State Machines

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State Machines

- **State Machines** or **Statechart Diagrams** give us the means to control these decisions
- Each state is like a **"mode of operation"** for the object the **Statechart Diagram** is considering

Activity vs. State Machines

- In UML semantics **Activity Diagrams** are reducible to **State Machines** with some additional notations
- In **Activity Diagrams** the vertices represent the carrying out of an activity and the edges represent the transition on the completion of one collection of activities to the commencement of a new collection of activities
- **Activity Diagrams** capture high level activities' aspects
- In **State Machines** the vertices represent **states** of an **object** in a class and edges represent occurrences of **events**

State Machine Basics

- Simple,
- Complex States
  - Composite and Submachine States
  - Concurrent Substates
  - History States
  - Synch States
- Transitions
- Synchronization Bars and Decision Points
- Transition types
- Transitions to/from Composite States
- Actions

Events

- Internal or External Events trigger some activity that changes the state of the system and of some of its parts
- Events pass information, which is elaborated by Objects operations. Objects realize Events
- Design involves examining events in a State Machine and considering how those events will be supported by system objects

States

- A state is a condition of being at a certain time
- Objects (or Systems) can be viewed as moving **from state to state**
- A point in the lifecycle of a model element that satisfies some condition, where some particular action is being performed or where some event is waited
- **Start** and **End** States

Actions

- **States** can trigger **actions**
- **States** can have a second compartment that contains **actions** or activities performed while an entity is in a given state
- An **action** is an atomic execution and therefore completes **without interruption**
- Five triggers for actions:
  - **On Entry**, **Do**, **On Event**, **On Exit** and **Include**
- An activity captures complex behaviour that may run for a long duration
  - An activity may be interrupted by events, in which case it does not complete

Simple and Composite States

- **Simple states** - simplest of all states, they have no substates
- **Composite states** – have one or more regions for substates.
- **Submachine states** – semantically equivalent to composite states, submachine states have substates that are contained within a substate machine
- An **History State** - indicated by a circle with an H inside it - allows the re-entering of a composite state at the point which it was last left

Concurrent Substates and Regions

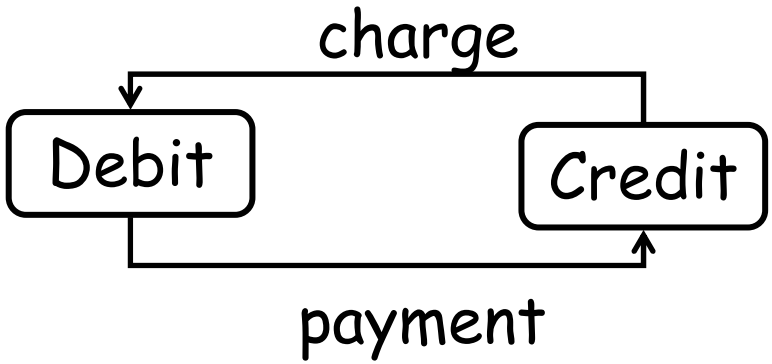
- **Concurrent Substates** are independent and can complete at different times
- Each substate is separated from the others by a dashed line

Transitions

- Viewing a system as a set of states and **transitions between states** is very useful for describing complex behaviors
- Understanding state transitions is part of system analysis and design
- A **Transition** is the movement from one state to another state
- Transitions between states occur as follows:
  1. An **element** is in a source **state**
  2. An **event** occurs
  3. An **action** is performed
  4. The **element** enters a target **state**
- **Multiple transitions** occur either when different events result in a state terminating or when there are guard conditions on the transitions
- A transition without an event and action is known as **automatic transitions**

A Transition Example

Transitions between the **Credit** and **Debit states** of an **Account class**



Transition Types

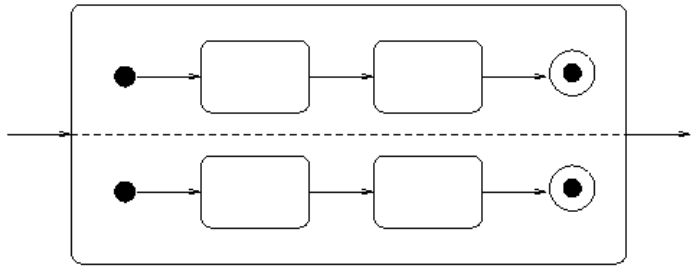
- **Compound Transition** – A representation of the change from one complete state machine configuration to another.
- **High-level Transition** – A transition from a composite state.
- **Internal Transition** – A transition between states within the same composite state. Note that transitions between regions of the same composite state are not allowed.
- **Completion Transition** – A transition from a state that has no explicit trigger.

Synchronization Bars and Decision Points

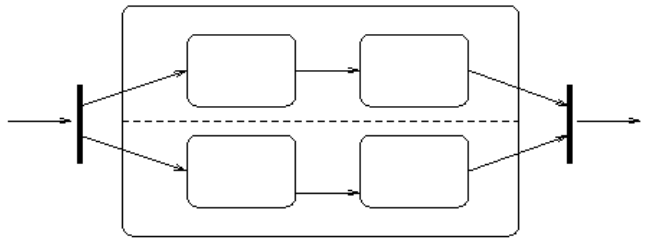
- **Synchronization Bars**
  - Allow the representation of **concurrent** states
  - Let transitions to split or combine
  - It is **important** when the overall state of a class is split into concurrent states that these states are re-combined on the same diagram
- **Decision Points**
  - Let a transition to split along a number of transitions based on a **condition**

Transitions to/from Composite States

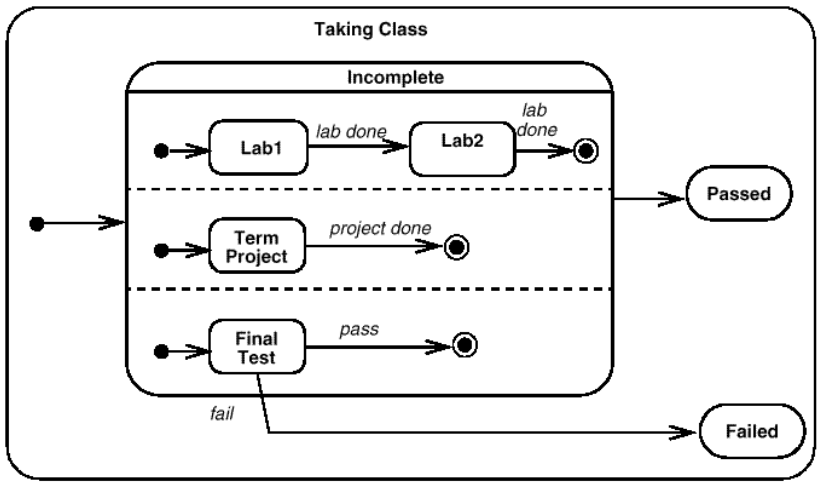
- **To composite state's boundary**
  - start the subflow at the initial state of the composite state
  - If the composite state is concurrent, then the transition is to each of the initial states
- **From composite state's boundary**
  - Immediate and effective on any of the substates
- **To the substates**
- **From substates out to other states**



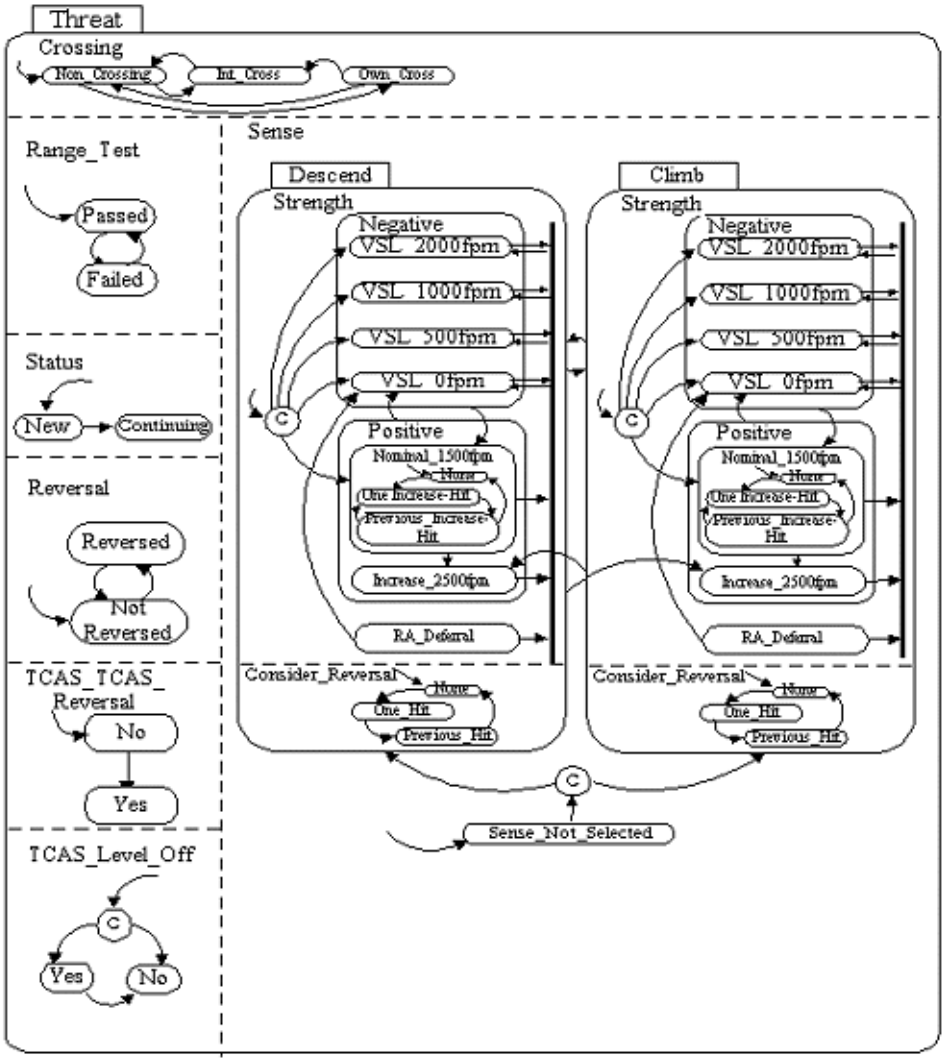
(a) State with internal concurrency



(b) Equivalent state with external synchronisation



An Example of a Very Complex State



TCAS
Traffic Alert /Collision Avoidance System

Designing Classes with States Diagrams

- Keep the state diagram **simple**
  - State diagrams can very quickly become extremely complex and confusing
  - At all time, you should follow the aesthetic rule: ***"Less is More"***
- If the state diagram gets too complex consider **splitting** it into smaller classes
- Document states thoroughly
- Check **consistency** with the other view of the dynamics
- Think about compound state changes in a collaboration or sequence

Building Statechart Diagrams

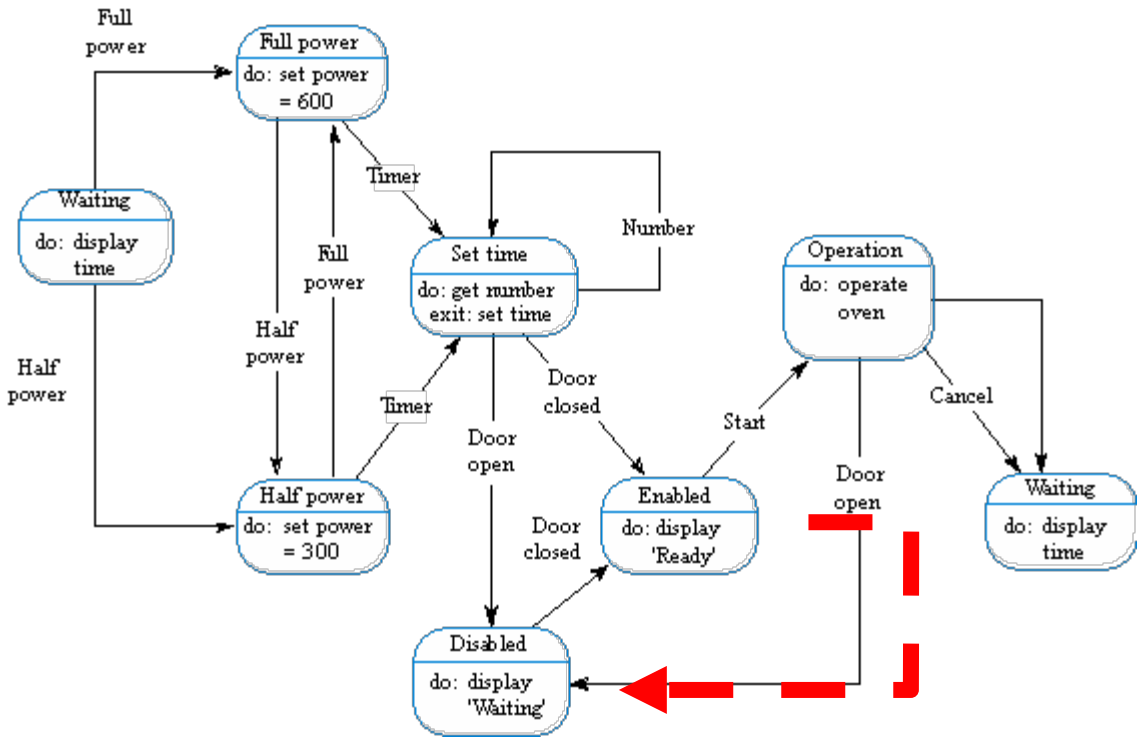
1. Identify **entities** that have **complex behaviour** - Identify a **class** participating in **behavour** whose lifecycle is to be specified
2. Model **states** - Determine the **initial** and **final states** of the entity
3. Model **transitions**
4. Model **events** - Identify the **events** that affect the entity
5. Working from the initial state, trace the impact of events and identify intermediate states
6. Identify any **entry** and **exit actions** on the states
7. Expand states using substates where necessary
8. If the entity is a class, check that the action in the state are supported by the operations and relationships of the class, and if not extend the class
9. Refine and elaborate as required

A Simple Statechart Model

A Simple Microwave Oven

1. Select the power level
2. Input the cooking time
3. Press start

- **Safety.** The oven should not operate when the door is open



Types of State Machines

- **Behavioral state machines** show the behavior of model elements such as objects. A behavioral state machine represents a specific implementation of an element.
- **Protocol state machines** show the bahavior of a protocol. They show how participants may trigger changes in a protocol's state and the corresponding changes in the system.

Some (Open) Questions

- What are the **benefits** of having states in a system?
- What are the **costs** of having states in a system?
- Every state should have an edge for every message in the class - is this the right view?
- How does this description of state relate to design by contract?
- How would you check that a Java implementation was consistent with a state diagram?
- How does this differ with the treatment of state in programming languages?
- What does this say about the different between **modeling** and **programming**?

Readings

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- **UML course textbook**
  - Chapter 12 on State Machines

Suggested Readings

- D. Harel. *Statecharts: A Visual Formalism for Complex Systems*. In Science of Computer Programming 8(1987):231-274.

Summary

- Statechart Diagrams
- Activity vs. Statechart Diagrams
- Statechart Diagrams Basics
  - States and Events, Transitions, Actions, Synchronization Bars, Decision Points, Complex States (i.e., Composite States, Concurrent Substates, History States, Synch States)
- Building Statechart Diagrams