Software Design, Modelling and Analysis in UML

Lecture 7: Class Diagrams II

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Contents & Goals

Last Lecture:

- Representing class diagrams as (extended) signatures — for the moment without associations: later.

This Lecture:

- **Educational Objectives:** Capabilities for following tasks/questions.
  - Could you please map this class diagram to a signature?
  - What if things are missing?
  - Could you please map this signature to a class diagram?
  - What is the semantics of 'abstract'?
  - What is visibility good for?
- **Content:**
  - Map class diagram to (extended) signature cont'd.
  - Stereotypes – for documentation.
  - Visibility as an extension of well-typedness.

Mapping UML CDs to Extended Signatures

Recall

Example Cont'd

Diagram:

$$\begin{array}{|c|}\hline \langle\langle S_1,\dots,S_k\rangle\rangle \\ C \\ \hline \xi_1\ v_1 : T_1 = expr_0^1\ \{P_{1,1},\dots,P_{1,m_1}\} \\ \vdots \\ \xi_\ell\ v_\ell : T_\ell = expr_0^\ell\ \{P_{\ell,1},\dots,P_{\ell,m_\ell}\} \\ \hline \end{array}$$

$\leadsto$

$\mathcal{S}$:

$$C(n) := \langle C, \{S_1,\dots,S_k\}, a(n), t(n)\rangle$$

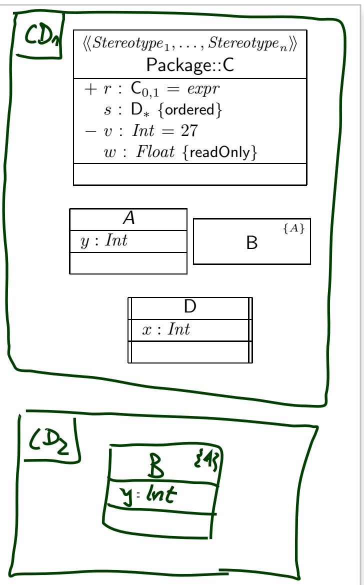
$$V(n) := \{\langle v_1 : T_1, \xi_1, expr_0^1, \{P_{1,1},\dots,P_{1,m_1}\}\rangle,\dots,$$
$$\langle v_\ell : T_\ell, \xi_\ell, expr_0^\ell, \{P_{\ell,1},\dots,P_{\ell,m_\ell}\}\rangle\}$$

$$atr(n) := \{C \mapsto \{v_1,\dots,v_\ell\}\}$$

$\vdots$

$\langle s : D_*, +, ?, \{ordered\}\rangle$

$\langle s : D_*, +, \emptyset, \{ordered\}\rangle$



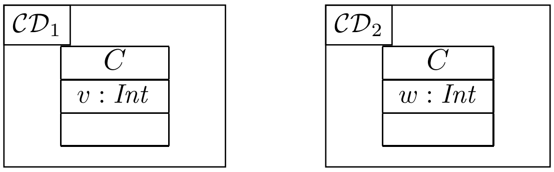
Is the Mapping a Function?

Question: Is $\mathscr{S}(\mathscr{C}\mathscr{D})$ **well-defined**?

There are two possible **sources for problems**:

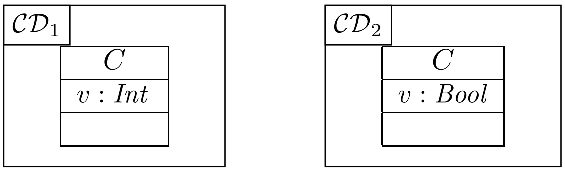
(1) A **class** C may appear in **multiple** class **diagrams**:

(i)



$\mathscr{S} = (\{Int\}, \{C\},$
$\{v : Int, w : Int\},$
$\{C \mapsto \{v, w\}\})$

(ii)



Simply **forbid** the case (ii) — easy syntactical check on diagram.

Is the Mapping a Function?

(2) An **attribute** v may appear in **multiple classes** with different type:

Two approaches: $\mathscr{S} = (\{Bool, Int\}, \{C, D\}, \{v : Bool,\ v : Int\}$
$\{C \mapsto \{v\} \ldots$ which?

- Require **unique** attribute names.
  This requirement can easily be established (implicitly, behind the scenes) by viewing v as an abbreviation for

$$C{::}v \quad \text{or} \quad D{::}v$$

  depending on the context. ($C{::}v : Bool$ and $D{::}v : Int$ are then unique.)

- Subtle, formalist's approach: observe that

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

  are **different things** in V. We don't follow that path...

$\langle v : Bool, +, [illegible], \emptyset \rangle \neq \langle v : Int, +, [illegible], \emptyset \rangle$

$atr: C \mapsto \{\langle v : Bool, +, [illegible], \emptyset \rangle\}$
$D \mapsto \{\langle v : Int, +, [illegible], \emptyset \rangle\}$

Class Diagram Semantics

Semantics

The semantics of a set of **class diagrams** $\mathscr{CD}$ is the induced **signature** $\mathscr{S}(\mathscr{CD})$.

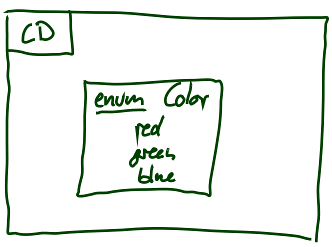
The **signature** induces a set of **system states** $\Sigma_{\mathscr{S}}^{\mathscr{D}}$ (given a **structure** $\mathscr{D}$).

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

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

from diagram

$\mathscr{S} = (\{Color\}, \ldots$



$\rightsquigarrow \mathscr{D}(Color) = \{red, green, blue\}$

from diagram

Semantics

The semantics of a set of **class diagrams** $\mathscr{C}\mathscr{D}$ is the induced **signature** $\mathscr{S}(\mathscr{C}\mathscr{D})$.

The **signature** induces a set of **system states** $\Sigma_{\mathscr{S}}^{\mathscr{D}}$ (given a **structure** $\mathscr{D}$).

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

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

- What is the effect on $\Sigma_{\mathscr{S}}^{\mathscr{D}}$? **Little.**

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

  $$\sigma : \mathscr{D}(\mathscr{C}) \nrightarrow (V \nrightarrow (\mathscr{D}(\mathscr{T}) \cup \mathscr{D}(\mathscr{C}_*)))$$

  abstract

  is now **only** called **system state** if and only if, for all $\langle C, S_C, 1, t\rangle \in \mathscr{C}$,

  $$\mathrm{dom}(\sigma) \cap \mathscr{D}(C) = \emptyset.$$

  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 σ.

    Later: relevant for behaviour, i.e., how system states evolve over time.
  - **Stereotypes**: in a minute.

- **Attributes**:
  - **Initial value expression**: not represented in σ.

    Later: provides an initial value as effect of "creation action".
  - **Visibility**: not represented in σ.

    Later: viewed as additional **typing information** for well-formedness of actions; and with inheritance.
  - **Properties**: such as `readOnly`, `ordered`, `composite` (**Deprecated** in the standard.)
    - `readOnly` — **later** treated similar to visibility.
    - `ordered` — not considered in our UML fragment ($\rightarrow$ sets vs. sequences).
    - `composite` — cf. lecture on associations.

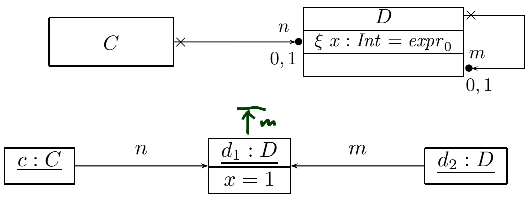
Rhapsody Demo I

RECALL: SEND <u>ME</u> YOUR POOL-ACCOUNT NAME
(<u>meyerp</u>, NOT: ab124, xh702 (RZ))

Visibility

The Intuition by Example

$$\mathscr{S} = (\{Int\}, \{C, D\}, \{n : D_{0,1}, m : D_{0,1}, \langle x : Int, \xi, expr_0, \emptyset\rangle\}, \{C \mapsto \{n\}, D \mapsto \{x, m\}\}$$



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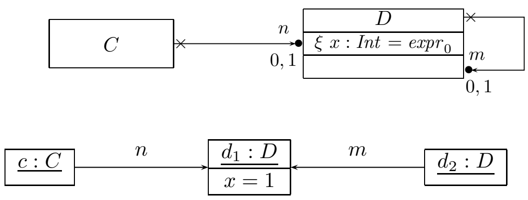

Assume $w_1 : \tau_C$ and $w_2 : \tau_D$ are logical variables.

Which of the following **syntactically correct** (?) OCL expressions **should** we consider to be **well-typed**?

ξ of x:	public	private	protected	package
$w_1 \,.\, n \,.\, x = 0$			later	not
$w_2 \,.\, m \,.\, x = 0$			later	not

The Intuition by Example

$\mathscr{S} = (\{Int\}, \{C, D\}, \{n : D_{0,1}, m : D_{0,1},$
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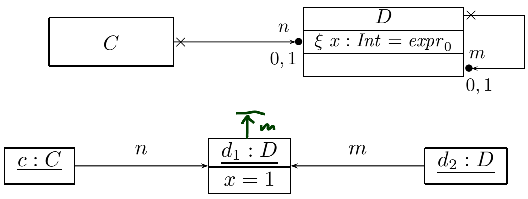

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Which of the following **syntactically correct** (?) OCL expressions **should** we consider to be **well-typed**?

ξ of x:	public	private	protected	package
$w_1 . n . x = 0$	✓	✓	later	not
	✗	✗		
	?	?		
$w_2 . m . x = 0$	✓	✓	later	not
	✗	✗		
	?	?		

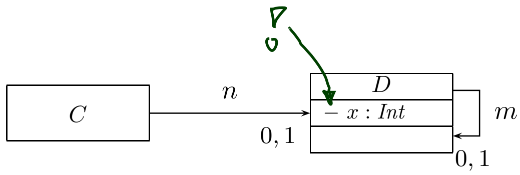
by class (OCL, C++, Java, ..)

by object

Context

$\mathscr{S} = (\{Int\}, \{C, D\}, \{n : D_{0,1}, m : D_{0,1},$
$\langle x : Int, \xi, expr_0, \emptyset\rangle\},$
$\{C \mapsto \{n\}, D \mapsto \{x, m\}\}$

- **By example**:



$\underbrace{self_D} . x > 0$ ✓

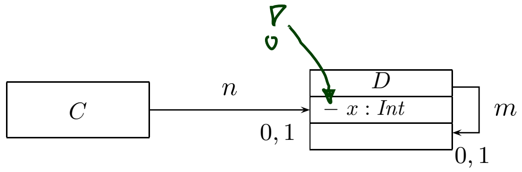
$\underbrace{self_D . m}_{: \tau_D} . x > 0$ ✓

$\underbrace{self_C . n}_{: \tau_C} . x > 0$ ✗

Context

$$\mathscr{S} = (\{Int\}, \{C, D\}, \{n : D_{0,1}, m : D_{0,1},$$
$$\langle x : Int, \xi, expr_0, \emptyset\rangle\},$$
$$\{C \mapsto \{n\}, D \mapsto \{x, m\}\}$$

- **By example**:



$$\underbrace{self_D} . x > 0 \quad ✓$$

$$\underbrace{self_D . m}_{:\tau_D} . x > 0 \quad ✓$$

$$\underbrace{self_C . n}_{:\tau_C} . x > 0 \quad ✗$$

- That is, whether an expression involving attributes with visibility is well-typed **depends** on the class of objects for which it is evaluated.
- Visibility is '**by class**' — **not** 'by object'.

Attribute Access in Context

Recall: attribute access in OCL Expressions, $C, D \in \mathscr{C}$.

$v(expr_1)$	$: \tau_C \to \cancel{\tau(v)}\ T$	• $v : T \in atr(C)$, $T \in \mathscr{T}$,
$r_1(expr_1)$	$: \tau_C \to \tau_D$	• $r_1 : D_{0,1} \in atr(C)$,
$r_2(expr_1)$	$: \tau_C \to Set(\tau_D)$	• $r_2 : D_* \in atr(C)$,

New rules for well-typedness **considering visibility**:

- $v(w) \quad : \tau_C \to T \qquad w : \tau_C, \quad v : T \in atr(C), T \in \mathscr{T}$
- $r_1(w) \quad : \tau_C \to \tau_D \qquad w : \tau_C, \quad r_1 : D_{0,1} \in atr(C)$
- $r_2(w) \quad : \tau_C \to Set(\tau_D) \qquad w : \tau_C, \quad r_1 : D_* \in atr(C)$

- $v(expr_1(w)) \quad : \tau_C \to T \qquad \langle v : T, \xi, expr_0, P\rangle \in atr(C)$, $T \in \mathscr{T}$,
  $\underbrace{expr_1(w)} : \tau_C$, $\underbrace{w : \tau_{C_1} \text{ and } C_1 = C}$, or $\underbrace{\xi = +}$

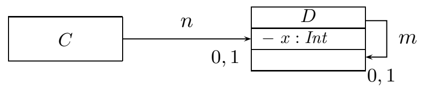
- $r_1(expr_1(w)) \quad : \tau_C \to \tau_D \qquad \langle r_1 : D_{0,1}, \xi, expr_0, P\rangle \in atr(C)$,
  $expr_1(w) : \tau_C$, $w : \tau_{C_1}$ and $C_1 = C$, or $\xi = +$

- $r_2(expr_1(w)) \quad : \tau_C \to Set(\tau_D) \qquad \langle r_2 : D_*, \xi, expr_0, P\rangle \in atr(C)$,
  $expr_1(w) : \tau_C$, $w : \tau_{C_1}$ and $C_1 = C$, or $\xi = +$

Example

- (i) $v(w)$ $\quad : \tau_C \to T$ $\qquad w : \tau_C, \quad v : T \in atr(C),\ T \in \mathscr{T}$
- (ii) $r_1(w)$ $\quad : \tau_C \to \tau_D$ $\qquad w : \tau_C, \quad r_1 : D_{0,1} \in atr(C)$
- (iii) $v(expr_1(w))$ $\quad : \tau_C \to T$ $\qquad \langle v : T, \xi, expr_0, P\rangle \in atr(C),\ T \in \mathscr{T},$ $\quad expr_1(w) : \tau_C, \quad w : \tau_{C_1}$ and $C_1 = C$, $\quad$ or $\xi = +$
- (iv) $r_1(expr_1(w))$ $\quad : \tau_C \to \tau_D$ $\qquad \langle r_1 : D_{0,1}, \xi, expr_0, P\rangle \in atr(C),$ $\quad expr_1(w) : \tau_C, \quad w : \tau_{C_1}$ and $C_1 = C$, $\quad$ or $\xi = +$

$v(\,r_1^1(\ldots(r_1^n(w))))$



- $self_D\,.\,x > 0$ $\rightsquigarrow$ $x(self_D) > 0$ ok, by (i)
- $self_D\,.\,m\,.\,x > 0$ $\rightsquigarrow$ $x(m(self_D)) > 0$ ok, by ~~(iv)~~, (iii) $\quad \overbrace{m(\underbrace{self_D}_{:\tau_D})}^{:\tau_D}$ ok by (i)
- $self_C\,.\,n\,.\,x > 0$ $\rightsquigarrow$ $x(n(self_C)) > 0$ not ok by (iii) [and (i), (ii), and (iv) obviously] $\quad \overbrace{n(\underbrace{self_C}_{:\tau_C})}^{:\tau_D}$ $\neq$ and $\xi = -$

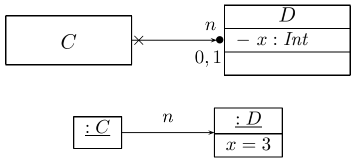
The Semantics of Visibility

- **Observation**:
  - Whether an expression **does** or **does not** respect visibility is **a matter of well-typedness only**.
  - We only evaluate (= apply I to) **well-typed** expressions.

$\rightarrow$ We **need not** adjust the interpretation function I to support visibility.

Just decide: should we take visibility into account yes / no, and check well-typedness by the new / old rules.

What is Visibility Good For?



- Visibility is a property of attributes — is it useful to consider it in OCL?
- In other words: given the diagram above, **is it useful** to state the following invariant (even though x is private in D)

context C inv : $n.x > 0$?

It depends. (cf. OMG (2006), Sect. 12 and 9.2.2)

- **Constraints and pre/post conditions**:
  - Visibility is **sometimes not** taken into account. To state "global" requirements, it may be adequate to have a "global view", i.e. be able to "look into" all objects.
  - But: visibility supports "narrow interfaces", "information hiding", and similar **good design practices**. To be more robust against changes, try to state requirements only in the terms which are visible to a class.

  Rule-of-thumb: if attributes are important to state requirements on design models, leave them public or provide get-methods (later).
- **Guards** and **operation bodies**:
  - If in doubt, **yes** (= do take visibility into account).

  Any so-called **action language** typically takes visibility into account.

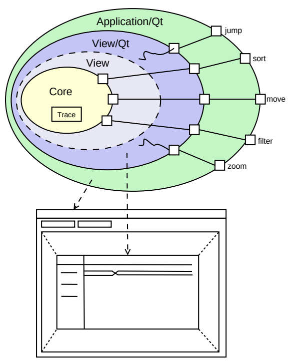
Stereotypes

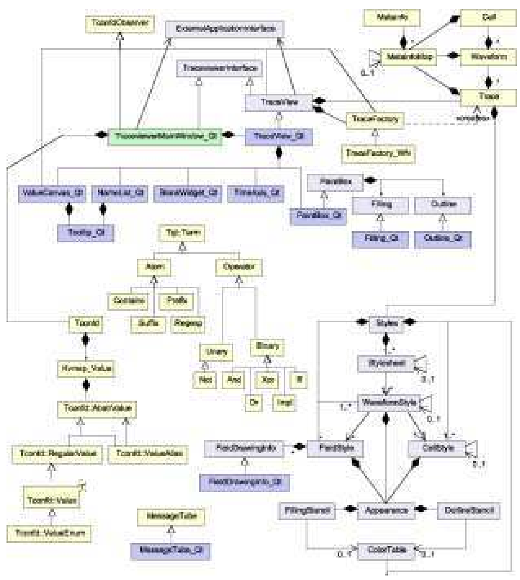
Stereotypes as Labels or Tags

«blue»
C

- What are Stereotypes?
  - **Not** represented in system states.
  - **Not** contributing to typing rules / well-formedness.
- Oestereich (2006):
  View stereotypes as (additional) "**labelling**" ("tags") or as "**grouping**".
- Useful for documentation and model-driven development, e.g. code-generation:
  - **Documentation**: e.g. layers of an architecture.
    Sometimes, packages (cf. OMG (2011a,b)) are sufficient and "right".
  - **Model Driven Architecture** (MDA): **later**.

Example: Stereotypes for Documentation





- **Example**: Timing Diagram Viewer
  Schumann et al. (2008)
- Architecture has four layers:
  - core, data layer
  - abstract view layer
  - toolkit-specific view layer/widget
  - application using widget

  Stereotype "=" layer "=" colour.

Other Examples

- Use stereotypes 'Team$_1$', 'Team$_2$', 'Team$_3$' and assign stereotype Team$_i$ to class C if Team$_i$ is responsible for class C.
- Use stereotypes to label classes with licensing information (e.g., LGPL vs. proprietary).
- Use stereotypes 'Server$_A$', 'Server$_B$' to indicate where objects should be stored.
- Use stereotypes to label classes with states in the development process like "under development", "submitted for testing", "accepted".
- etc. etc.

Necessary: a **common idea** of what each stereotype stands for.

(To be defined / agreed on by the team, not the job of the UML consortium.)

References

References

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