6. Modeling Objects and Classes

Prof. O. Nierstrasz
Roadmap

- UML Overview
- Classes, attributes and operations
- UML Lines and Arrows
- Parameterized Classes, Interfaces and Utilities
- Objects, Associations
- Inheritance
- Patterns, Constraints and Contracts
Sources


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UML

What is UML?

> uniform notation: Booch + OMT + Use Cases (+ state charts)
  > UML is not a method or process
  > … The Unified Development Process is

Why a Graphical Modeling Language?

> Software projects are carried out in team
> Team members need to communicate
  > … sometimes even with the end users
> “One picture conveys a thousand words”
  > the question is only which words
  > Need for different views on the same software artifact
Why UML?

Why UML?

> Reduces *risks* by documenting assumptions
  — domain models, requirements, architecture, design, implementation …

> Represents industry *standard*
  — more tool support, more people understand your diagrams, less education

> Is reasonably *well-defined*
  — ... although there are interpretations and dialects

> Is *open*
  — stereotypes, tags and constraints to extend basic constructs
  — has a meta-meta-model for advanced extensions
UML History

> 1994: Grady Booch (Booch method) + James Rumbaugh (OMT) at Rational
> 1994: Ivar Jacobson (OOSE, use cases) joined Rational
   — “The three amigos”
> 1996: Rational formed a consortium to support UML
> 1997: UML1.0 submitted to OMG by consortium
> 1997: UML 1.1 accepted as OMG standard
   — However, OMG names it UML1.0
> 1998-…: Revisions UML1.2 - 1.5
> 2005: Major revision to UML2.0, includes OCL
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“Class diagrams show generic descriptions of possible systems, and object diagrams show particular instantiations of systems and their behaviour.”

Attributes and operations are also collectively called **features**.

**Danger:** class diagrams risk turning into data models. Be sure to focus on behaviour.
Visibility and Scope of Features

**Stereotype**
(what “kind” of class is it?)

**User-defined properties**
(e.g., readonly, owner = “Pingu”)

Don’t worry about visibility too early!

**underlined** attributes have **class scope**

+ = “public”
# = “protected”
- = “private”

**italic attributes** are **abstract**

An ellipsis signals that further entries are not shown
Attributes and Operations

Attributes are specified as:

name: type = initialValue { property string }

Operations are specified as:

name (param: type = defaultValue, ...) : resultType
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UML Lines and Arrows

- Constraint
  (usually annotated)

- Association
  e.g., «uses»

- Dependency
  e.g., «requires», «imports» ...

- Navigable
  association
  e.g., part-of

- Realization
  e.g., class/template, class/interface

- “Generalization”
  i.e., specialization (!)
  e.g., class/superclass, concrete/abstract class

- Aggregation
  i.e., “consists of”

- “Composition”
  i.e., containment
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Parameterized (aka “template” or “generic”) classes are depicted with their parameters shown in a **dashed box**.

**Figure 13-180.** Template notation with use of parameter as a reference
Interfaces, equivalent to abstract classes with no attributes, are represented as classes with the stereotype «interface» or, alternatively, with the “Lollipop-Notation”:

![Diagram of interfaces and their realization](image)

**Figure B-5.** Realization of an interface
Utilities

A utility is a grouping of global attributes and operations. It is represented as a class with the stereotype «utility». Utilities may be parameterized.

<table>
<thead>
<tr>
<th>«Utility»</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MathPack</strong></td>
</tr>
<tr>
<td>randomSeed : long = 0</td>
</tr>
<tr>
<td>pi : long = 3.14158265358979</td>
</tr>
<tr>
<td>sin (angle : double) : double</td>
</tr>
<tr>
<td>cos (angle : double) : double</td>
</tr>
<tr>
<td>random () : double</td>
</tr>
</tbody>
</table>

```
return sin (angle + pi/2.0);
```

**NB:** A utility’s attributes are already interpreted as being in class scope, so it is redundant to underline them.

A “note” is a text comment associated with a view, and represented as box with the top right corner folded over.
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Objects are shown as rectangles with their name and type underlined in one compartment, and attribute values, optionally, in a second compartment.

![Object notation example](image)

**Figure 13-134. Object notation**

At least one of the name or the type must be present.
**Associations** represent structural relationships between objects

— usually *binary* (but may be ternary etc.)
— optional *name* and *direction*
— (unique) *role names* and *multiplicities* at end-points

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*Figure 4-2. Association notation*
> The multiplicity of an association constrains how many entities one may be associated with

— Examples:

<table>
<thead>
<tr>
<th>Multiplicity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0..1</td>
<td>Zero or one entity</td>
</tr>
<tr>
<td>1</td>
<td>Exactly one entity</td>
</tr>
<tr>
<td>*</td>
<td>Any number of entities</td>
</tr>
<tr>
<td>1..*</td>
<td>One or more entities</td>
</tr>
<tr>
<td>1..n</td>
<td>One to n entities</td>
</tr>
<tr>
<td></td>
<td>And so on …</td>
</tr>
</tbody>
</table>
Associations and Attributes

> Associations may be implemented as attributes
  — But need not be …
Aggregation is denoted by a *diamond* and indicates a *part-whole dependency*:

A hollow diamond indicates a *reference*; a solid diamond an *implementation* (i.e., ownership).

**Aggregation**: parts may be shared.

**Composition**: one part belongs to one whole.

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**Figure 13-29.** Various adornments on association ends
Association Classes

An association may be an instance of an association class:

![Diagram showing association classes]

In many cases the association class only stores attributes, and its name can be left out.
Qualified Associations

A **qualified association** uses a special *qualifier value* to identify the object at the other end of the association.

*NB: Qualifiers are part of the association, not the class*

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**Figure 4-4.** Qualified association
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A **subclass** specializes its superclass:

![Diagram showing generalization]

**Figure 4-7.** Generalization notation
What is Inheritance For?

> New software often builds on old software by imitation, refinement or combination.

> Similarly, classes may be extensions, specializations or combinations of existing classes.
Generalization expresses ...

**Conceptual hierarchy:**
> conceptually related classes can be organized into a *specialization* hierarchy
  — people, employees, managers
  — geometric objects ...

**Polymorphism:**
> objects of distinct, but related classes may be *uniformly treated* by clients
  — array of geometric objects

**Software reuse:**
> related classes may *share* interfaces, data structures or behaviour
  — geometric objects ...
The different faces of inheritance

**Is-a**

**Polymorphism**

**Reuse**
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Design Patterns as Collaborations

The CallQueue class plays the subject role in the collaboration.

<table>
<thead>
<tr>
<th>CallQueue</th>
</tr>
</thead>
<tbody>
<tr>
<td>queue: List of Call</td>
</tr>
<tr>
<td>source: Object</td>
</tr>
<tr>
<td>waitAlarm: Alarm</td>
</tr>
<tr>
<td>capacity: Integer</td>
</tr>
</tbody>
</table>

The SlidingBarIcon class plays the handler role.

<table>
<thead>
<tr>
<th>SlidingBarIcon</th>
</tr>
</thead>
<tbody>
<tr>
<td>reading: Real</td>
</tr>
<tr>
<td>color: Color</td>
</tr>
<tr>
<td>range: Interval</td>
</tr>
</tbody>
</table>

Observer

binding of the Observer pattern

{ handler.reading = length (subject.queue) |
range = (0 .. capacity) }

some constraints on the pattern

Figure 13-144. Binding of a pattern to make a collaboration
Constraints are *restrictions* on values attached to classes or associations.

**Figure 4-12.** Constraints
OCL — Object Constraint Language

> Used to express queries and constraints over UML diagrams

— Navigate associations:
  – `Person.boss.employer`

— Select subsets:
  – `Company.employee->select(title="Manager")`

— Boolean and arithmetic operators:
  – `Person.salary < Person.boss.salary`
Combine constraints with stereotypes:

NB: «invariant», «precondition», and «postcondition» are predefined in UML.

Figure 13-147. Precondition

Figure 13-145. Postcondition
Using the Notation

During Analysis:
- Capture classes visible to users
- Document attributes and responsibilities
- Identify associations and collaborations
- Identify conceptual hierarchies
- Capture all visible features

During Design:
- Specify contracts and operations
- Decompose complex objects
- Factor out common interfaces and functionalities

The graphical notation is only one part of the analysis or design document. For example, a data dictionary cataloguing and describing all names of classes, roles, associations, etc., must be maintained throughout the project.
What you should know!

> How do you represent classes, objects and associations?
> How do you specify the visibility of attributes and operations to clients?
> How is a utility different from a class? How is it similar?
> Why do we need both named associations and roles?
> Why is inheritance useful in analysis? In design?
> How are constraints specified?
Can you answer the following questions?

> Why would you want a feature to have class scope?
> Why don’t you need to show operations when depicting an object?
> Why aren’t associations drawn with arrowheads?
> How is aggregation different from any other kind of association?
> How are associations realized in an implementation language?
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