Software Design, Modelling and Analysis in UML

Lecture 16: Hierarchical State Machines I

2015-01-15

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

Albert-Ludwigs-Universität Freiburg, Germany

Contents & Goals

Last Lecture:

- Missing transformers: create and destroy
- Step and run-to-completion (RTC) step, divergence

This Lecture:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - What does this State Machine mean? What happens if I inject this event?
  - Can you please model the following behaviour.
  - 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:**
  - Putting it all together: UML model semantics (so far)
  - State Machines and OCL
  - Hierarchical State Machines Syntax
  - Initial and Final State

Putting It All Together

The Missing Piece: Initial States

Recall: a labelled transition system is $(S, \to, S_0)$. We **have**

- S: system configurations (σ, ε)
- $\to$: labelled transition relation $(\sigma, \varepsilon) \xrightarrow[u]{(cons, Snd)} (\sigma', \varepsilon')$.

Wanted: initial states S_0.

Proposal:
Require a (finite) set of **object diagrams** $\mathcal{OD}$ as part of a UML model

$$(\mathscr{CD}, \mathscr{SM}, \mathscr{OD}).$$

And set

$$S_0 = \{(\sigma, \varepsilon) \mid \sigma \in G^{-1}(\mathcal{OD}), \mathcal{OD} \in \mathscr{OD}, \varepsilon \text{ empty}\}.$$

Other Approach: (used by Rhapsody tool) multiplicity of classes.
We can read that as an abbreviation for an object diagram.

Semantics of UML Model — So Far

The **semantics** of the **UML model**

$$\mathcal{M} = (\mathscr{CD}, \mathscr{SM}, \mathscr{OD})$$

where

- some classes in $\mathscr{CD}$ are stereotyped as 'signal' (standard), some signals and attributes are stereotyped as 'external' (non-standard),
- there is a 1-to-1 relation between classes and state machines,
- $\mathscr{OD}$ is a set of object diagrams over $\mathscr{CD}$,

is the **transition system** $(S, \to, S_0)$ constructed on the previous slide.

The **computations of** $\mathcal{M}$ are the computations of $(S, \to, S_0)$.

State Machines and OCL

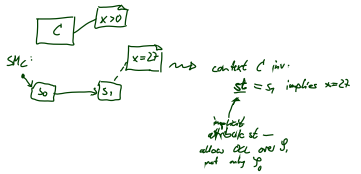
OCL Constraints and Behaviour

- Let $\mathcal{M} = (\mathscr{CD}, \mathscr{SM}, \mathscr{OD})$ be a UML model.
- We call $\mathcal{M}$ **consistent** iff, for each OCL constraint $expr \in Inv(\mathscr{CD}) \cup Inv(\mathscr{SM})$

  $\sigma \models expr$ for each "reasonable point" (σ, ε) of computations of $\mathcal{M}$.

  (Cf. exercises and tutorial for discussion of "reasonable point".)

Note: we could define $Inv(\mathscr{SM})$ similar to $Inv(\mathscr{CD})$.



OCL Constraints and Behaviour

- Let $\mathcal{M} = (\mathscr{CD}, \mathscr{SM}, \mathscr{OD})$ be a UML model.
- We call $\mathcal{M}$ **consistent** iff, for each OCL constraint $expr \in Inv(\mathscr{CD})$,

  $\sigma \models expr$ for each "reasonable point" (σ, ε) of computations of $\mathcal{M}$.

  (Cf. exercises and tutorial for discussion of "reasonable point".)

Note: we could define $Inv(\mathscr{SM})$ similar to $Inv(\mathscr{CD})$.

→ OUR CHOICE: check for each (σ, ε) in a computation (step granularity)

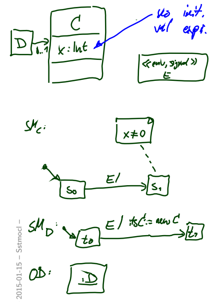
Pragmatics:

- In **UML-as-blueprint mode**, if $\mathscr{SM}$ doesn't exist yet, then $\mathcal{M} = (\mathscr{CD}, \emptyset, \mathscr{OD})$ is typically asking the developer to provide $\mathscr{SM}$ such that $\mathcal{M}' = (\mathscr{CD}, \mathscr{SM}, \mathscr{OD})$ is consistent.

  If the developer makes a mistake, then $\mathcal{M}'$ is inconsistent.

- **Not common**: if $\mathscr{SM}$ is given, then constraints are also considered when choosing transitions in the RTC-algorithm. In other words: even in presence of mistakes, the $\mathscr{SM}$ never move to inconsistent configurations.

Pragmatics: Example



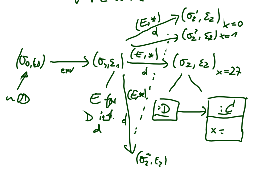
(1) $\mathcal{M}$ is not consistent ("broken") because there is a comp. path leading to a (σ, ε) s.t. $\sigma \not\models Inv(\mathcal{M})$

(2) "dear developer, I want
- states s_0, s_1
- E must move me from s_0 to s_1
- in s_1, x must not be 0

do THAT!"

IN EACH SYSTEM STATE σ,
FOR EACH ALIVE OBJECT $u \in dom(\sigma)$, $u \in \mathscr{D}(C)$
EACH OF u's ATTRIBUTES HAS
A (DEFINITE) VALUE!

$\forall v \in atr(C) \bullet \sigma(u)(v) \in \mathscr{D}(type(v))$



Rhapsody Demo II