Software Design, Modelling and Analysis in UML

Lecture 15: Hierarchical State Machines III

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Prof. Dr. Andreas Podelski, **Dr. Bernd Westphal**

Albert-Ludwigs-Universität Freiburg, Germany

Contents & Goals

Last Lecture:

- Hierarchical State Machines: partial order, "lca", orthogonality, ...

This Lecture:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - What does this **hierarchical** State Machine mean? What **may happen** if I inject this event?
  - What is: AND-State, OR-State, pseudo-state, entry/exit/do, final state, ...
- **Content:**
  - Legal Transitions
  - Exit/Entry, internal transitions
  - History and others
  - Rhapsody Demo

Composite States

(formalisation follows [Damm et al., 2003])

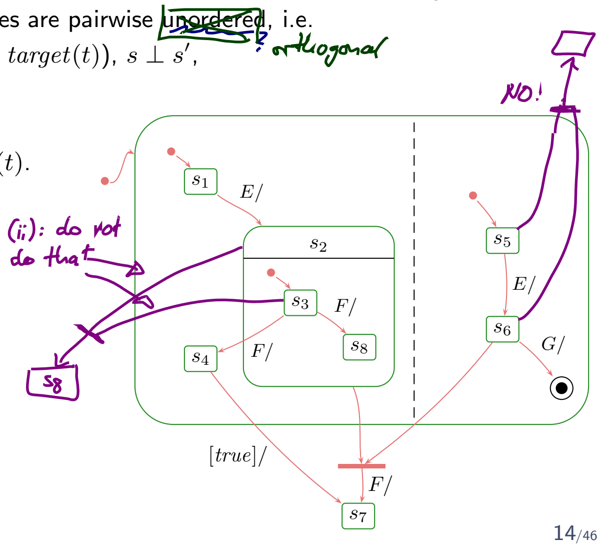
Legal Transitions

A hiearchical state-machine $(S, kind, region, \rightarrow, \psi, annot)$ is called **well-formed** if and only if for all transitions $t \in \rightarrow$,

- (i) source and destination are consistent, i.e. $\downarrow source(t)$ and $\downarrow target(t)$,] redundant
- (ii) source (and destination) states are pairwise ~~unordered~~ orthogonal, i.e.
  - forall $s, s' \in source(t)$ $(\in target(t))$, $s \perp s'$,
- (iii) the top state is neither source nor destination, i.e.
  - $top \notin source(t) \cup source(t)$.
- Recall: final states are not sources of transitions.

Example:

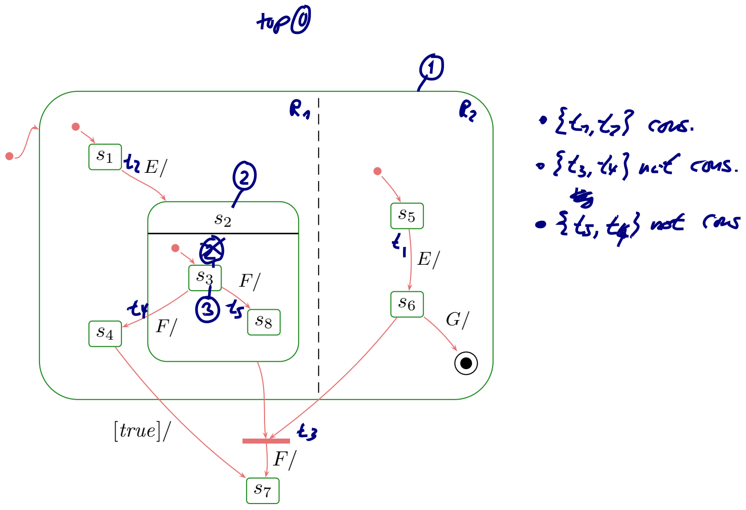
CLAIM: (ii) ⇒ (i)



The Depth of States

- $depth(top) = 0$,
- $depth(s') = depth(s) + 1$, for all $s' \in child(s)$

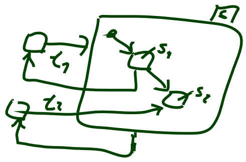
Example:



Enabledness in Hierarchical State-Machines

- The **scope** ("set of possibly affected states") of a transition t is the **least common region** of (maximal wrt. to ≤)
$$source(t) \cup target(t).$$
- Two transitions t_1, t_2 are called **consistent** if and only if their scopes are orthogonal (i.e. states in scopes pairwise orthogonal).
- The **priority** of transition t is the depth of its innermost source state, i.e.
$$prio(t) := \max\{depth(s) \mid s \in source(t)\}$$
- A set of transitions $T \subseteq \rightarrow$ is **enabled** in an object u if and only if
  - T is consistent,
  - T is maximal wrt. priority,
  - all transitions in T share the same trigger,
  - all guards are satisfied by $\sigma(u)$, and
  - for all $t \in T$, the source states are active, i.e.
$$source(t) \subseteq \sigma(u)(st) \ (\subseteq S).$$

Transitions in Hierarchical State-Machines



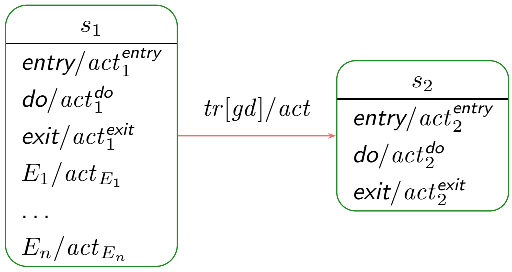
- Let T be a set of transitions enabled in u.
- Then $(\sigma, \varepsilon) \xrightarrow[u]{(cons, Snd)} (\sigma', \varepsilon')$ if
  - $\sigma'(u)(st)$ consists of the target states of T, (and their recursive parents)

    i.e. for simple states the simple states themselves, for composite states the initial states,
  - σ', ε', $cons$, and Snd are the effect of firing each transition $t \in T$ **one by one**, **in any order**, i.e. for each $t \in T$,
    - the exit transformer of all affected states, highest depth first,
    - the transformer of t,
    - the entry transformer of all affected states, lowest depth first.

$\rightsquigarrow$ adjust (2.), (3.), (5.) accordingly.

Entry/Do/Exit Actions, Internal Transitions

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). $E_1, \dots, E_n \in \mathcal{E}$, ‘entry’, ‘do’, ‘exit’ are reserved names!

- Recall: each action's supposed to have a transformer. Here: $t_{act_1^{entry}}$, $t_{act_1^{exit}}$, ...
- Taking the transition above then amounts to applying

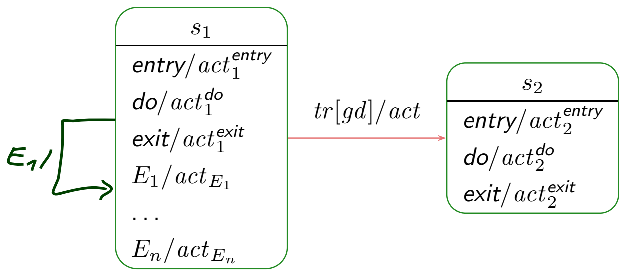
$$t_{act_{s_2}^{entry}} \circ t_{act} \circ t_{act_{s_1}^{exit}}(s) \quad \sim t_{s_2}^{entry}(t_{act}(t_{s_1}^{exit}(s)))$$

instead of only

$$t_{act}$$

$\leadsto$ adjust (2.), (3.) accordingly.

Internal Transitions



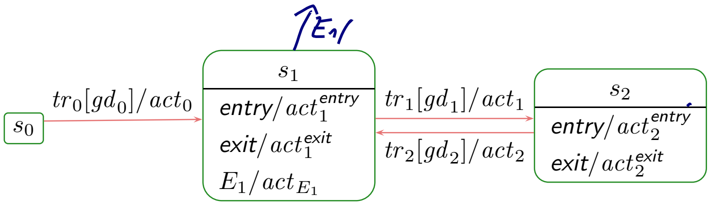
- For **internal transitions**, taking the one for E_1, for instance, still amounts to taking **only** $t_{act_{E_1}}$.
- Intuition: The state is neither left nor entered, so: no exit, no entry.

  $\leadsto$ adjust (2.) accordingly.

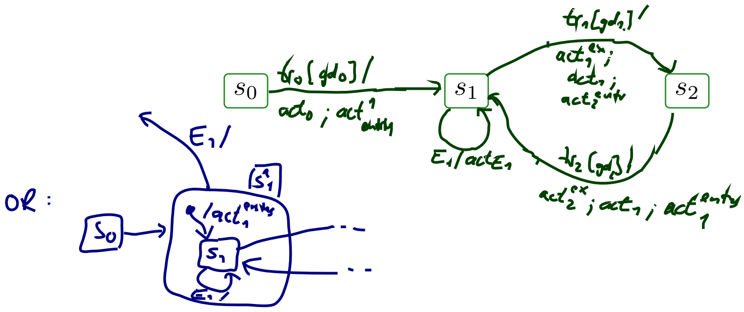
- Note: internal transitions also start a run-to-completion step.
- Note: the standard seems not to clarify whether internal transitions have **priority** over regular transitions with the same trigger at the same state.

  Some code generators assume that internal transitions have priority!

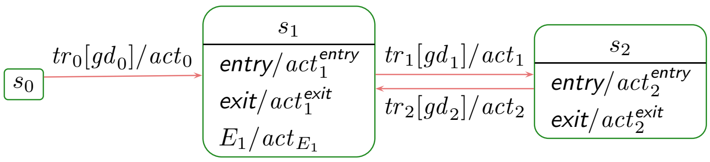
Alternative View: Entry/Exit/Internal as Abbreviations



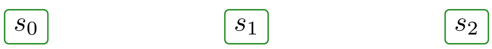
- ... as abbrevation for ...



Alternative View: Entry/Exit/Internal as Abbreviations

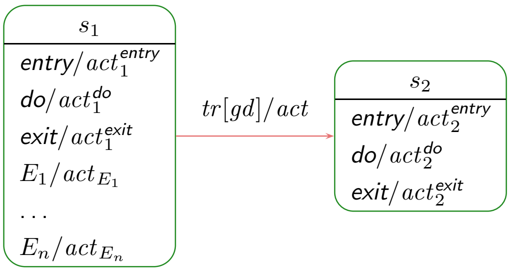


- ... as abbrevation for ...



- 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 (see later).
- Abbreviation may avoid confusion in context of hierarchical states (see later).

Do Actions



- **Intuition**: after entering a state, start its do-action.
- If the do-action terminates,
  - then the state is considered **completed**,
- 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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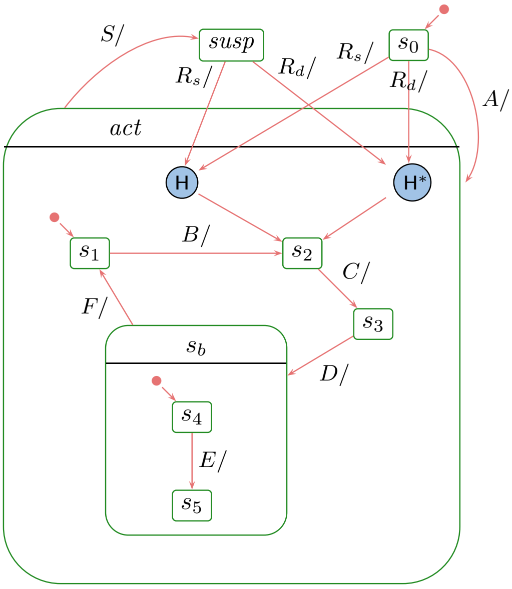
The Concept of History, and Other Pseudo-States

– 15 – 2012-01-18 – main –

History and Deep History: By Example

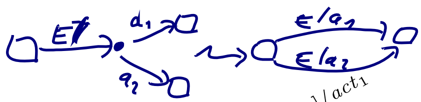


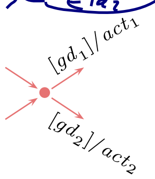
What happens on...

- R_s?
  s_0, s_2
- R_d?
  s_0, s_2
- A, B, C, S, R_s?
  $s_0, s_1, s_2, s_3, susp, s_3$
- A, B, S, R_d? (C)
  $s_0, s_1, s_2, s_3, susp, s_3$
- A, B, C, D, E, R_s? (S)
  $s_0, s_1, s_2, s_3, s_4, s_5, susp, s_4$
- A, B, C, D, R_d?
  $s_0, s_1, s_2, s_3, s_4, s_5, susp, s_5$

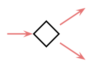
deep vs. shallow

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



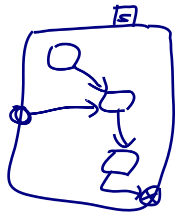
- Choice: (**"dynamic conditional branch"**)
  - **evil**: may get stuck
  - enters the transition **without knowing** whether there's an enabled path
  - at best, use "else" and convince yourself that it cannot get stuck
  - maybe even better: **avoid**

Note: not so sure about naming and symbols, e.g.,
I'd guessed it was just the other way round...

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, 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.

Contemporary UML Modelling Tools

References

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