

Object Modeling with OMG UML Tutorial Series

# Introduction to UML: Structural Modeling and Use Cases

Cris Kobryn

Co-Chair UML Revision Task Force  
November 2000



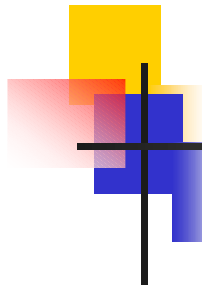
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# Overview

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- Tutorial series
- Quick tour
- Structural modeling
- Use case modeling



# Tutorial Series

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- Lecture 1: Introduction to UML: Structural Modeling and Use Cases
- Lecture 2: Behavioral Modeling with UML
- Lecture 3: Advanced Modeling with UML
- Lecture 4: Metadata Integration with UML, MOF and XMI



# Tutorial Goals

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- What you will learn:

- what the UML is and what is it not
- UML's basic constructs, rules and diagram techniques
- how the UML can model large, complex systems
- how the UML can specify systems in an implementation-independent manner
- how UML, XMI and MOF can facilitate metadata integration

- What you will not learn:

- Object Modeling 101
- object methods or processes
- Metamodeling 101



# Quick Tour

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- Why do we model?
- What is the UML?
- Foundation elements
- Unifying concepts
- Language architecture
- Relation to other OMG technologies



# Why do we model?

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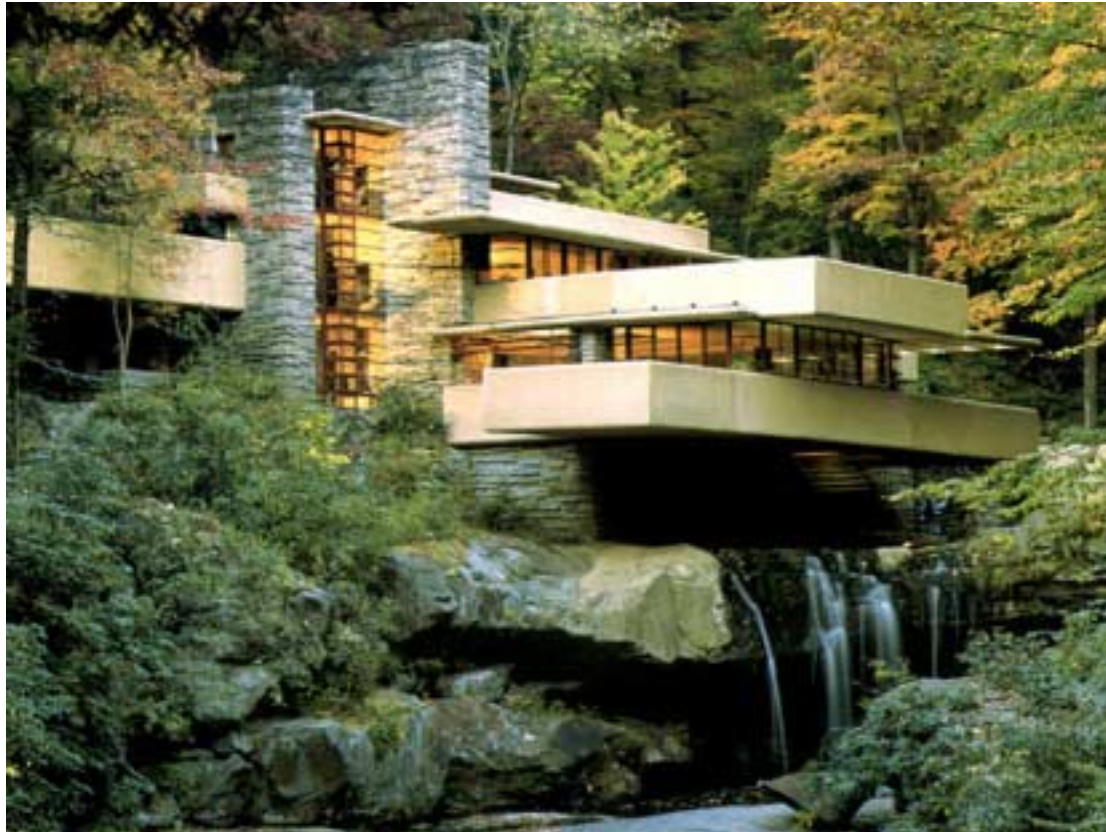
- Provide structure for problem solving
- Experiment to explore multiple solutions
- Furnish abstractions to manage complexity
- Reduce time-to-market for business problem solutions
- Decrease development costs
- Manage the risk of mistakes

# The Challenge



Tijuana “shantytown”:  
<http://www.maclester.edu/~jschatz/residential.html>

# The Vision



Fallingwater:

<http://www.adelaide.net.au/~jpolias/FLW/Images/FallingWater.jpeg>





# Why do we model graphically?

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- Graphics reveal data.

- Edward Tufte

- The Visual Display of Quantitative Information,*  
1983

- 1 bitmap = 1 megaword.

- Anonymous visual modeler



# Quick Tour

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- The UML is a graphical language for
  - specifying
  - visualizing
  - constructing
  - documentingthe artifacts of software systems
- Added to the list of OMG adopted technologies in November 1997 as UML 1.1
- Most recent minor revision is UML 1.3, adopted in November 1999



# UML Goals

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- Define an easy-to-learn but semantically rich visual modeling language
- Unify the Booch, OMT, and Objectory modeling languages
- Include ideas from other modeling languages
- Incorporate industry best practices
- Address contemporary software development issues
  - scale, distribution, concurrency, executability, etc.
- Provide flexibility for applying different processes
- Enable model interchange and define repository interfaces

# OMG UML Evolution

2002  
(planned major revision)

2001  
(planned minor revision)

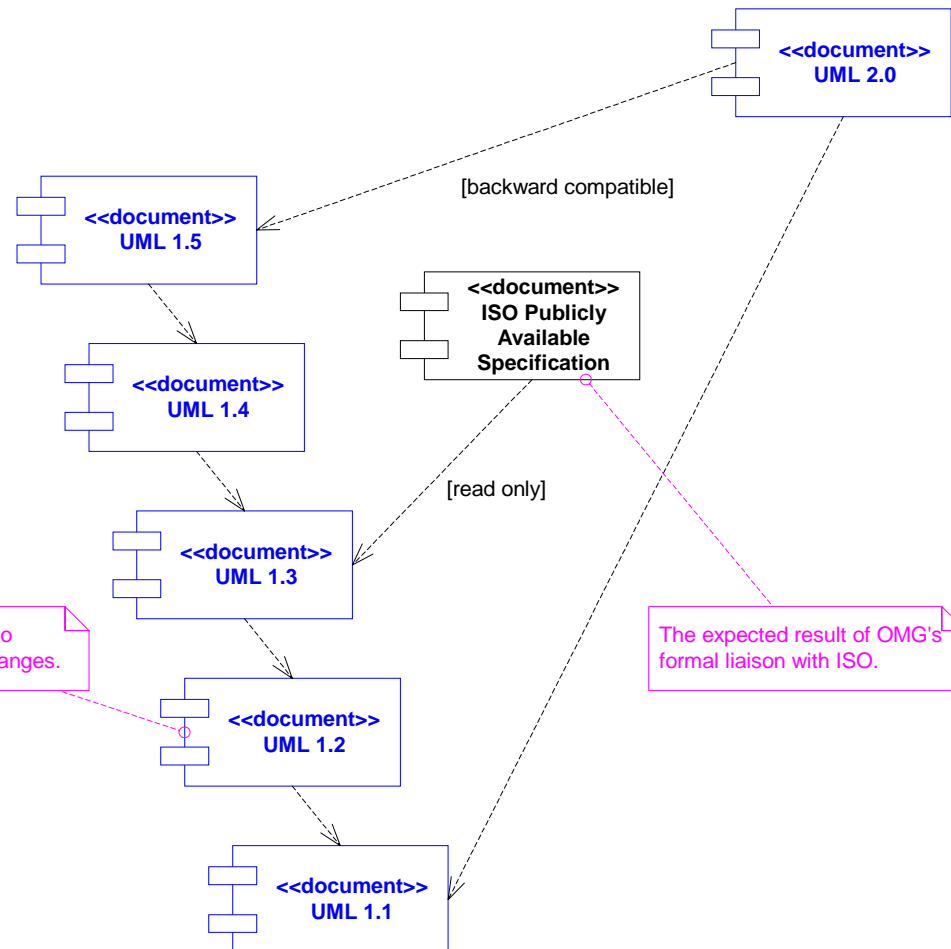
Q4 2000  
(planned minor revision)

1999

Editorial revision with no  
significant technical changes.

1998

1997  
(adopted by OMG)





# OMG UML Contributors

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Aonix

Colorado State University

Computer Associates

Concept Five

Data Access

EDS

Enea Data

Hewlett-Packard

IBM

I-Logix

InLine Software

Intellicorp

Kabira Technologies

Klasse Objecten

Lockheed Martin

Microsoft

ObjecTime

Oracle

Ptech

OAQ Technology Solutions

Rational Software

Reich

SAP

Softeam

Sterling Software

Sun

Taskon

Telelogic

Unisys

...



# OMG UML 1.3 Specification

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- UML Summary
- UML Semantics
- UML Notation Guide
- UML Standard Profiles
  - Software Development Processes
  - Business Modeling
- UML CORBAfacility Interface Definition
- UML XML Metadata Interchange DTD
- Object Constraint Language



# Tutorial Focus: the Language

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- language = syntax + semantics
  - syntax = rules by which language elements (e.g., words) are assembled into expressions (e.g., phrases, clauses)
  - semantics = rules by which syntactic expressions are assigned meanings
- *UML Notation Guide* – defines UML's graphic syntax
- *UML Semantics* – defines UML's semantics



# Foundation Concepts

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- Building blocks
- Well-formedness rules



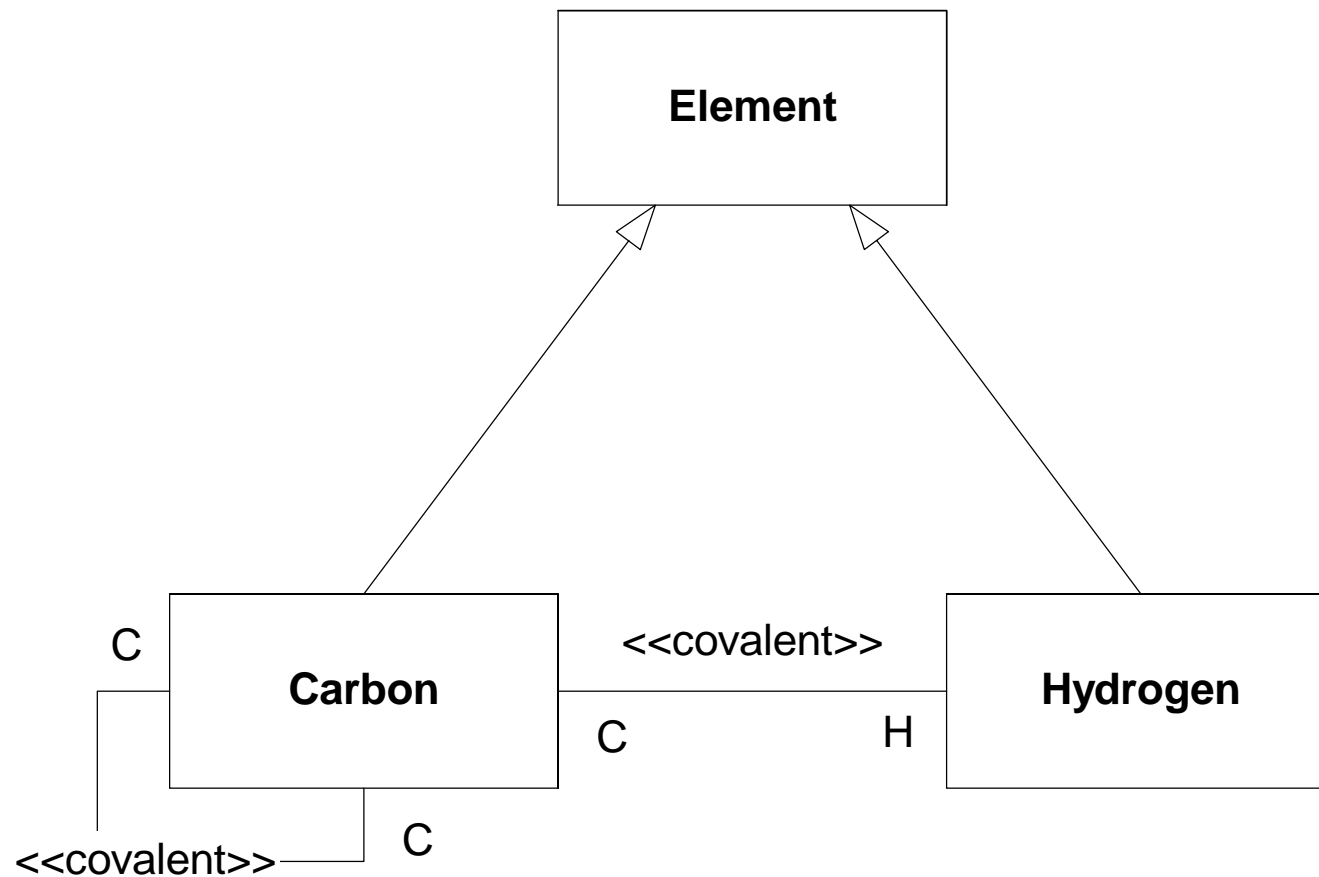


# Building Blocks

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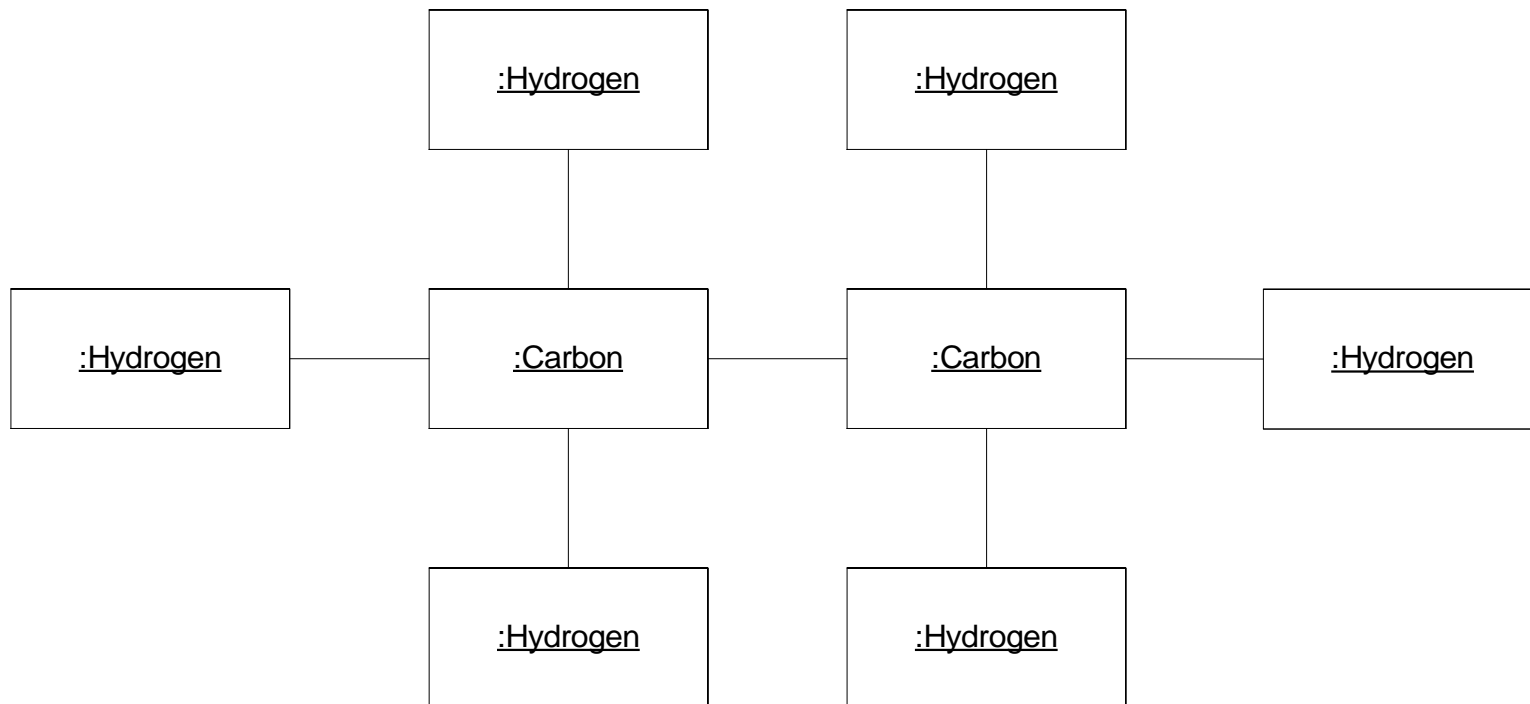
- The basic building blocks of UML are:
- model elements (classes, interfaces, components, use cases, etc.)
  - relationships (associations, generalization, dependencies, etc.)
  - diagrams (class diagrams, use case diagrams, interaction diagrams, etc.)
  - Simple building blocks are used to create large, complex structures
    - cf. elements, bonds and molecules in chemistry
    - cf. components, connectors and circuit boards in hardware

# Diagram: Classifier View





# Diagram: Instance View





# Well-Formedness Rules

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- Well-formed: indicates that a model or model fragment adheres to all semantic and syntactic rules that apply to it.
- UML specifies rules for:
  - naming
  - scoping
  - visibility
  - integrity
  - execution (limited)
- However, during iterative, incremental development it is expected that models will be incomplete and inconsistent.



## Well-Formedness Rules (cont'd)

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- Example of semantic rule: Class [1]

- **English:** If a Class is concrete, all the Operations of the Class should have a realizing Method in the full descriptor.
- **OCL:** `not self.isAbstract implies  
self.allOperations->  
forAll (op | self.allMethods->  
exists (m | m.specification->  
includes(op)))`



## Well-Formedness Rules (cont'd)

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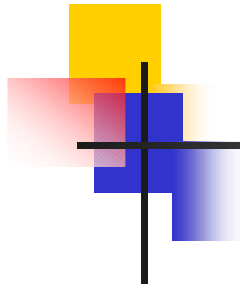
- Example of syntactic rules: Class
  - **Basic Notation:** A class is drawn as a solid-outline rectangle with three compartments separated by horizontal lines.
  - **Presentation Option:** Either or both of the attribute and operation compartments may be suppressed.
- Example of syntactic guideline: Class
  - **Style Guideline:** Begin class names with an uppercase letter.



# Unifying Concepts

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- classifier-instance dichotomy
  - e.g., an object is an instance of a class OR a class is the classifier of an object
- specification-realization dichotomy
  - e.g., an interface is a specification of a class OR a class is a realization of an interface
- analysis-time vs. design-time vs. run-time
  - modeling phases ("process creep")
  - usage guidelines suggested, not enforced



# Language Architecture

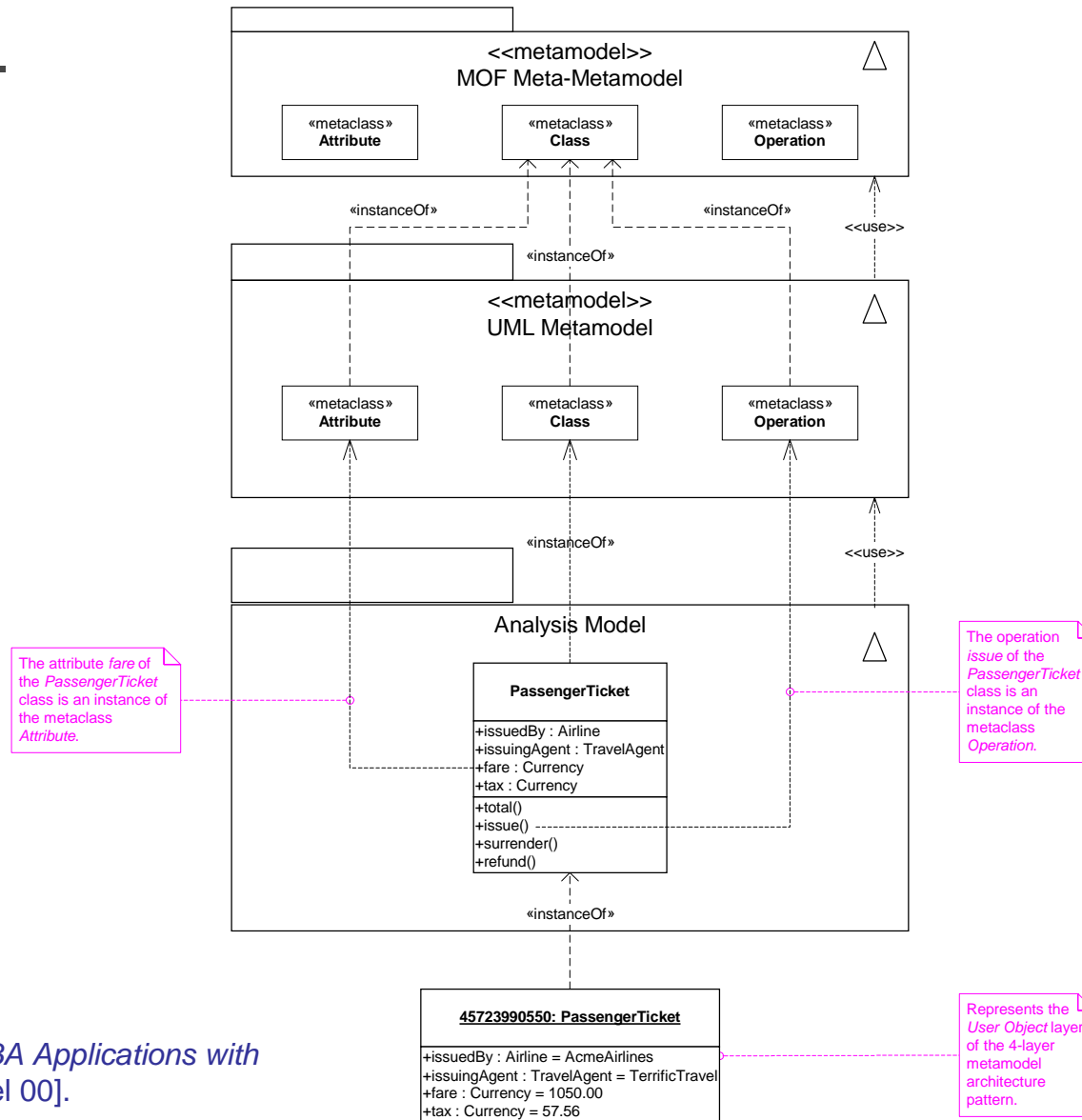
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- Metamodel architecture
- Package structure

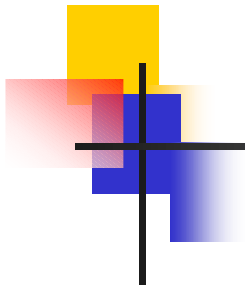




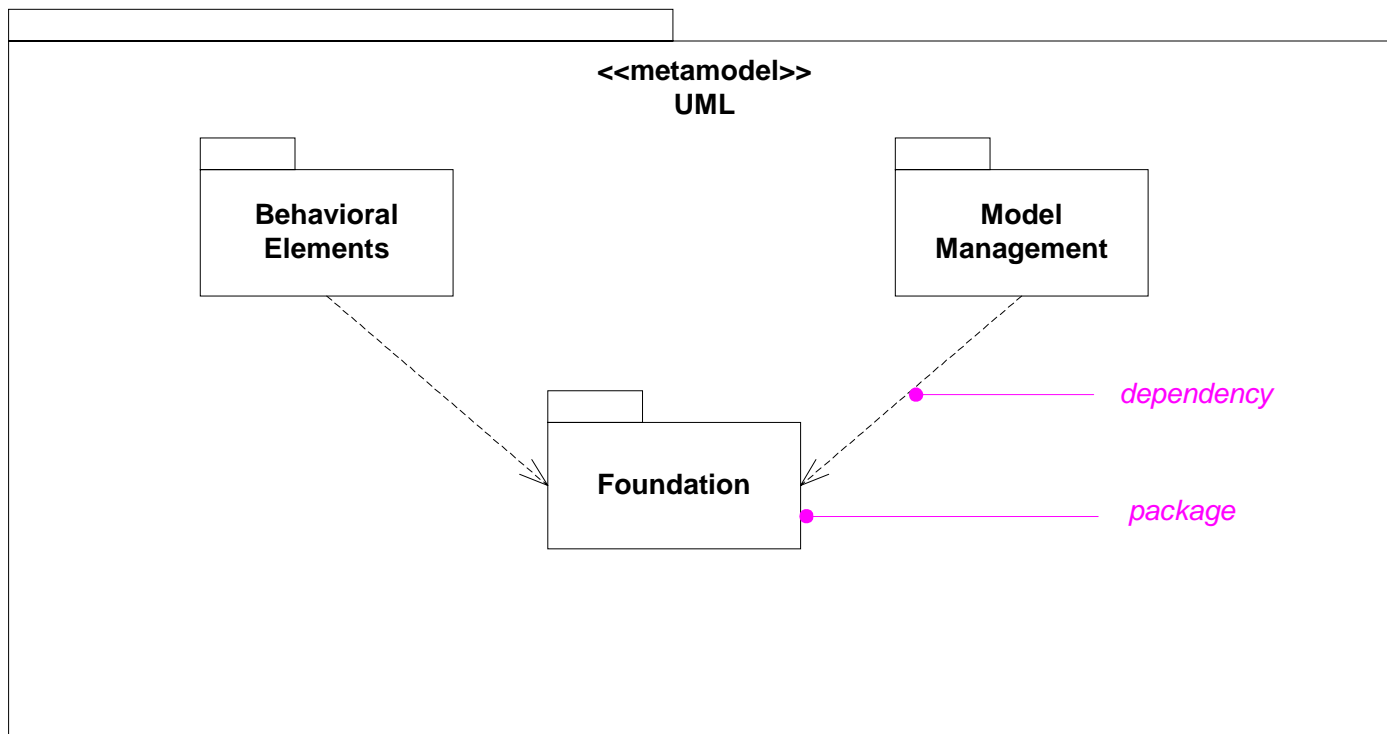
# Metamodel Architecture



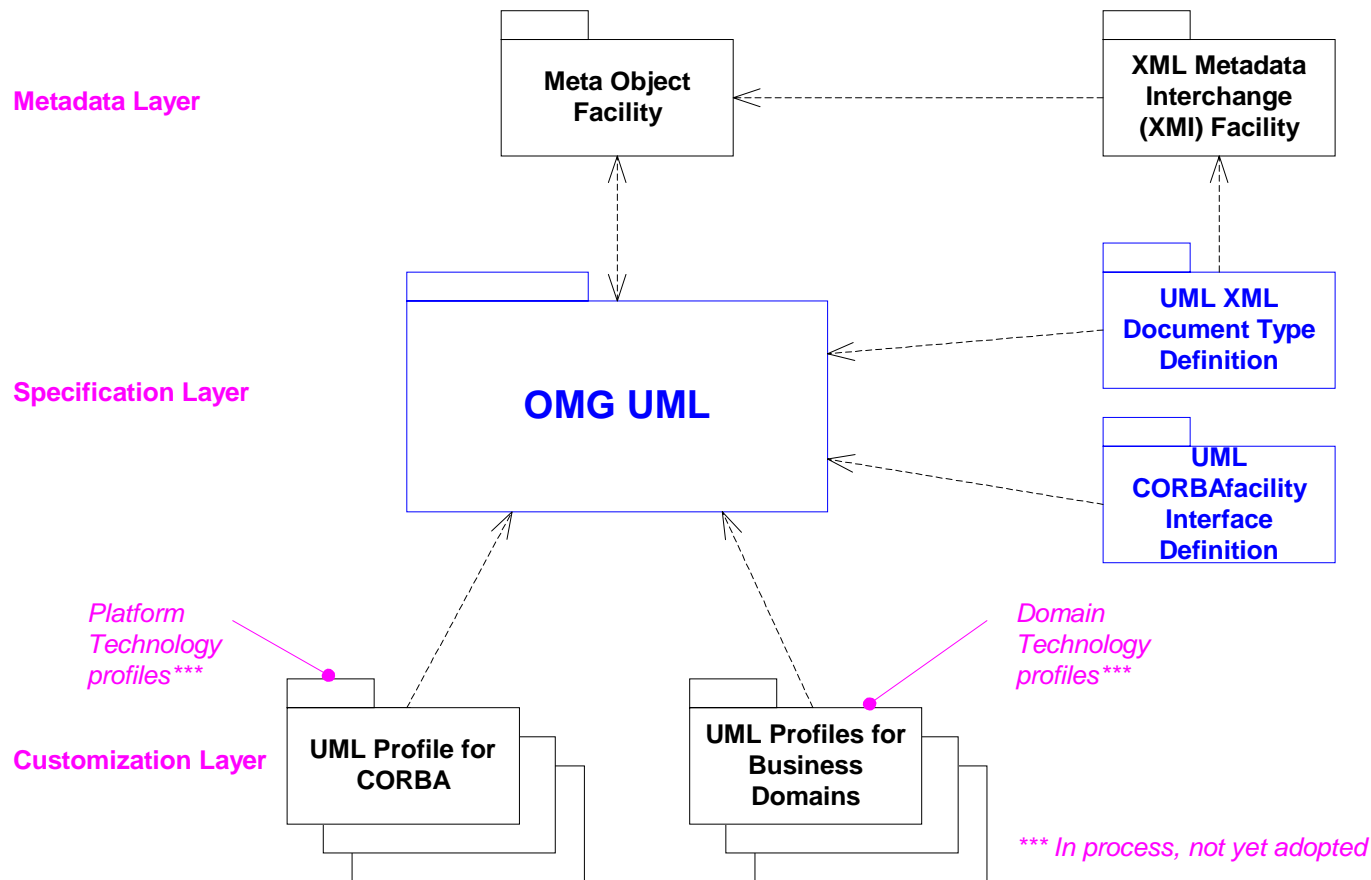
From *Modeling CORBA Applications with UML* chapter in [Siegel 00].



# Package Structure



# Relation to Other OMG Technologies





# Structural Modeling

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- What is structural modeling?
- Core concepts
- Diagram tour
- When to model structure
- Modeling tips
- Example: Interface-based design

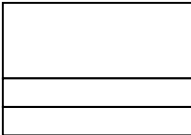


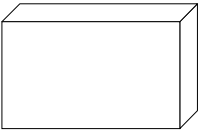


## What is structural modeling?

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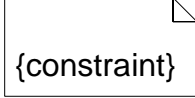
- Structural model: a view of an system that emphasizes the structure of the objects, including their classifiers, relationships, attributes and operations.

## *Structural Modeling: Core Elements*

<b>Construct</b>	<b>Description</b>	<b>Syntax</b>
<b>class</b>	a description of a set of objects that share the same attributes, operations, methods, relationships and semantics.	 A rectangular box divided into three horizontal compartments: the top compartment is for the class name, the middle for attributes, and the bottom for operations.
<b>interface</b>	a named set of operations that characterize the behavior of an element.	 A rectangular box with the stereotype «interface» in the top-left corner. A small circle is located at the top-left corner of the box, and a horizontal line extends from it to the left.
<b>component</b>	a physical, replaceable part of a system that packages implementation and provides the realization of a set of interfaces.	 A rectangular box with two small rectangular ports on its left side, representing provided and required interfaces.
<b>node</b>	a run-time physical object that represents a computational resource.	 A three-dimensional rectangular box representing a physical node or computational resource.



## *Structural Modeling: Core Elements* (cont'd)

Construct	Description	Syntax
<b>constraint</b> <sup>1</sup>	a semantic condition or restriction.	

<sup>1</sup> An extension mechanism useful for specifying structural elements.


## Structural Modeling: Core Relationships

Construct	Description	Syntax
<b>association</b>	a relationship between two or more classifiers that involves connections among their instances.	_____
<b>aggregation</b>	A special form of association that specifies a whole-part relationship between the aggregate (whole) and the component part.	_____◇
<b>generalization</b>	a taxonomic relationship between a more general and a more specific element.	_____▷
<b>dependency</b>	a relationship between two modeling elements, in which a change to one modeling element (the independent element) will affect the other modeling element (the dependent element).	----->





## *Structural Modeling: Core Relationships* (cont'd)

<b>Construct</b>	<b>Description</b>	<b>Syntax</b>
<b>realization</b>	a relationship between a specification and its implementation.	



# Structural Diagram Tour

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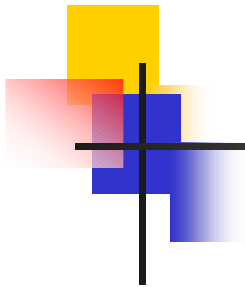
- Show the static structure of the model
  - the entities that exist (e.g., classes, interfaces, components, nodes)
  - internal structure
  - relationship to other entities
- Do not show
  - temporal information
- Kinds
  - static structural diagrams
    - class diagram
    - object diagram
  - implementation diagrams
    - component diagram
    - deployment diagram



# Static Structural Diagrams

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- Shows a graph of classifier elements connected by static relationships.
- kinds
  - class diagram: classifier view
  - object diagram: instance view



# Classes

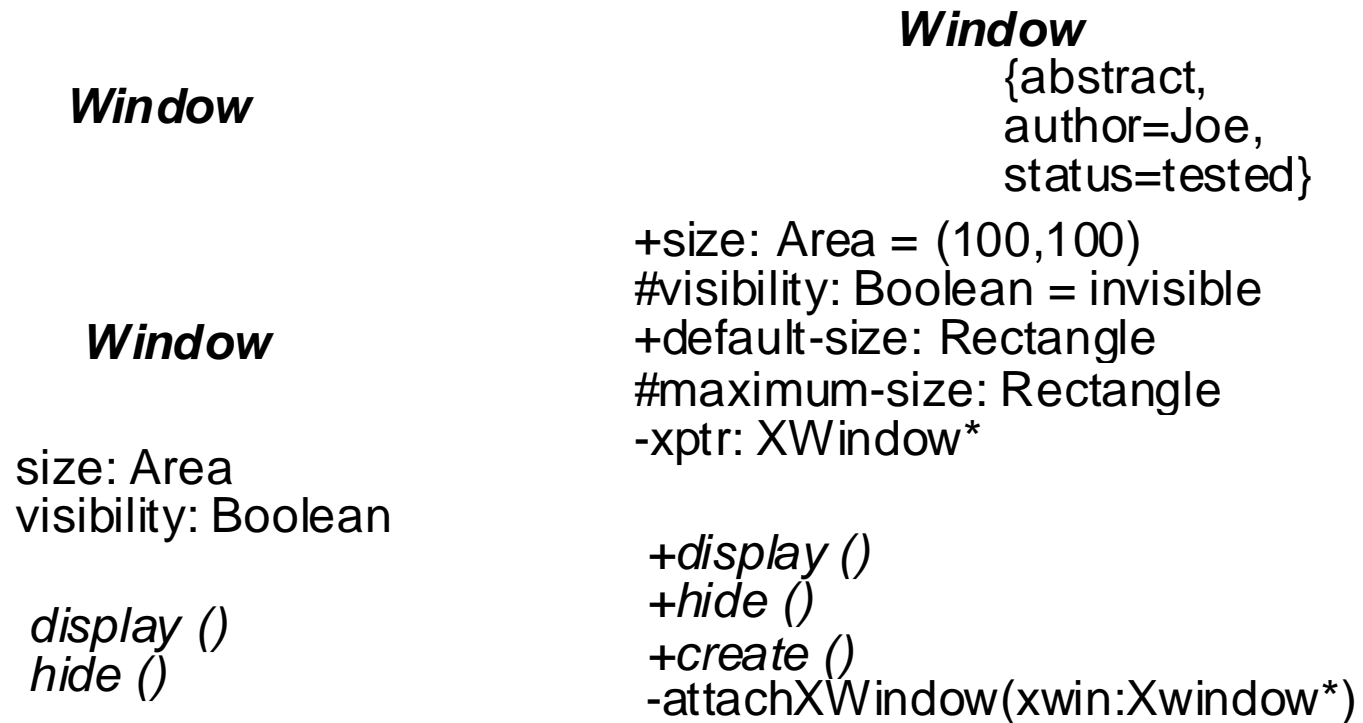


Fig. 3-17, UML Notation Guide



# Classes: compartments with names

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## **Reservation**

### **operations**

guarantee()  
cancel ()  
change (newDate: Date)

### **responsibilities**

bill no-shows  
match to available rooms

### **exceptions**

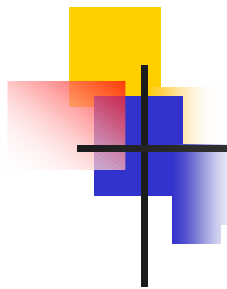
invalid credit card

Fig. 3-20, *UML Notation Guide*

\*

```
report () — — — — — { if isTripped  
                        then station.alert(self)}
```

# Introduction to UML



# Interfaces

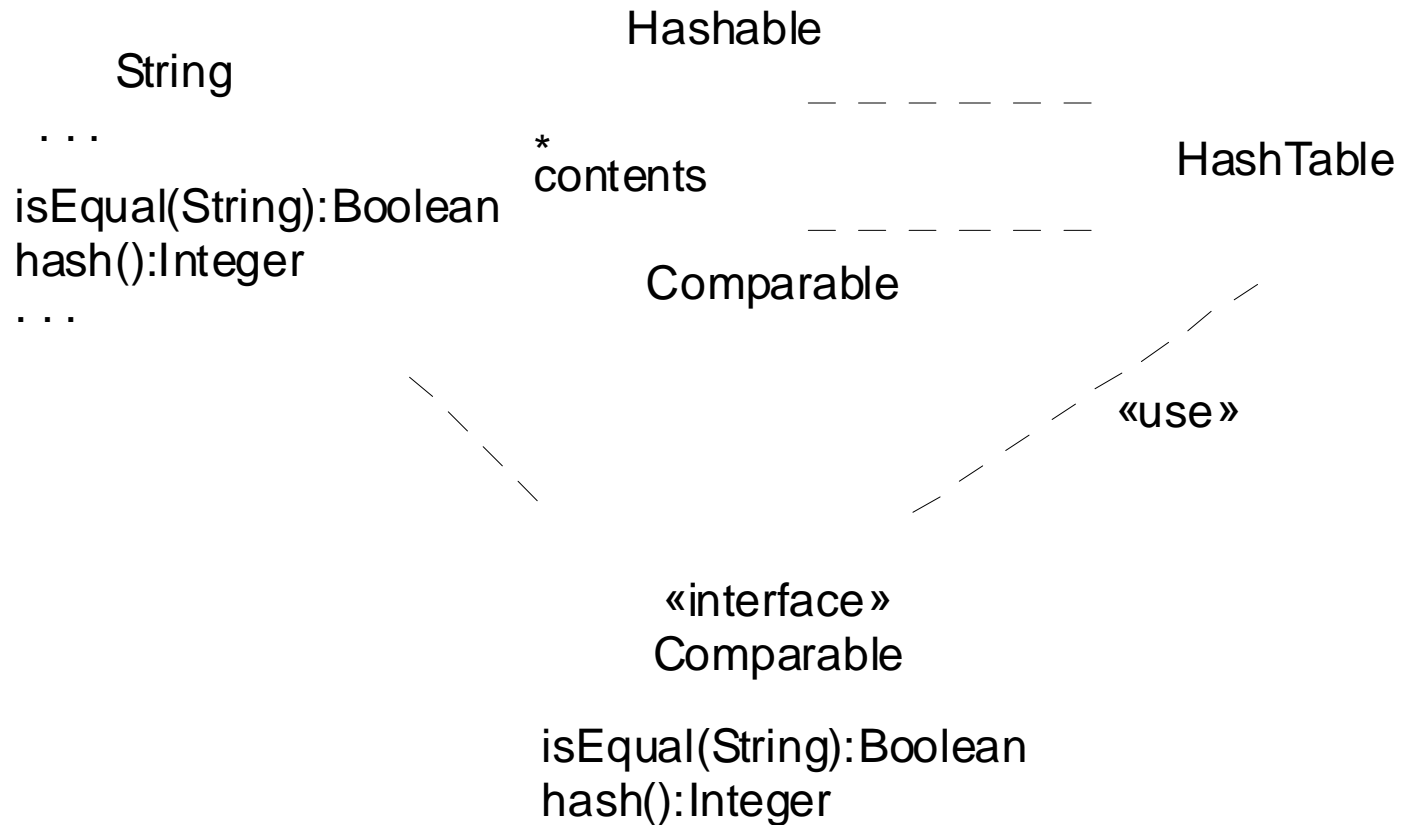


Fig. 3-24, *UML Notation Guide*

# Associations

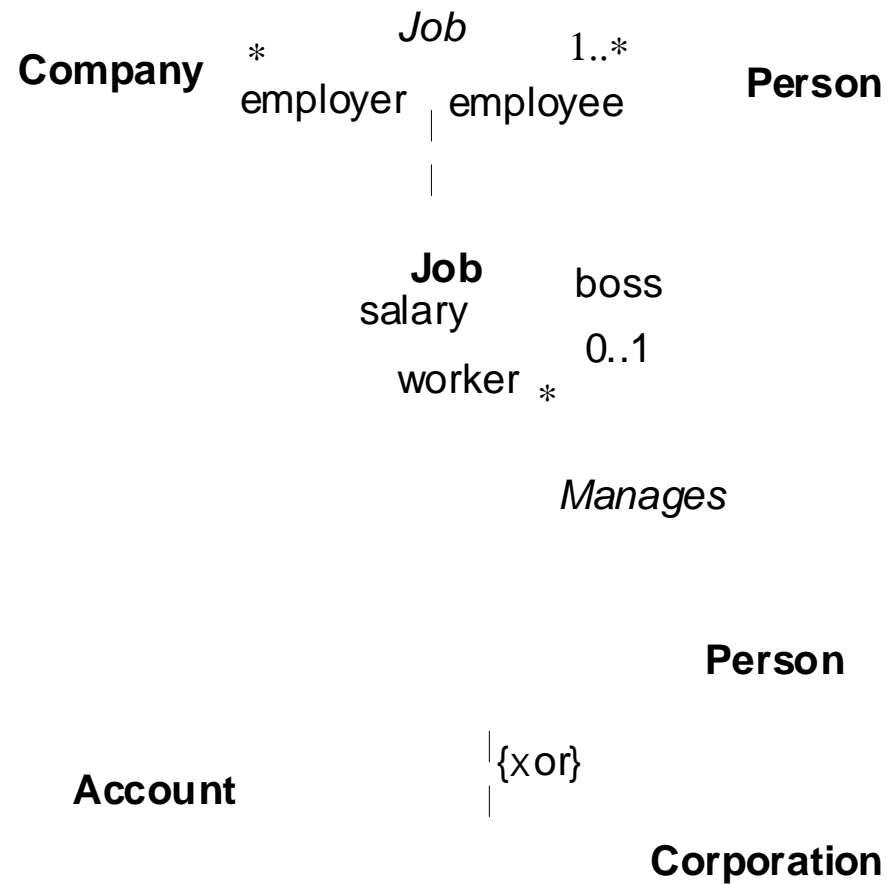
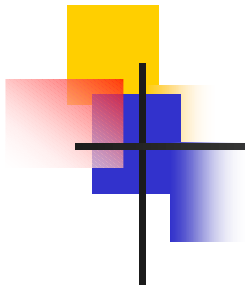


Fig. 3-31, *UML Notation Guide*





# Association Ends

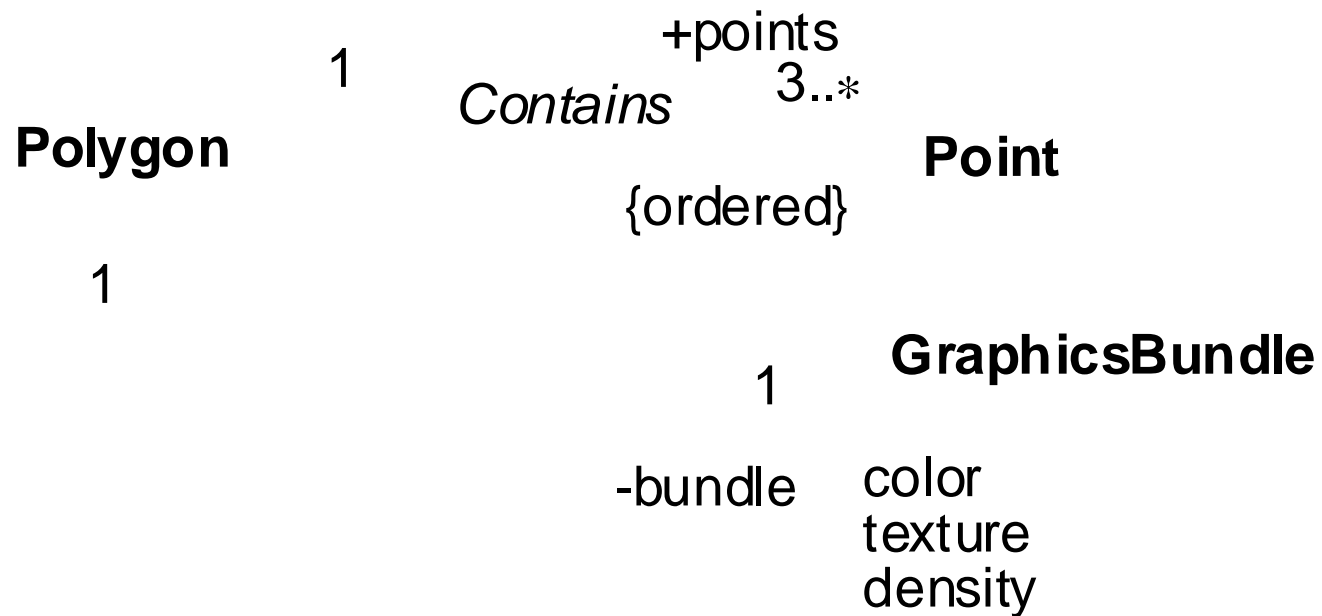
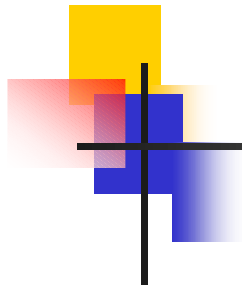


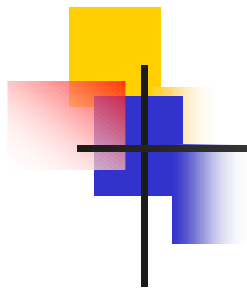
Fig. 3-32, *UML Notation Guide*



# Ternary Associations



Fig. 3-31, *UML Notation Guide*



# Composition

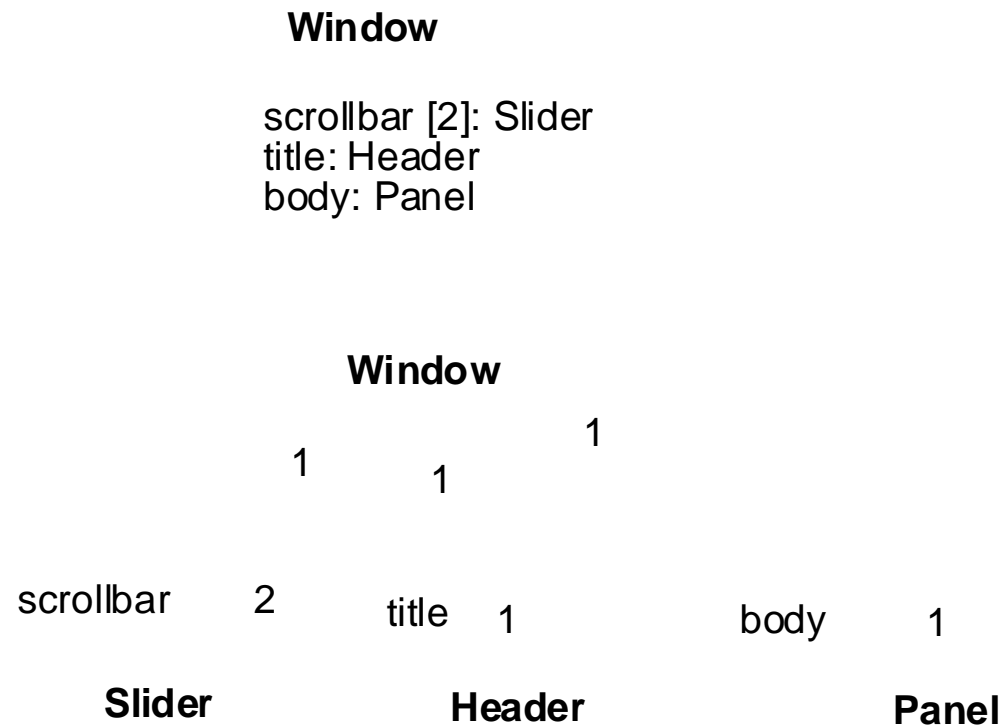
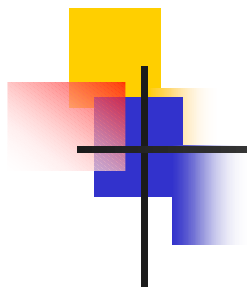


Fig. 3-36, *UML Notation Guide*



# Composition

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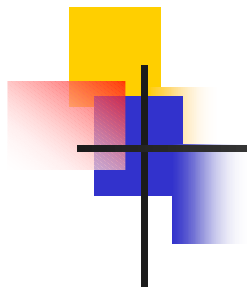
## Window

scrollbar:Slider 2

title:Header 1

body:Panel 1

Fig. 3-36, *UML Notation Guide*



# Generalization

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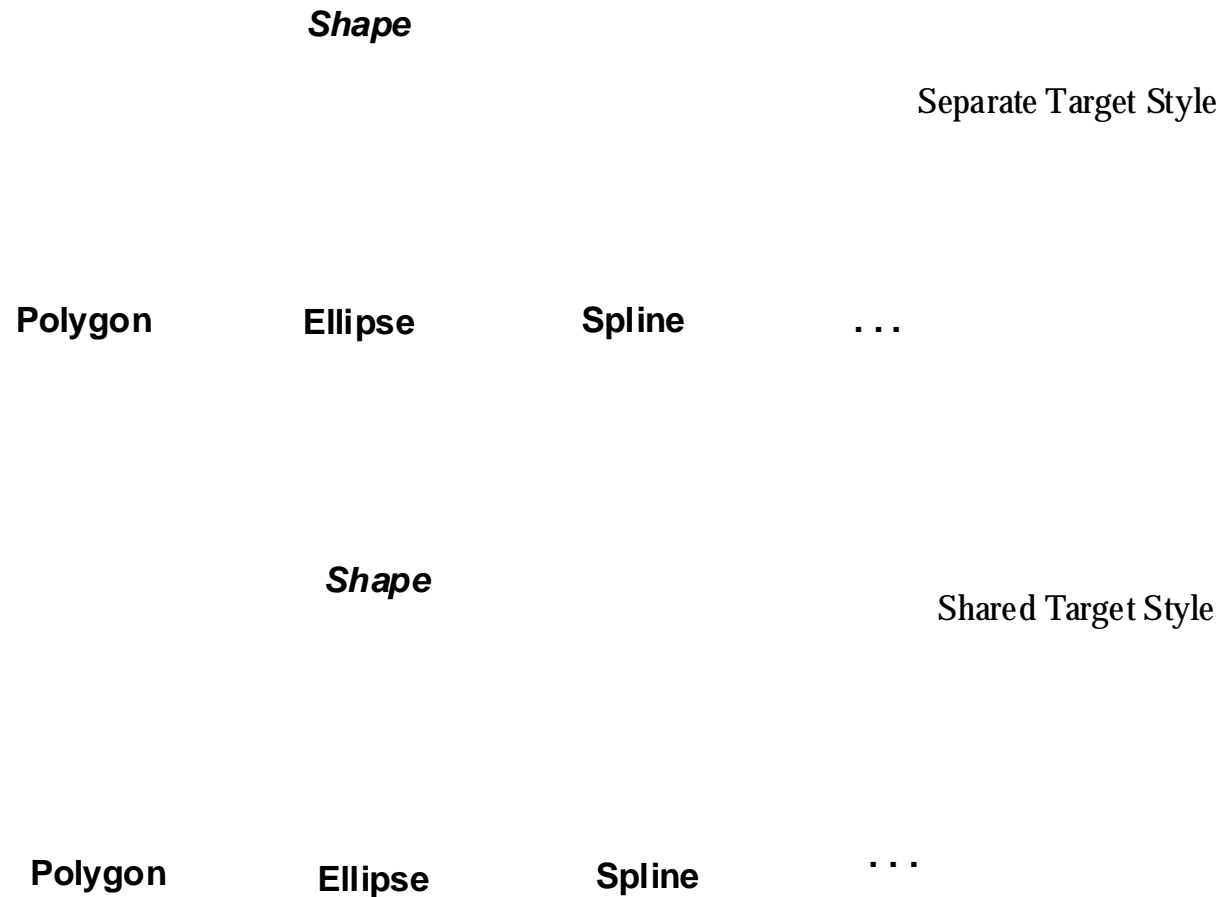
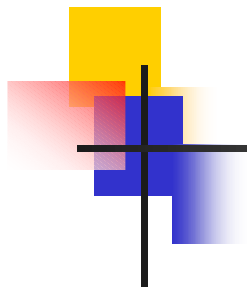


Fig. 3-38, *UML Notation Guide*



# Generalization

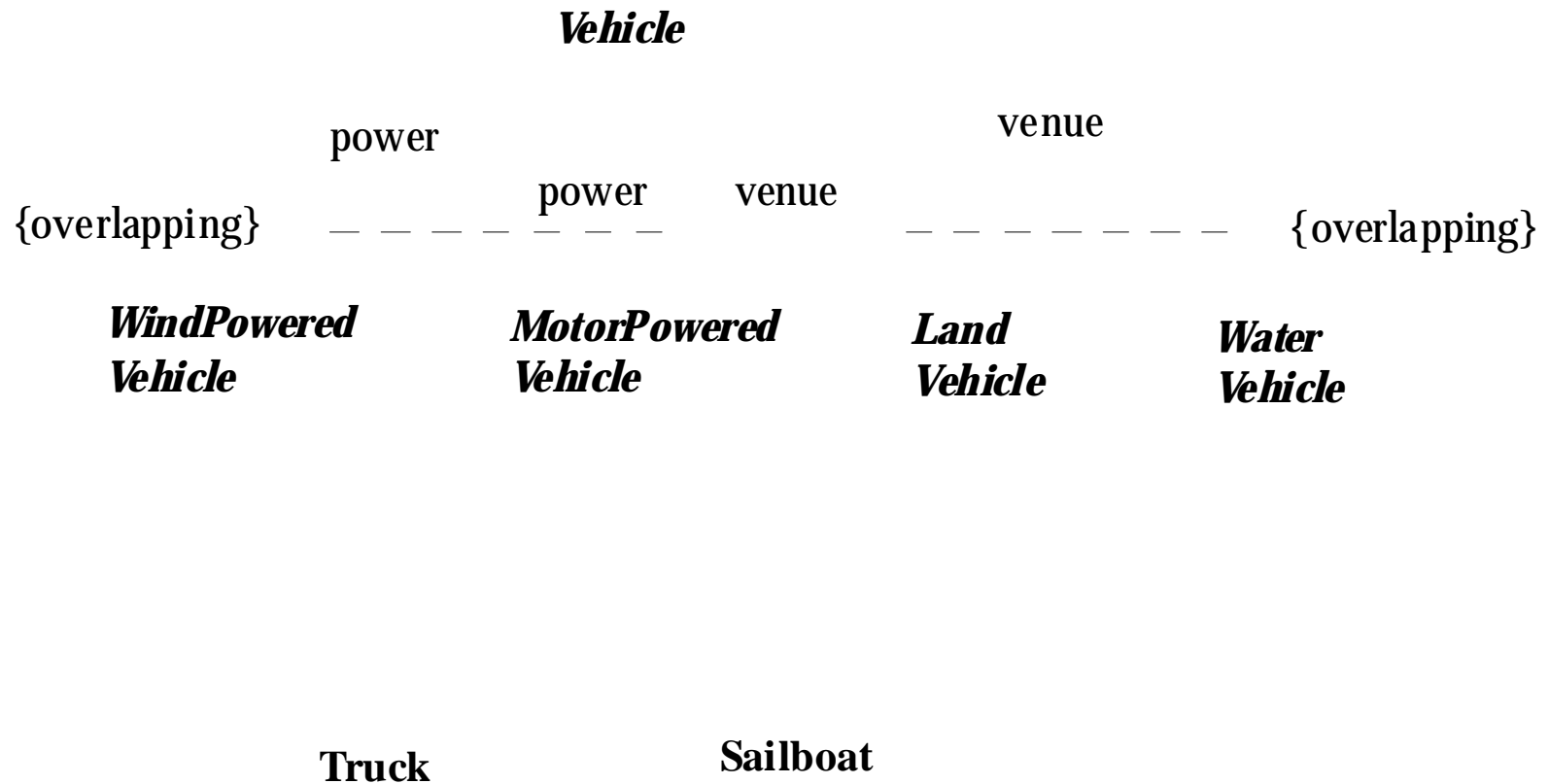
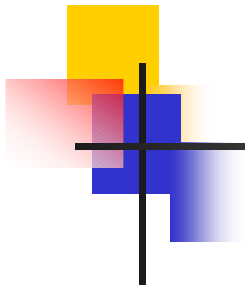


Fig. 3-39, *UML Notation Guide*



# Dependencies

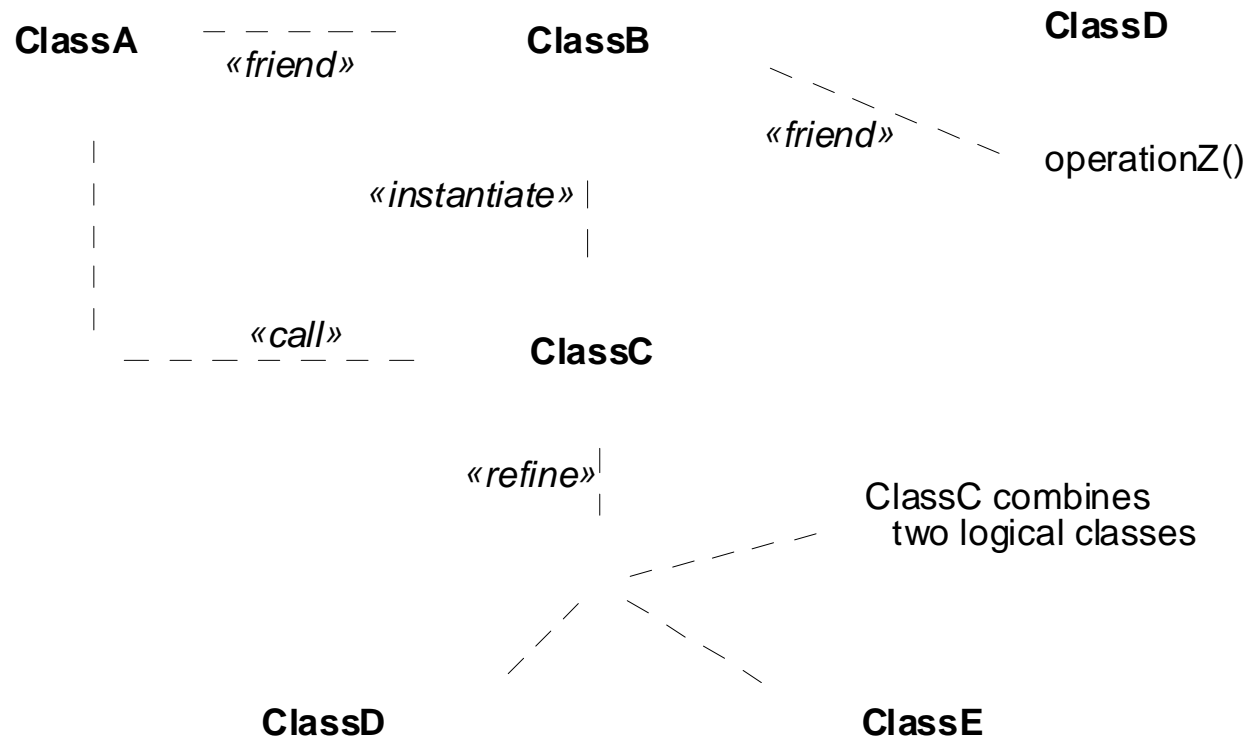
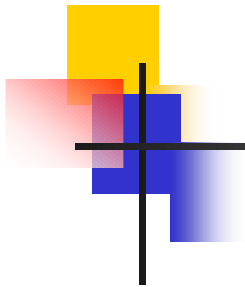


Fig. 3-41, *UML Notation Guide*



# Dependencies

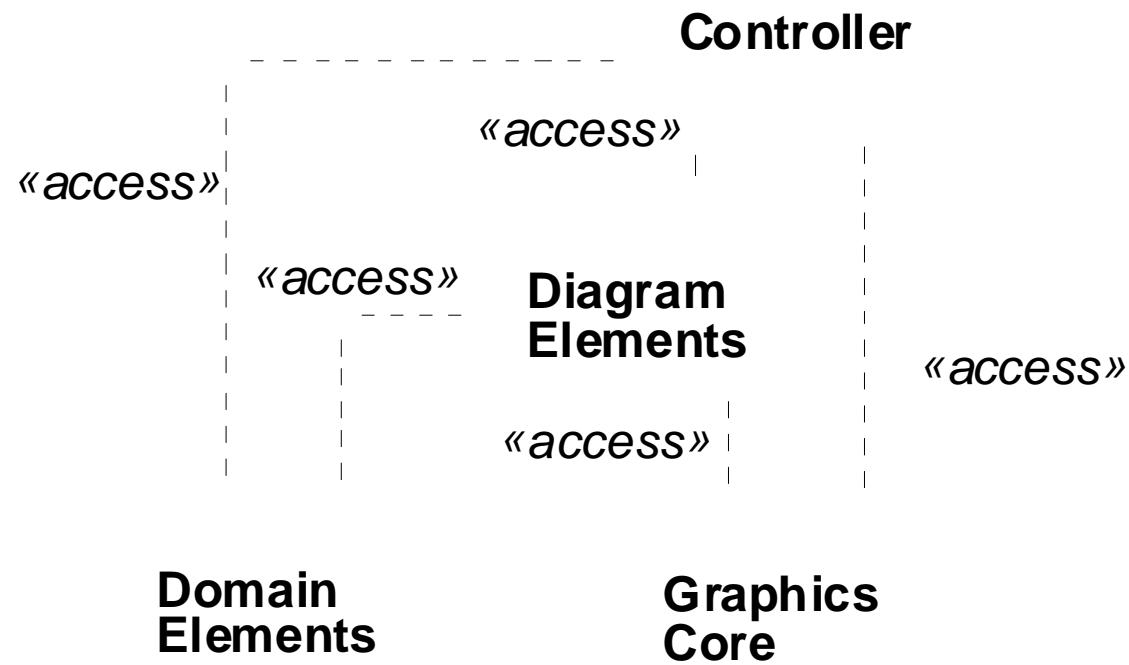
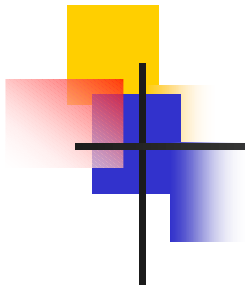


Fig. 3-42, *UML Notation Guide*





# Objects

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triangle : Polygon

center = (0,0)  
vertices = ((0,0),(4,0),(4,3))  
borderColor = black  
fillColor = white

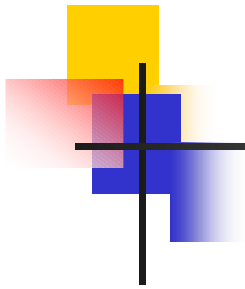
triangle

:Polygon

triangle: Polygon

scheduler

Fig. 3-29, *UML Notation Guide*



# Composite objects

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awindow : Window

horizontalBar:ScrollBar

verticalBar:ScrollBar

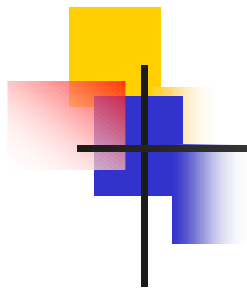
moves

surface:Pane

moves

title:TitleBar

Fig. 3-30, *UML Notation Guide*



# Links

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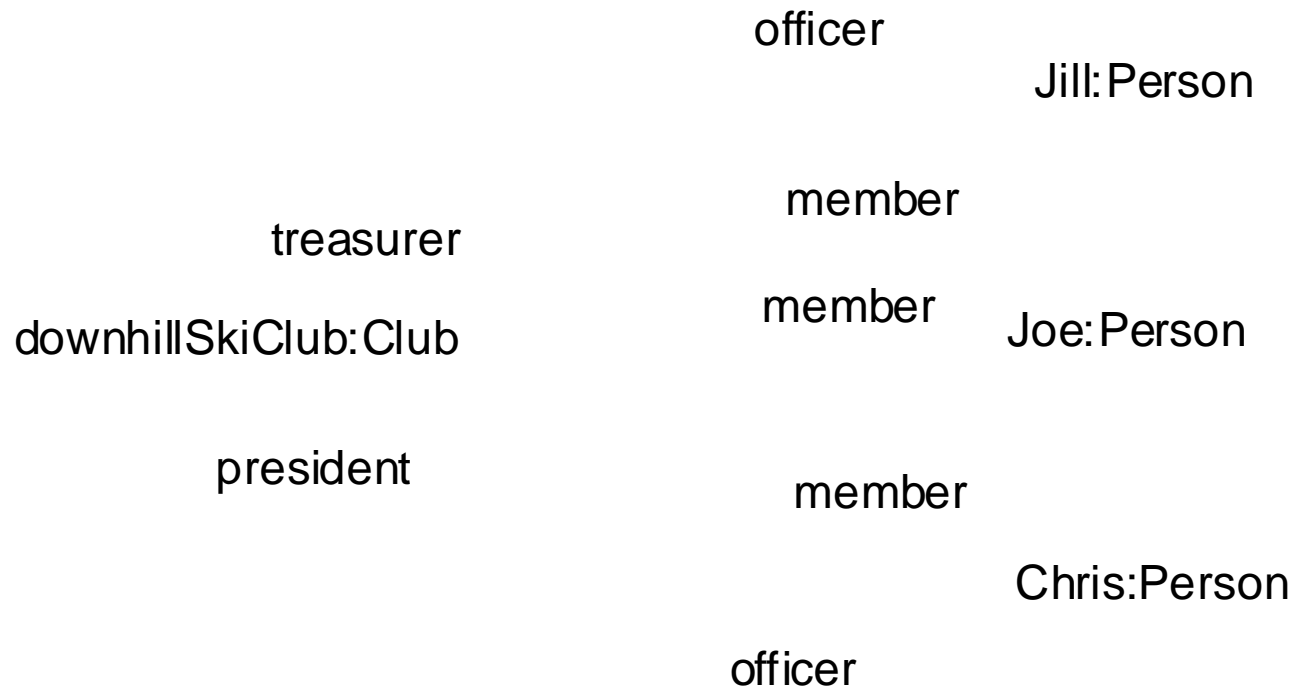
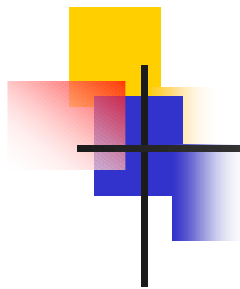


Fig. 3-37, *UML Notation Guide*



# Constraints and Comments

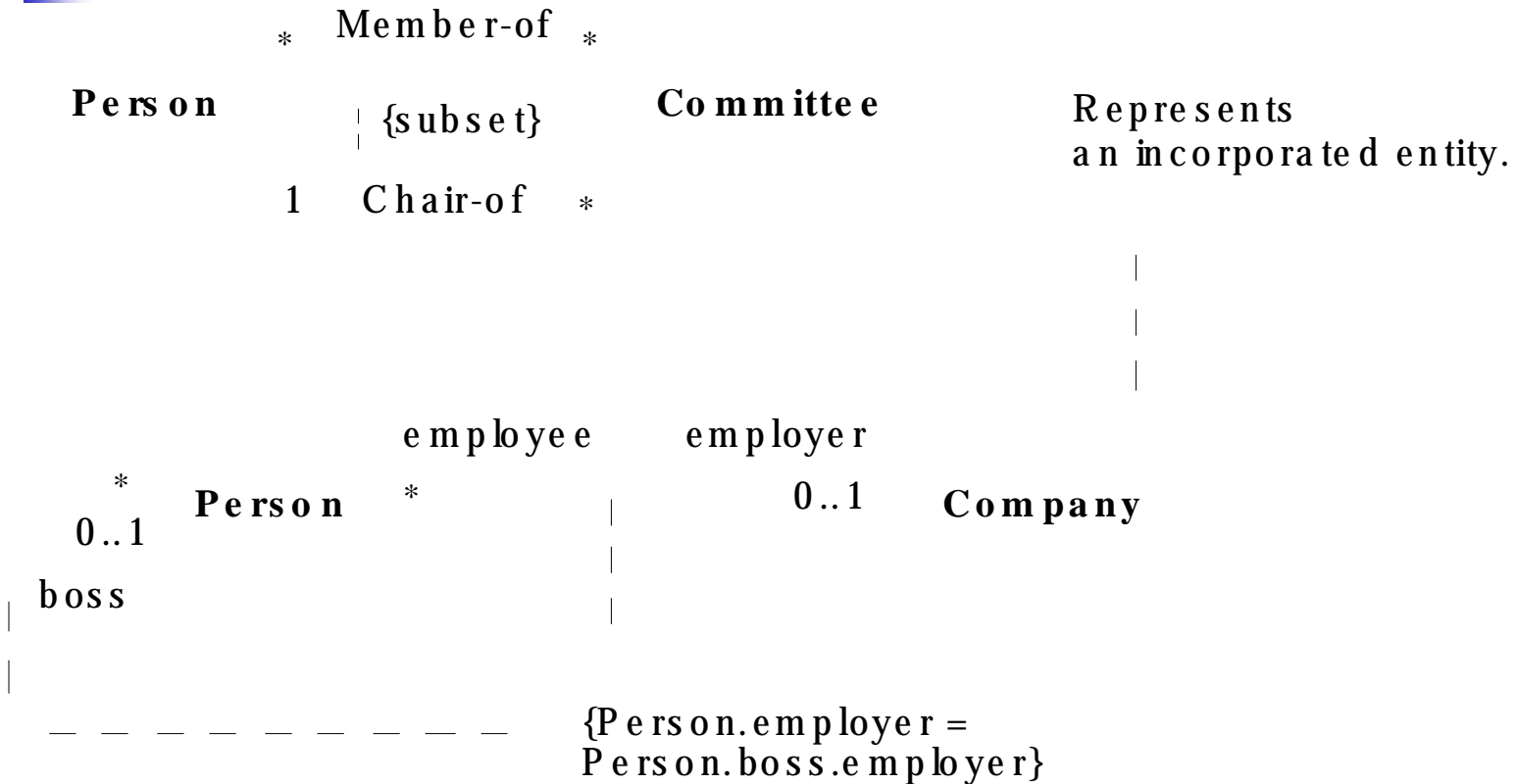


Fig. 3-15, *UML Notation Guide*



# Implementation Diagrams

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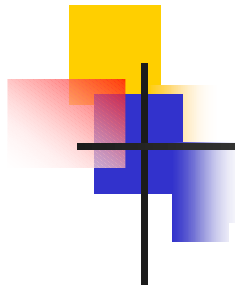
- Show aspects of model implementation, including source code structure and run-time implementation structure
- Kinds
  - component diagram
  - deployment diagram



# Component Diagram

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- Shows the organizations and dependencies among software components
- Components include
  - source code components
  - binary code components
  - executable components



# Components

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**Dictionary**

Spell-check

Synonyms

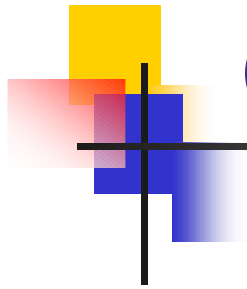
mymailer: **Mailer**

+Mailbox

+RoutingList

-MailQueue

Fig. 3-84, *UML Notation Guide*



# Component Diagram

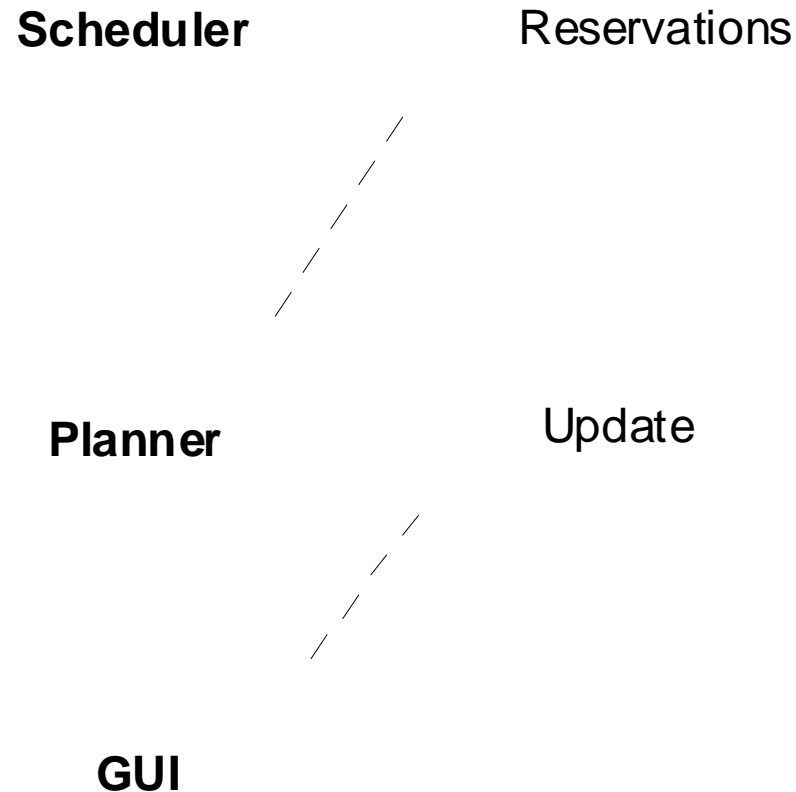


Fig. 3-81, *UML Notation Guide*





# Deployment Diagram

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- Shows the configuration of run-time processing elements and the software components, processes and objects that live on them
- Deployment diagrams may be used to show which components may run on which nodes

# Deployment Diagram

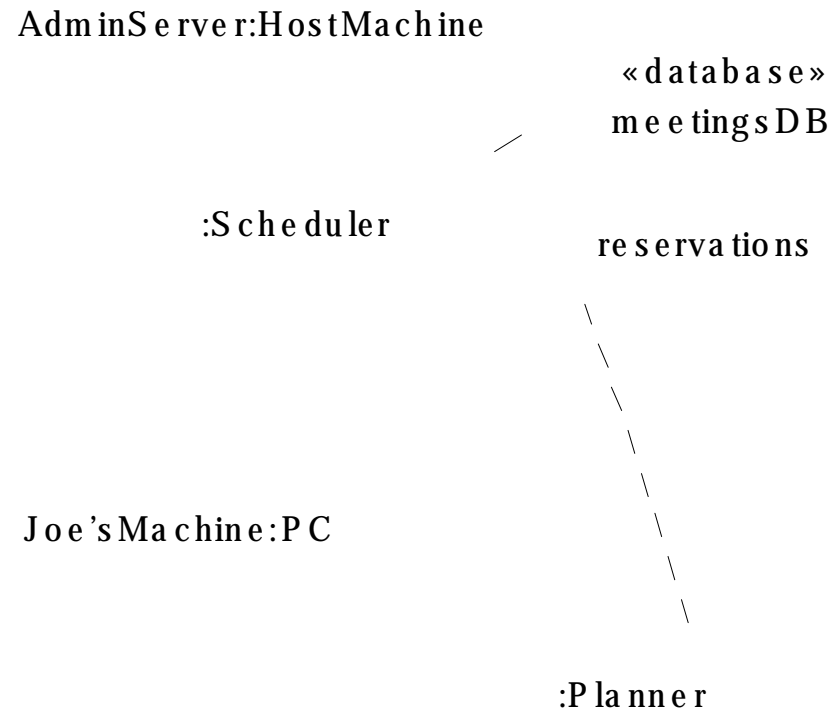


Fig. 3-82, *UML Notation Guide*

# Deployment Diagram (cont'd)

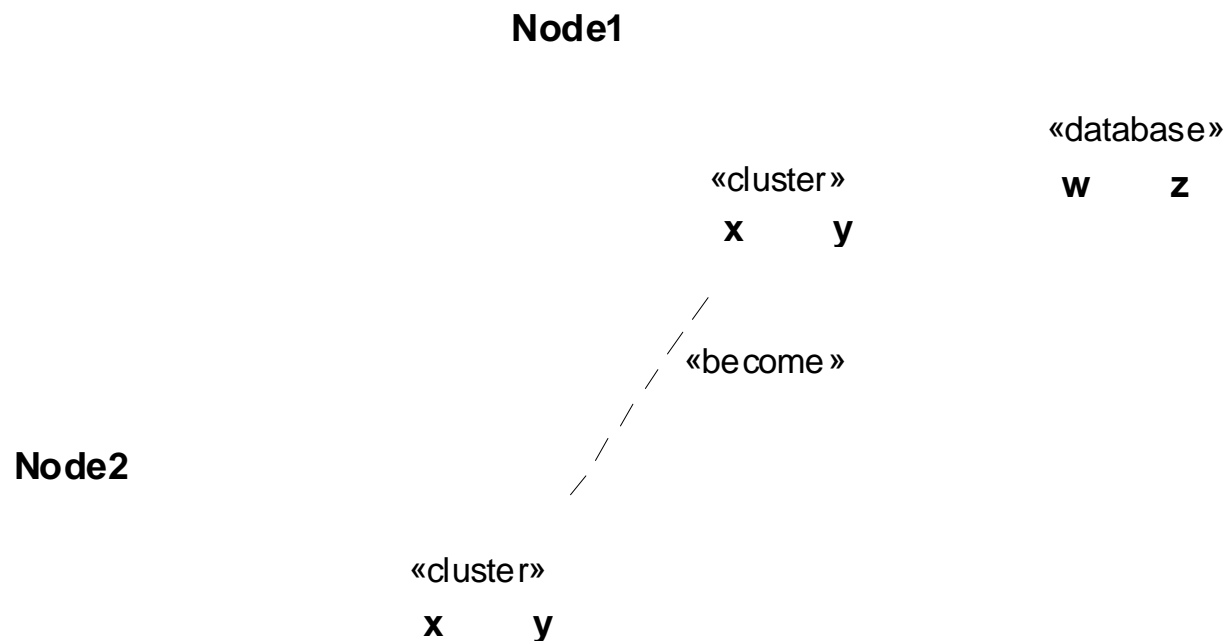


Fig. 3-83, *UML Notation Guide*



## When to model structure

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- Adopt an opportunistic top-down+bottom-up approach to modeling structure
  - Specify the top-level structure using “architecturally significant” classifiers and model management constructs (packages, models, subsystems; see Tutorial 3)
  - Specify lower-level structure as you discover detail re classifiers and relationships
- If you understand your domain well you can frequently start with structural modeling; otherwise
  - If you start with use case modeling (as with a use-case driven method) make sure that your structural model is consistent with your use cases
  - If you start with role modeling (as with a collaboration-driven method) make sure that your structural model is consistent with your collaborations



# Structural Modeling Tips

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- Define a “skeleton” (or “backbone”) that can be extended and refined as you learn more about your domain.
- Focus on using basic constructs well; add advanced constructs and/or notation only as required.
- Defer implementation concerns until late in the modeling process.
- Structural diagrams should
  - emphasize a particular aspect of the structural model
  - contain classifiers at the same level of abstraction
- Large numbers of classifiers should be organized into packages (see Lecture 3)



# Example: Interface-based design

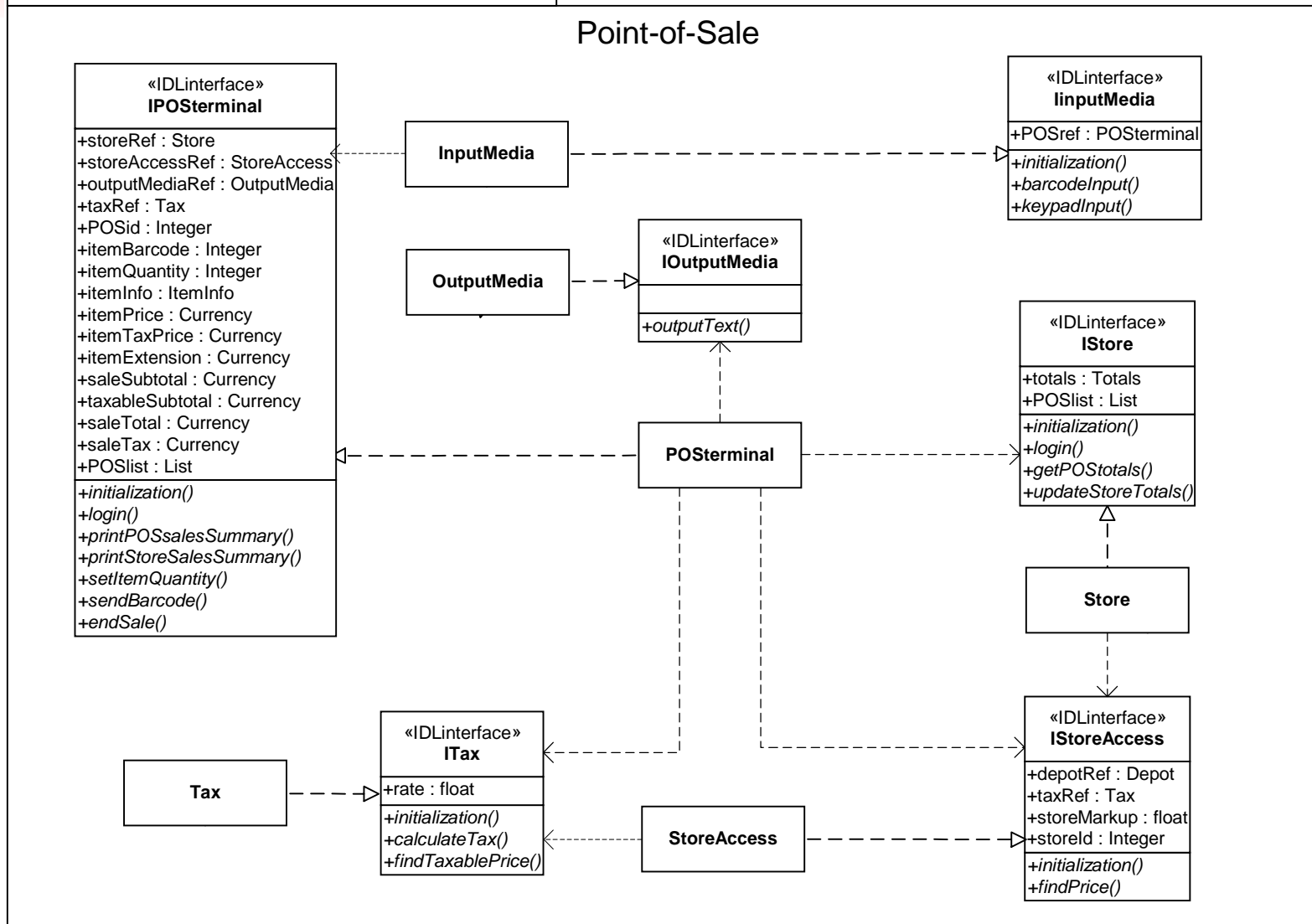
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```
module POS
{
    typedef long    POSId;
    typedef string  Barcode;

    interface InputMedia
    {
        typedef string OperatorCmd;
        void          BarcodeInput(in Barcode Item);
        void          KeypadInput(in OperatorCmd Cmd);
    };
    interface OutputMedia
    {....};
    interface POSTerminal
    {....};
};
```

Ch. 26, *CORBA Fundamentals and Programming* (2<sup>nd</sup> ed.), [Siegel 00]

From *Modeling CORBA Applications with UML* chapter in [Siegel 00].





# Use Case Modeling

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- What is use case modeling?
- Core concepts
- Diagram tour
- When to model use cases
- Modeling tips
- Example: Online HR System




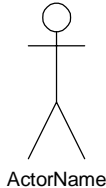



## What is use case modeling?

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- use case model: a view of a system that emphasizes the behavior as it appears to outside users. A use case model partitions system functionality into transactions ('use cases') that are meaningful to users ('actors').

## Use Case Modeling: Core Elements

Construct	Description	Syntax
<b>use case</b>	A sequence of actions, including variants, that a system (or other entity) can perform, interacting with actors of the system.	
<b>actor</b>	A coherent set of roles that users of use cases play when interacting with these use cases.	
<b>system boundary</b>	Represents the boundary between the physical system and the actors who interact with the physical system.	




## Use Case Modeling: Core Relationships

Construct	Description	Syntax
<b>association</b>	The participation of an actor in a use case. i.e., instance of an actor and instances of a use case communicate with each other.	_____
<b>extend</b>	A relationship from an <i>extension</i> use case to a <i>base</i> use case, specifying how the behavior for the extension use case can be inserted into the behavior defined for the base use case.	<<extend>> ----->
<b>generalization</b>	A taxonomic relationship between a more general use case and a more specific use case.	—————>



## Use Case Modeling: Core Relationships (cont'd)

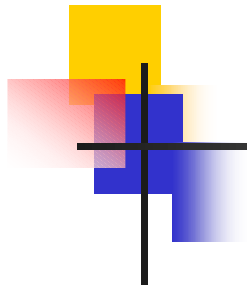
Construct	Description	Syntax
<b>include</b>	An relationship from a <i>base</i> use case to an <i>inclusion</i> use case, specifying how the behavior for the inclusion use case is inserted into the behavior defined for the base use case.	<pre>&lt;&lt;include&gt;&gt;</pre> 



# Use Case Diagram Tour

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- Shows use cases, actor and their relationships
- Use case internals can be specified by text and/or interaction diagrams (see Lecture 2)
- Kinds
  - use case diagram
  - use case description



# Use Case Diagram

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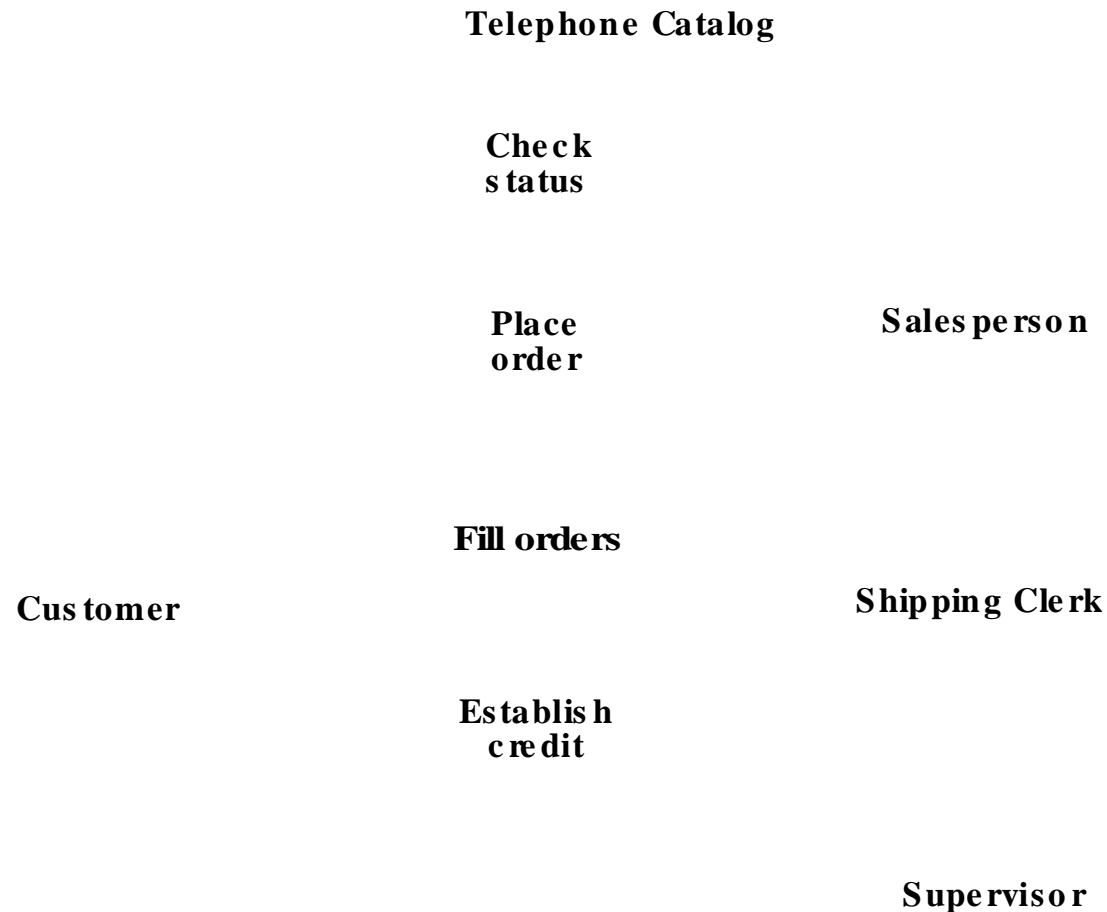


Fig. 3-44, *UML Notation Guide*

# Use Case Relationships

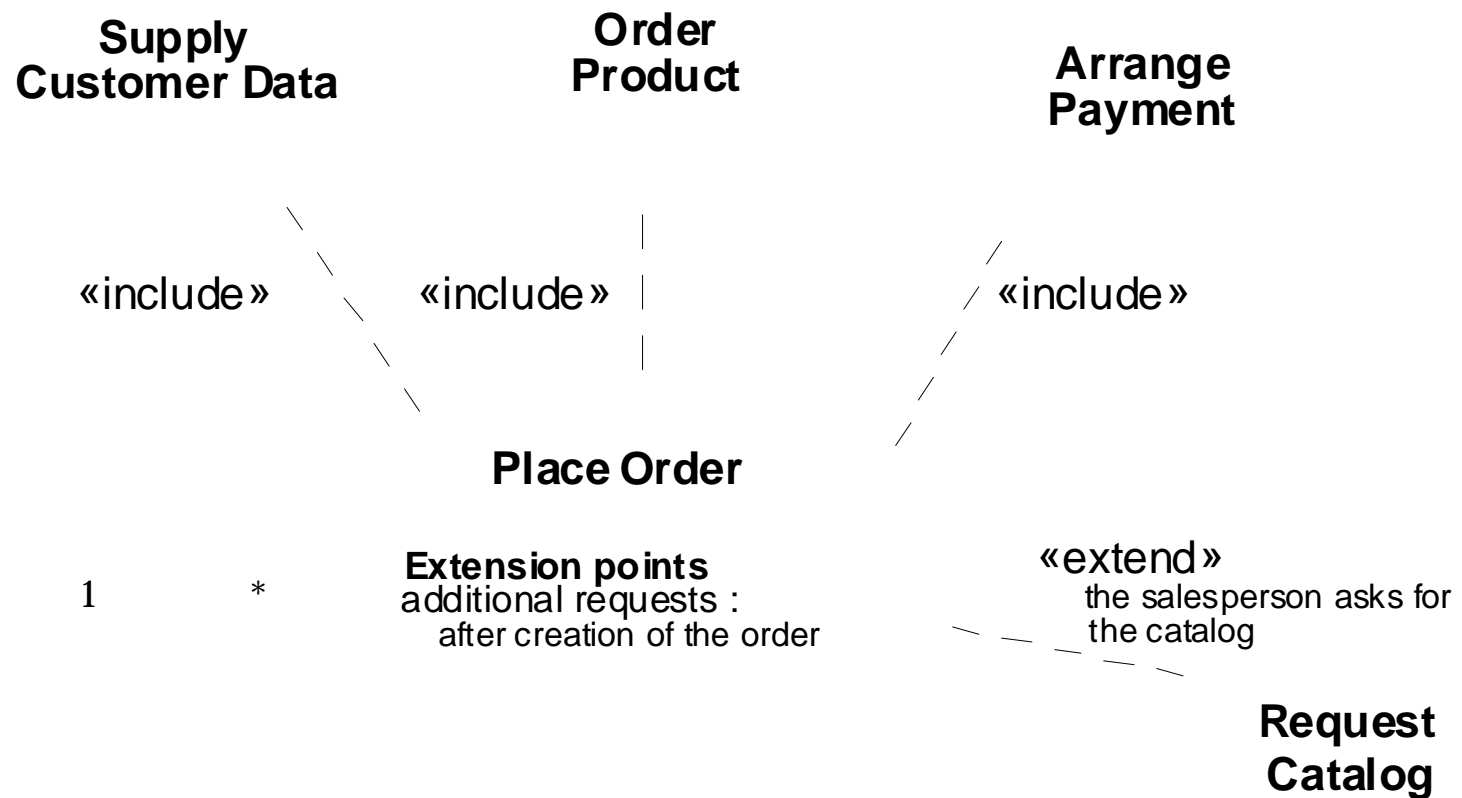


Fig. 3-45, *UML Notation Guide*



# Actor Relationships

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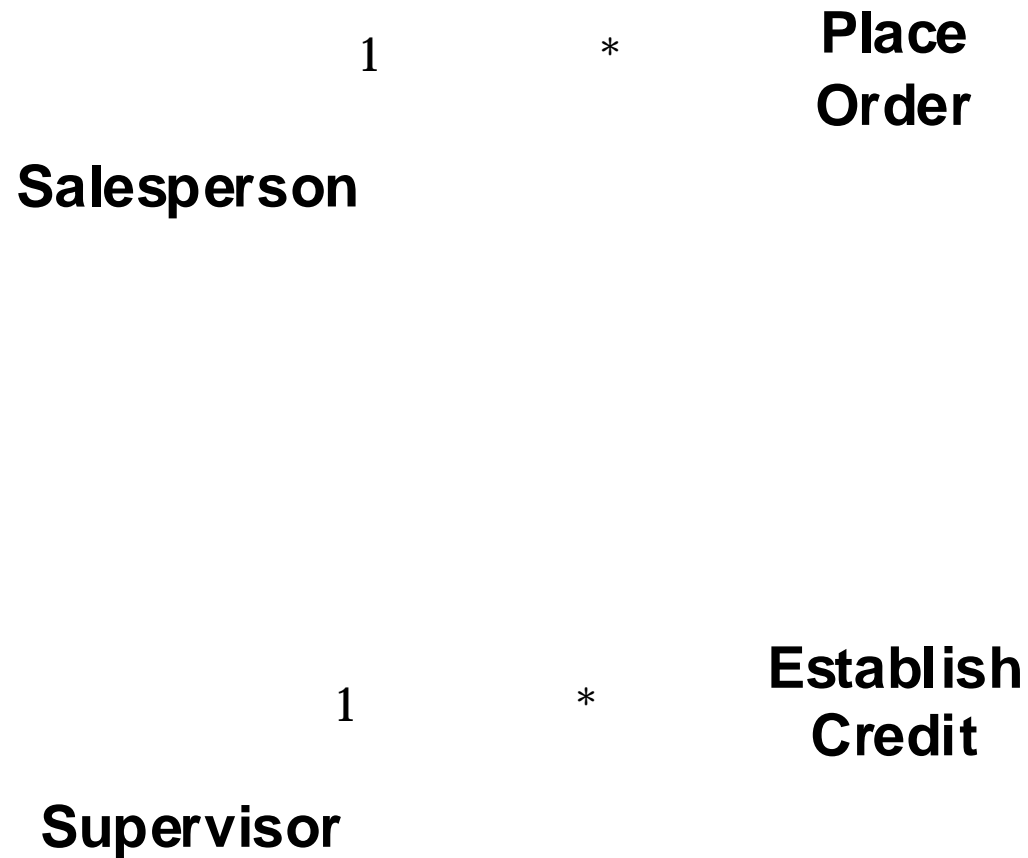


Fig. 3-46, *UML Notation Guide*





# Use Case Description: Change Flight

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■ **Actors:** traveler, client account db, airline reservation system

■ **Preconditions:**

- Traveler has logged on to the system and selected 'change flight itinerary' option

■ **Basic course**

- System retrieves traveler's account and flight itinerary from client account database
- System asks traveler to select itinerary segment she wants to change; traveler selects itinerary segment.
- System asks traveler for new departure and destination information; traveler provides information.
- If flights are available then
- ...
- System displays transaction summary.

■ **Alternative courses**

- If no flights are available then ...



## When to model use cases

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- Model user requirements with use cases.
- Model test scenarios with use cases.
- If you are using a use-case driven method
  - start with use cases and derive your structural and behavioral models from it.
- If you are not using a use-case driven method
  - make sure that your use cases are consistent with your structural and behavioral models.



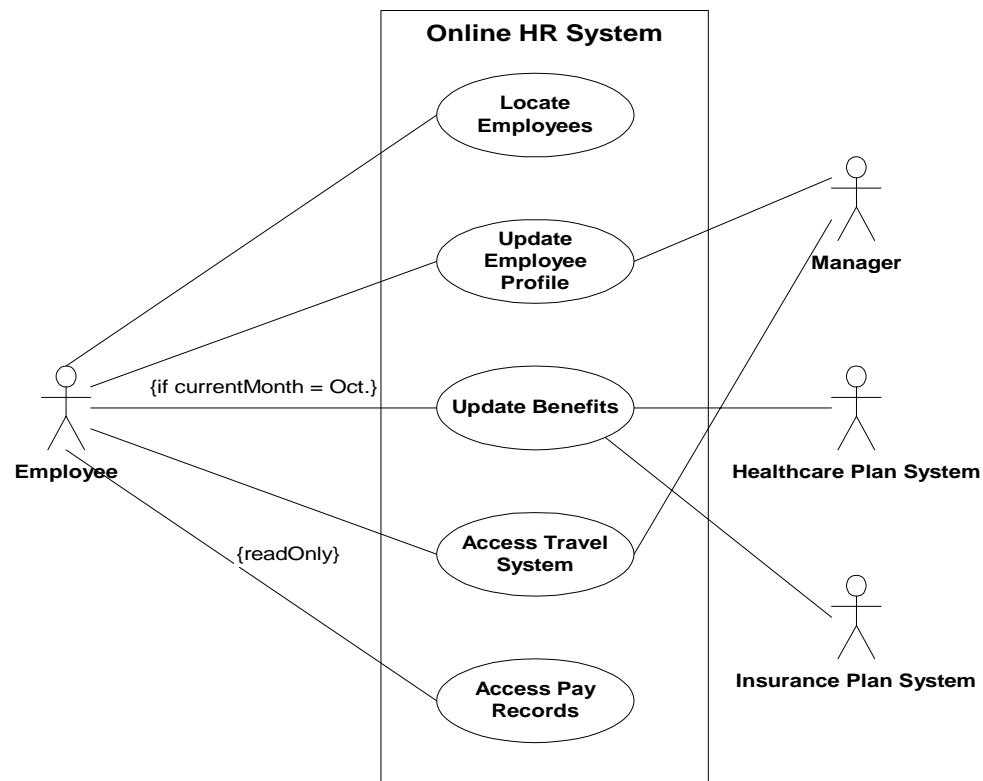
# Use Case Modeling Tips

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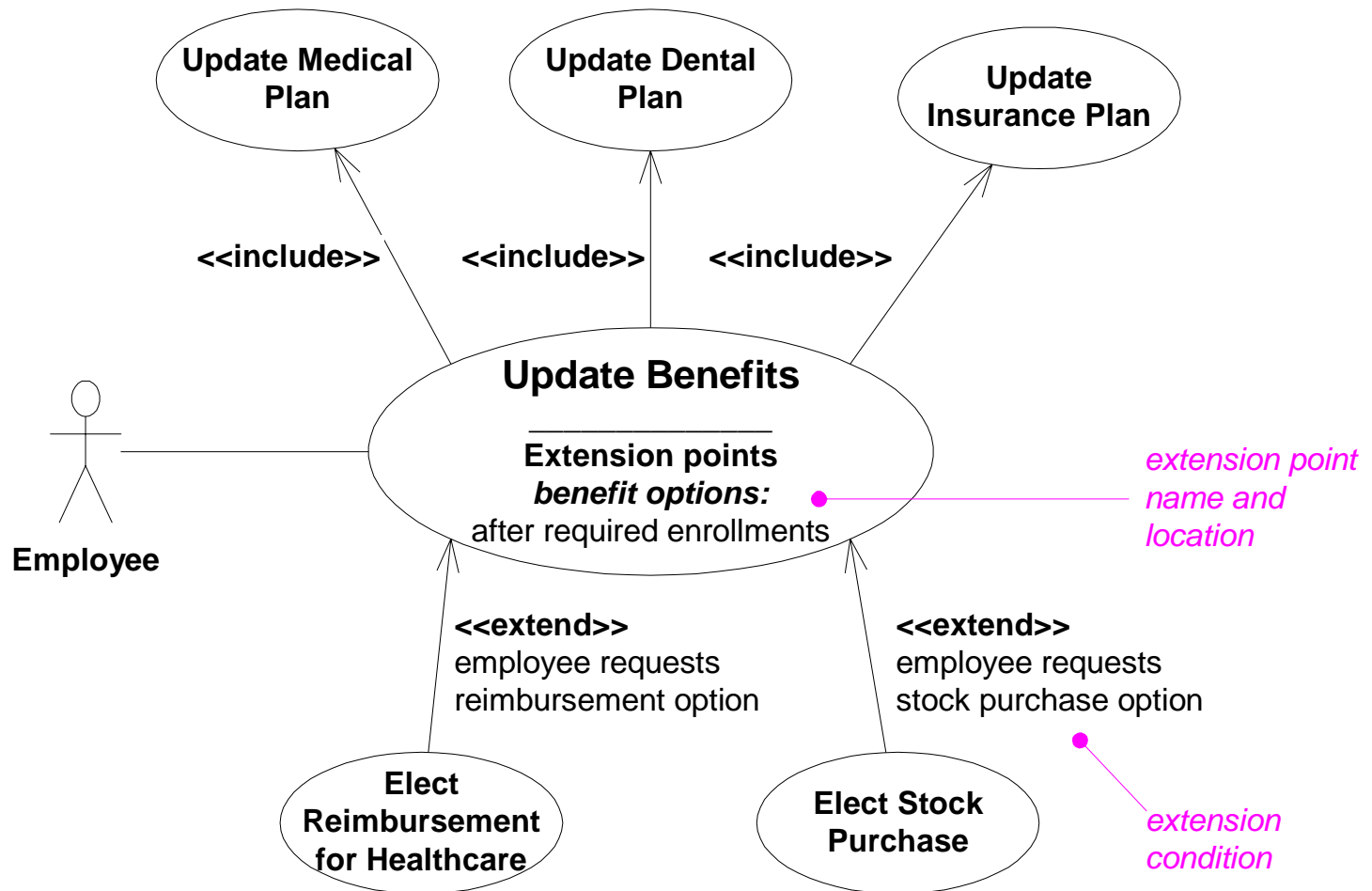
Make sure that each use case describes a significant chunk of system usage that is understandable by both domain experts and programmers

- When defining use cases in text, use nouns and verbs accurately and consistently to help derive objects and messages for interaction diagrams (see Lecture 2)
- Factor out common usages that are required by multiple use cases
  - If the usage is required use <<include>>
  - If the base use case is complete and the usage may be optional, consider use <<extend>>
- A use case diagram should
  - contain only use cases at the same level of abstraction
  - include only actors who are required
- Large numbers of use cases should be organized into packages (see Lecture 3)

# Example: Online HR System



# Online HR System: Use Case Relationships





# Online HR System: Update Benefits Use Case

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■ **Actors:** employee, employee account db, healthcare plan system, insurance plan system

■ **Preconditions:**

- Employee has logged on to the system and selected 'update benefits' option

■ **Basic course**

- System retrieves employee account from employee account db
- System asks employee to select medical plan type; **include** Update Medical Plan.
- System asks employee to select dental plan type; **include** Update Dental Plan.
- ...

■ **Alternative courses**

- If health plan is not available in the employee's area the employee is informed and asked to select another plan...



# Wrap Up

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- Ideas to take away
- Preview of next tutorial
- References
- Further info



# Ideas to Take Away

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- UML is effective for modeling large, complex software systems
- It is simple to learn for most developers, but provides advanced features for expert analysts, designers and architects
- It can specify systems in an implementation-independent manner
- 10-20% of the constructs are used 80-90% of the time
- Structural modeling specifies a skeleton that can be refined and extended with additional structure and behavior
- Use case modeling specifies the functional requirements of system in an object-oriented manner





# Preview - Next Tutorial

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- Behavioral Modeling with UML
  - Behavioral modeling overview
  - Interactions
  - Collaborations
  - Statecharts
  - Activity Graphs



# References

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- *OMG UML Specification v. 1.3*, OMG doc# ad/06-08-99
- [Kobryn 99] *UML 2001: A Standardization Odyssey*, Communications of the ACM, Oct. 1999.
- [Kobryn 00] "Modeling CORBA Applications with UML," chapter contribution to [Siegel 00] *CORBA 3 Fundamentals and Programming* (2<sup>nd</sup> ed.), Wiley, 2000.



# Further Info

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## Web:

- UML 1.4 RTF: [www.celigent.com/omg/umlrtf](http://www.celigent.com/omg/umlrtf)
- OMG UML Tutorials: [www.celigent.com/omg/umlrtf/tutorials.htm](http://www.celigent.com/omg/umlrtf/tutorials.htm)
- UML 2.0 Working Group: [www.celigent.com/omg/adptf/wgs/uml2wg.htm](http://www.celigent.com/omg/adptf/wgs/uml2wg.htm)
- OMG UML Resources: [www.omg.org/uml/](http://www.omg.org/uml/)

## ■ Email

- [uml-rtf@omg.org](mailto:uml-rtf@omg.org)
- [ckobryn@acm.org](mailto:ckobryn@acm.org)

## ■ Conferences & workshops

- OMG UML Workshop: *UML in the .com Enterprise*, Palm Springs, California, Nov. 2000
- UML World 2001, location and dates TBA
- UML 2001, Toronto, Canada, Oct. 2001