Software Design, Modelling and Analysis in UML

Lecture 07: Class Diagrams II

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Prof. Dr. Andreas Podelski, Dr. Bernd Westphal

Albert-Ludwigs-Universität Freiburg, Germany

Contents & Goals

Last Lecture:
- Representing class diagrams as (extended) signatures — for the moment without associations (see Lecture 08).

This Lecture:
- Educational Objectives: Capabilities for following tasks/questions.
  - What is a class diagram?
  - For what purposes are class diagrams useful?
  - Could you please map this class diagram to a signature?
  - Could you please map this signature to a class diagram?
  - What is visibility good for?

- Content:
  - Map class diagram to (extended) signature cont’d.
  - Stereotypes – for documentation.
  - Visibility as an extension of well-typedness.
A class box \( n \) induces an (extended) signature class as follows:

\[
\begin{align*}
\xi_1: \tau_1 &= v_0.1 \{P_{1,1}, \ldots, P_{1,m_1}\} \\
\xi_\ell: \tau_\ell &= v_0.\ell \{P_{\ell,1}, \ldots, P_{\ell,m_\ell}\} \\
C(n) &:= \langle \xi_1, \ldots, \xi_k \rangle \\
V(n) &:= \{\langle v_1: \tau_1, \xi_1, v_0.1, \{P_{1,1}, \ldots, P_{1,m_1}\}\rangle, \ldots, \langle v_\ell: \tau_\ell, \xi_\ell, v_0.\ell, \{P_{\ell,1}, \ldots, P_{\ell,m_\ell}\}\rangle\} \\
\text{atr}(n) &:= \{C \mapsto \{v_1, \ldots, v_\ell\}\}
\end{align*}
\]

where

- “abstract” is determined by the font:
  \[ a(n) = \begin{cases} 
  \text{true} & \text{if } n = \Box \text{ or } n = \Box(n) \\
  \text{false} & \text{otherwise}
  \end{cases} \]

- “active” is determined by the frame:
  \[ t(n) = \begin{cases} 
  \text{true} & \text{if } n = \Box \text{ or } n = \Box \\
  \text{false} & \text{otherwise}
  \end{cases} \]
Recall: Example

\[ Y = \{ \text{true}, \{ \text{C, D} \}, \{ \langle \text{C} \colon y \colon \text{bit}, \ldots, \text{x}, \text{p} \rangle, \langle \text{D} \colon y \colon \text{bit} \rangle, \ldots, \text{x}, \text{p} \rangle \} \}

\]

\[ Y = \{ \text{true}, \{ \text{C, D} \}, \{ \langle \text{C} \colon y \colon \text{bit}, \ldots, \text{x}, \text{p} \rangle, \langle \text{D} \colon y \colon \text{bit} \rangle, \ldots, \text{x}, \text{p} \rangle \} \]

\[ Y = \{ \text{true}, \{ \text{C, D} \}, \{ \langle \text{C} \colon y \colon \text{bit}, \ldots, \text{x}, \text{p} \rangle, \langle \text{D} \colon y \colon \text{bit} \rangle, \ldots, \text{x}, \text{p} \rangle \} \]
What If Things Are Missing?

- For instance, what about the box above?
- \( v \) has **no visibility**, **no initial value**, and (strictly speaking) **no properties**.

**It depends.**
- What does the standard say? [OMG, 2007a, 121]
  
  "**Presentation Options.**
  The type, visibility, default, multiplicity, property string may be suppressed from being displayed, even if there are values in the model."

- **Visibility:** There is no "no visibility" — an attribute **has** a visibility in the (extended) signature.
  Some (and we) assume **public** as default, but conventions may vary.

- **Initial value:** some assume it **given by domain** (such as “leftmost value”, but what is “leftmost” of \( \mathbb{Z} \)?)
  Some (and we) understand **non-deterministic initialisation**.

- **Properties:** probably safe to assume \( \emptyset \) if not given at all.

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From Class Diagrams to Extended Signatures

- We view a **class diagram** \( C D \) as a graph with nodes \( \{ n_1, \ldots, n_N \} \)
  (each “class rectangle” is a node).

\[
\begin{align*}
C(CD) & := \bigcup_{i=1}^N \{ C(n_i) \mid 1 \leq n_i \leq N \} \\
V(CD) & := \bigcup_{i=1}^N V(n_i) \\
\text{atr}(CD) & := \bigcup_{i=1}^N \text{atr}(n_i)
\end{align*}
\]

- In a **UML model**, we can have **finitely many** class diagrams,

\[
C(D) = \{ CD_1, \ldots, CD_k \},
\]

which **induce** the following signature:

\[
\mathcal{S}(C(D)) = \left( \mathcal{T}, \bigcup_{i=1}^k C(D_i), \bigcup_{i=1}^k V(CD_i), \bigcup_{i=1}^k \text{atr}(CD_i) \right)
\]

(Assuming \( \mathcal{T} \) given. In “reality” (i.e. in full UML), we can introduce types in class diagrams, the class diagram then contributes to \( T \). Example: enumeration types.)
Is the Mapping a Function?

- Is \( \mathcal{F}(CD) \) well-defined?

Two possible sources for problems:

1. A class \( C \) may appear in multiple class diagrams:

   (i) \( CD_1 \)
   
   \[
   \begin{array}{c}
   C \\
   v : \text{Int}
   \end{array}
   \]
   
   \( CD_2 \)
   
   \[
   \begin{array}{c}
   C \\
   w : \text{Int}
   \end{array}
   \]

   (ii) \( CD_1 \)
   
   \[
   \begin{array}{c}
   C \\
   v : \text{Int}
   \end{array}
   \]
   
   \( CD_2 \)
   
   \[
   \begin{array}{c}
   C \\
   w : \text{Bool}
   \end{array}
   \]

   Simply forbid the case (ii) — easy syntactical check on diagram.
Is the Mapping a Function?

(2) An attribute $v$ may appear in multiple classes:

\[
\begin{array}{c}
C \\
\hline
v : \text{Bool} \\
\end{array}
\quad
\begin{array}{c}
D \\
\hline
v : \text{Int} \\
\end{array}
\]

Two approaches:

- Require **unique** attribute names. This requirement can easily be established (implicitly, behind the scenes) by viewing $v$ as an abbreviation for $C::v$ or $D::v$ depending on the context. ($C::v : \text{Bool}$ and $D::v : \text{Int}$ are unique.)

- Subtle, formalist’s approach: observe that

\[
\langle v : \text{Bool}, \ldots \rangle \quad \text{and} \quad \langle v : \text{Int}, \ldots \rangle
\]

are **different things** in $V$. But we don’t follow that path...
The semantics of a set of class diagrams $\mathcal{C}$ first of all is the induced (extended) signature $\mathcal{S}(\mathcal{C})$.

The signature gives rise to a set of system states given a structure $\mathcal{D}$.

- Do we need to redefine/extend $\mathcal{D}$? **No.**

(Would be different if we considered the definition of enumeration types in class diagrams. Then the domain of an enumeration type $\tau$, i.e. the set $\mathcal{D}(\tau)$, would be determined by the class diagram, and not free for choice.)

• What is the effect on $\Sigma_{\mathcal{D}}$? **Little.**

For now, we only **remove** abstract class instances, i.e.

$$
\sigma : \mathcal{D}(\mathcal{C}) \rightarrow (V \rightarrow (\mathcal{D}(\mathcal{F}) \cup \mathcal{D}(\mathcal{C}_*)))
$$

is now only called system state if and only if, for all $(\mathcal{C}, \mathcal{S}_C, 1, t) \in \mathcal{C}$,

$$
\operatorname{dom}(\sigma) \cap \mathcal{D}(\mathcal{C}) = \emptyset.
$$

With $a = 0$ as default “abstractness”, the earlier definitions apply directly.

We’ll revisit this when discussing inheritance.
What About The Rest?

- **Classes:**
  - **Active:** not represented in $\sigma$.
    - **Later:** relevant for behaviour, i.e., how system states evolve over time.
  - **Stereotypes:** in a minute.

- **Attributes:**
  - **Initial value:** not represented in $\sigma$.
    - **Later:** provides an initial value as effect of "creation action".
  - **Visibility:** not represented in $\sigma$.
    - **Later:** viewed as additional **typing information** for well-formedness of system transformers; and with inheritance.

- **Properties:** such as **readOnly**, **ordered**, **composite**
  - **readOnly** — **later** treated similar to visibility.
  - **ordered** — not considered in our UML fragment ($\rightarrow$ sets vs. sequences).
  - **composite** — cf. lecture on associations.

**Stereotypes**
Stereotypes as Labels or Tags

- So, a class is \( \langle C, S_C, a, t \rangle \) with the abstractness flag \( a \), activeness flag \( t \), and a set of stereotypes \( S_C \).

- What are Stereotypes?
  - **Not** represented in system states.
  - **Not** contributing to typing rules.
    (cf. later lecture on type theory for UML)

- [Oestereich, 2006]: View stereotypes as (additional) “labelling” (“tags”) or as “grouping”.
  Useful for documentation and MDA.

- **Documentation**: e.g. layers of an architecture.
  Sometimes, packages (cf. the standard) are sufficient and “right”.

- **Model Driven Architecture** (MDA): later.

Example: Stereotypes for Documentation

- Example: Timing Diagram Viewer [Schumann et al., 2008]
  - Architecture of four layers:
    - core, data layer
    - abstract view layer
    - toolkit-specific view layer/widget
    - application using widget
  - Stereotype “=” layer “=” colour
Stereotypes as Inheritance

- Another view (due to whom?): distinguish
  
  - **Technical Inheritance**
    
    If the target platform, such as the programming language for the implementation of the blueprint, is object-oriented, assume a 1-to-1 relation between inheritance in the model and on the target platform.

  - **Conceptual Inheritance**
    
    Only meaningful with a common idea of what stereotypes stand for. For instance, one could label each class with the team that is responsible for realising it. Or with licensing information (e.g., LGPL and proprietary). Or one could have labels understood by code generators (cf. lecture on MDSE).

- Confusing:
  
  - Inheritance is often referred to as the “is a”-relation. Sharing a stereotype also expresses “being something”.

  - We can always (ab-)use UML-inheritance for the conceptual case, e.g.

```
    +---+    +----+
    | Cell|    | Trace|
    +----+    +----+
        |     +----+
        |         | Trace
        v         v
    +---+    +----+
    | Core|    |            |
    +----+    +----+
```

Visibility
\[ S = (\{\text{Int}\}, \{C, D\}, \{n : D_{0,1}, \\ m : D_{0,1}, \langle x : \text{Int, } \xi, \text{expr}_0, \emptyset \rangle\}, \{C \mapsto \{n\}, D \mapsto \{x, m\}\} \]

\[ C \xrightarrow{n} 0.1 \]
\[ D \xrightarrow{\xi : \text{Int} = \text{expr}_0} m \]

\[ e : C \xrightarrow{n} d_1 : D \xrightarrow{\xi : \text{Int} = \text{expr}_0} \xi \xrightarrow{x = 1} \]
\[ d_2 : D \]

Assume \( w_1 : \tau_C \) and \( w_2 : \tau_D \) are logical variables. Which of the following syntactically correct (?) OCL expressions shall we consider to be well-typed?

<table>
<thead>
<tr>
<th>( \xi ) of ( x )</th>
<th>public</th>
<th>private</th>
<th>protected</th>
<th>package</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n \cdot x = 0 )</td>
<td>✔️</td>
<td>✔️</td>
<td>later</td>
<td>not</td>
</tr>
<tr>
<td>( x(n(\omega_1)) )</td>
<td>✘</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>( m \cdot x = 0 )</td>
<td></td>
<td>✘</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>( x(\mathsf{null}(\omega_2)) )</td>
<td>✔️</td>
<td></td>
<td>✔️</td>
<td></td>
</tr>
</tbody>
</table>

References


