

Software Design, Modelling and Analysis in UML

Lecture 9: Class Diagrams IV

2016-11-29

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Content

- **Associations: The Rest**
 - Visibility, Navigability, Properties,
 - Ownership, "Diamonds",
 - Multiplicity
- **Back to the Main Track**
- **OCL in (Class) Diagrams**
- What makes a class diagram a **good class diagram**?
 - Web-Shop Examples
 - The Elements of UML 2.0 Style
 - Example: Game Architecture

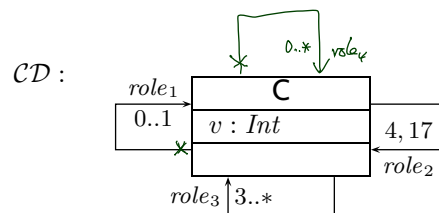
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Associations: The Rest

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Multiplicities



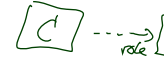
context C inv: $role_3 \rightarrow size \geq 3$

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Multiplicities as Constraints

Recall: Multiplicity is a term of the form $\underbrace{N_1..N_2, \dots, N_{2k-1}..N_{2k}}$
 where $N_i \leq N_{i+1}$ for $1 \leq i \leq 2k$, $N_1, \dots, N_{2k-1} \in \mathbb{N}$, $N_{2k} \in \mathbb{N} \cup \{*\}$.



Define $\mu_{\text{OCL}}^C(\text{role}) :=$

context $C \text{ inv} : (N_1 \leq \text{role} \rightarrow \text{size}() \leq N_2)$ or ... or $(N_{2k-1} \leq \text{role} \rightarrow \text{size}() \leq N_{2k})$
omit if $N_{2k} = *$

for each $\langle r : \dots, \langle \text{role} : D, \mu, _ , _ , _ , _ \rangle, \dots, \langle \text{role}' : \overset{C}{_}, _ , _ , _ , _ \rangle, \dots \rangle \in V$ or

$\langle r : \dots, \langle \text{role}' : \overset{C}{_}, _ , _ , _ , _ \rangle, \dots, \langle \text{role} : D, \mu, _ , _ , _ , _ \rangle, \dots \rangle \in V,$

with $\text{role} \neq \text{role}'$, if $\mu \neq 0..1$, $\mu \neq 1..1$, and

$\mu_{\text{OCL}}^C(\text{role}) := \text{context } C \text{ inv} : \text{not}(\text{ocllsUndefined}(\text{role}))$

if $\mu = 1..1$.

Note: in n -ary associations with $n > 2$, there is redundancy.



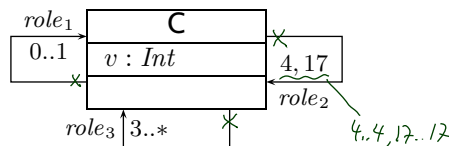
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Multiplicities as Constraints Example

$\mu_{\text{OCL}}^C(\text{role}) = \text{context } C \text{ inv} :$
 $(N_1 \leq \text{role} \rightarrow \text{size}() \leq N_2)$ or ... or $(N_{2k-1} \leq \text{role} \rightarrow \text{size}() \leq N_{2k})$
 $\mu_{\text{OCL}}^C(\text{role}) = \text{context } C \text{ inv} : \text{not}(\text{ocllsUndefined}(\text{role}))$

$CD :$



- $\{ \text{context } C \text{ inv} : 3 \in \text{role}_3 \rightarrow \text{size}() \leq 4 \text{ or } 17 \leq \text{role}_2 \rightarrow \text{size}() \leq 17 \}$
 $= \{ \text{context } C \text{ inv} : \text{role}_2 \rightarrow \text{size}() = 4 \text{ or } \text{role}_2 \rightarrow \text{size}() = 17 \}$
- $\{ \text{context } C \text{ inv} : 4 \in \text{role}_2 \rightarrow \text{size}() \leq 4 \text{ or } 17 \in \text{role}_2 \rightarrow \text{size}() \leq 17 \}$

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Back to the Main Track

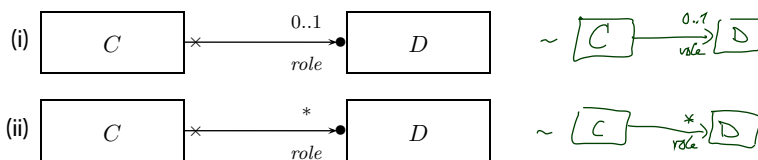
Back to the main track:

Recall: on some earlier slides we said, the extension of the signature is **only** to study associations in “full beauty”.

For the remainder of the course, we should look for something simpler...

Proposal:

- **from now on**, we only use associations of the form



(And we may omit the non-navigability and ownership symbols.)

- Form (i) introduces $role : \mathcal{D}_{0,1}$, and form (ii) introduces $role : \mathcal{D}_*$ in the set of attributes V .
- In both cases, $role \in atr(C)$.
- We drop λ and go back to our nice σ with $\sigma(u)(role) \subseteq \mathcal{D}(D)$.

OCL Constraints in (Class) Diagrams

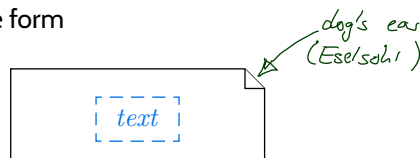
Where Shall We Put OCL Constraints?

Three options:

- (o) Separate document.
- (i) Notes.
- (ii) Particular dedicated places.

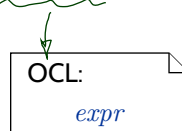
(i) Notes:

A UML **note** is a picture of the form

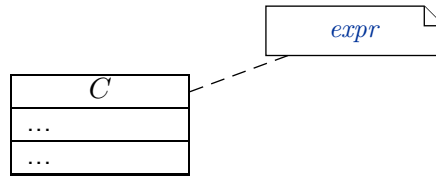


text can principally be **everything**, in particular **comments** and **constraints**.

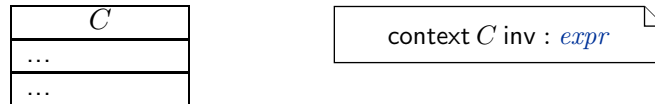
Sometimes, content is **explicitly classified** for clarity:



OCL in Notes: Conventions

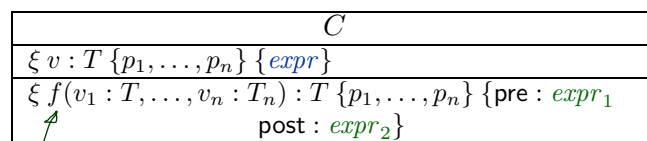


stands for



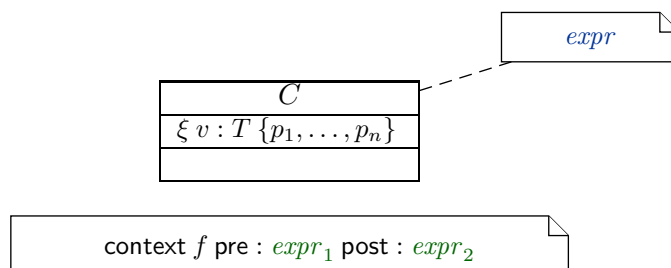
Where Shall We Put OCL Constraints?

(ii) **Particular dedicated places** in class diagrams: (behavioural features: later)



↑
behavioural
feature

For simplicity, we view the above as an abbreviation for



Invariants of a Class Diagram

- Let \mathcal{CD} be a class diagram.
- We are (now) able to recognise OCL constraints when we see them, so define

$$Inv(\mathcal{CD})$$

as the set $\{\varphi_1, \dots, \varphi_n\}$ of OCL constraints **occurring** in notes in \mathcal{CD} – after **unfolding** all **graphical** abbreviations (cf. previous slides).

- As usual:** consider all invariants in all notes in any class diagram – plus implicit multiplicity-induced invariants.

$$Inv(\mathcal{CD}) = \bigcup_{\mathcal{CD} \in \mathcal{CD}} Inv(\mathcal{CD}) \cup \begin{matrix} \text{only applies in the} \\ \text{general setting} \\ \text{for associations} \end{matrix}$$

$$\{\mu_{OCL}^C(role) \mid \langle r : \dots, \langle role : D, \mu, _ , _ , _ \rangle, \dots, \langle role' : C, _ , _ , _ , _ \rangle, \dots \rangle \in V \text{ or} \\ \langle r : \dots, \langle role' : C, _ , _ , _ , _ \rangle, \dots, \langle role : D, \mu, _ , _ , _ \rangle, \dots \rangle \in V\}.$$

- Analogously:** $Inv(\cdot)$ for any kind of diagram (like **state machine diagrams**).

Semantics of a Class Diagram

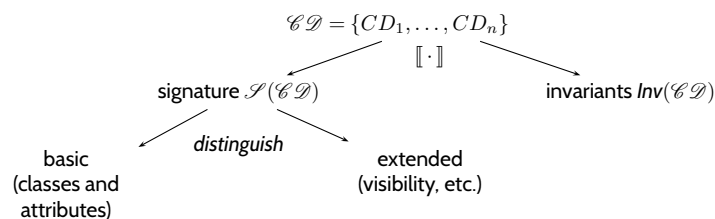
Definition. Let \mathcal{CD} be a set of class diagrams.

We say, the **semantics** of \mathcal{CD} is the signature it induces and the set of OCL constraints occurring in \mathcal{CD} , denoted

$$\llbracket \mathcal{CD} \rrbracket := \langle \mathcal{S}(\mathcal{CD}), Inv(\mathcal{CD}) \rangle.$$

Given a structure \mathcal{D} of \mathcal{S} (and thus of \mathcal{CD}), the class diagrams **describe** the system states $\Sigma_{\mathcal{D}}$, of which **some** may satisfy $Inv(\mathcal{CD})$.

In pictures:



Pragmatics

Recall: a UML **model** is an image or pre-image of a software system.

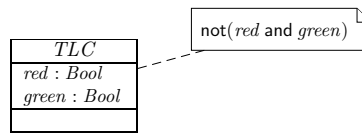
A set of class diagrams \mathcal{CD} describes the **structure** of system states.

Together with the invariants $Inv(\mathcal{CD})$ it can be used to state:

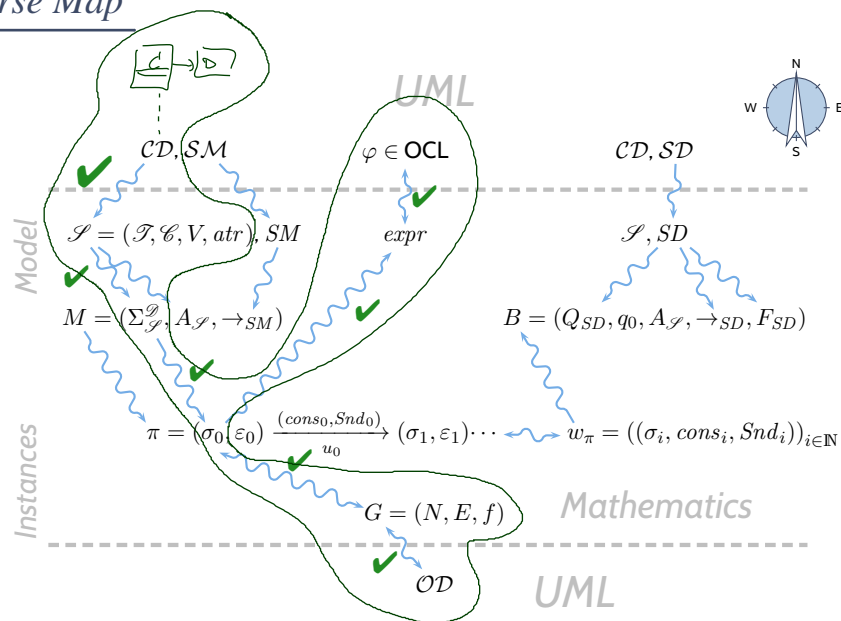
- **Pre-image:** Dear programmer, please provide an implementation which **uses** only system states that satisfy $Inv(\mathcal{CD})$.
- **Post-image:** Dear user/maintainer, in the existing system, only system states which satisfy $Inv(\mathcal{CD})$ are **used**.

(The exact meaning of “**use**” will become clear when we study behaviour – intuitively: the system states that are reachable from the initial system state(s) by calling methods or firing transitions in state-machines.)

Example: highly abstract model of traffic lights controller.



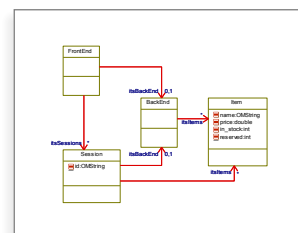
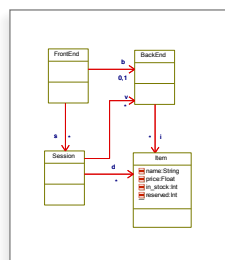
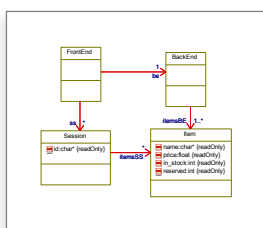
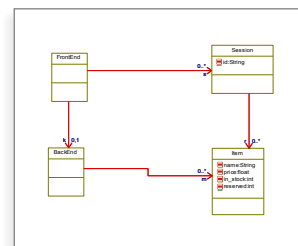
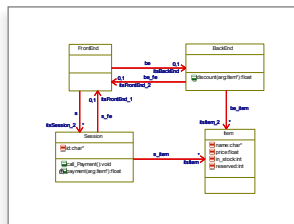
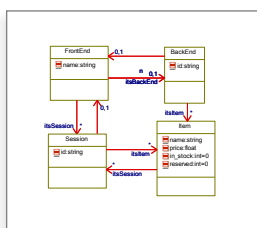
Course Map



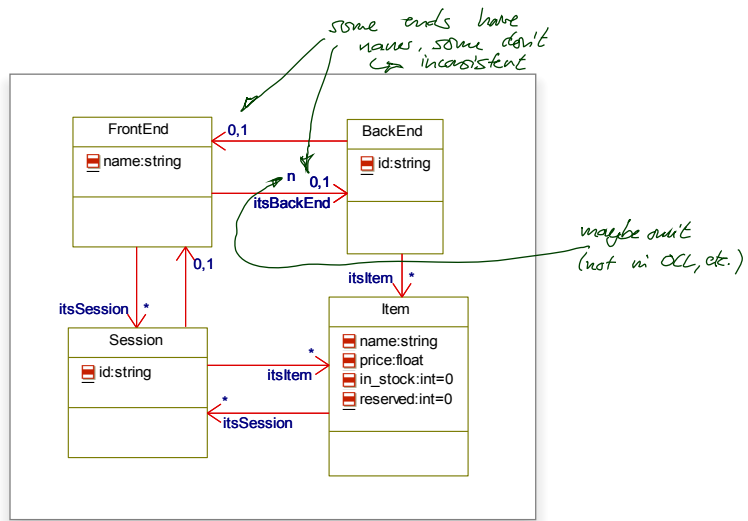
Design Guidelines for (Class) Diagram

(partly following Ambler (2005))

Some Web-Shop Class Diagrams

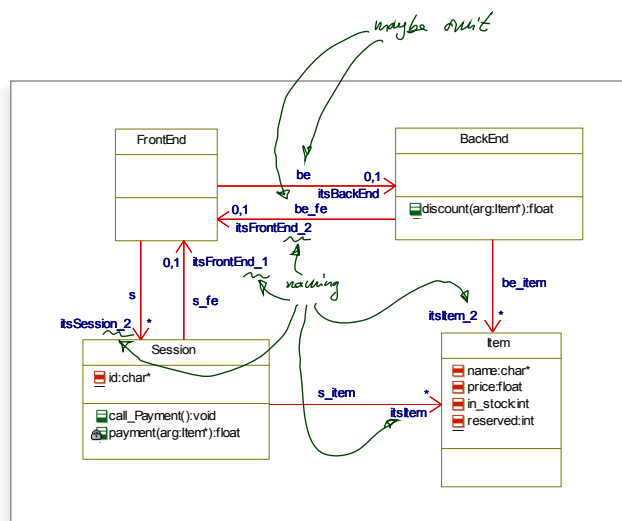


A Closer Look

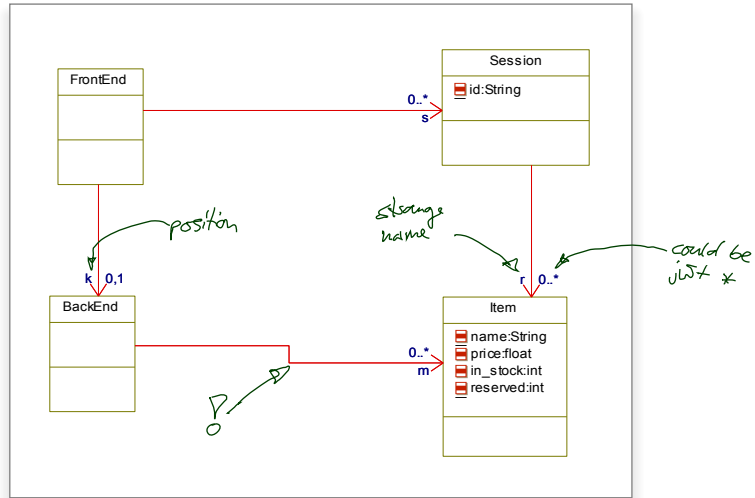


$V = \langle n: \langle itsBackEnd: BackEnd, +, \dots \rangle, \dots \rangle$

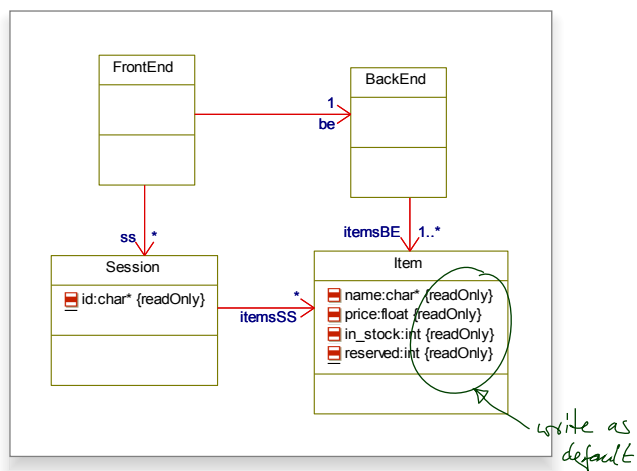
A Closer Look



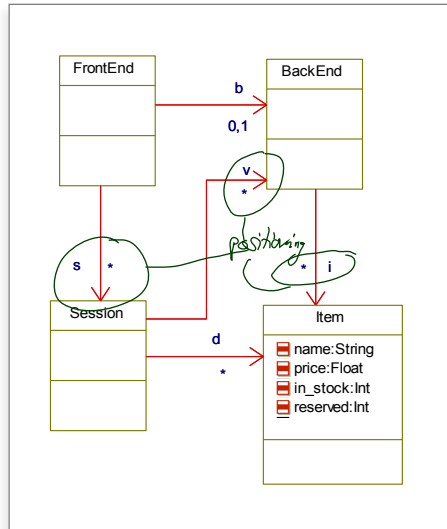
A Closer Look



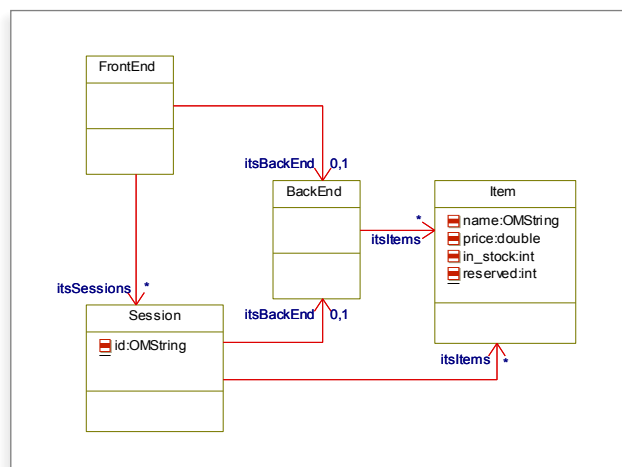
A Closer Look



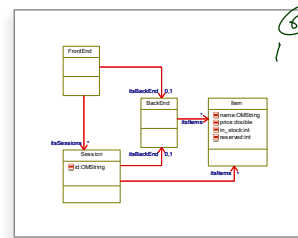
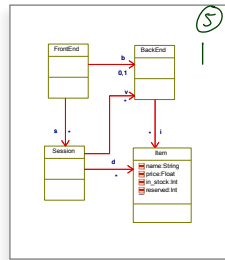
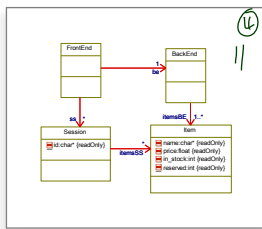
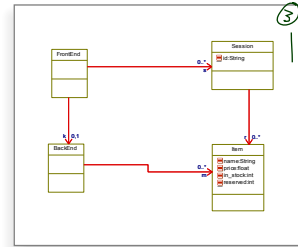
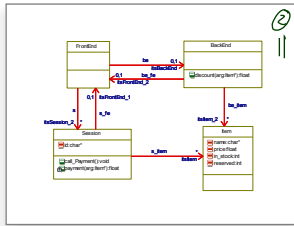
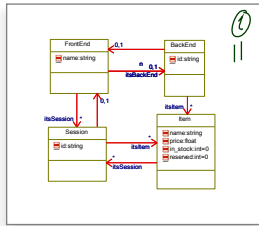
A Closer Look



A Closer Look



Some Web-Shop Class Diagrams



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So: what makes a class diagram a good class diagram?

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Main and General Modelling Guideline

Be good to your audience.

“Imagine you’re given **your** diagram \mathcal{D} and asked to conduct task \mathcal{T} .”

- Can you do \mathcal{T} with \mathcal{D} ?
(semantics sufficiently clear? all necessary information available? ...)
- Does doing \mathcal{T} with \mathcal{D} cost you more nerves/time/money/... than it should?”
(syntactical well-formedness? readability? intention of deviations from standard syntax clear? reasonable selection of information? layout? ...)

In other words:

- the things **most relevant** for task \mathcal{T} , do they **stand out** in \mathcal{D} ?
- the things **less relevant** for task \mathcal{T} , do they **disturb** in \mathcal{D} ?

Main and General Quality Criterion

- **Q:** When is a (class) diagram a good diagram?
- **A:** If it serves its purpose/makes its point.

Examples for purposes and points and rules-of-thumb:

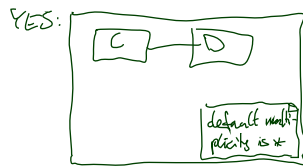
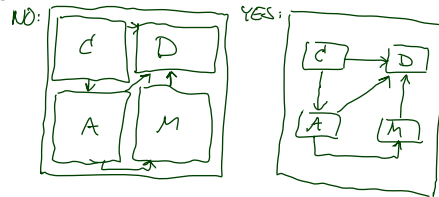
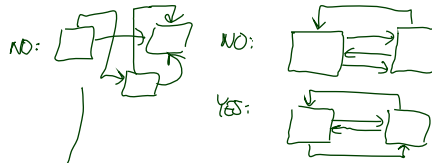
- **Analysis/Design**
 - realizable, no contradictions
 - abstract, focused, admitting degrees of freedom for (more detailed) design
 - platform independent – as far as possible but not (artificially) farer
- **Implementation/A**
 - close to target platform
($C_{0,1}$ is easy for Java, C_* comes at a cost – other way round for RDB)
- **Implementation/B**
 - complete, executable
- **Documentation**
 - Right level of abstraction: “if you’ve only one diagram to spend, illustrate the concepts, the architecture, the difficult part”
 - The more detailed the documentation, the higher the probability for regression
“outdated/wrong documentation is worse than none”

General Diagramming Guidelines Ambler (2005)

(Note: "Exceptions prove the rule.")

2.1 Readability

- 1.-3. Support Readability of Lines
- 4. Apply Consistently Sized Symbols
- 9. Minimize the Number of 'Bubbles' / Things
- 10. Include White-Space in Diagrams
- 13. Provide a Notational Legend



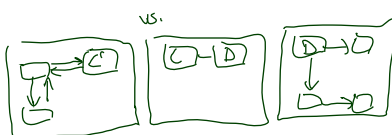
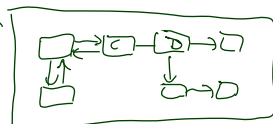
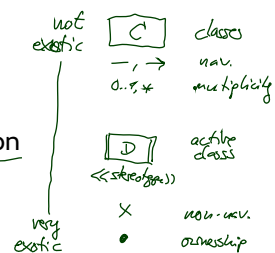
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General Diagramming Guidelines Ambler (2005)

2.2 Simplicity

- 14. Show Only What You Have to Show
- 15. Prefer Well-Known Notation over Exotic Notation
- 16. Large vs. Small Diagrams
- 18. Content First, Appearance Second



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General Diagramming Guidelines Ambler (2005)

- **2.2 Simplicity**

- 14. Show Only What You Have to Show
- 15. Prefer Well-Known Notation over Exotic Notation
- 16. Large vs. Small Diagrams
- 18. Content First, Appearance Second

- **2.3 Naming**

- 20. Set and (23. Consistently) Follow Effective Naming Conventions

- **2.4 General**

- 24. Indicate Unknowns with Question-Marks
- 25. Consider Applying Color to Your Diagram
- 26. Apply Color Sparingly

Class Diagram Guidelines Ambler (2005)

- **5.1 General Guidelines**

- 88. Indicate Visibility Only on Design Models (**in contrast to analysis models**)

- **5.2 Class Style Guidelines**

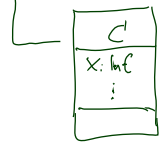
- 96. Prefer Complete Singular Nouns for Class Names
- 97. Name Operations with Strong Verbs
- 99. Do Not Model Scaffolding Code [**Except for Exceptions**]

e.g. get/set methods

Class Diagram Guidelines Ambler (2005)

5.2 Class Style Guidelines

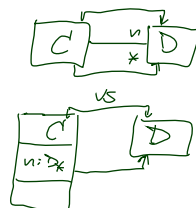
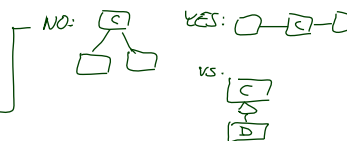
- 103. Never Show Classes with Just Two Compartments
- 104. Label Uncommon Class Compartments
- 105. Include an Ellipsis (...) at the End of an Incomplete List
- 107. List Operations/Attributes in Order of Decreasing Visibility
(from + to -)



Class Diagram Guidelines Ambler (2005)

5.3 Relationships

- 112. Model Relationships Horizontally
- 115. Model a Dependency When the Relationship is Transitory
- 117. Always Indicate the Multiplicity
(or have good defaults)
- 118. Avoid Multiplicity "*"
- 119. Replace Relationship Lines with Attribute Types
(to have fewer lines)



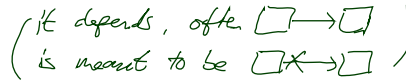
Class Diagram Guidelines Ambler (2005)

- **5.4 Associations**



- 127. Indicate Role Names When Multiple Associations Between Two Classes Exist
- 129. Make Associations Bidirectional Only When Collaboration Occurs in Both Directions

- **131. Avoid Indicating Non-Navigability**



- 133. Question Multiplicities Involving Minimums and Maximums
e.g. 3..10

- **5.6 Aggregation and Composition**

- → exercises



Tell Them What You've Told Them...

- **Associations:**

- view **multiplicities** as shorthand for **constraints**,
- **OCL constraints** can be added to a class diagram in **notes** or at **dedicated places**.
- The semantics of a **class diagram** is its (extended) signature, and a set of (explicit and implicit) OCL constraints.
- **Class Diagrams** can be "drawn" **well** or **not so well**.
- A **diagram** is a **good diagram** if it serves its purpose.
- Purposes (for class diagrams):
 - **Documentation of the top-level architecture.**
 - **Documentation of the structural design decisions.**
 - Details can go into comments in the code.
- **Ambler (2005): The Elements of UML 2.0 Style.**

References

References

Ambler, S. W. (2005). *The Elements of UML 2.0 Style*. Cambridge University Press.

OMG (2011a). Unified modeling language: Infrastructure, version 2.4.1. Technical Report formal/2011-08-05.

OMG (2011b). Unified modeling language: Superstructure, version 2.4.1. Technical Report formal/2011-08-06.