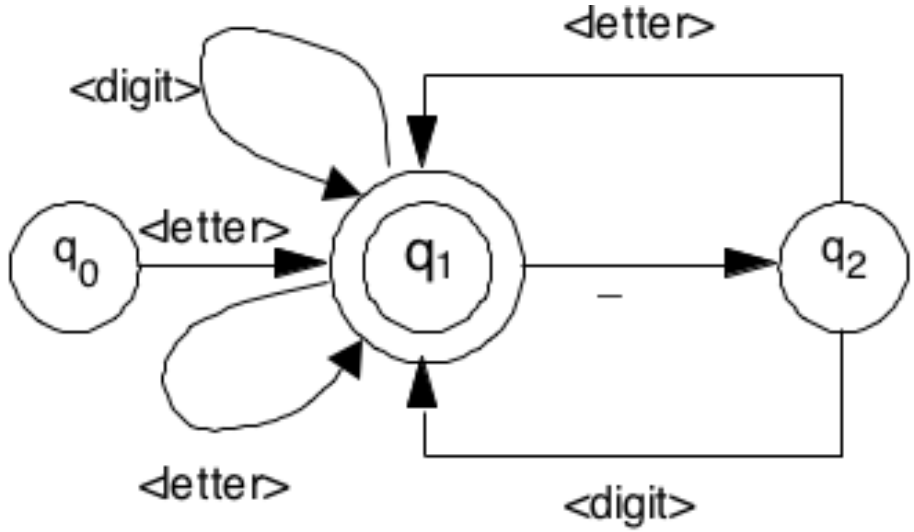
Classes of FSMs

- Deterministic/nondeterministic
- FSMs as recognizers - introduce final states
- FSMs as transducers - introduce set of output
- ...

FSMs as Recognizers



FSMs as Recognizers Continued



Legend: <letter> is an abbreviation for a set of arrows

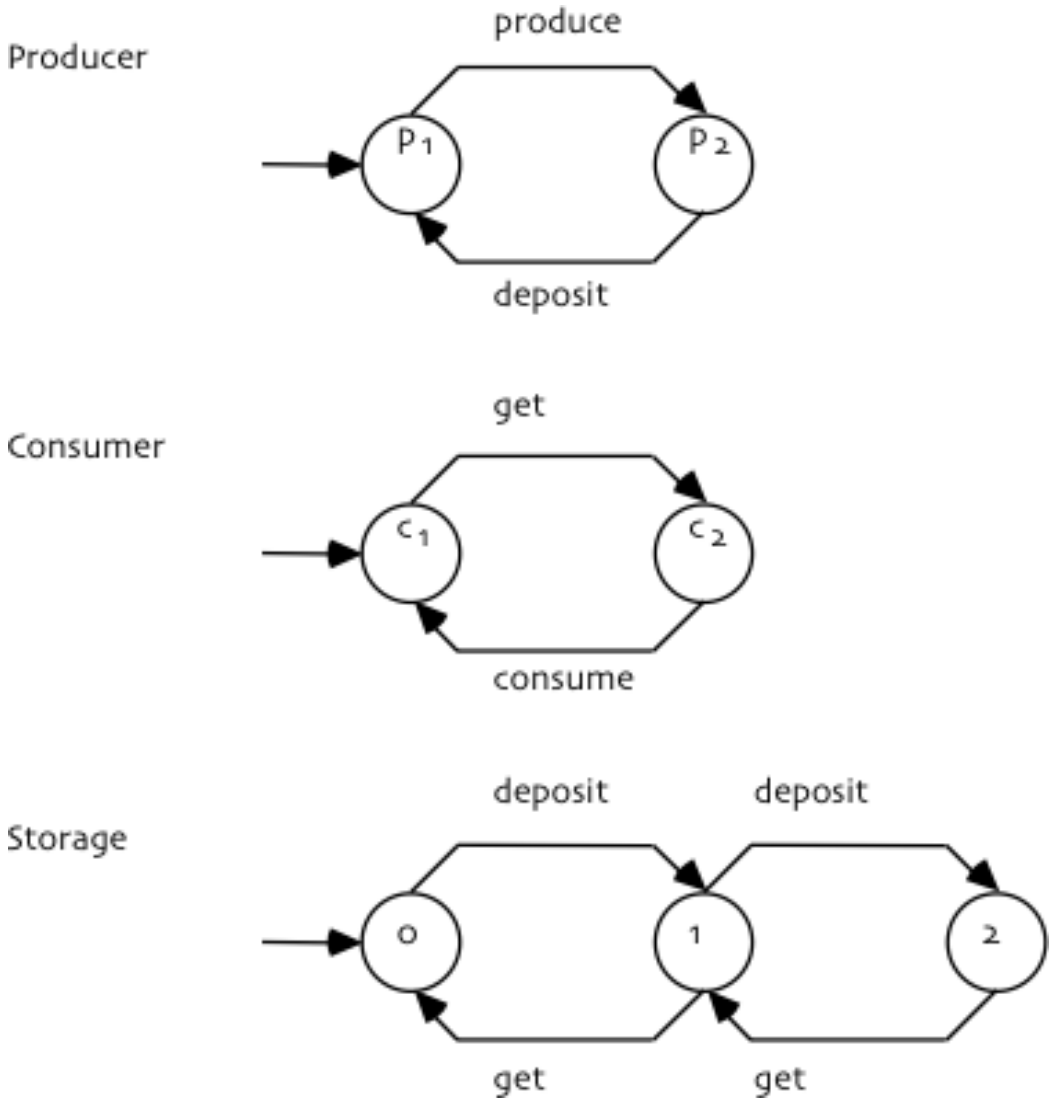
respectively

<digit> is an abbreviation for a set of arrows labeled 0, 1,..., 9, respectively

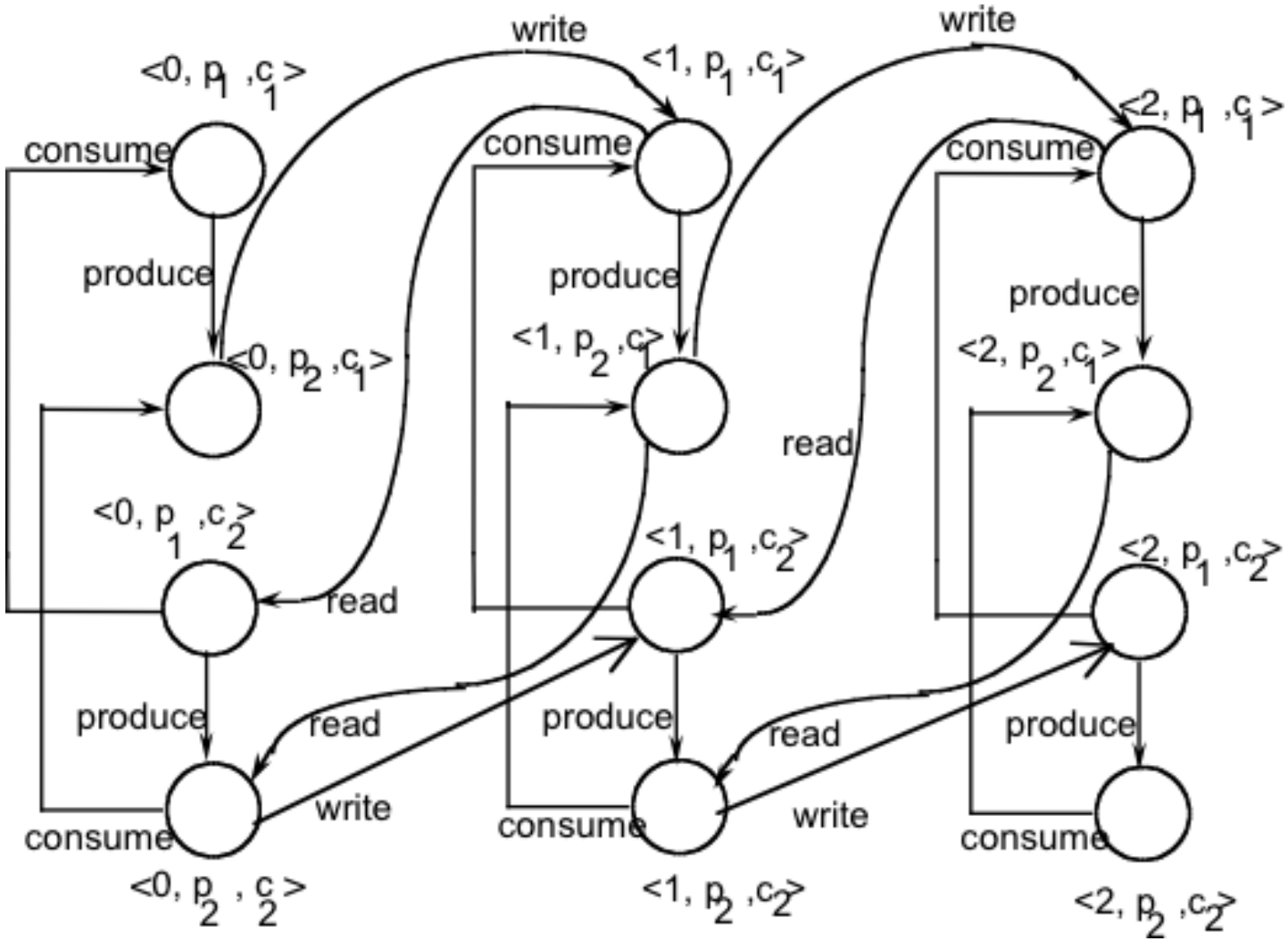
Limitations

- Finite memory
- State explosion - Given a number of FSMs with $k_1, k_2, ...k_m$ states, their composition is an FSM with $k1 \times k_2 \times ... \times k_n$. This growth is exponential with the number of FSMs, not linear (we would like it to be $k_1 + k_2 + ... + k_n$)

State Explosion: An Example



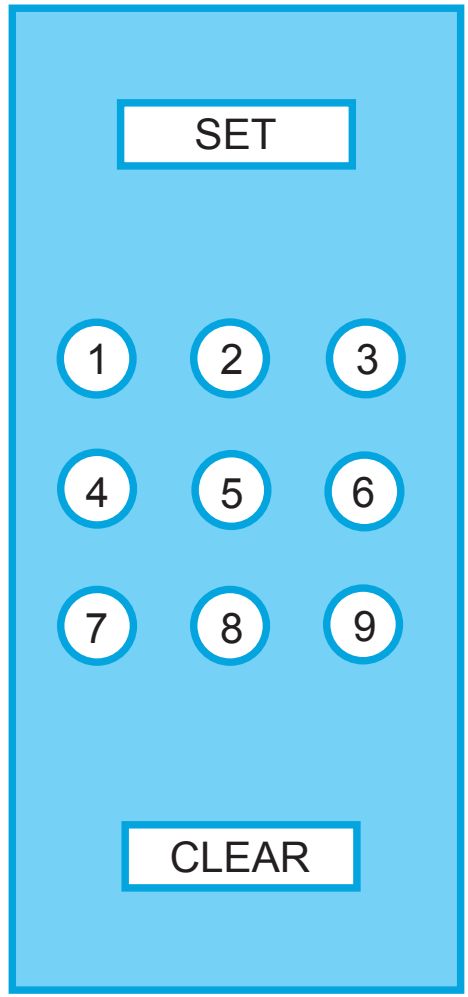
The Resulting FSM



Events Versus Conditions

- Events can be viewed as "pulses" in time - they do not last (retain their values)
- Conditions may retain their values indefinitely

FSM Example: Security Alarm



Security Alarm Example Continued