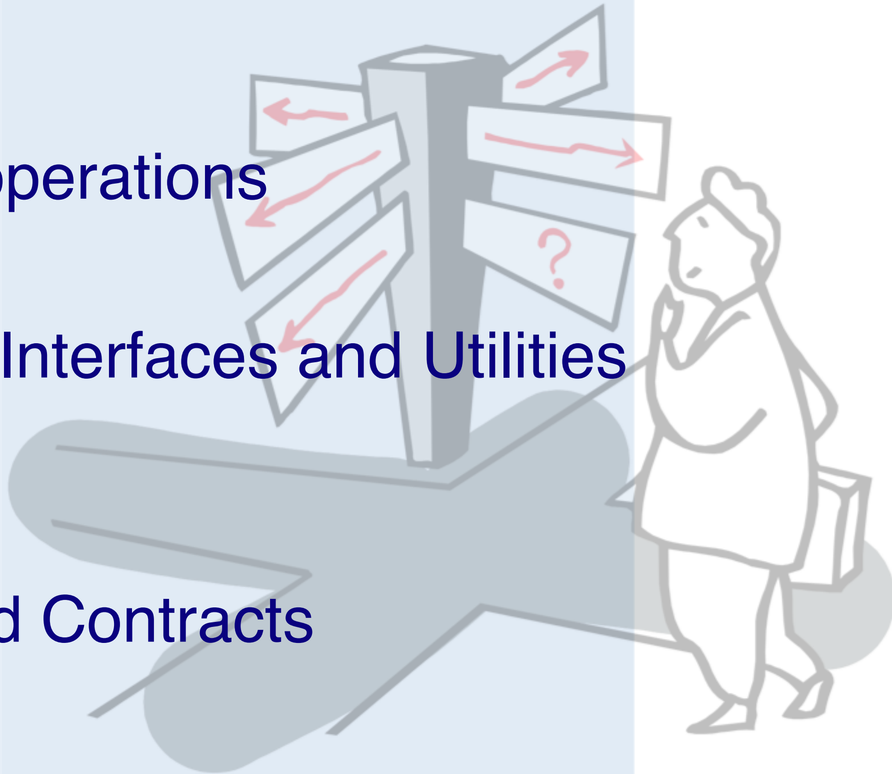
UNIVERSITÄT BERN

Introduction to Software Engineering

6. Modeling Objects and Classes

Roadmap

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



Sources

> *The Unified Modeling Language Reference Manual*, James Rumbaugh, Ivar Jacobson and Grady Booch, Addison Wesley, 1999.

> *UML Distilled*, Martin Fowler, Kendall Scott, Addison-Wesley, Second Edition, 2000.

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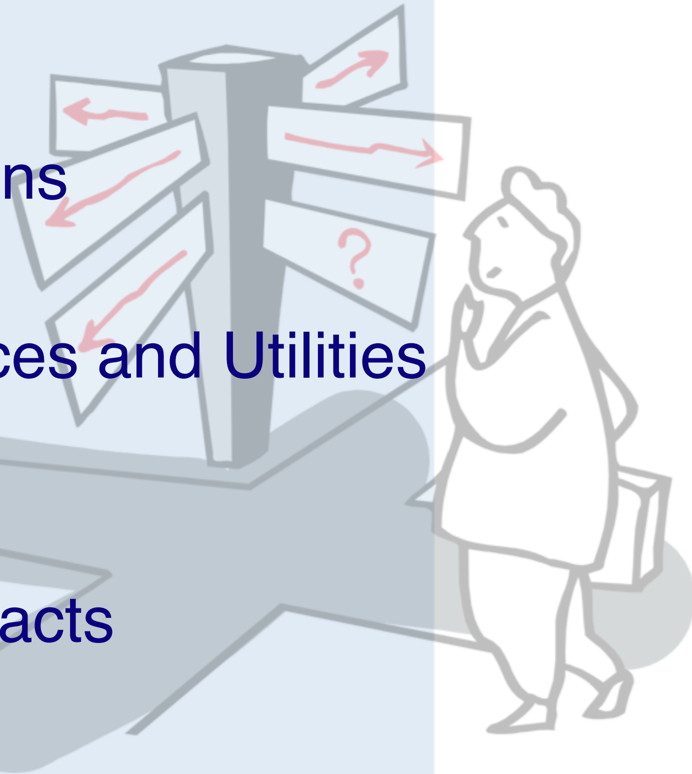


UML

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

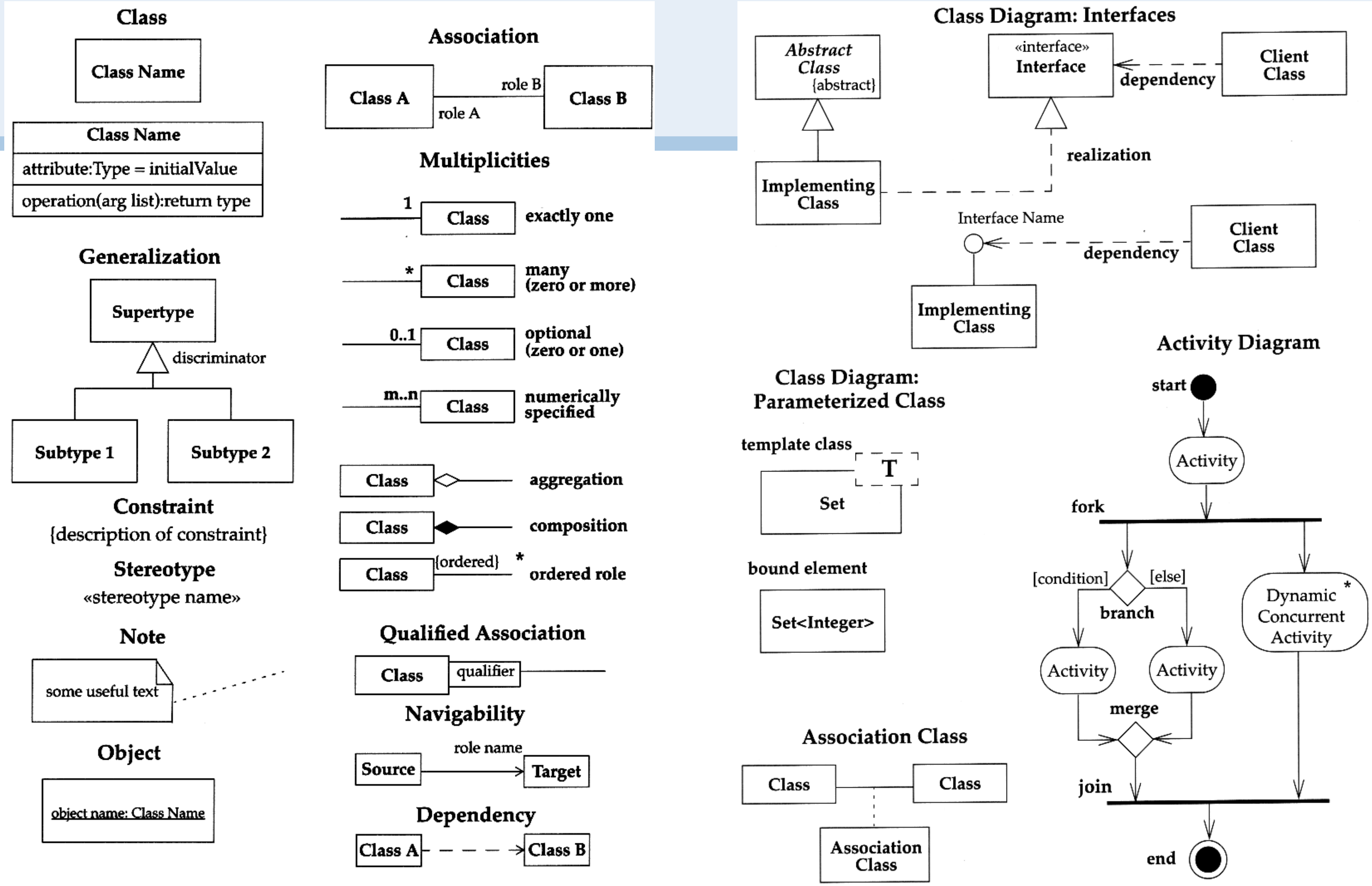
Why UML?

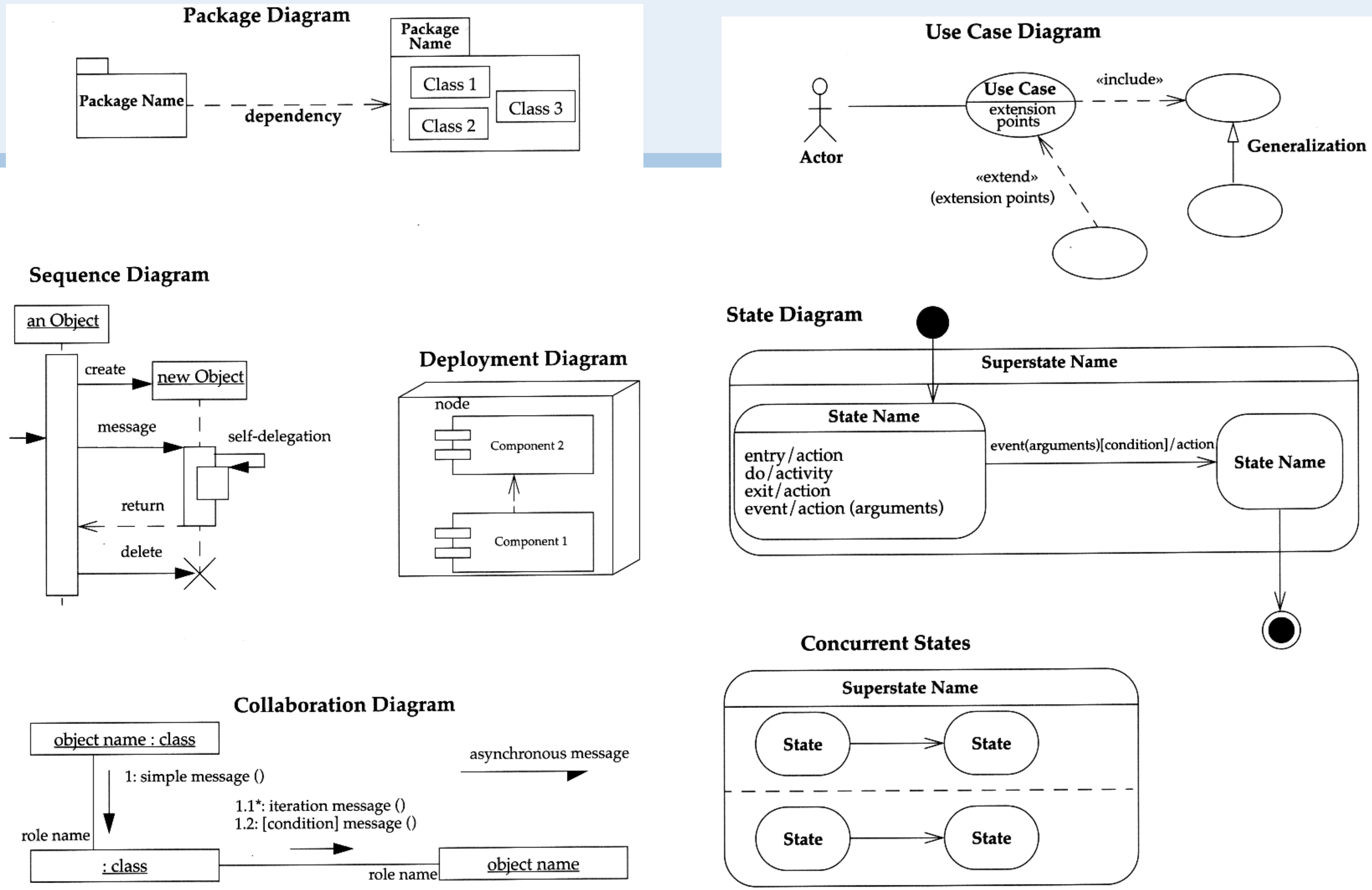
Why UML?

- 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

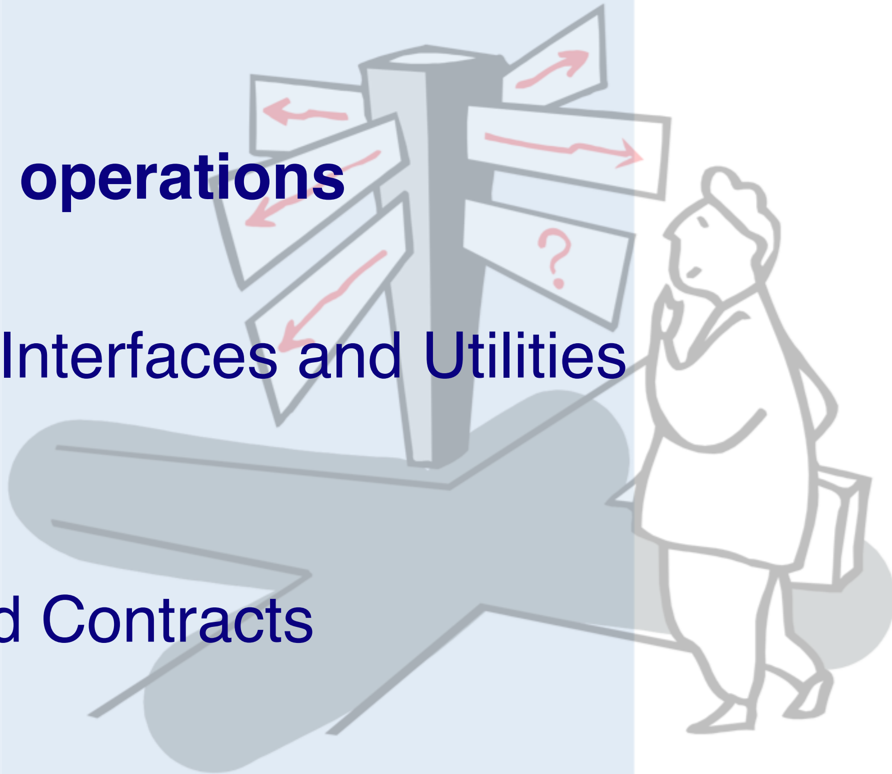
- 1994: Grady Booch (Booch method) + James Rumbaugh (OMT) at Rational
- 1994: Ivar Jacobson (OOSE, use cases) joined Rational
  - "The three amigos"
- 1996: Rational formed a consortium to support UML
- 1997: UML1.0 submitted to OMG by consortium
- 1997: UML 1.1 accepted as OMG standard
  - However, OMG names it UML1.0
- 1998-...: Revisions UML1.2 - 1.5
- 2005: Major revision to UML2.0, includes OCL


Class
Class Name
Class Name
attribute:Type = initialValue
operation(arg list):return type
Generalization
Supertype
discriminator
Subtype 1
Subtype 2
Constraint
{description of constraint}
Stereotype
«stereotype name»
Note
some useful text
Object
object name: Class Name
Association
Class A
role B
role A
Class B
Multiplicities
1
Class
exactly one
*
Class
many (zero or more)
0..1
Class
optional (zero or one)
m..n
Class
numerically specified
Class
aggregation
Class
composition
Class
{ordered}
*
ordered role
Qualified Association
Class
qualifier
Navigability
Source
role name
Target
Dependency
Class A
Class B
Class Diagram: Interfaces
Abstract Class
{abstract}
«interface»
Interface
dependency
Client Class
realization
Implementing Class
Interface Name
dependency
Client Class
Implementing Class
Class Diagram: Parameterized Class
template class
T
Set
bound element
Set<Integer>
Association Class
Class
Class
Association Class
Activity Diagram
start
Activity
fork
[condition]
[else]
branch
Dynamic Concurrent Activity
*
Activity
Activity
merge
join
end



UML Distilled

Roadmap



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- UML Lines and Arrows
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Class Diagrams

"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*

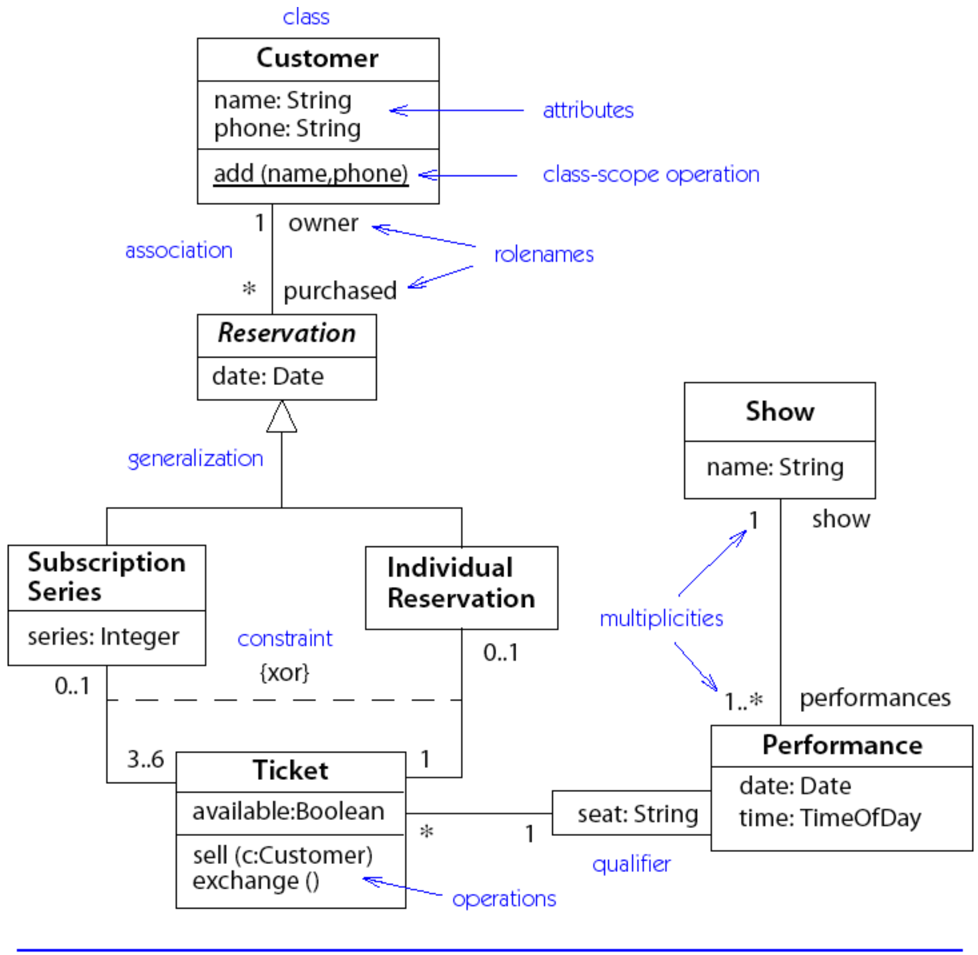
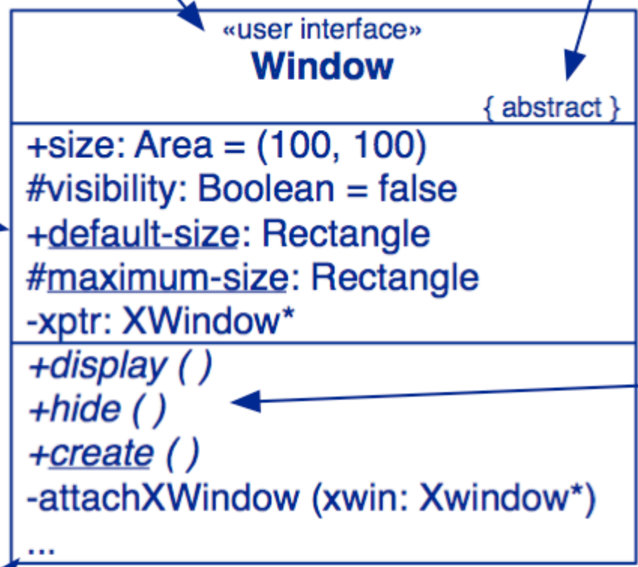


Figure 3-1. *Class diagram*

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

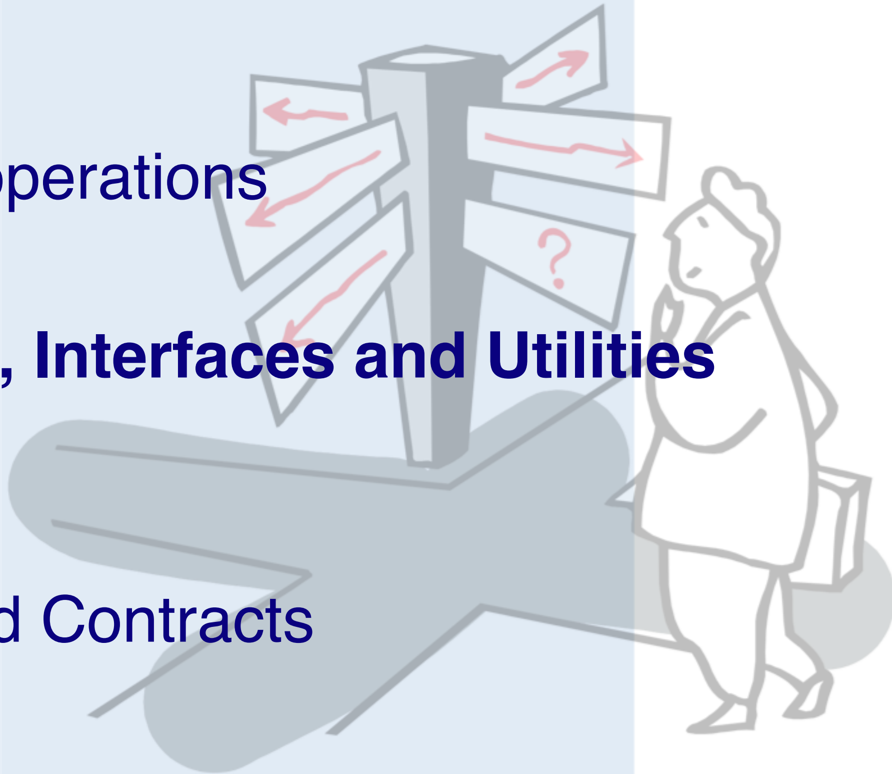
Realization
e.g., class/template, class/interface

"Generalization"
i.e., specialization (!)
e.g., class/superclass, concrete/abstract class

Aggregation
i.e., "consists of"

"Composition"
i.e., containment

Roadmap



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Parameterized Classes

Parameterized (aka “template” or “generic”) classes are depicted with their parameters shown in a *dashed box*.

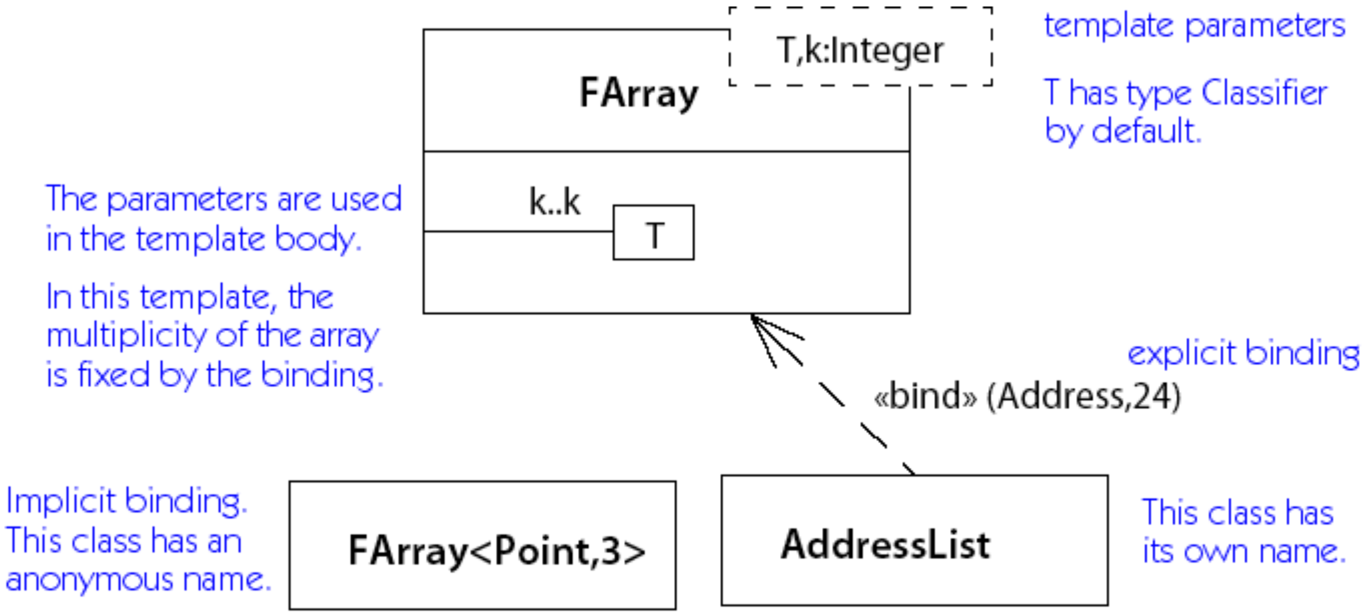


Figure 13-180. *Template notation with use of parameter as a reference*

Interfaces

Interfaces, equivalent to abstract classes with no attributes, are represented as classes with the stereotype «interface» or, alternatively, with the "Lollipop-Notation":

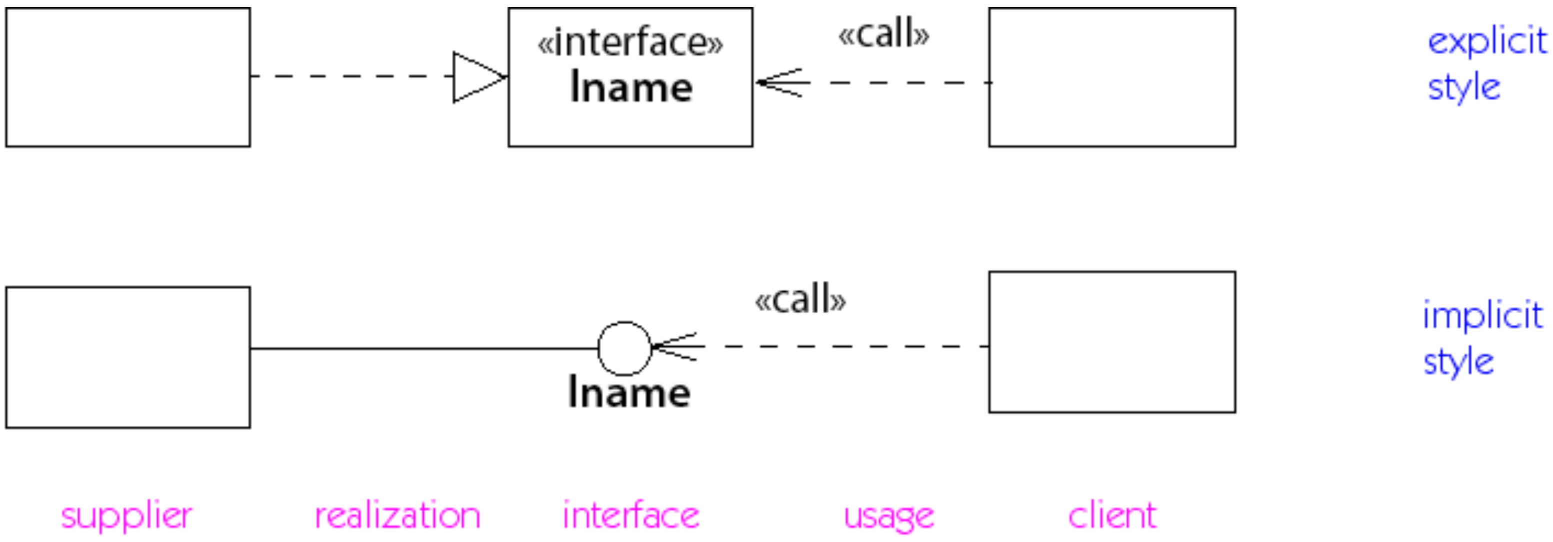
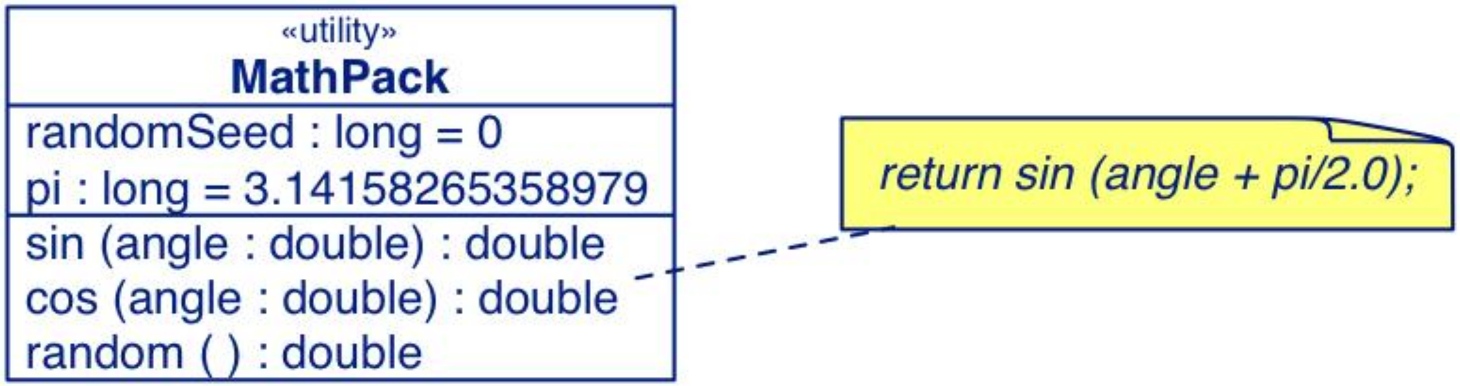


Figure B-5. *Realization of an interface*

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.



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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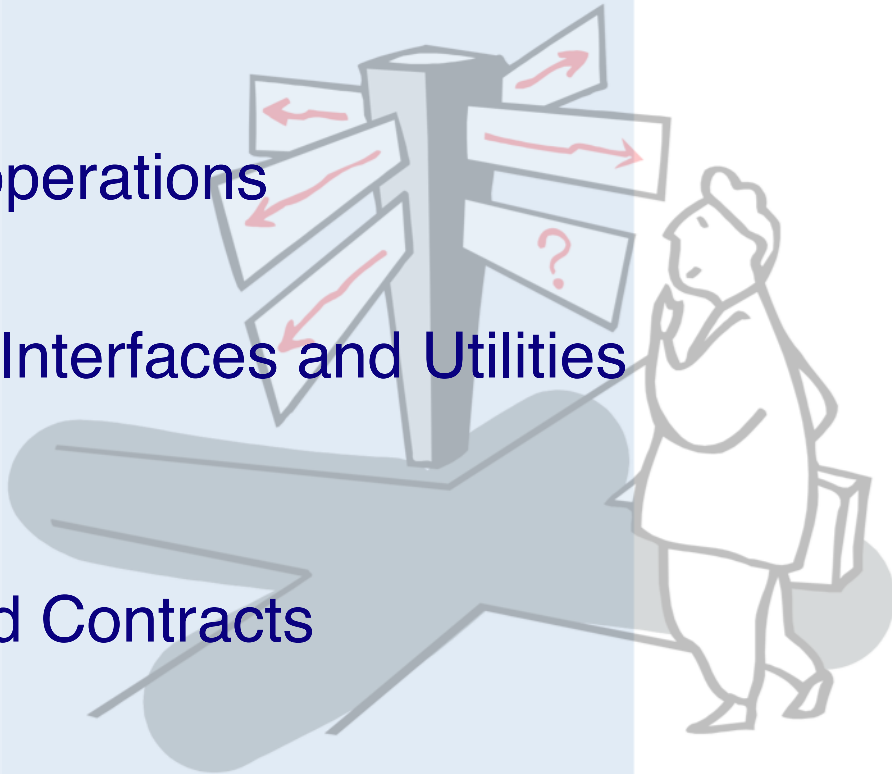


Objects

Objects are shown as rectangles with their name and type underlined in one compartment, and attribute values, optionally, in a second compartment.

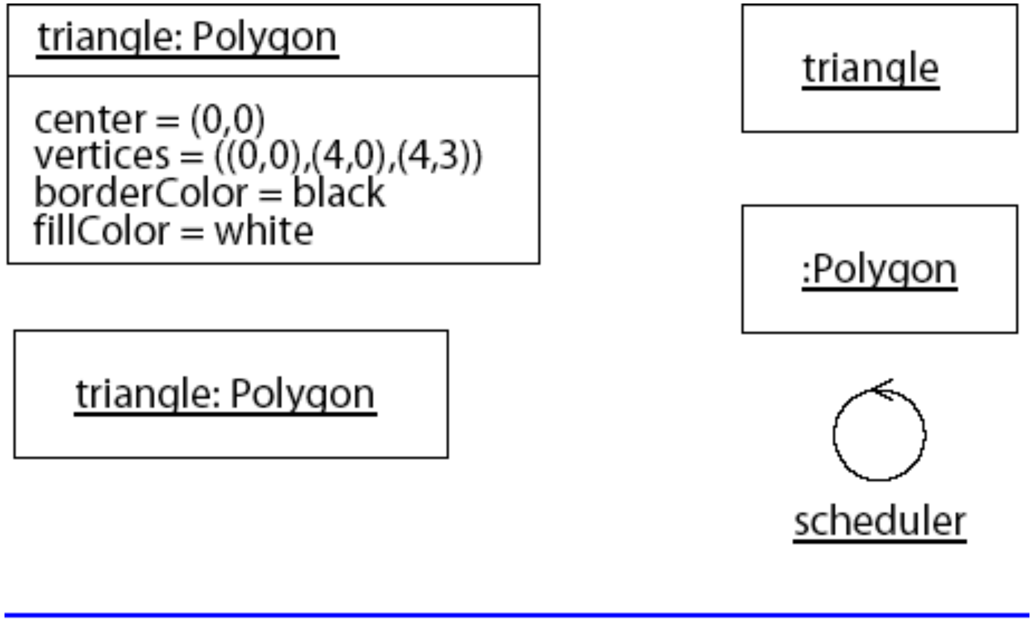


Figure 13-134. *Object notation*

At least one of the name or the type must be present.

Associations

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

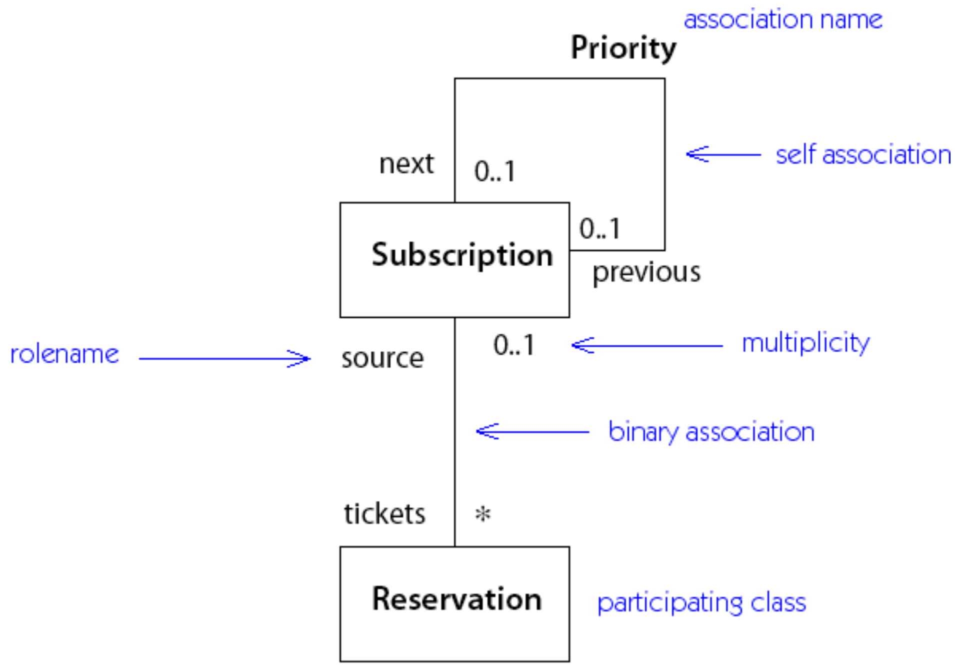


Figure 4-2. *Association notation*

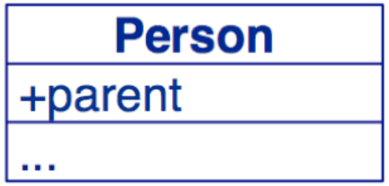
Multiplicity

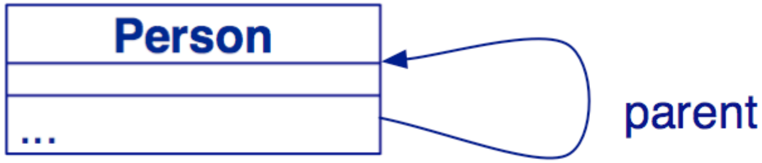
> The multiplicity of an association constrains how many entities one may be associated with
  - Examples:

0..1	Zero or one entity
1	Exactly one entity
*	Any number of entities
1..*	One or more entities
1..n	One to n entities
	And so on …

Associations and Attributes

> Associations may be implemented as attributes
  — But need not be …





Aggregation and Composition

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).

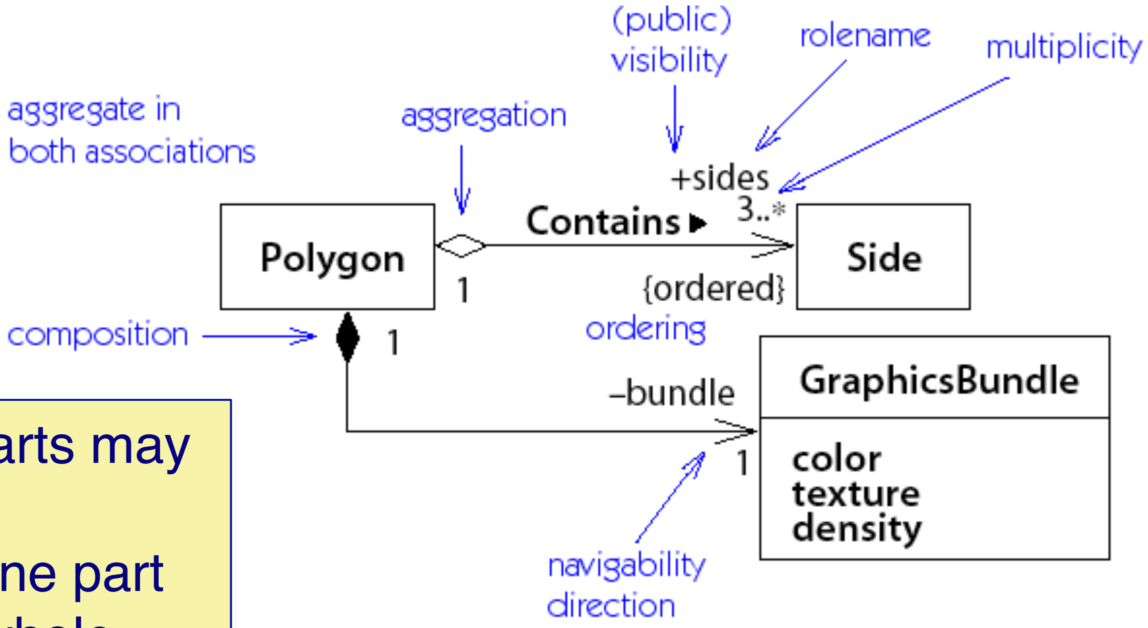


Figure 13-29. *Various adornments on association ends*

Aggregation: parts may be shared.
Composition: one part belongs to one whole.

Association Classes

An association may be an instance of an association class:

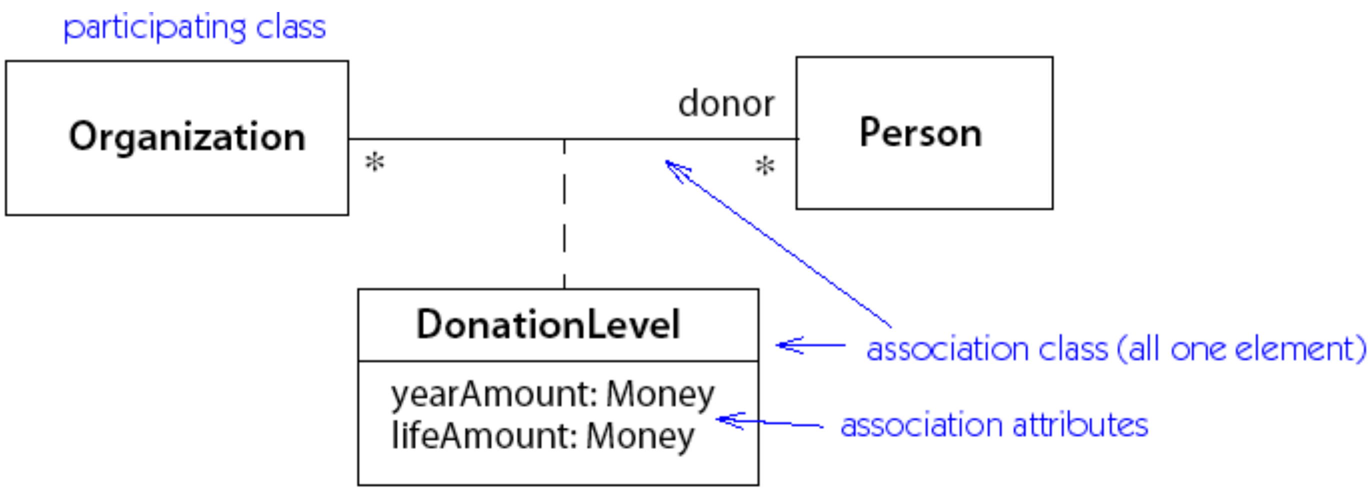


Figure 4-3. *Association class*

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

Qualified Associations

A <u>qualified association</u> 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

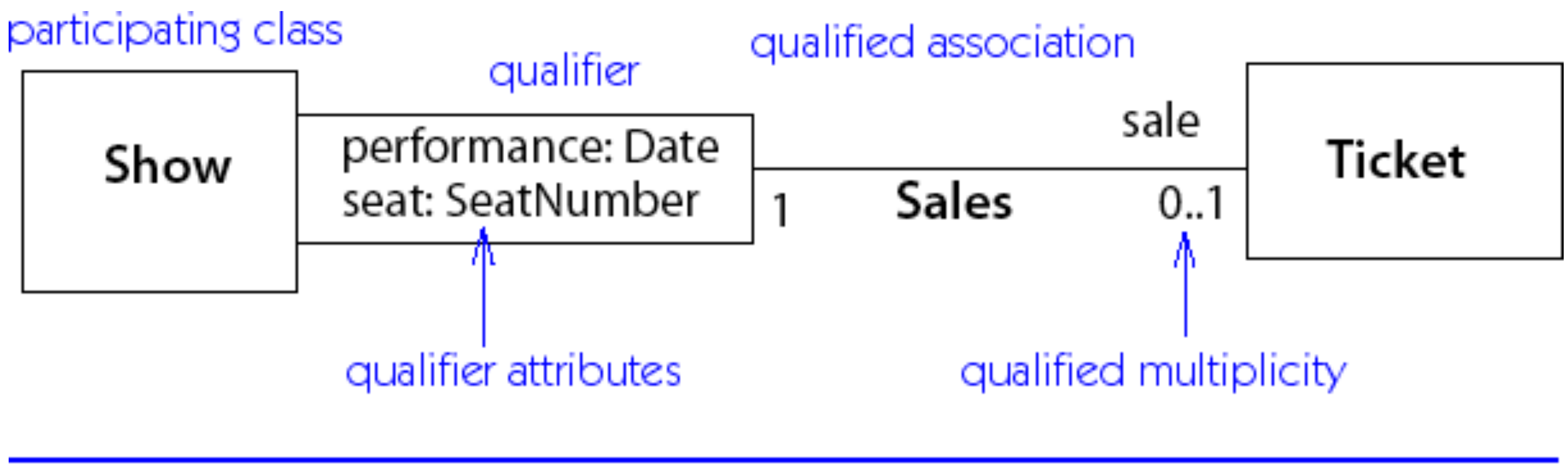
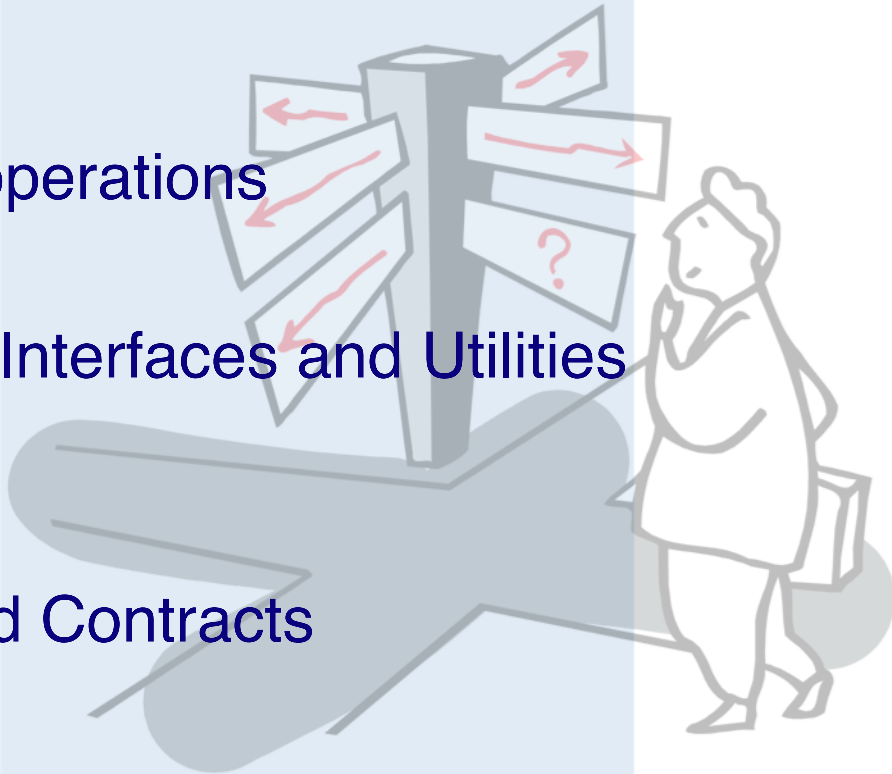


Figure 4-4. *Qualified association*

Roadmap



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Generalization

A <u>subclass</u> specializes its superclass:

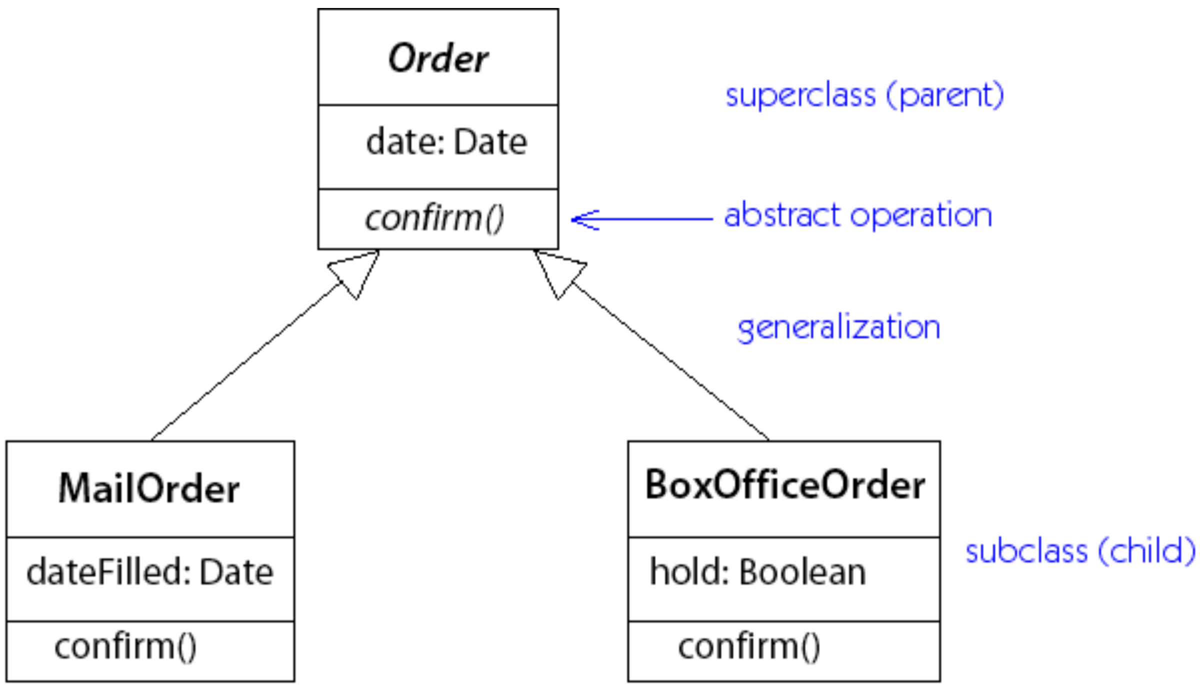


Figure 4-7. *Generalization notation*

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 ...

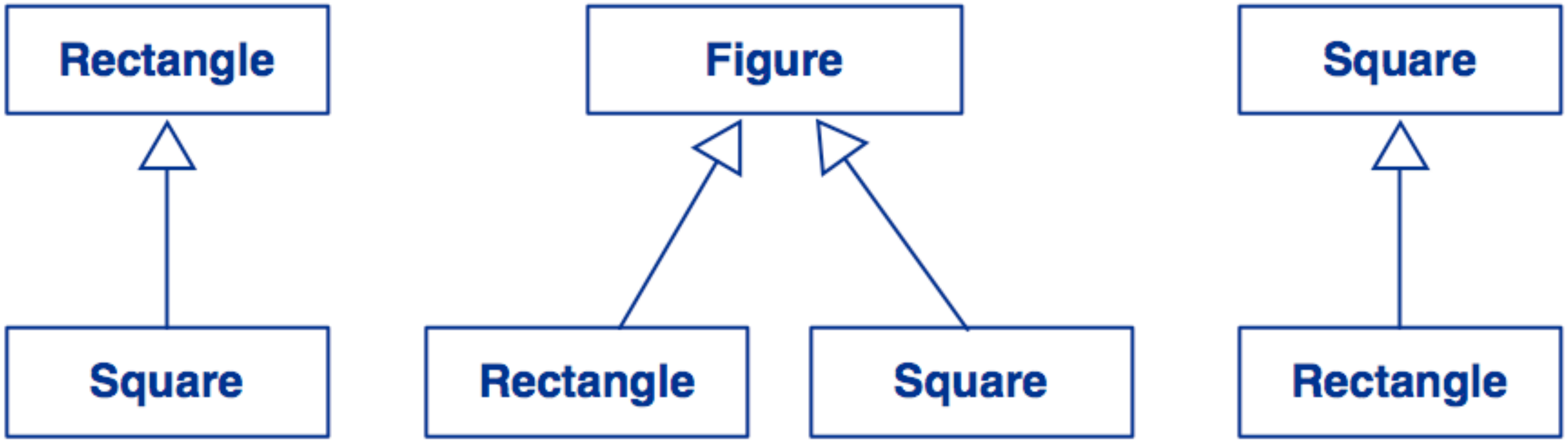
Polymorphism:

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

Software reuse:

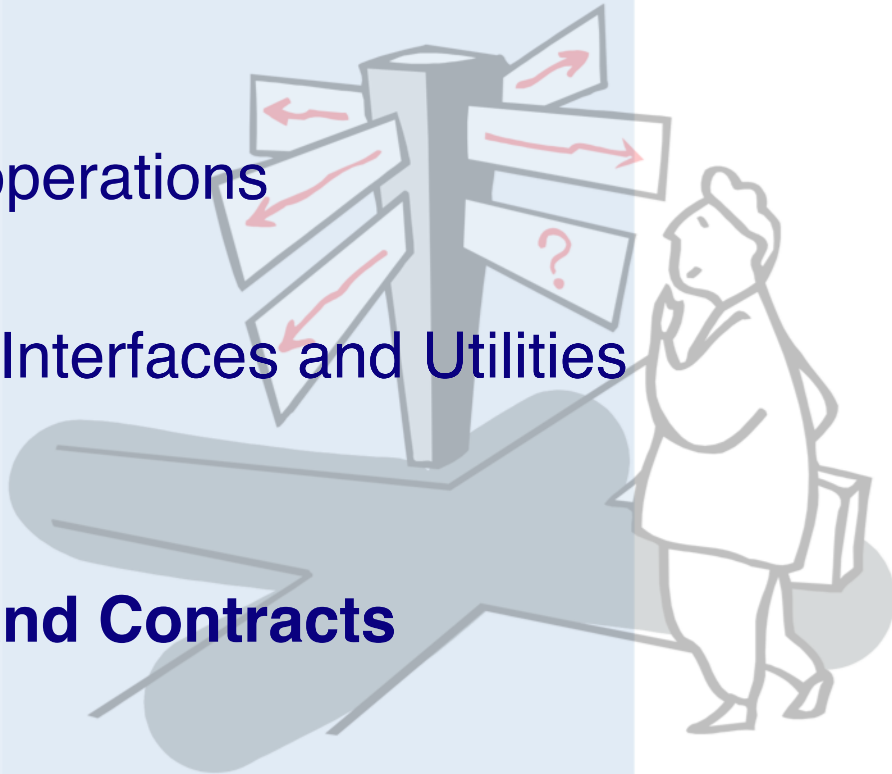
- related classes may *share* interfaces, data structures or behaviour
  - — geometric objects ...

The different faces of inheritance



Is-a *Polymorphism* *Reuse*

Roadmap



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Design Patterns as Collaborations

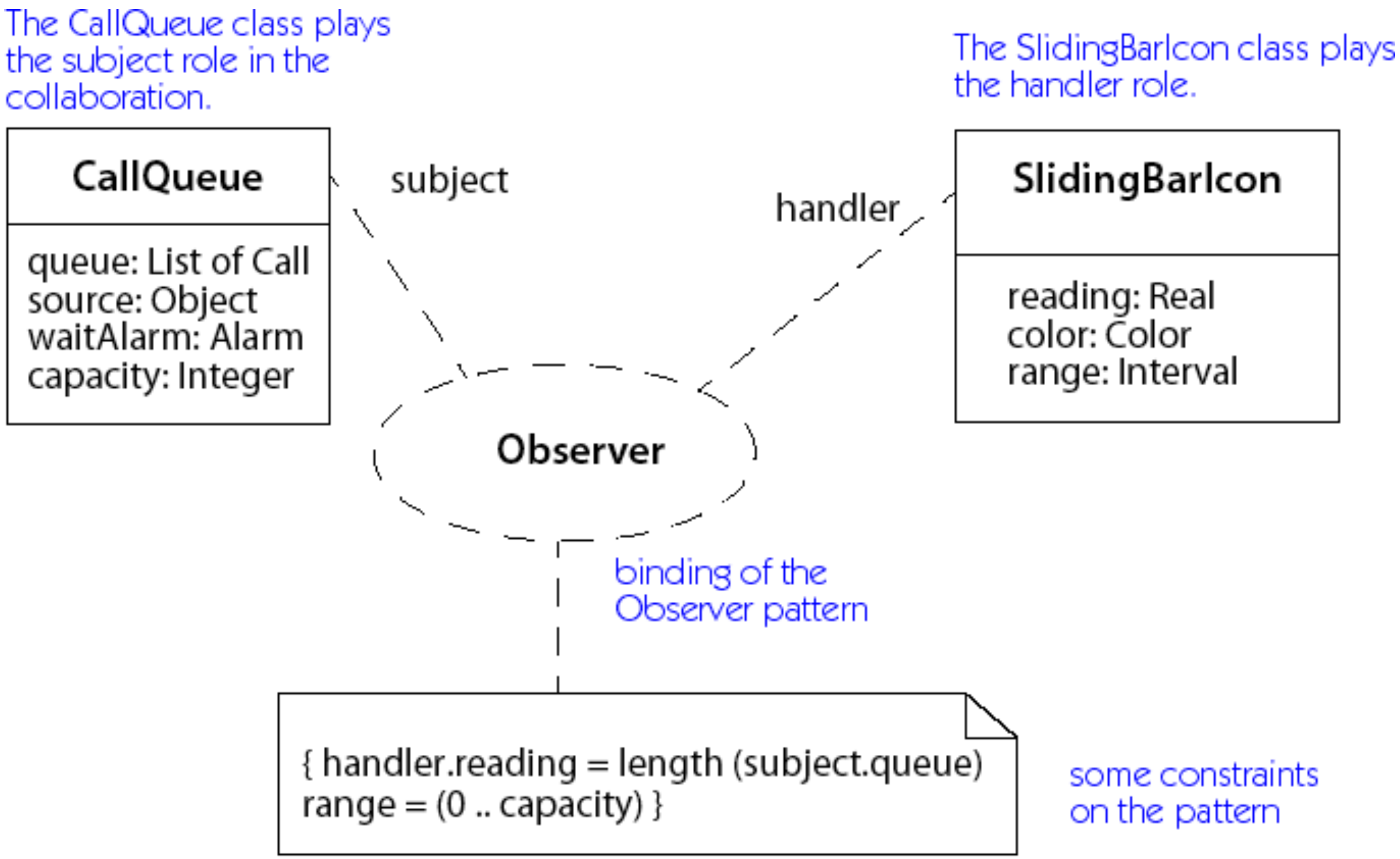

Figure 13-144. *Binding of a pattern to make a collaboration*

Constraints

Constraints are *restrictions* on values attached to classes or associations.

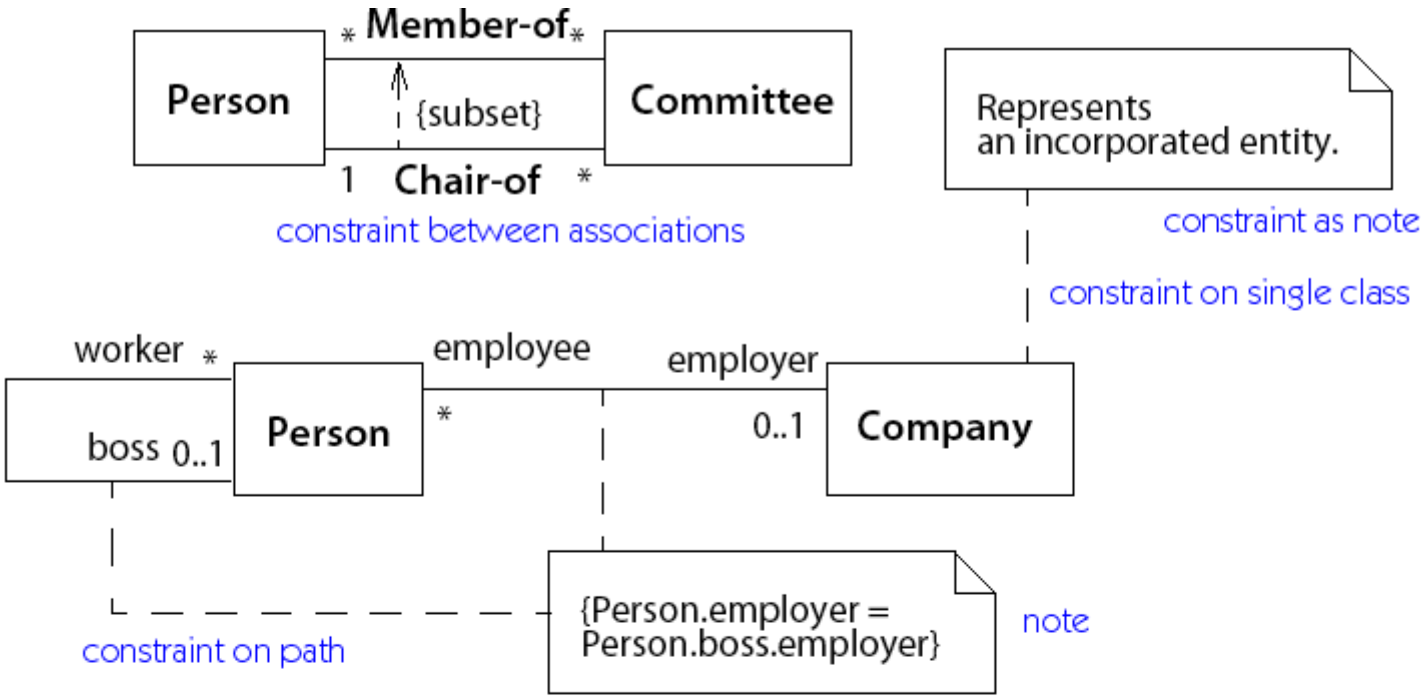

Figure 4-12. *Constraints*

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*

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Design by Contract in UML

Combine constraints with stereotypes:

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

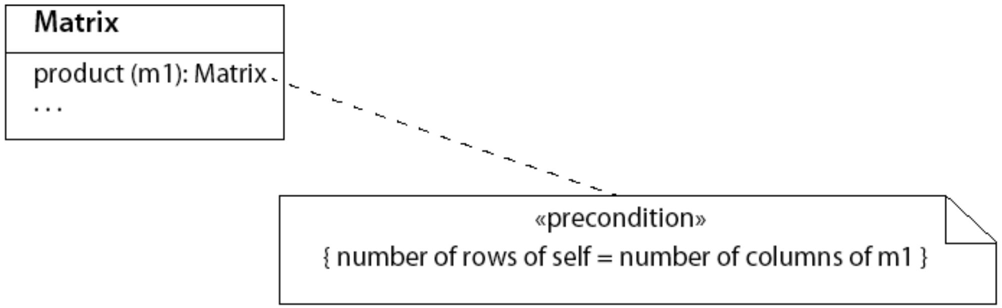

Figure 13-147. *Precondition*

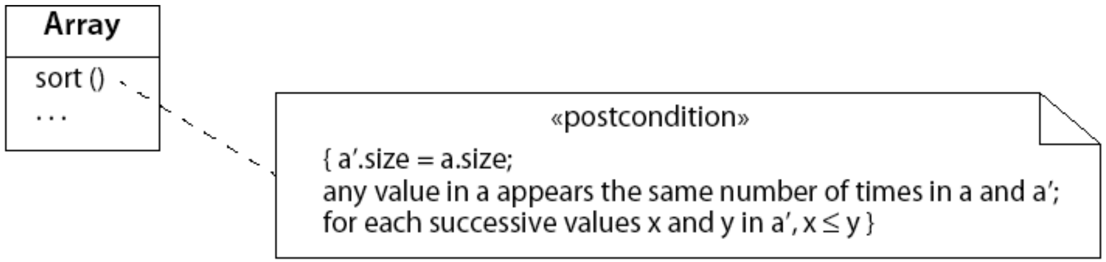

Figure 13-145. *Postcondition*

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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