Embedded Systems
Lecture 4: Statecharts

Björn Franke
University of Edinburgh
Overview

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

• Statecharts were introduced by David Harel in 1987
  

• 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:
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

![Diagram](image)

• 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
Now, consider setting the alarm time.

![Diagram of alarm time setting process](image-url)
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

Start

White's turn: black moves → white moves

Black's turn: black moves → stalemate

Checkmate: White wins

Checkmate: Black wins

Draw: Black wins

White wins: Black wins
Vending Machine Model

**Idle**
- \(\text{coins in(amount)}\) / set balance
- cancel / refund coins

**Collecting money**
- \(\text{coins in(amount)}\) / add to balance
- select(item)
- [item empty]
- [change<0]
- [change=0]
- [change>0]

- do: test item and compute change
- do: dispense item
- do: make change
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, ...