Software Design, Modelling and Analysis in UML

Lecture 16: Hierarchical State Machines III

2017-01-12

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  - **Entry and Exit Points**
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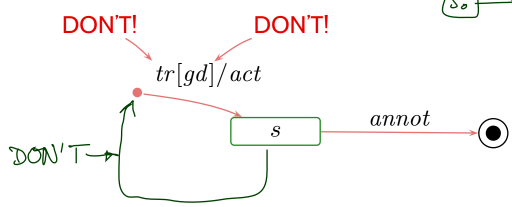
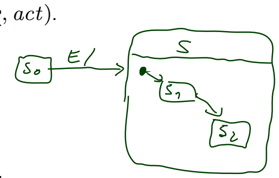
Additional Well-Formedness Constraints

- Each non-empty region has **exactly one** initial pseudo-state and **at least one** transition from there to a state of the region, i.e.
  - for each $s \in S$ with $region(s) = \{S_1, \dots, S_n\}$,
  - for each $1 \le i \le n$, there exists exactly one initial pseudo-state $(s_1^i, \mathit{init}) \in S_i$ and at least one transition $t \in \rightarrow$ with s_1^i as source,
- Initial pseudo-states are not targets of transitions.

For simplicity:

- The target of a transition with initial pseudo-state source in S_i is (also) in S_i.
- Transitions from initial pseudo-states have no trigger or guard, i.e. $t \in \rightarrow$ from s with $kind(s) = st$ implies $annot(t) = (\_, \mathit{true}, act)$.
- Final states are not sources of transitions.

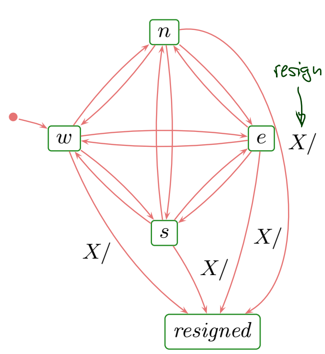




An Intuition for "Or-States"

- In a sense, composite states are about
  - **abbreviation**,
  - **structuring**, and
  - **avoiding redundancy**.

- **Idea**: instead of



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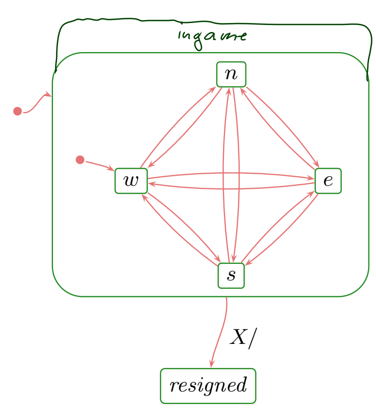
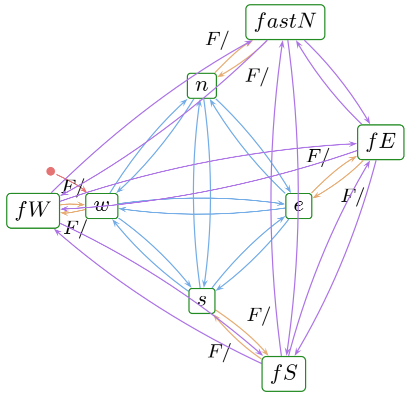


An Intuition for “And-States”

and instead of



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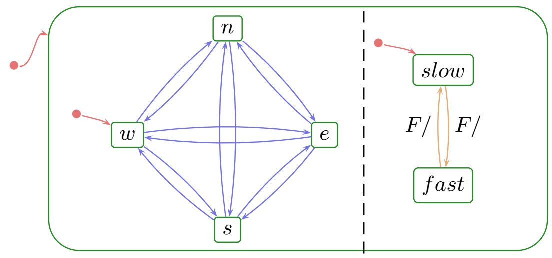
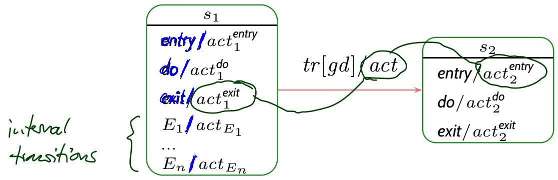


Entry and Exit Actions

Entry/Do/Exit Actions



- In general, with each state $s \in S$ there is associated
  - an **entry**, a **do**, and an **exit** action (default: **skip**)
  - a possibly empty set of trigger/action pairs called **internal transitions**, (default: empty).

    Note: 'entry', 'do', 'exit' are reserved names; $E_1, \dots, E_n \in \mathscr{E}$.

- **Recall**: each action is supposed to have a transformer; assume $t_{act_1^{\text{entry}}}, t_{act_1^{\text{exit}}}, \dots$
- Taking the transition above then amounts to applying

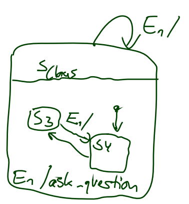
$$t_{act_2^{\text{entry}}} \circ t_{act} \circ t_{act_1^{\text{exit}}}$$

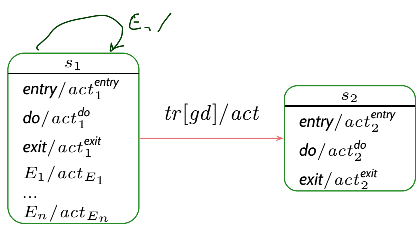
instead of just

$$t_{act}$$

$\rightsquigarrow$ adjust Rules (ii), (iii), and (v) accordingly.

Internal Transitions





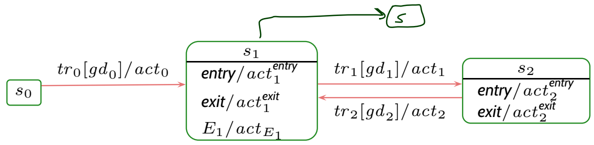
- Taking an **internal transition**, e.g. on E_1, only executes $t_{act_{E_1}}$.
- **Intuition**: The state is neither left nor entered, so: no exit, no entry action.
- **Note**: internal transitions also start a run-to-completion step.

$\rightsquigarrow$ adjust Rules (i), (ii), and (v) accordingly.

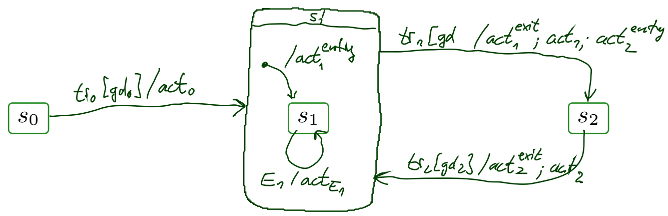
Note: the standard seems not to clarify whether internal transitions have **priority** over regular transitions with the same trigger at the same state.

Some code generators assume that internal transitions have priority!

Alternative View: Entry / Exit / Internal as Abbreviations



Can be viewed as abbrevation for …



- **That is**: Entry / Internal / Exit don't add expressive power to Core State Machines.
  If internal actions should have priority, s_1 can be embedded into an OR-state.
- The "'abbreviation view'" may avoid confusion in the context of hierarchical states.

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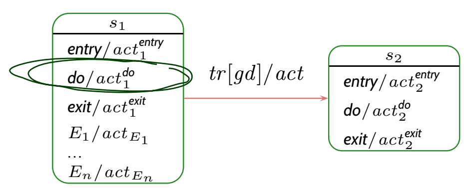
Do Actions



- **Intuition**: after entering a state, start its do-action.
- If the do-action terminates,
  - then the state is considered **completed** (like reaching a **final state** child (→ in a minute)),
  - then rule (iii) (continue) may apply
- otherwise,
  - if the state is left before termination, the do-action is stopped.

- Recall the overall UML State Machine philosophy:

  "An object is either idle or doing a run-to-completion step."

- Now, what is it exactly while the do action is executing...?

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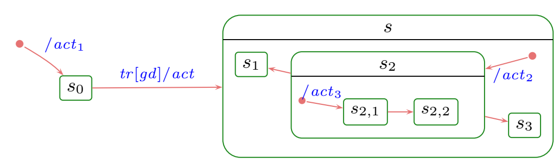
Initial and Final States

Initial Pseudostate



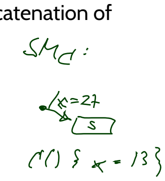
Principle:

- when entering a non-simple state,
- then go to the destination state of a transition with initial pseudo-state source,
- execute the action of the chosen initiation transition(s) **between** exit and entry actions.

Recall: For simplicity, we assume exactly one initiation transition per non-empty region.
Could also be: "'at least one'" and choosing one non-deterministically.

Special case: the region of top.

- If class C has a state-machine, then "create-C transformer" is the concatenation of
  - the transformer of the "constructor" of C (here not introduced explicitly) and
  - a transformer corresponding to one initiation transition of the top region.



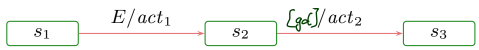
Final States

- If $(\sigma, \varepsilon) \xrightarrow[u]{(cons, Snd)} (\sigma', \varepsilon')$
  and all **simple states** s in $\sigma'(u)(st)$ are **final**, i.e. $kind(s) = \textit{fin}$, then
  - stay **unstable** if there is a common parent of the simple states in $\sigma(u)(st)$ which is source of a transition without trigger and satisfied guard,
  - otherwise **kill** (destroy) object u.

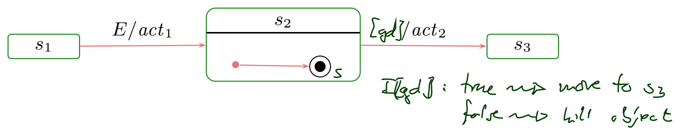
$\rightsquigarrow$ adjust Rules (i), (ii), (iii), and (v) accordingly.

Observation: u never "survives" reaching a state $(s, \textit{fin})$ with $s \in child(top)$.

Observation:



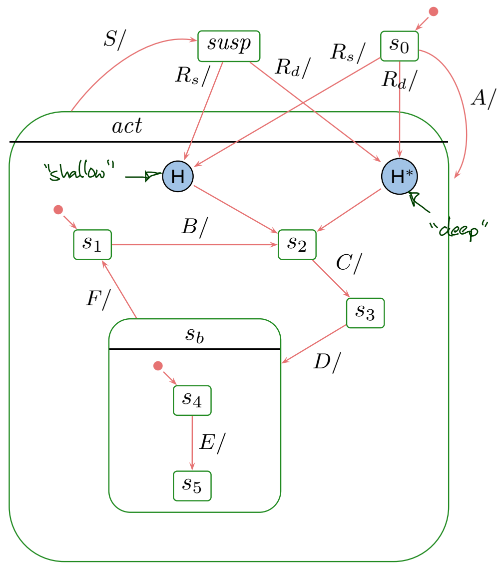
vs.



Rhapsody Demo: Automated Testing

The Concept of History, and Other Pseudo-States

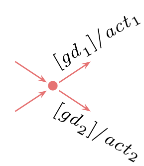
History and Deep History: By Example



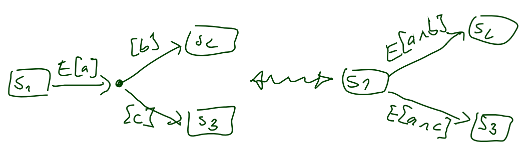
What happens on...

- R_s?
  s0, s2
- R_d?
  s0, s2
- A, B, C, S, R_s?
  s0, s1, s2, s3, susp, s3
- A, B, C, S, R_d?
  ——, ——, s3
- A, B, C, D, E, S, R_s?
  s0, s1, s2, s3, s4, s5, susp, s4
- A, B, C, D, E, S, R_d?
  ——, ——, susp, s5

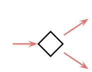
Junction and Choice

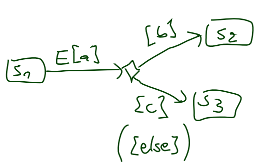


- Junction (**"static conditional branch"**):

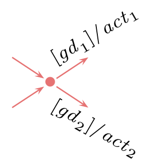


- Choice: (**"dynamic conditional branch"**)

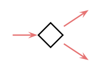




Junction and Choice



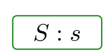
- Junction (**"static conditional branch"**):
  - **good**: abbreviation
  - unfolds to so many similar transitions with different guards, the unfolded transitions are then checked for enabledness
  - at best, start with trigger, branch into conditions, then apply actions

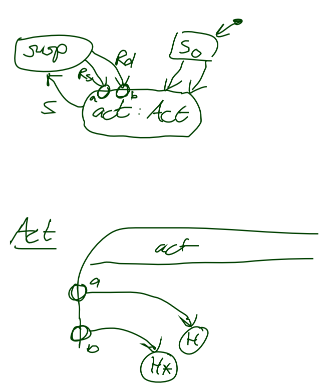


- Choice: (**"dynamic conditional branch"**)
  - **evil**: may get stuck
  - enters the transition **without knowing** whether there's an enabled path
  - at best, use "else" and convince yourself that it cannot get stuck
  - maybe even better: **avoid**

Entry and Exit Point, Submachine State, Terminate

- Hierarchical states can be **"folded"** for readability. (but: this can also hinder readability.)
- Can even be taken from a different state-machine for re-use.





Entry and Exit Point, Submachine State, Terminate

- Hierarchical states can be **“folded”** for readability.
  (but: this can also hinder readability.)
- Can even be taken from a different state-machine for re-use. $S : s$
- **Entry/exit points** ○ ⊗
  - Provide connection points for finer integration into the current level, finer than just via initial state.
  - Semantically a bit tricky:
    - **First** the exit action of the exiting state,
    - **then** the actions of the transition,
    - **then** the entry actions of the entered state,
    - **then** action of the transition from the entry point to an internal state,
    - and **then** that internal state's entry action.
- **Terminate Pseudo-State** ×
  - When a terminate pseudo-state is reached, the object taking the transition is immediately killed.

Rhapsody : (T)

Tell Them What You've Told Them…

- OR- and AND-states could also be explained as an “unfolding” into core state machines.
- They add **conciseness**, not **expressive power**.
- The remaining pseudo-states (history, junction, choice, etc.) are not so difficult.
- Modelling guideline: Avoid **choice**.
- Rhapsody also supports **non-active objects** – their instances share an event pool with an **active object**.

References

References

Harel, D. and Gery, E. (1997). Executable object modeling with statecharts. *IEEE Computer*, 30(7):31–42.

OMG (2011a). Unified modeling language: Infrastructure, version 2.4.1. Technical Report formal/2011-08-05.

OMG (2011b). Unified modeling language: Superstructure, version 2.4.1. Technical Report formal/2011-08-06.