

Lecture 11: Structural Software Modelling II

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Basic Object System Structure Example

Wanted: a structure for signature

$$\mathcal{S}_0 = \{(Int, Bool), (C, D), f: Int, p: C_0, n: C_1, C \rightarrow [p, n], D \rightarrow \{p, x\}\},$$

$$(f: Int \rightarrow Bool, g: \omega \rightarrow Int), (C \rightarrow A, D \rightarrow \{f, g, \omega\})\}$$

A structure \mathcal{G} must

- $f \in \text{to_some } \mathcal{S}(C, C \in \mathcal{G} \text{ to some definition } \mathcal{S}(C) \text{ infinite private disjoint})$
- $C_1 \text{ and } C_0 \text{ for } C \in \mathcal{G} \Rightarrow \mathcal{S}(C_0) = \mathcal{S}(C_1) = 2^{|\mathcal{S}(C)|}$

$$\mathcal{G}(Int) = \mathbb{Z}$$

$$\mathcal{G}(Bool) = \{t, f\}$$

$$\mathcal{G}(C_0) = \mathbb{N} \times \{C\} = \{t_0, f_0, \dots\}$$

$$\mathcal{G}(C_1) = \mathbb{N} \times \{C\} = \{t_1, f_1, \dots\}$$

$$\mathcal{G}(D) = \mathbb{N} \times \{D\} = \{t_2, f_2, \dots\}$$

$$\mathcal{G}(C_0, 1) = \mathcal{G}(C_1) = 2^{\mathbb{N}}$$

$$\mathcal{G}(D, 1) = \mathcal{G}(D) = 2^{\mathbb{N}}$$

Topic Area Architecture & Design: Content

V1.10 * Introduction and Vocabulary
* Software Modelling
...
V1.11 * Modelling structure
...
V1.12 * Principles of Design
...
V1.13 * Design Patterns
...
V1.14 * Modelling behaviour
...
V1.15 * Communicating Finite Automata (CFA)
...
V1.16 * Updatable query language
...
V1.17 * CFA vs. Software
...
V1.18 * Unified Modelling Language (UML)
...
V1.19 * basic state machines
...
V1.20 * an outlook on theoretical state-machines
...
V1.21 * Model-driven/-based Software Engineering

From Abstract to Concrete Syntax

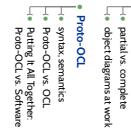
$\mathcal{P} = (\mathcal{S}, \mathcal{G}, V, \sigma, F, mth)$

$\mathcal{S} = \{Int, Bool\}$

$\mathcal{G} = \{C, D\}$

$V = \{t, f, \omega, Int, C, D, A, B, \{p, q, r\}, \{p_1, q_1, r_1\}, \{p_2, q_2, r_2\}, \{p_3, q_3, r_3\}, \{p_4, q_4, r_4\}, \{p_5, q_5, r_5\}, \{p_6, q_6, r_6\}, \{p_7, q_7, r_7\}, \{p_8, q_8, r_8\}, \{p_9, q_9, r_9\}, \{p_{10}, q_{10}, r_{10}\}, \{p_{11}, q_{11}, r_{11}\}, \{p_{12}, q_{12}, r_{12}\}, \{p_{13}, q_{13}, r_{13}\}, \{p_{14}, q_{14}, r_{14}\}, \{p_{15}, q_{15}, r_{15}\}, \{p_{16}, q_{16}, r_{16}\}, \{p_{17}, q_{17}, r_{17}\}, \{p_{18}, q_{18}, r_{18}\}, \{p_{19}, q_{19}, r_{19}\}, \{p_{20}, q_{20}, r_{20}\}, \{p_{21}, q_{21}, r_{21}\}, \{p_{22}, q_{22}, r_{22}\}, \{p_{23}, q_{23}, r_{23}\}, \{p_{24}, q_{24}, r_{24}\}, \{p_{25}, q_{25}, r_{25}\}, \{p_{26}, q_{26}, r_{26}\}, \{p_{27}, q_{27}, r_{27}\}, \{p_{28}, q_{28}, r_{28}\}, \{p_{29}, q_{29}, r_{29}\}, \{p_{30}, q_{30}, r_{30}\}, \{p_{31}, q_{31}, r_{31}\}, \{p_{32}, q_{32}, r_{32}\}, \{p_{33}, q_{33}, r_{33}\}, \{p_{34}, q_{34}, r_{34}\}, \{p_{35}, q_{35}, r_{35}\}, \{p_{36}, q_{36}, r_{36}\}, \{p_{37}, q_{37}, 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q_{73}, r_{73}\}, \{p_{74}, q_{74}, r_{74}\}, \{p_{75}, q_{75}, r_{75}\}, \{p_{76}, q_{76}, r_{76}\}, \{p_{77}, q_{77}, r_{77}\}, \{p_{78}, q_{78}, r_{78}\}, \{p_{79}, q_{79}, r_{79}\}, \{p_{80}, q_{80}, r_{80}\}, \{p_{81}, q_{81}, r_{81}\}, \{p_{82}, q_{82}, r_{82}\}, \{p_{83}, q_{83}, r_{83}\}, \{p_{84}, q_{84}, r_{84}\}, \{p_{85}, q_{85}, r_{85}\}, \{p_{86}, q_{86}, r_{86}\}, \{p_{87}, q_{87}, r_{87}\}, \{p_{88}, q_{88}, r_{88}\}, \{p_{89}, q_{89}, r_{89}\}, \{p_{90}, q_{90}, r_{90}\}, \{p_{91}, q_{91}, r_{91}\}, \{p_{92}, q_{92}, r_{92}\}, \{p_{93}, q_{93}, r_{93}\}, \{p_{94}, q_{94}, r_{94}\}, \{p_{95}, q_{95}, r_{95}\}, \{p_{96}, q_{96}, r_{96}\}, \{p_{97}, q_{97}, r_{97}\}, \{p_{98}, q_{98}, r_{98}\}, \{p_{99}, q_{99}, r_{99}\}, \{p_{100}, q_{100}, r_{100}\}, \{p_{101}, q_{101}, r_{101}\}, \{p_{102}, q_{102}, r_{102}\}, \{p_{103}, q_{103}, r_{103}\}, \{p_{104}, q_{104}, r_{104}\}, \{p_{105}, q_{105}, r_{105}\}, \{p_{106}, q_{106}, r_{106}\}, \{p_{107}, q_{107}, r_{107}\}, 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Object Diagrams Cont'd



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Object Diagrams Cont'd

- **Dangling References**
- partial vs. complete object diagrams at work
- syntax semantics
- Proto-OC vs. OCL
- Putting it All Together
- Proto-OC vs. Software

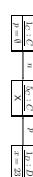
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Special Case: Dangling Reference

Definition:
Let $\sigma \in \mathcal{S}^{\mathcal{C}}$ be a system state and $u \in \text{dom}(\sigma)$ an live object of class C in σ . We say $y \in \text{attr}(C)$ is a **dangling reference** in u if and only if $r : C_0, i : r : C_1$, and u refers to a **non-live** object via r , i.e.

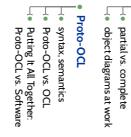
$$\langle \sigma_u \rangle(r) \not\subset \text{dom}(\sigma).$$

- $\sigma = \{l_C \mapsto \{p \mapsto \emptyset, n \mapsto \{\langle c \rangle\}, l_D \mapsto \{p \mapsto \{\langle c \rangle\}, x \mapsto 23\}\}$
- Object diagram representation:



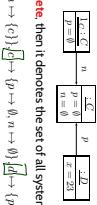
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Object Diagrams at Work



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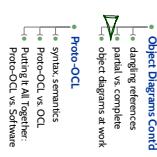
Special Case: Anonymous Objects

If the object diagramis considered as **complete**, then it denotes the set of all system states

$$\{l_C \mapsto \{p \mapsto \emptyset, n \mapsto \{\langle c \rangle\}\}, l_D \mapsto \{p \mapsto \emptyset, n \mapsto \emptyset\}\} \not\rightarrow \{p \mapsto \{\langle c \rangle, x \mapsto 23\}\}$$

where $c \in \mathcal{C}(C)$, $d \in \mathcal{C}(D)$, $c \neq l_C$.**Intuition:** different boxes represent different objects.

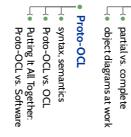
Content



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Object Diagrams at Work

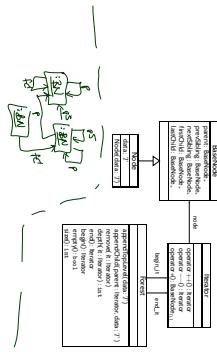
Object Diagrams Cont'd



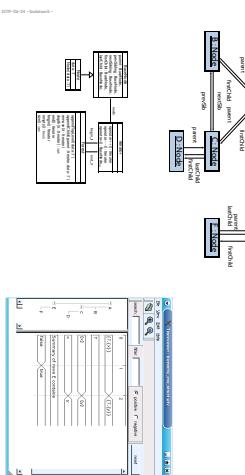
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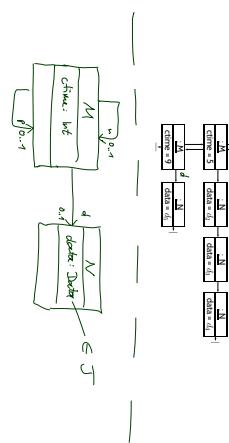
Example: Data Structure (Schumann et al., 2008)



Example: Illustrative Object Diagram (Schwanen et al., 2008)



Object Diagrams for Structural Analysis



Towards Object Constraint Logic (*OCL*) — “Proto-OCL” —

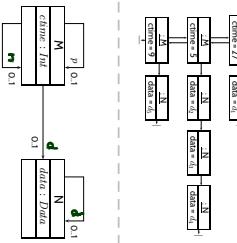
Content

- ```

graph TD
 OD[Object Diagrams Content] --- OCL[Proto-OCL]
 OD --- SD[syntax, semantics]
 OD --- PO[Proto-OCL vs. OCL]
 OD --- PIA[Putting it All Together]
 OD --- POVS[Proto-OCL vs. Software]
 OCL --- DR[dangling references]
 OCL --- PC[partial vs. complete]
 OCL --- ODW[object diagrams at work]

```

*Object Diagrams for Structural Analysis*



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## Where To Put OCL Constraints?

- Notes: A UML note is a diagram element of the form
 
- Sometimes, content is explicitly classified to clarify
 

### Conventions



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## Content

- Object Diagrams** Contd
  - dragging references
  - partial vs complete
  - object diagrams at work
- Proto-OCL**
  - syntax, semantics
  - Proto-OCL vs OCL
  - Putting All Together: Proto-OCL vs Software

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## Putting It All Together

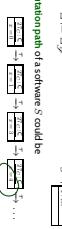
### Modelling Structure with Class Diagrams

Definition. Software is a free description  $S$  of a possibly infinite set  $[S]$  of finite or infinite computation paths of the form  $\sigma_0 \xrightarrow{\alpha_1} \sigma_1 \xrightarrow{\alpha_2} \sigma_2 \dots$ , where
 

- $\sigma_i \in \Sigma$ ;  $i \in \mathbb{N}$ , is called state (or configuration), and
- $\alpha_i \in A$ ;  $i \in \mathbb{N}$ , is called action (or event)

 The (possibly partial) function  $\sqcup : [S] \times [S] \rightarrow [S]$  is called interpretation of  $S$ .

$\Sigma := \bigcup_{i=1}^{\infty} \Sigma^i$



- The set of states  $\Sigma$  could be the set of system states as defined by a class diagram, e.g.

- A corresponding computation path of a software  $S$  could be
 
- if a requirement is formalised by the Proto-OCL constraint
  $F \quad \forall c \in \text{allSources} : x(c) < 4$ 
  - then  $S$  does not satisfy the requirement

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### More General: Software vs. Proto-OCL

- Let  $\mathcal{S}$  be an object system signature and a structure
- Let  $S$  be software with
  - states  $\Sigma \subseteq \Sigma^{\mathcal{S}}$  and
  - computation paths  $[S]$

- The set of states  $\Sigma$  could be the set of system states as defined by a class diagram, e.g.

$\Sigma := \bigcup_{i=1}^{\infty} \Sigma^i$



- We say  $[S]$  satisfies  $F$ , denoted by  $[S] \models F$ , if and only if for all  $\sigma_0 \xrightarrow{\alpha_1} \sigma_1 \xrightarrow{\alpha_2} \sigma_2 \dots \in [S]$  and all  $i \in \mathbb{N}_0$ ,

$I[F](\sigma_i, i) = \text{true}$ .

- We say  $[S]$  does not satisfy  $F$ , denoted by  $[S] \not\models F$ , if and only if there exists  $\sigma_0 \xrightarrow{\alpha_1} \sigma_1 \xrightarrow{\alpha_2} \sigma_2 \dots \in [S]$  and  $i \in \mathbb{N}_0$  such that  $I[F](\sigma_i, i) = \text{false}$ .

- Note:  $\neg([S] \not\models F)$  does not imply  $[S] \models F$ .

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### Topic Area Architecture & Design: Content

- V1.0
  - Introduction and vocabulary
  - Software Modelling
  - model, views, viewpoints, 4+1 view

#### Modelling structure

#### VL1.1

- (Simple) Class & Object diagrams
- (Simple) Object Constraint Language (OCL)

#### VL1.2

- Software Modelling
- modality, separation of concerns
- information hiding and data encapsulation
- abstract data types, object orientation

#### VL1.3

- Principles of Design
- modularity, separation of concerns

#### VL1.4

- Design Patterns
- Modelling behaviour
- Communication Finite Automata (CFA)
- Information Hiding
- Upward Query Language
- CFA vs. Software
- Unified Modelling Language (UML)
- basic state machines
- an outlook on hierarchical state machines

#### VL1.5

- Model-driven / based Software Engineering

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## Tell Them What You've Told Them...

- **Class Diagram** can be used to **graphically** visualize **models**.
- define an object system structure.
- **An Object System Structure** / **represents with a structure** ↗
- defines a set of **system states** ↗
- **A System State** ↗
  - can be visualized by an **Object Diagram**.
- **Pro-OCL** constraints can be evaluated on system states.
- A value over  $\Sigma_{i=1}^n$  satisfies **Object-OCL constraint**  $F_i$ , if, and only if,  $F_i$  evaluates to true in all system states on all the software computation paths.

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## References

### References

- Lüding, and Richter, H. (2013). *Software Engineering*, 4th printing, 3. edition.
- OMG (2006). Object Constraint Language, version 2.0. Technical Report formal/OCL-05-01.
- Schumann, M., Steinke, J., Deck, A., and Weigel, B. (2008). Traceview - technical documentation, version 1.0. Technical report, Chair for Object Technology, Universität Oldenburg und OTHS.
- Wamer, and Rege, A. (1999). *The Object Constraint Language*. Addison-Wesley.

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