Embedded Systems
Lecture 4: Statecharts

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Overview

- Statecharts
  - Definition
  - Depth
  - History, Default
  - Concurrency
  - Broadcast
  - Example

Statecharts

- Statecharts were introduced by David Harel in 1987
  - D. Harel, “Statecharts: A visual formalism for complex systems”, Science of Computer Programming 8, 1987, pp. 231-274.
- Statecharts are useful for describing large, complex, reactive systems
  - a reactive system is one which must continuously react to external and internal stimuli
- They are a graphic notation (“visual”)
- Lecture based on Kendra Cooper’s notes

Definition based on FSM

Statechart = state-diagrams
+ depth (also known as abstraction)
+ orthogonality (also known as concurrency)
+ broadcast communication

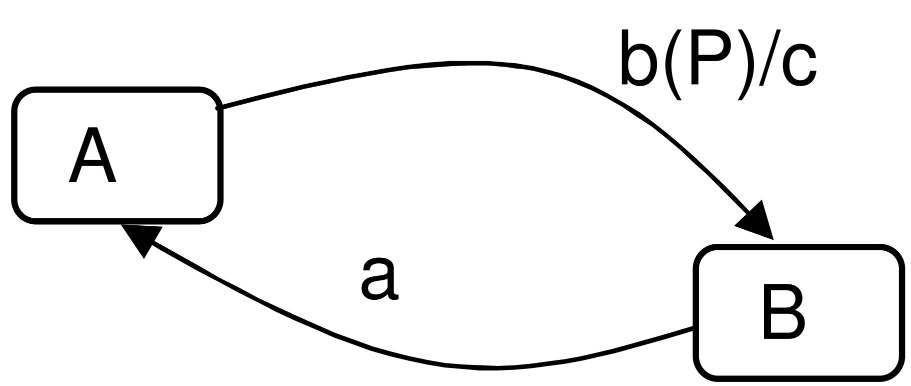
The Statechart notation is a kind of extended FSM with abstraction, concurrency, and communication.

State Diagrams

- Composed of **states, transitions**
- Transitions from one state to another happen when the **event** that is labeled on the arc (if any) occurs and the **condition** (if any) is true
- An **output** can be associated with the transition

Example

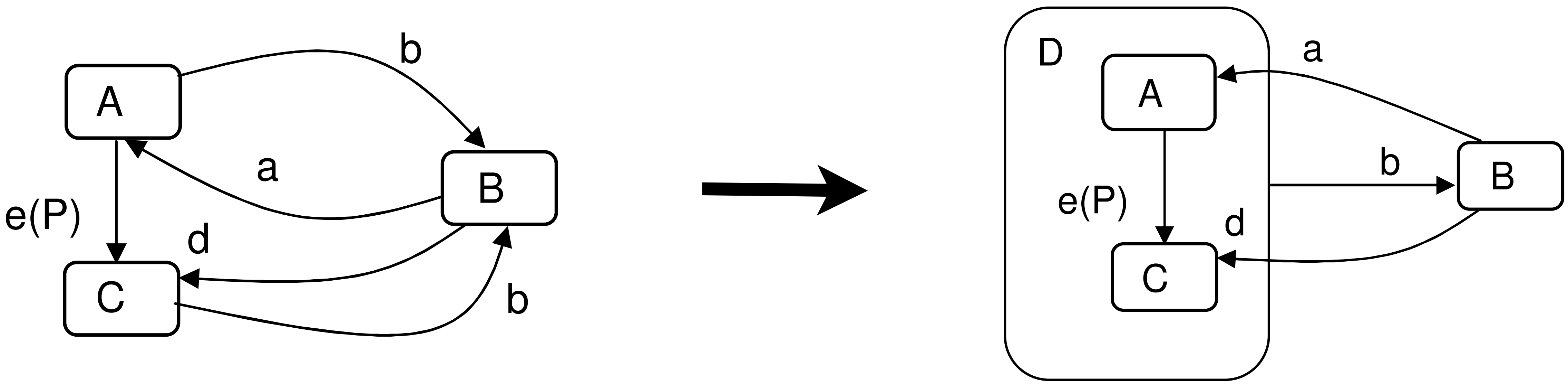
- State changes from A to B when **event** b occurs and the **condition** P is true; the **output** is c
  - c is **global** (can be seen everywhere in the Statechart model)
    - c can be used as an **input** on a transition
    - this supports **communication** in the model



Depth (Hierarchie)

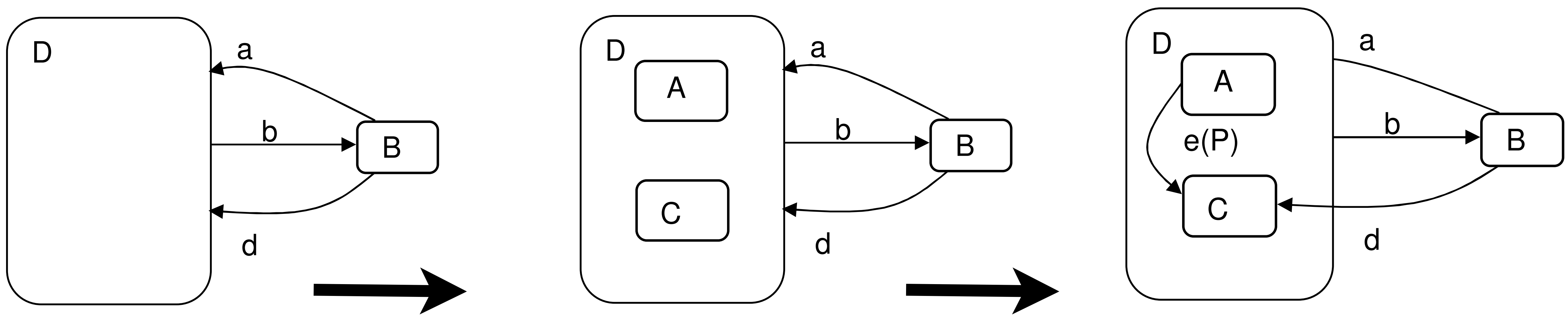
- Statecharts extend this with:
  - Refinement, clustering
  - AND, OR decomposition of states (actually XOR, not OR)

Example (Bottom-Up Clustering)



- D is called a **superstate.**
- The semantics (aka meaning) of superstate D is:
  - A xor C
  - The arc labeled b is a *common property* to the superstate D

Example (Top-Down Refinement)

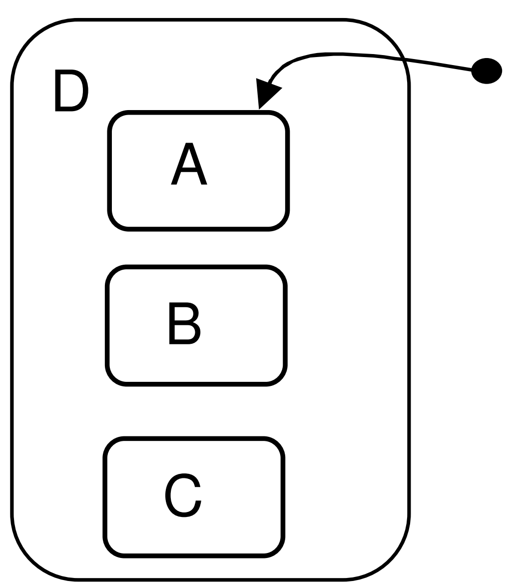


- State D is refined to include states A and C

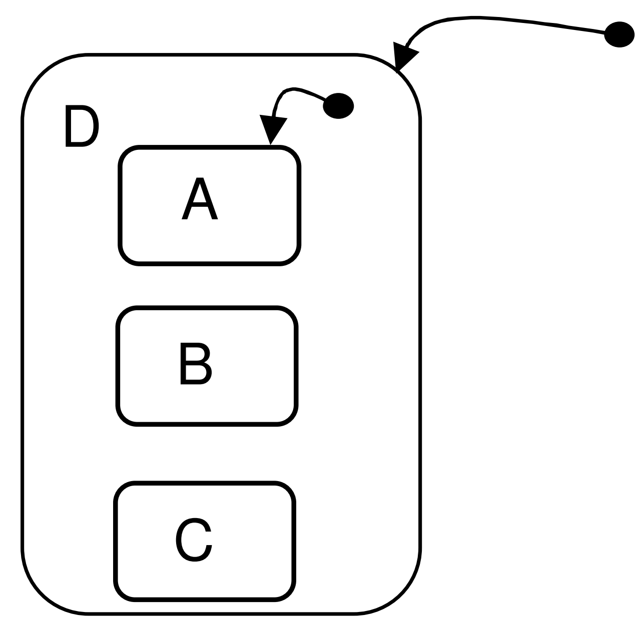
- The events a,d are underspecified (which one goes where?)
    - needs to be fixed
- The transition from A to C also needs to be specified for the example

Default state

- If we have substates A, B, and C and we want to enter state A by **default**
- We specify this using a small arrow:



or



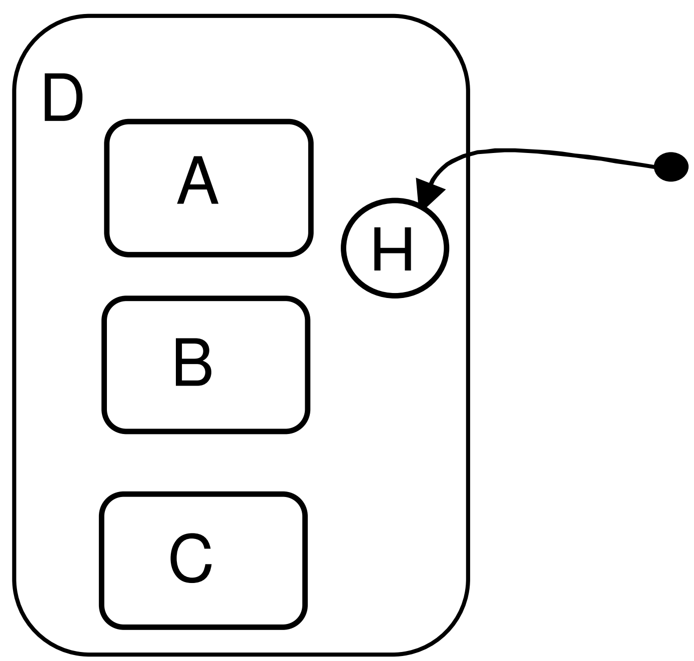
History State

- Can use a **history entrance** (H).
- The state entered is the last state the level was in when it existed.
    - The H entrance **overrides** a default state
    - The scope of the **H** entrance is the **current** level of the diagram
    - The scope of the **H*** entrance is to the **lowest** level of the diagram.

Example

- A timer that continues to count down as the state is entered and exited

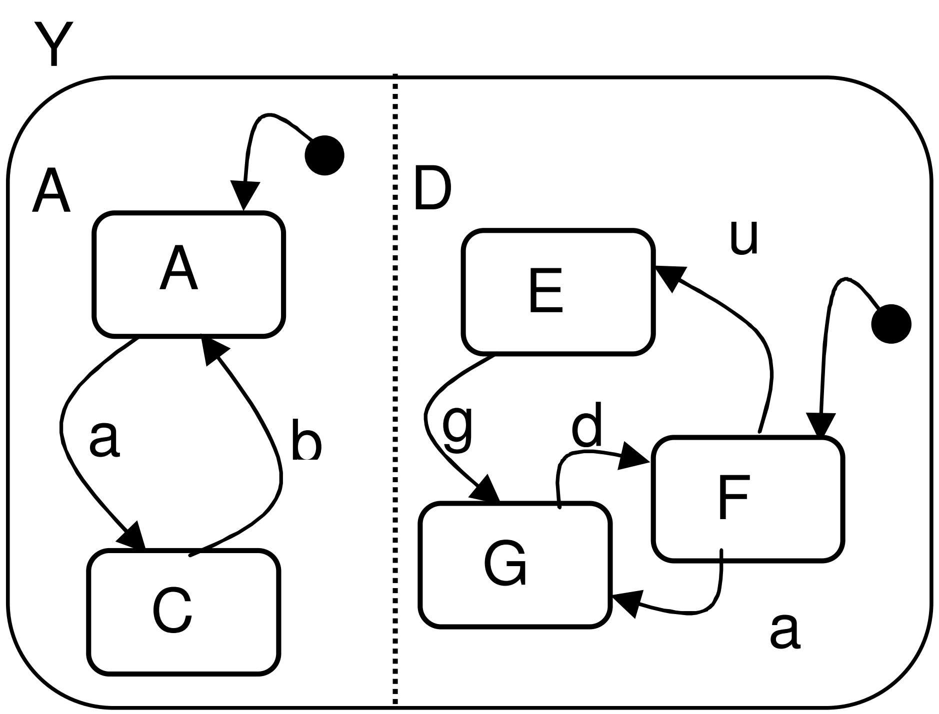
- The timer does not get reset when the state is entered



Orthogonality (Concurrency)

- AND

- Y is the *orthogonal product* of A and D



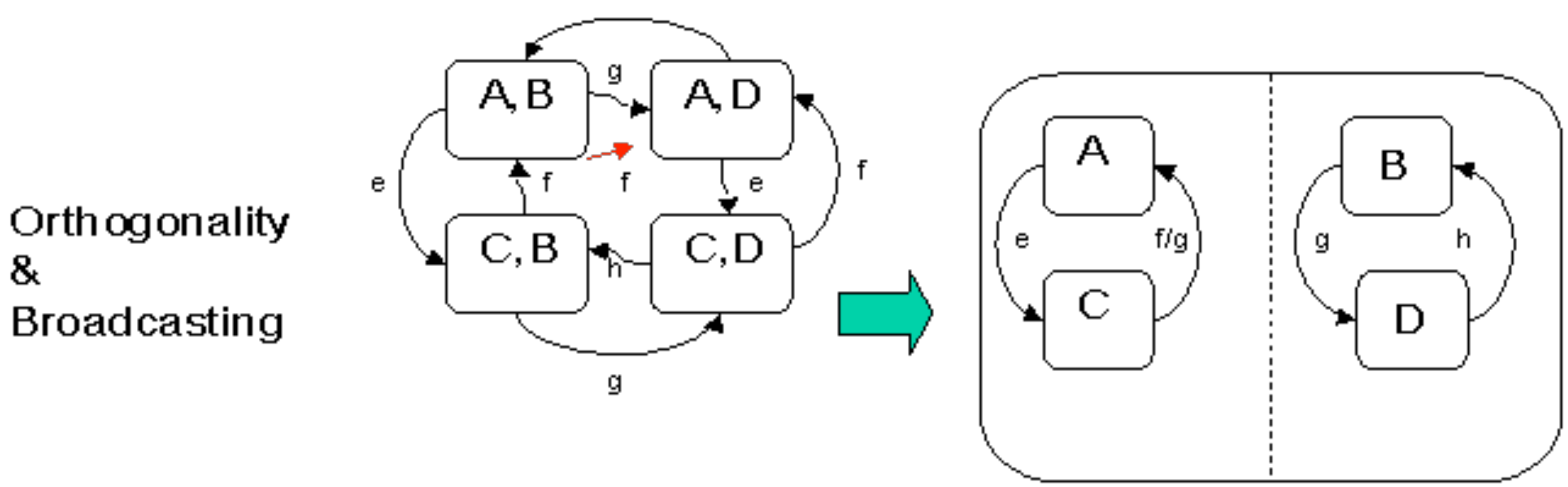
- From the default states:

- If event ‘a’ occurs, then the diagram moves from states A,F into state C,G at the same time (A is synchronised with D)

- If event ‘u’ occurs, then only D is affected and the diagram moves from A,F into state A, E (A is independent from D)

Broadcast Communication

- An event is seen everywhere in the diagram at the same time.

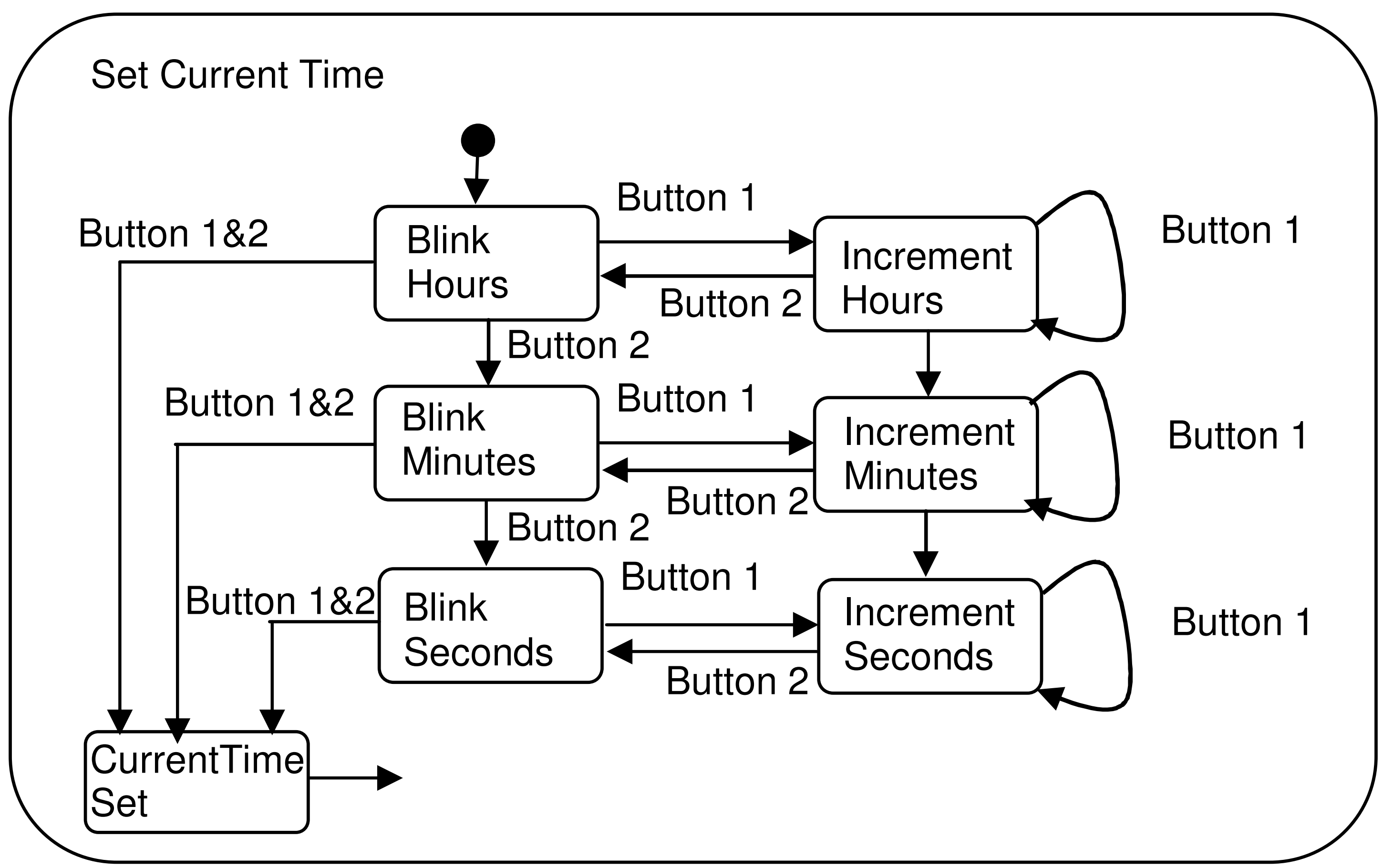


Example

- Specify the behaviour of an alarm clock using statecharts.
- Assumptions: The alarm clock has 2 buttons.

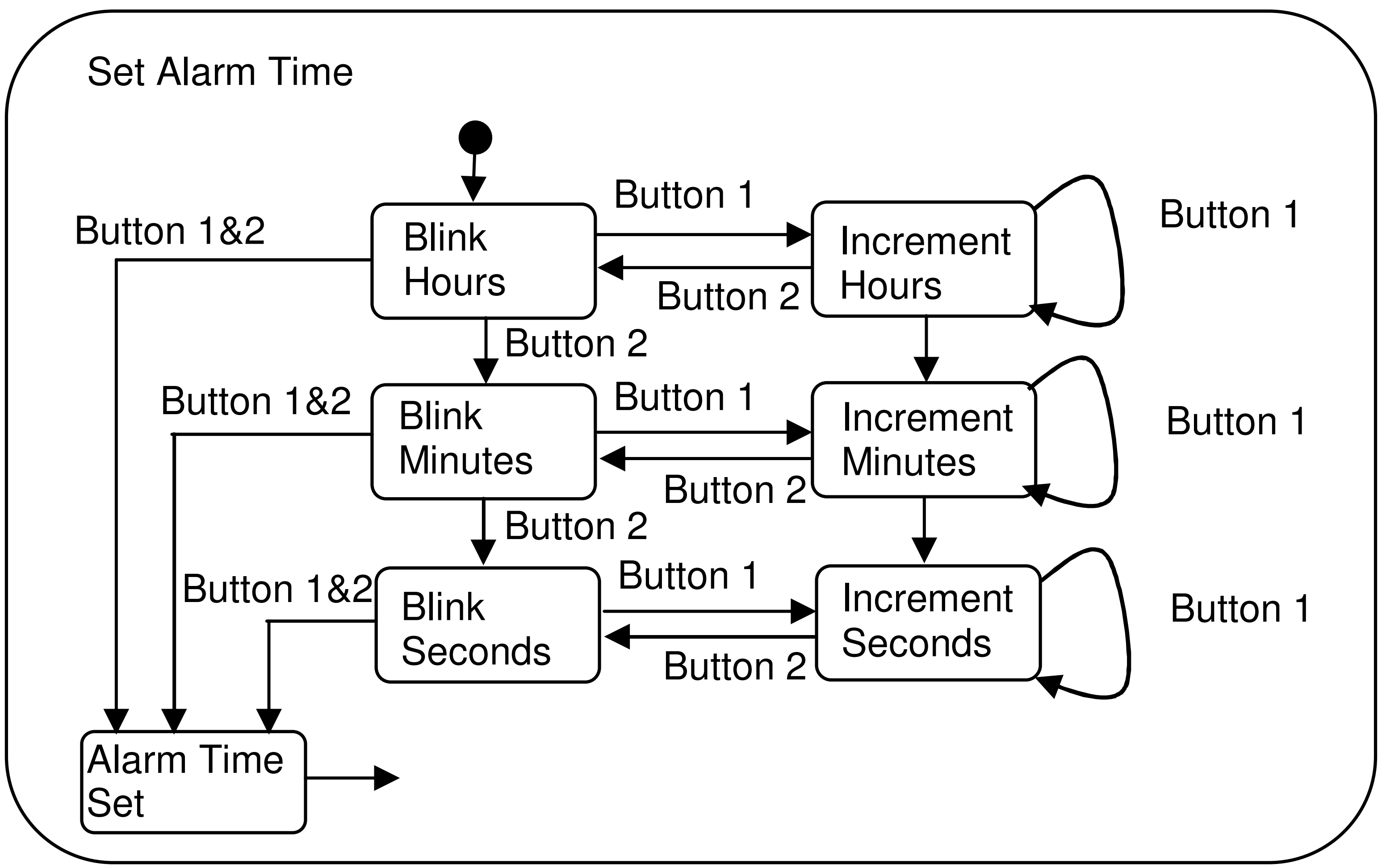
Example

- We can start with setting the current time.
  - Need to set hours, minutes, seconds
  - Need to decide which buttons (one, both together) do what



Example (continued)

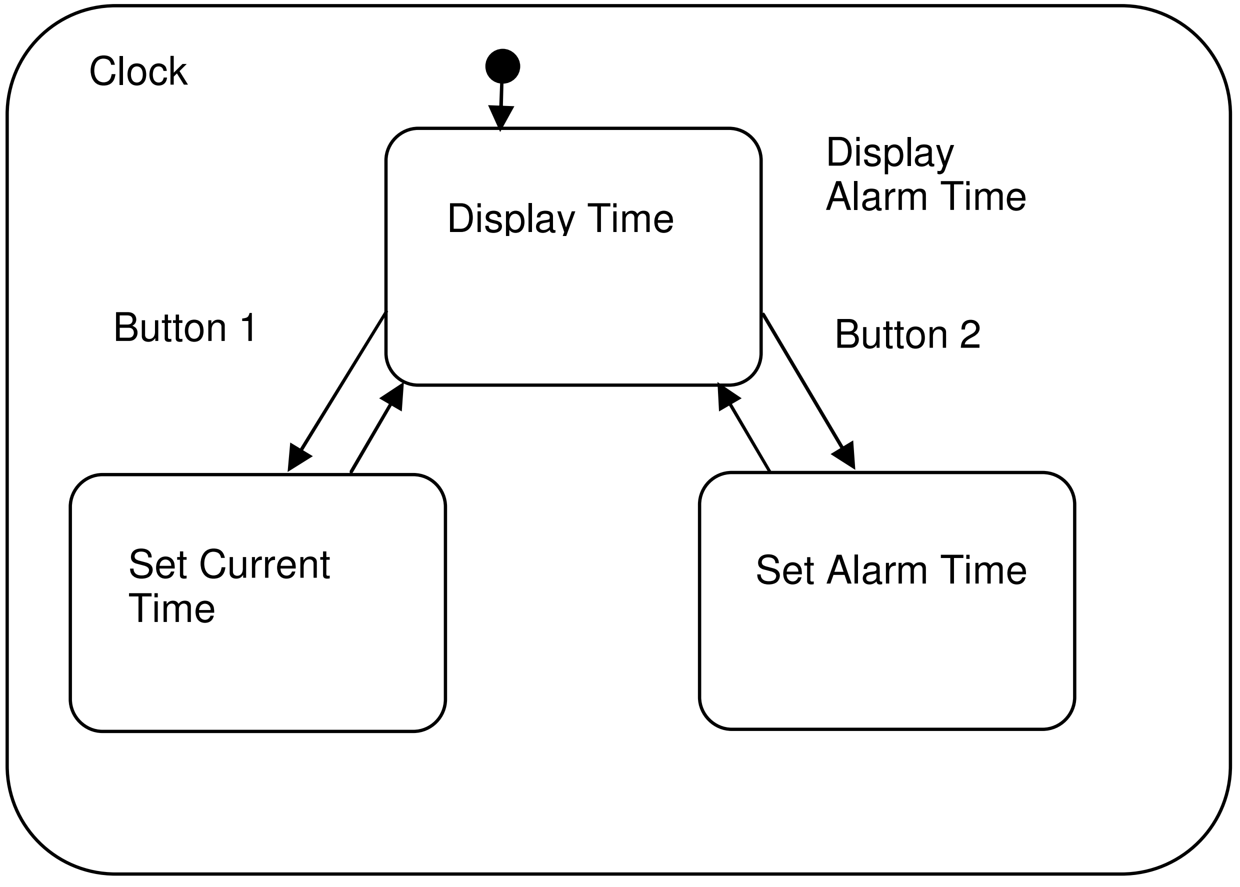
Now, consider setting the alarm time.



Example (continued)

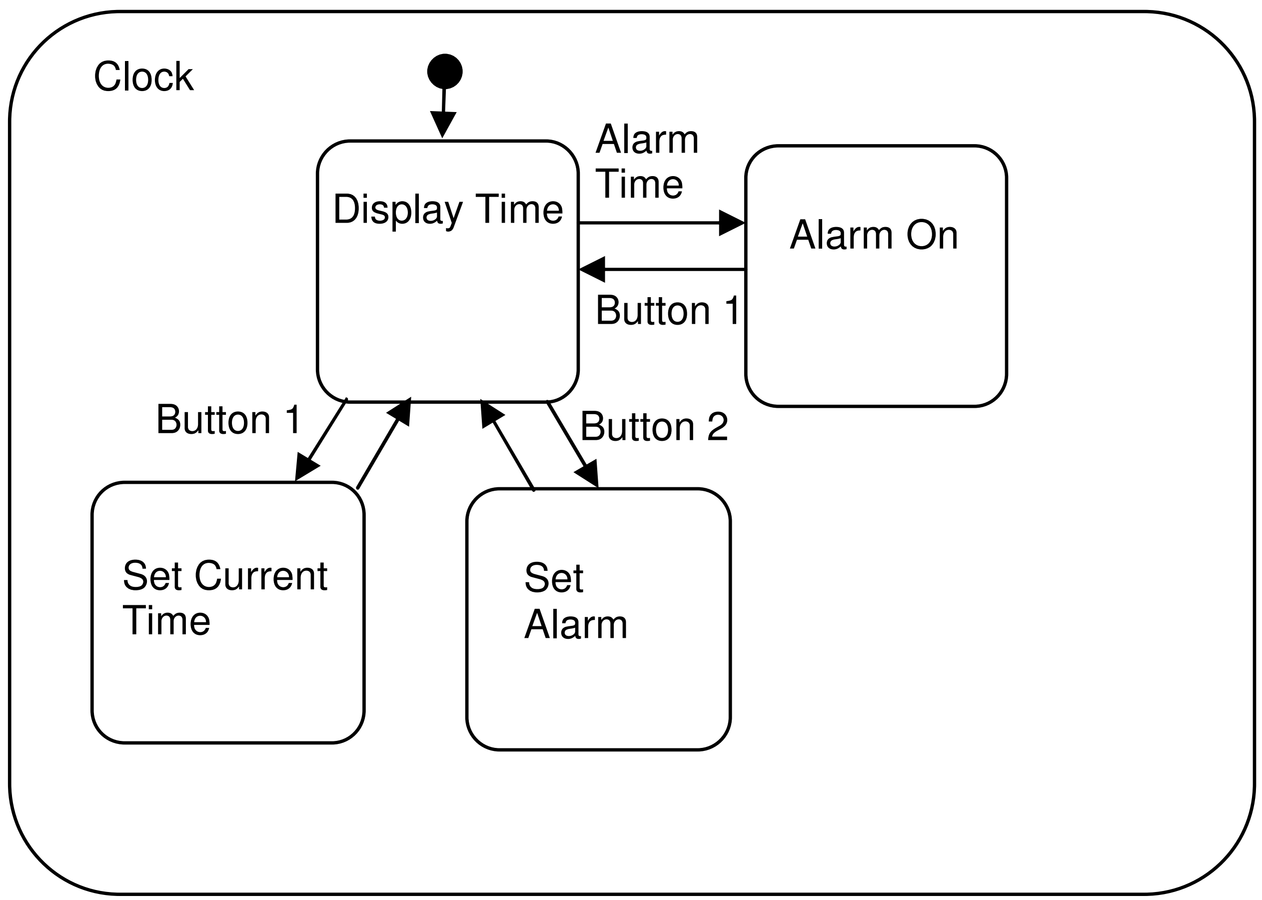
Now, consider how these superstates relate to one another?

- xor



Example (continued)

Now, extend the statechart to describe the alarm going off.



Example (Validation)

Now, validate the behavior of the statechart (i.e., does the statechart specify the system the way we want it to work)

Question: What happens if the alarm goes off for 5 minutes?

Display vs. Maintain the time?

Maintaining the time needs to occur concurrently with:

- the alarm going off
- setting the alarm time

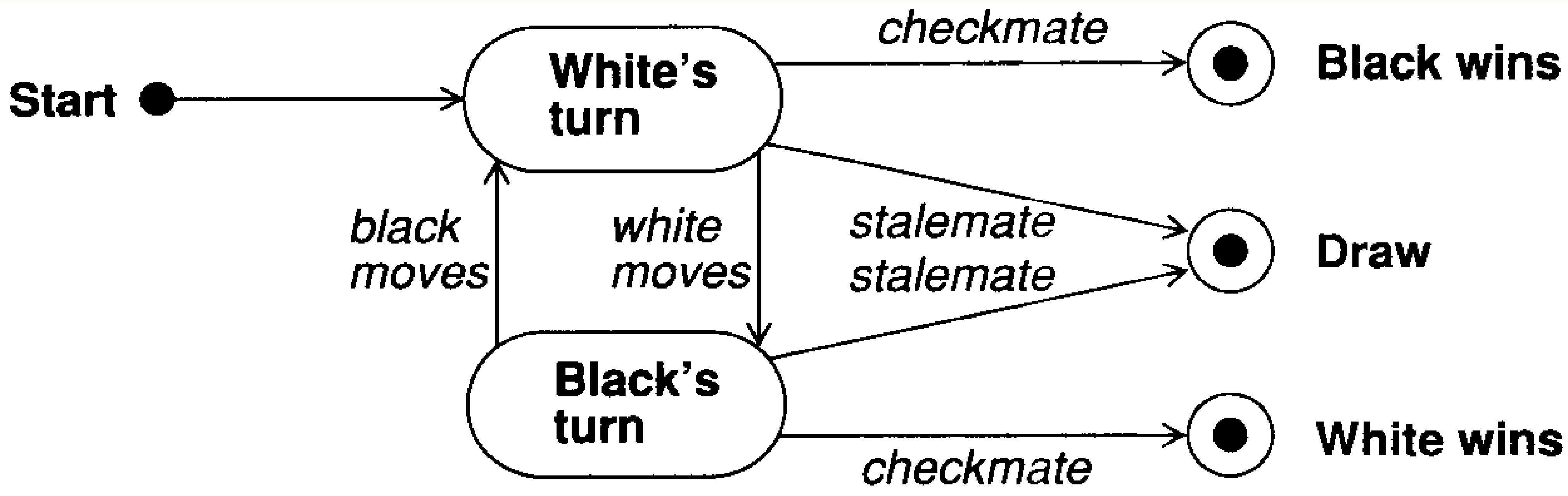
Question: Is it possible to display and maintain the current time concurrently?

Next step is to fix the statechart.
After it is fixed, need to re-validate the statechart.

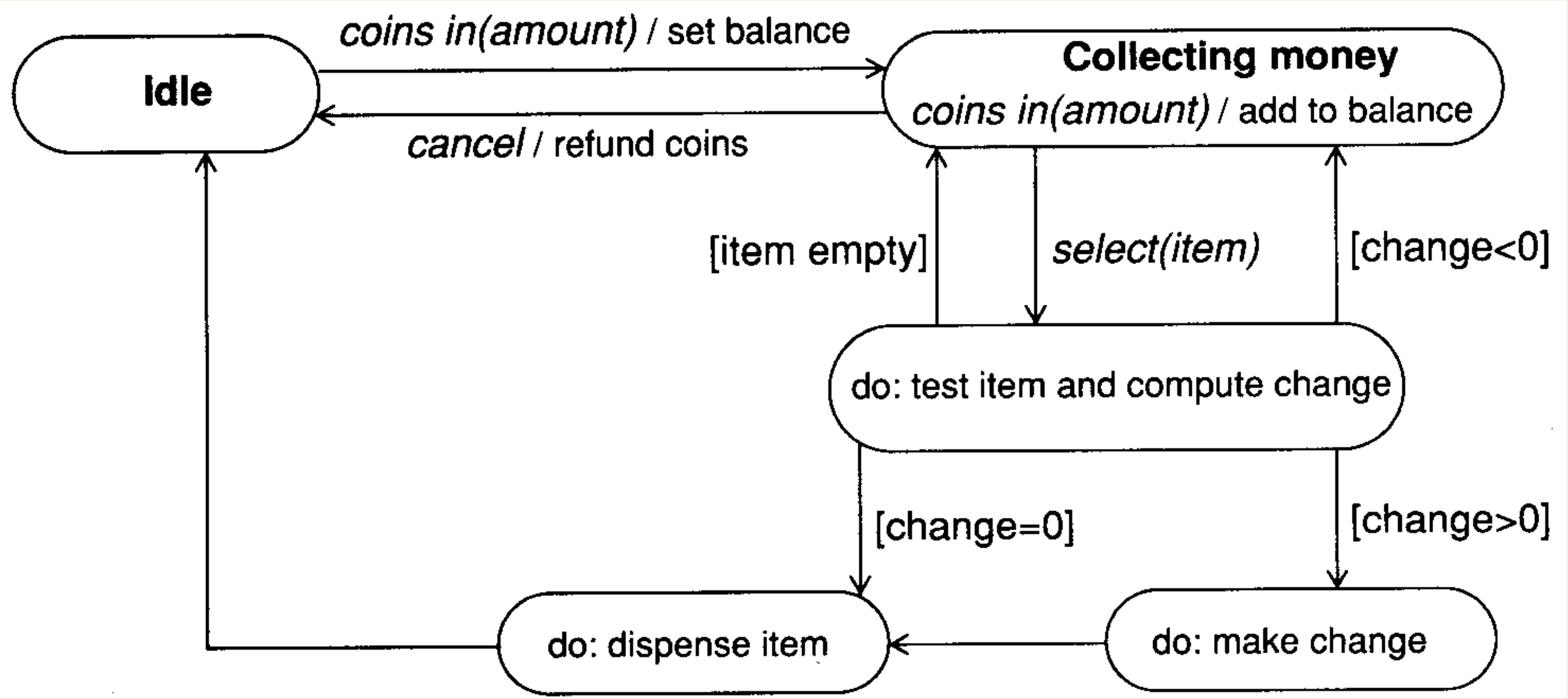
Example (Other Things to Consider)

- Is there a radio?
- Is there a snooze button?
- Is there a battery backup?
- ....

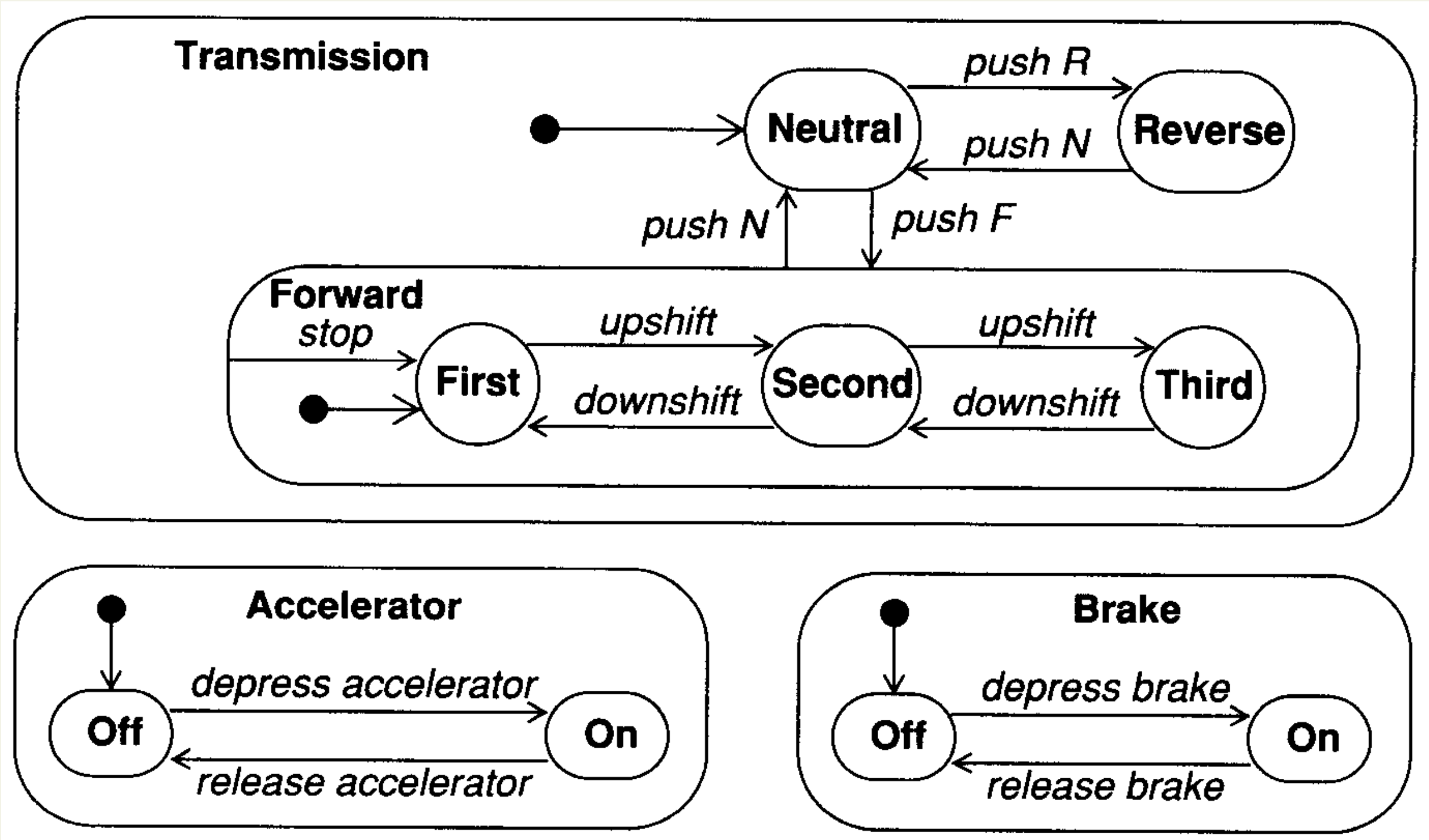
One-shot State Diagram for Chess Game



Vending Machine Model



An Aggregation and its Concurrent State Diagrams (1)



Summary

- Statecharts
  - State-Diagrams, Depth, Orthogonality, Broadcast Communication

Preview

- Imperative Programming Languages
- C, ADA, Real-Time Java, ...