Lecture 15: Modelling "State"

→ **What is State?**
- statespace for an object
- concrete vs. abstract states

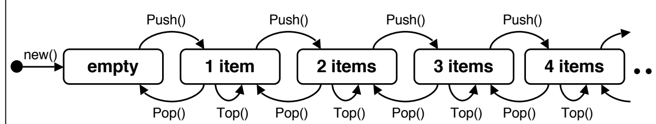
→ **Finite State Machines**
- states and transitions
- events and actions

→ **Modularized State machine models: Statecharts**
- superstates and substates
- Guidelines for drawing statecharts

Getting objects to behave

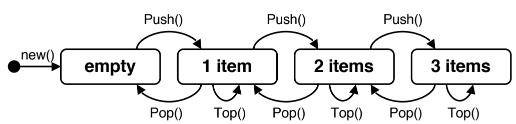
→ **All objects have "state"**
- The object either exists or it doesn't
- If it exists, then it has a value for each of its attributes
- Each possible assignment of values to attributes is a "state"
  - (and non-existence is a state, although we normally ignore it)

→ **E.g. For a stack object**



What does the model mean?

→ **Finite State Machines**
- There are a finite number of states (all attributes have finite ranges)
  - E.g. imagine a stack with max length = 3



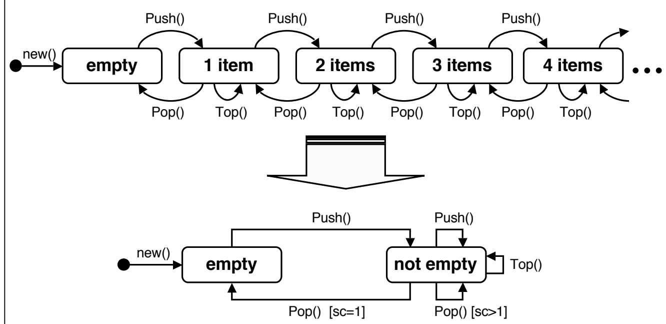
- The model specifies a set of traces
  - E.g. new();Push();Push();Top();Pop();Push()…
  - E.g. new();Push();Pop();Push();Pop()…
  - There may be an infinite number of traces (and traces may be of infinite length)
- The model excludes some behaviours
  - E.g. no trace can start with a Pop()
  - E.g. no trace may have more Pops than Pushes
  - E.g. no trace may have more than 3 Pushes without a Pop in between

Abstraction

→ **The state space of most objects is enormous**
- State space size is the product of the range of each attribute
  - E.g. object with five boolean attributes: 2^5+1 states
  - E.g. object with five integer attributes: $(maxint)^5+1$ states
  - E.g. object with five real-valued attributes: …?
- If we ignore computer representation limits, the state space is infinite

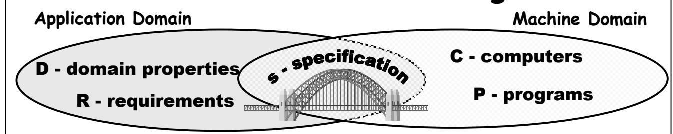
→ **Only part of that state space is "interesting"**
- Some states are not reachable
- Integer and real values usually only vary within some relevant range
- We're usually not interested in the actual values, just certain ranges:
  - E.g. for Age, we may be interested in age<18; 18≤age≤65; and age>65
  - E.g. for Cost, we may only be interested in cost≤budget, cost=0, cost>budget, and cost>(budget+10%)

Collapsing the state space



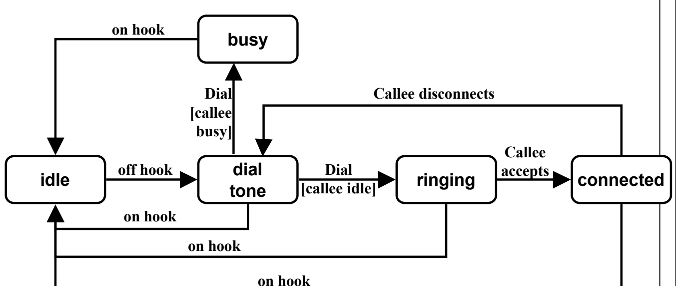
- The abstraction usually permits more traces
  - E.g. this model does not prevent traces with more pops than pushes
  - But it still says something useful

What are we modelling?

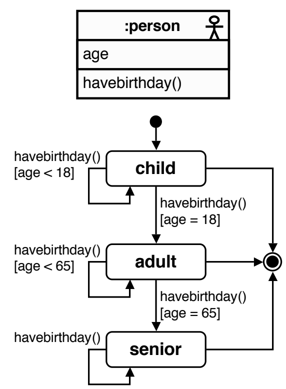


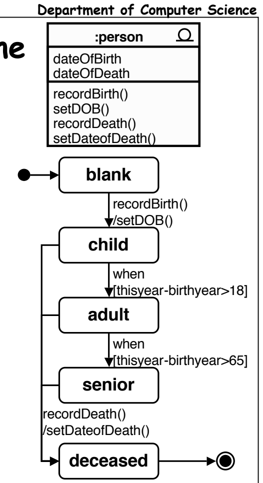
- Observed states of an application domain entity?
  - E.g. a phone can be idle, ringing, connected, …
  - Model shows the states an entity can be in, and how events can change its state
  - This is an indicative model
- Required behaviour of an application domain entity?
  - E.g. a telephone switch shall connect the phones only when the callee accepts the call
  - Model distinguishes between traces that are desired and those that are not
  - This is an optative model
- Specified behaviour of a machine domain entity?
  - E.g. when the user presses the 'connect' button the incoming call shall be connected
  - Model specifies how the machine should respond to input events
  - This is an optative model, in which all events are shared phenomena

Is this model indicative or optative?



the world vs. the machine





StateCharts

➜ **Notation:**

- States
  - "interesting" configurations of the values of an object's attributes
  - may include a specification of action to be taken on entry or exit
  - States may be nested
  - States may be "on" or "off" at any given moment
- Transitions
  - Are enabled when the state is "on"; disabled otherwise
  - Every transition has an event that acts as a trigger
  - A transition may also have a condition (or guard)
  - A transitions may also cause some action to be taken
  - When a transition is enabled, it can fire if the trigger event occurs and it guard is true
  - Syntax: event [guard] / action
- Events
  - occurrence of stimuli that can trigger an object to change its state
  - determine when transitions can fire

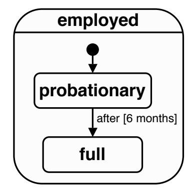
Superstates

➜ **States can be nested, to make diagrams simpler**

- A superstate consists of one or more states.
- Superstates make it possible to view a state diagram at different levels of abstraction.

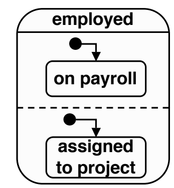
OR superstates

- when the superstate is "on", only one of its substates is "on"

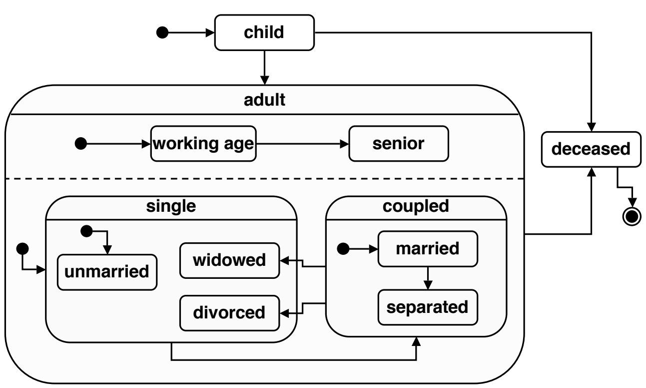


AND superstates (concurrent substates)

- When the superstate is "on", all of its states are also "on"
- Usually, the AND substates will be nested further as OR superstates



A more detailed example



States in UML

➜ **A state represents a time period during which**

- A predicate is true
  - e.g. (budget - expenses) > 0,
- An action is being performed, or an event is awaited:
  - e.g. checking inventory for order items
  - e.g. waiting for arrival of a missing order item

➜ **States can have associated activities:**

- do/activity
  - carries out some activity for as long as the state is "on"
- entry/action and exit/action
  - carry out the action whenever the state is entered (exited)
- include/stateDiagramName
  - "calls" another state diagram, allowing state diagrams to be nested

Events in UML

- **Events are happenings the system needs to know about**
  - Must be relevant to the system (or object) being modelled
  - Must be modellable as an instantaneous occurance (from the system's point of view)
    - E.g. completing an assignment, failing an exam, a system crash
  - Are implemented by message passing in an *OO* Design
- **In UML, there are four types of events:**
  - *Change events* occur when a condition becomes true
    - denoted by the keyword 'when'
    - e.g. when[balance < 0]
  - *Call events* occur when an object receives a call for one of its operations to be perfomed
  - *Signal events* occur when an object receives an explicit (real-time) signal
  - *Elapsed-time events* mark the passage of a designated period of time
    - e.g. after[10 seconds]

Checking your Statecharts

- **Consistency Checks**
  - All events in a statechart should appear as:
    - operations of an appropriate class in the class diagram
  - All actions in a statechart should appear as:
    - operations of an appropriate class in the class diagram and
- **Style Guidelines**
  - Give each state a unique, meaningful name
  - Only use superstates when the state behaviour is genuinely complex
  - Do not show too much detail on a single statechart
  - Use guard conditions carefully to ensure statechart is unambiguous
    - Statecharts should be deterministic (unless there is a good reason)
- **You probably shouldn't be using statecharts if:**
  - you find that most transitions are fired "when the state completes"
  - many of the trigger events are sent from the object to itself
  - your states do not correspond to the attribute assignments of the class