Object Modeling with OMG UML Tutorial Series

# Introduction to UML: Structural and Use Case Modeling

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# Overview

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

# Tutorial Series

- Lecture 1: Introduction to UML: Structural and Use Case Modeling
- Lecture 2: Behavioral Modeling with UML
- Lecture 3: Advanced Modeling with UML

[Note: This version of the tutorial series is based on *OMG UML Specification* v. 1.4, UML Revision Task Force recommended final draft, OMG doc# ad/01-02-13.]

# Tutorial Goals

- 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

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

# Why do we model?

- 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.macalester.edu/~jschatz/residential.html

# The Vision

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

# Why do we model graphically?

- Graphics reveal data.
  - Edward Tufte
    *The Visual Display of Quantitative Information, 1983*
- 1 bitmap = 1 megaword.
  - Anonymous visual modeler

# Quick Tour

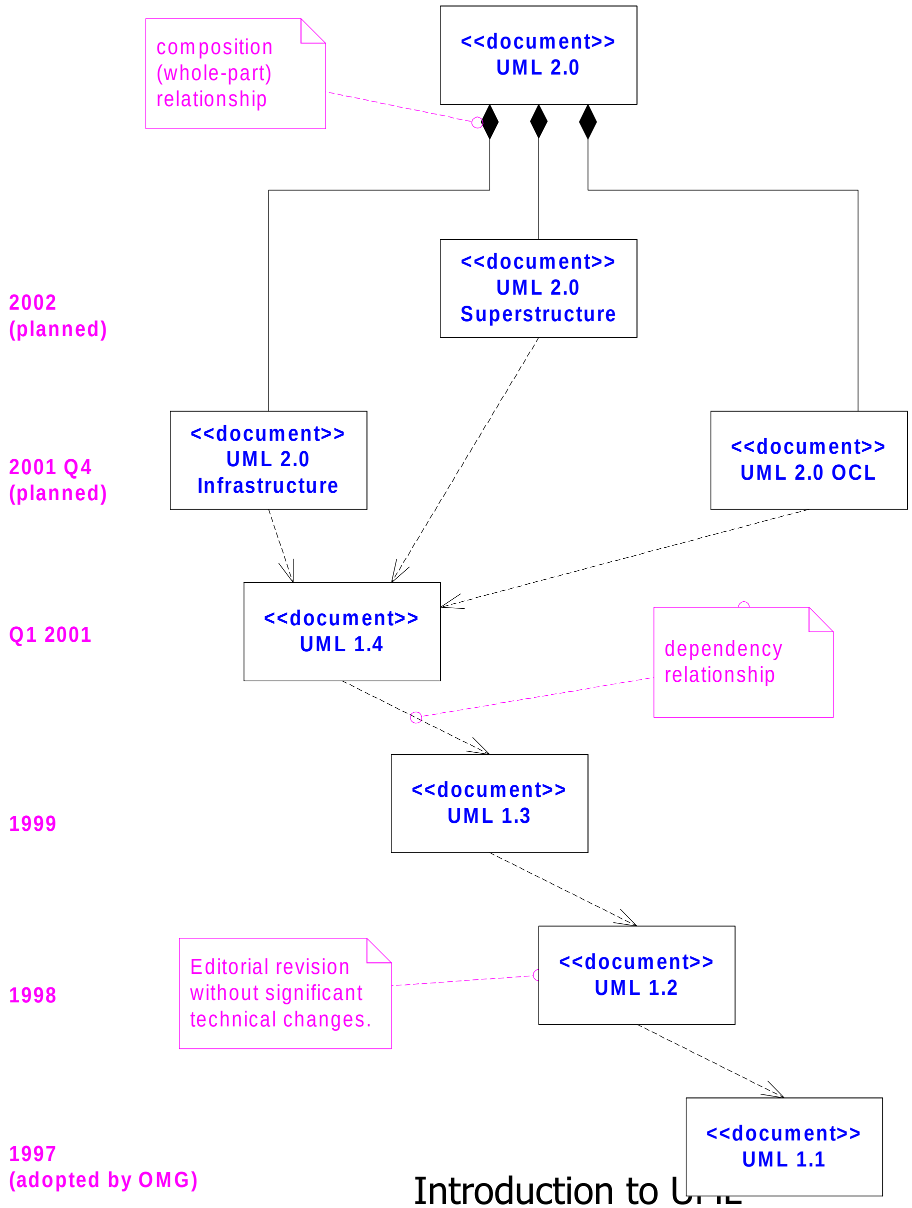
- The UML is a graphical language for
  - specifying
  - visualizing
  - constructing
  - documenting

  the 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
- Next minor revision will be UML 1.4, planned to be adopted in Q2 2001
- Next major revision will be UML 2.0, planned to be completed in 2002

# UML Goals

- 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




From [Kobryn 01a].

# OMG UML Contributors

Aonix
Colorado State University
Computer Associates
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Data Access
EDS
Enea Data
Hewlett-Packard
IBM
I-Logix
InLine Software
Intellicorp
Kabira Technologies
Klasse Objecten
Lockheed Martin

Microsoft
ObjecTime
Oracle
Ptech
OAO Technology Solutions
Rational Software
Reich
SAP
Softeam
Sterling Software
Sun
Taskon
Telelogic
Unisys
…

# OMG UML 1.4 Specification

- UML Summary
- UML Semantics
- UML Notation Guide
- UML Example Profiles
  - Software Development Processes
  - Business Modeling
- Model Interchange
  - Model Interchange Using XMI
  - Model Interchange Using CORBA IDL
- Object Constraint Language

# Tutorial Focus: the Language

- 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

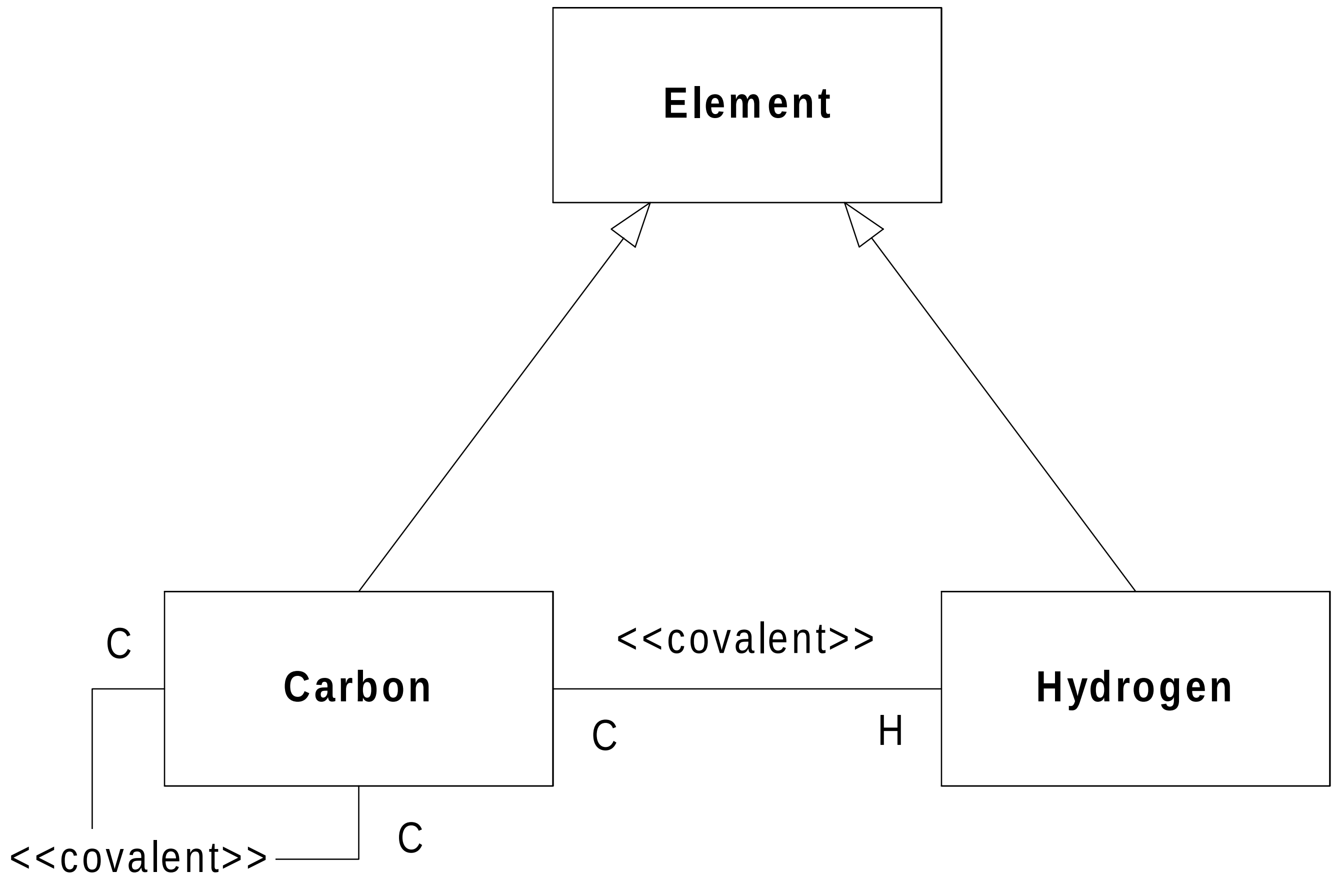
# Foundation Concepts

- Building blocks
- Well-formedness rules

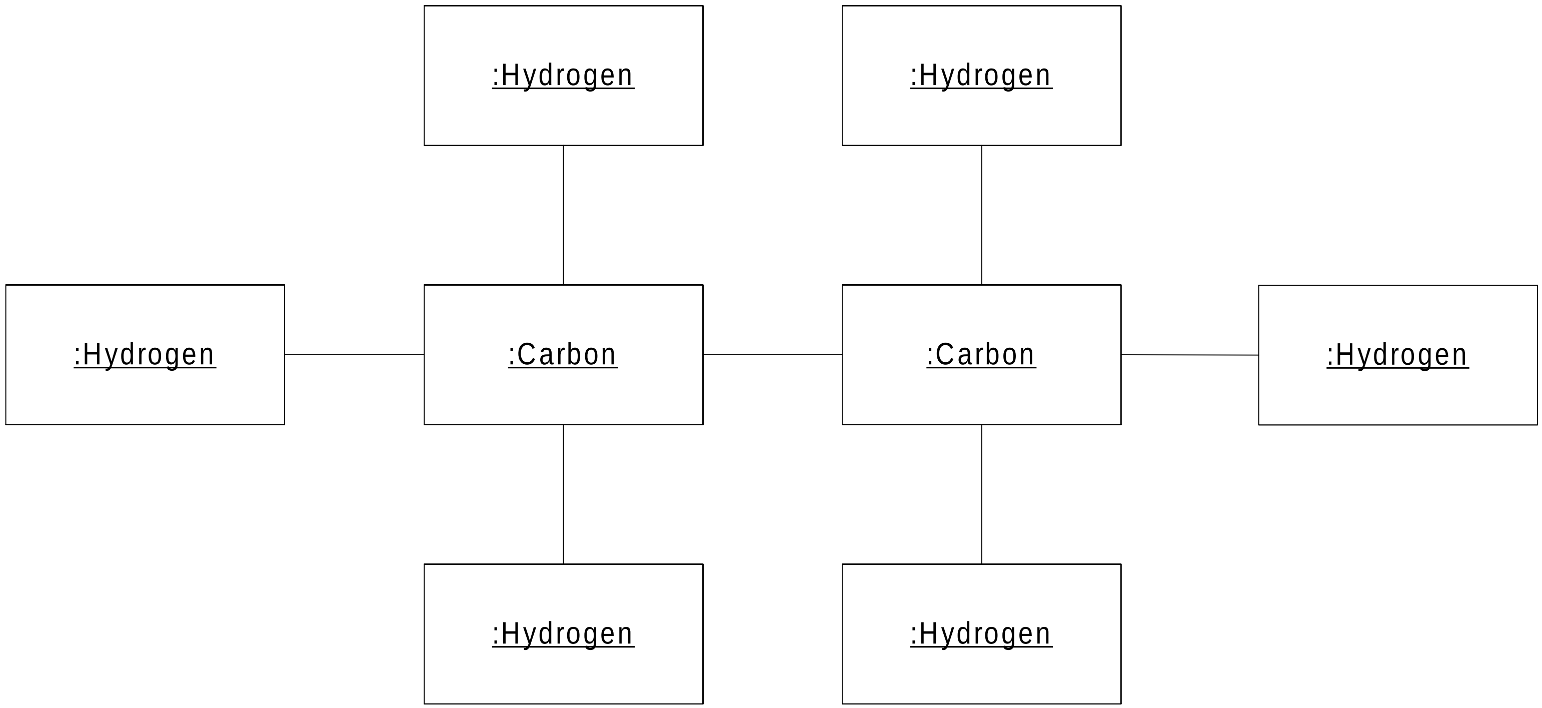
# Building Blocks

- 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

- 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)

- 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)

- 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.

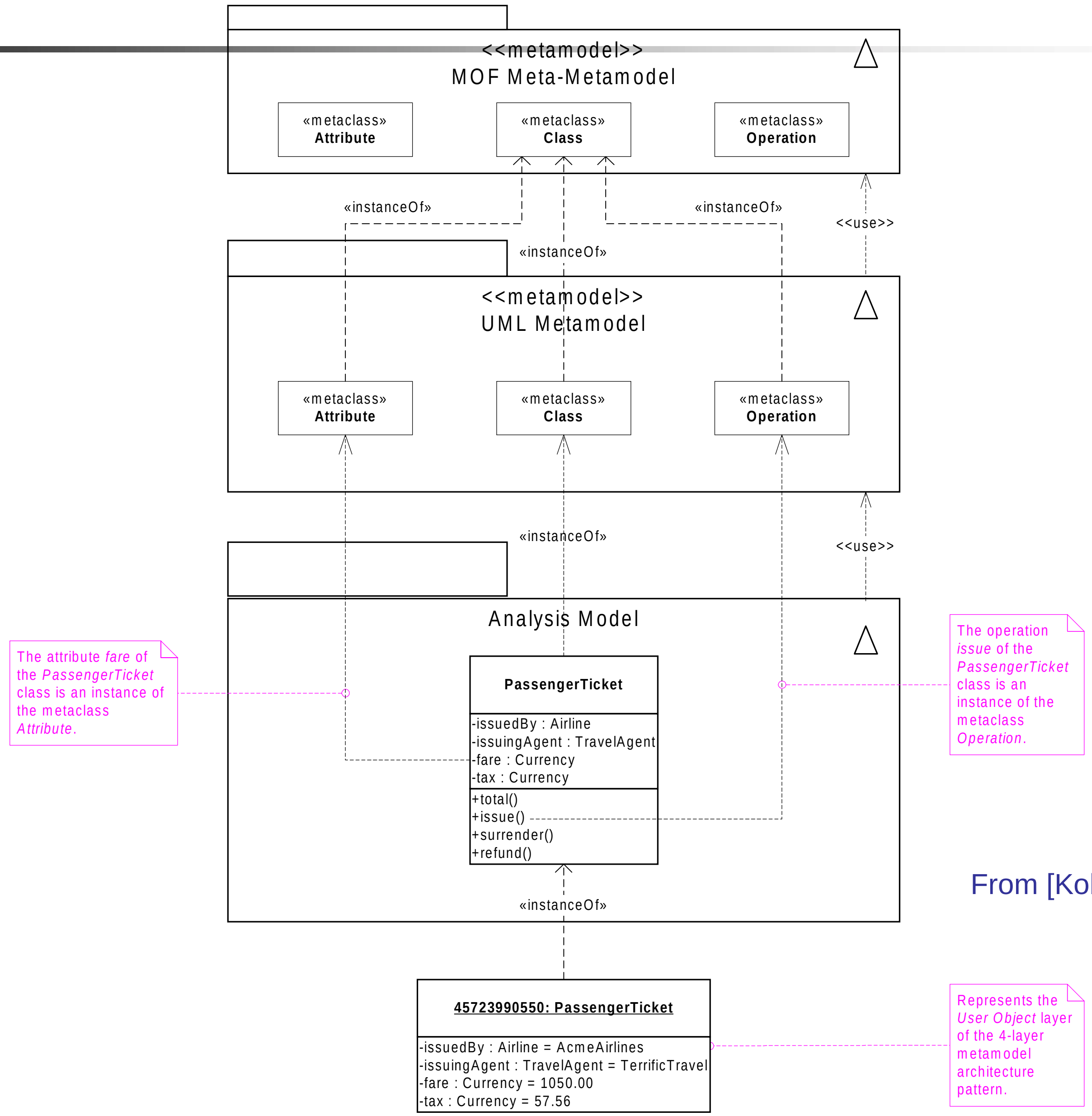
# Unifying Concepts

- 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

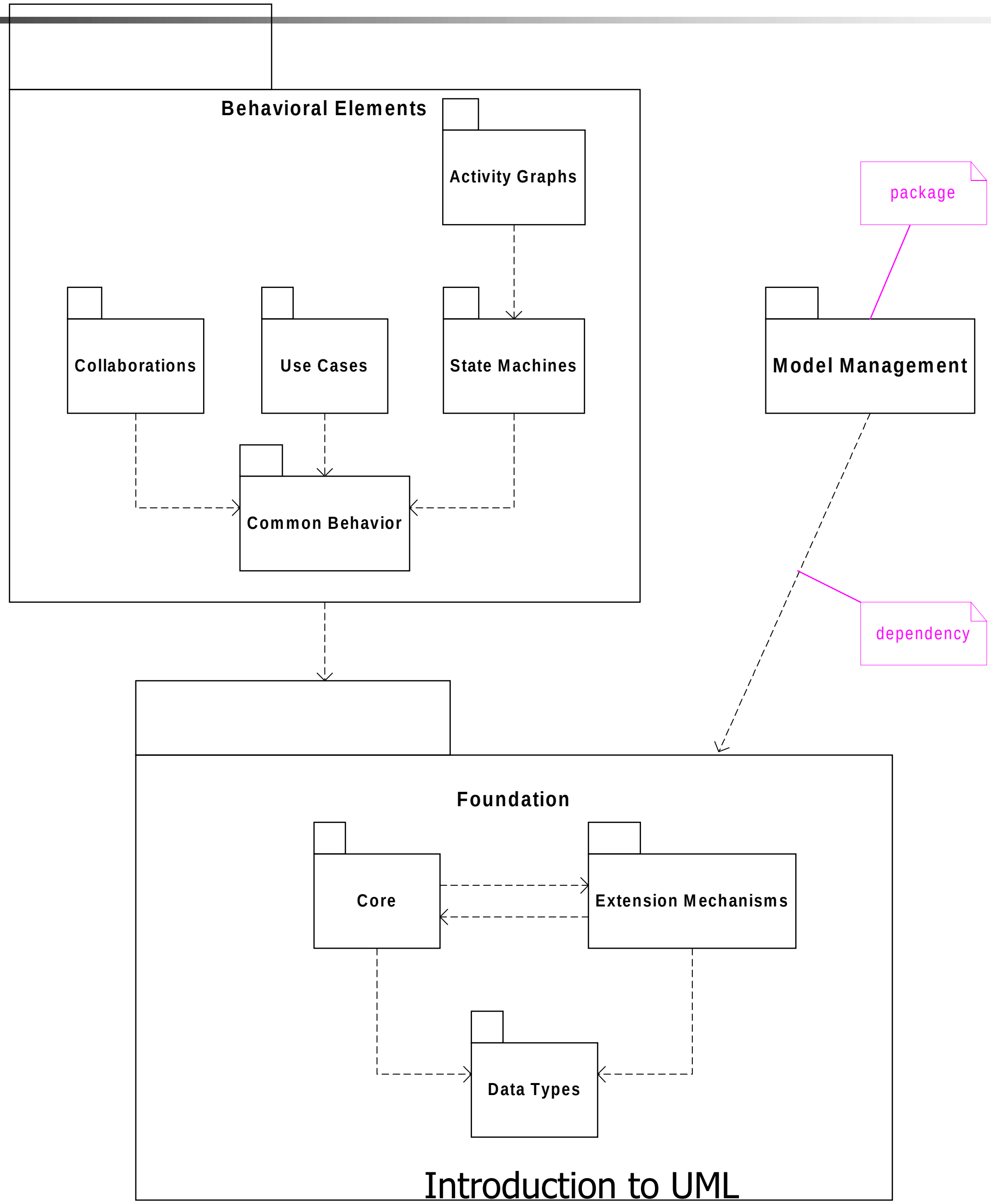
- Metamodel architecture
- Package structure

# Metamodel Architecture



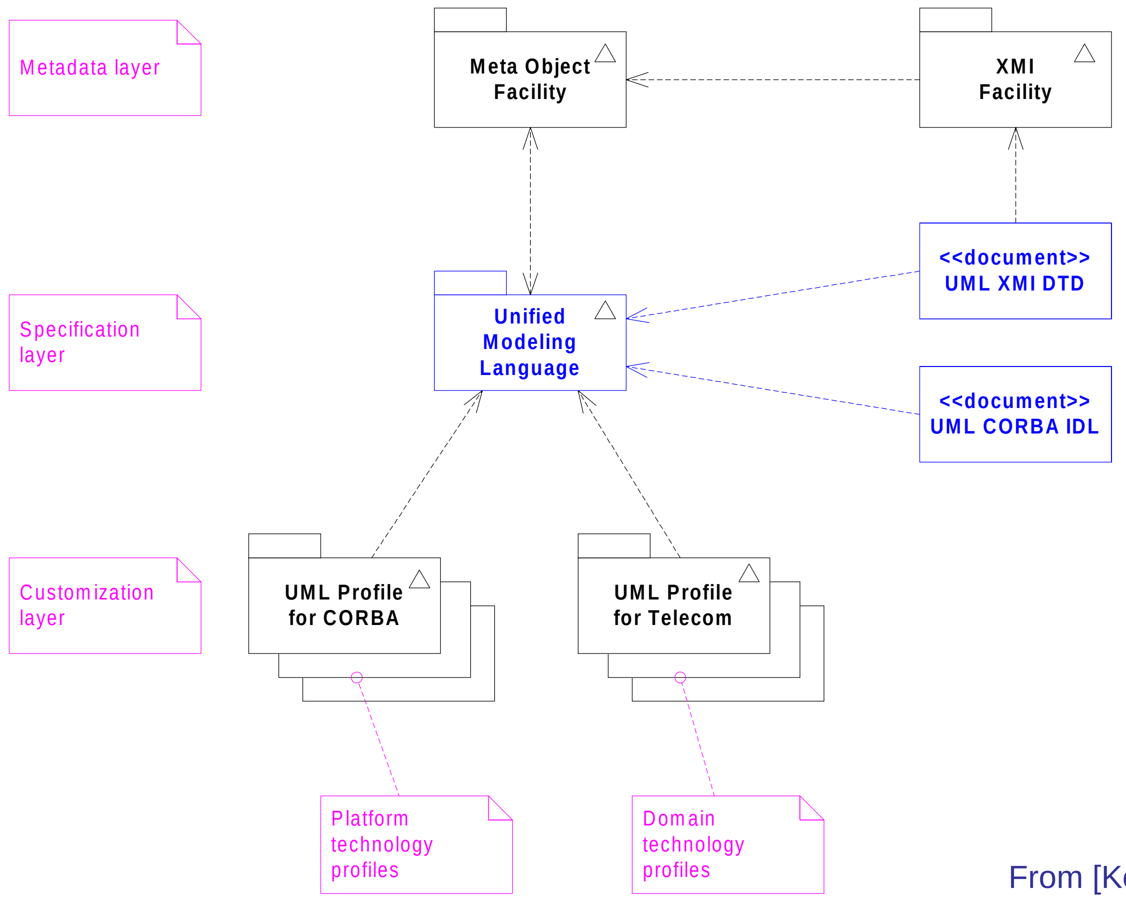

From [Kobryn 01b].

# UML Metamodel Layer




From [Kobryn 01b].

# Relationships to Other Modeling Technologies




From [Kobryn 01b].

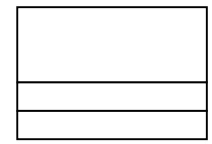
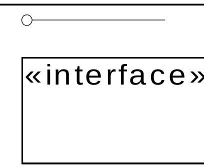
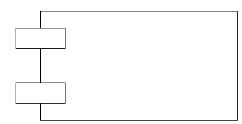
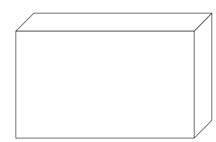
# Structural Modeling

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

# What is structural modeling?

- 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

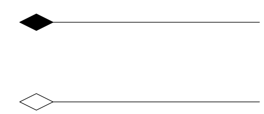
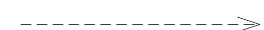
| Construct | Description | Syntax |
|---|---|---|
| **class** | a description of a set of objects that share the same attributes, operations, methods, relationships and semantics. |  |
| **interface** | a named set of operations that characterize the behavior of an element. |  |
| **component** | a modular, replaceable and significant part of a system that packages implementation and exposes a set of interfaces. |  |
| **node** | a run-time physical object that represents a computational resource. |  |

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

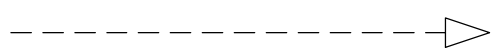
| Construct | Description | Syntax |
|---|---|---|
| **constraint**[1] | a semantic condition or restriction. |   |

[1] An extension mechanism useful for specifying structural elements.

# *Structural Modeling:* Core Relationships

| Construct | Description | Syntax |
|---|---|---|
| **association** | a relationship between two or more classifiers that involves connections among their instances. |  |
| **aggregation** | A special form of association that specifies a whole-part relationship between the aggregate (whole) and the component part. |  |
| **generalization** | a taxonomic relationship between a more general and a more specific element. |  |
| **dependency** | 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)

| Construct | Description | Syntax |
|---|---|---|
| **realization** | a relationship between a specification and its implementation. |  |

# Structural Diagram Tour

- 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

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

# Classes

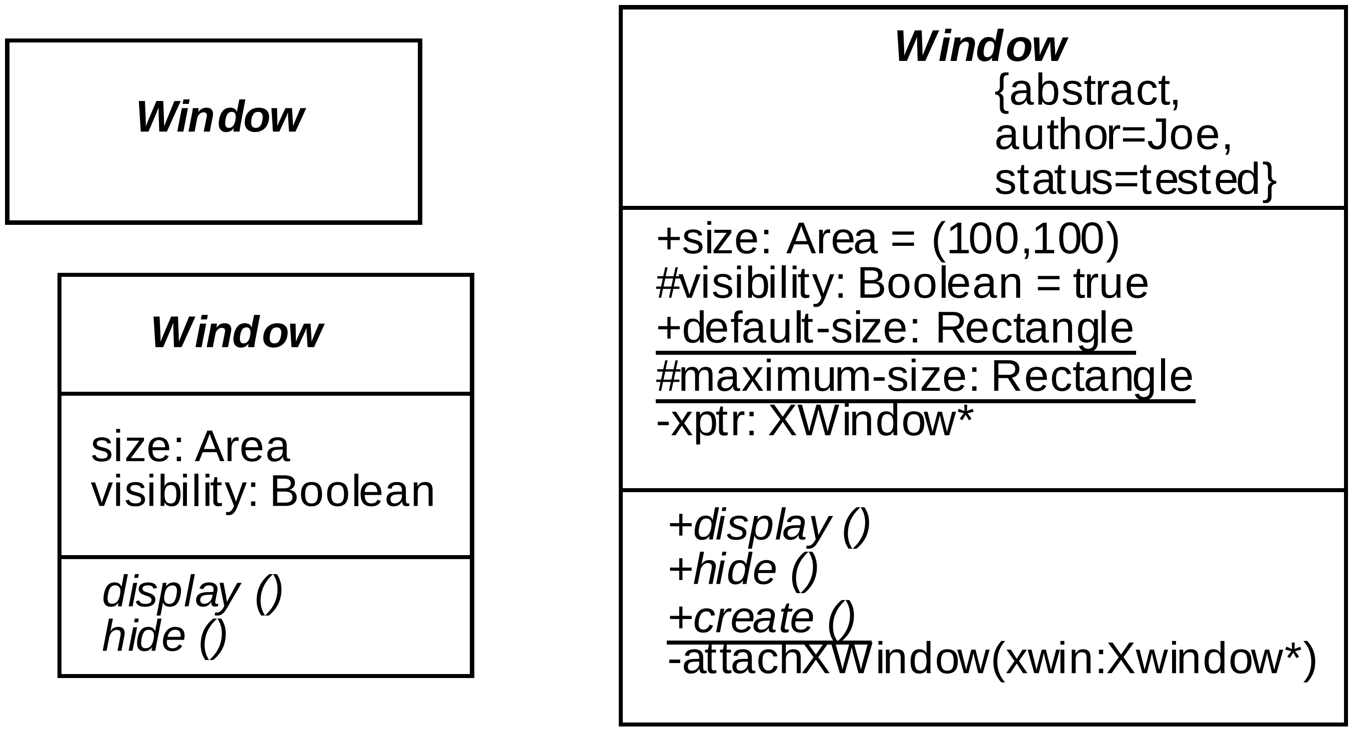



Fig. 3-20, *UML Notation Guide*

# Classes: compartments with names

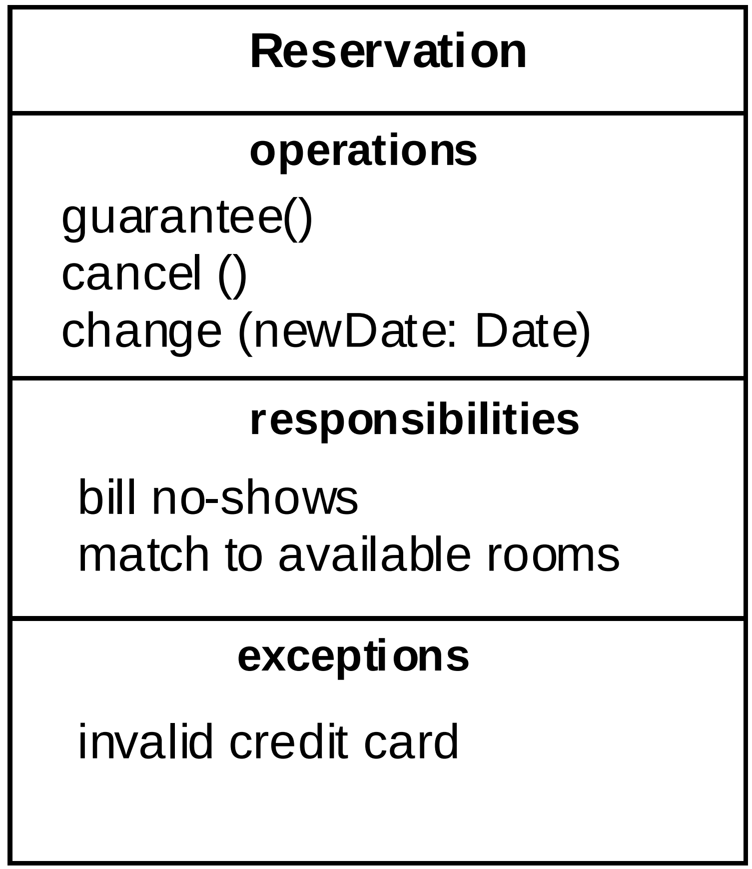



Fig. 3-23, *UML Notation Guide*

# Classes: method body

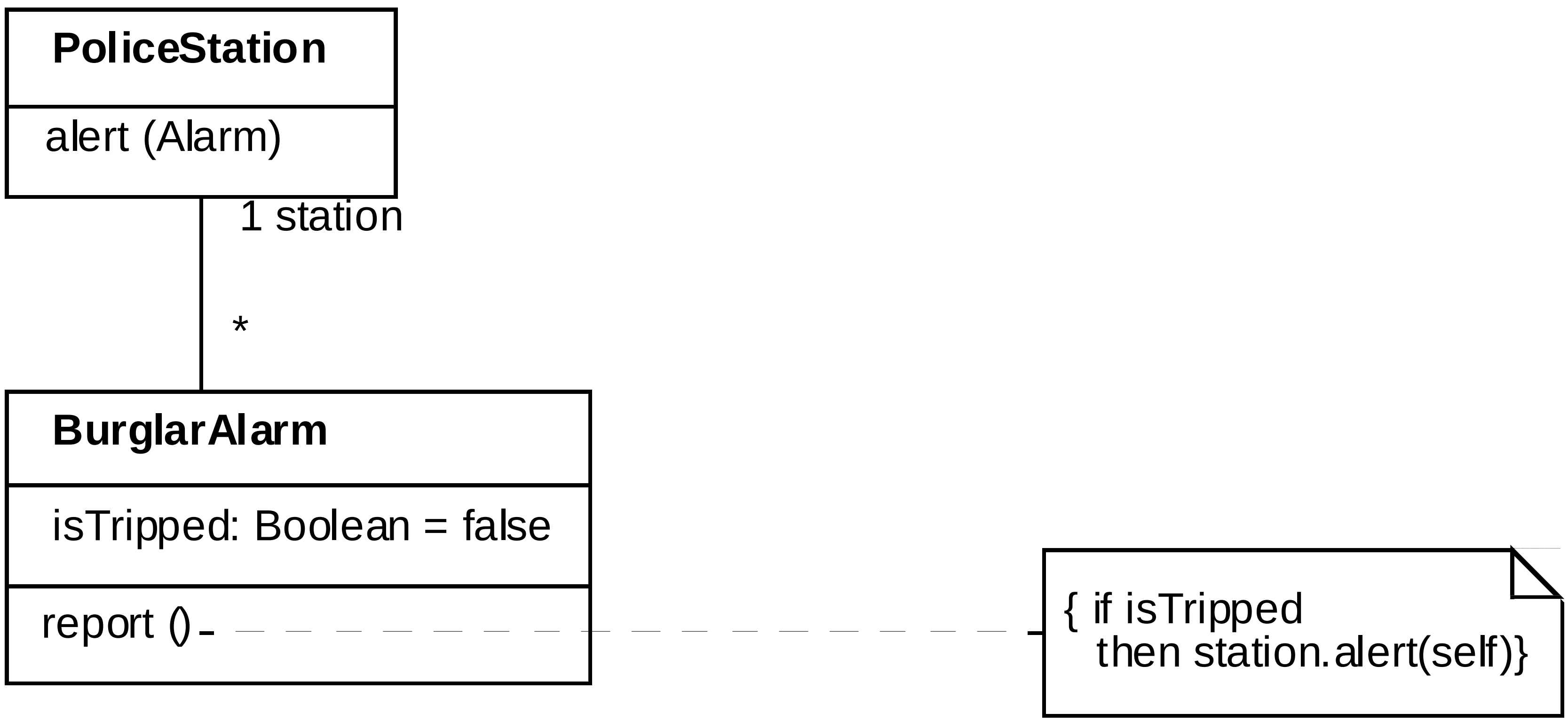



Fig. 3-24, *UML Notation Guide*

# Types and Implementation Classes

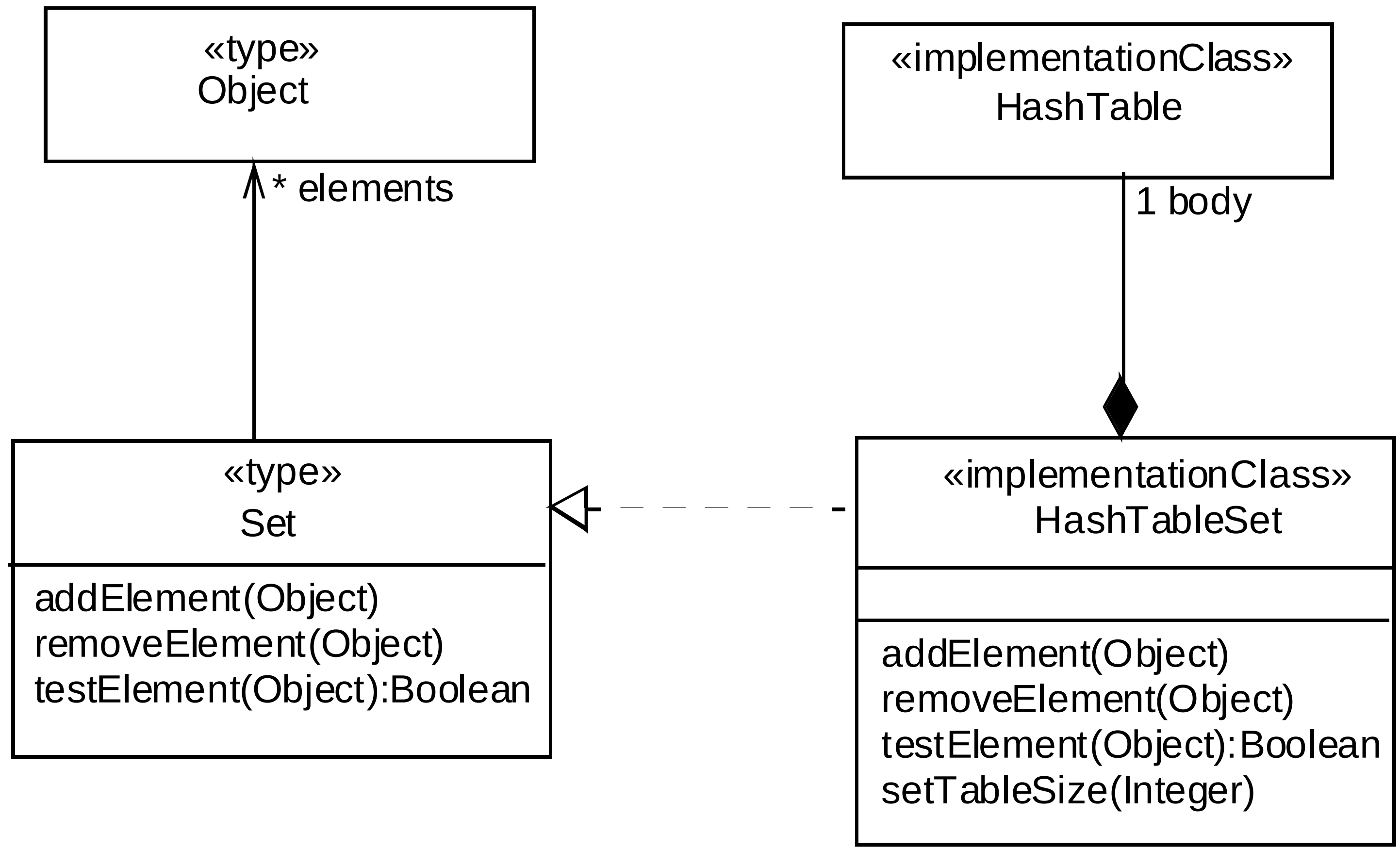



Fig. 3-27, *UML Notation Guide*

# Interfaces: Shorthand Notation

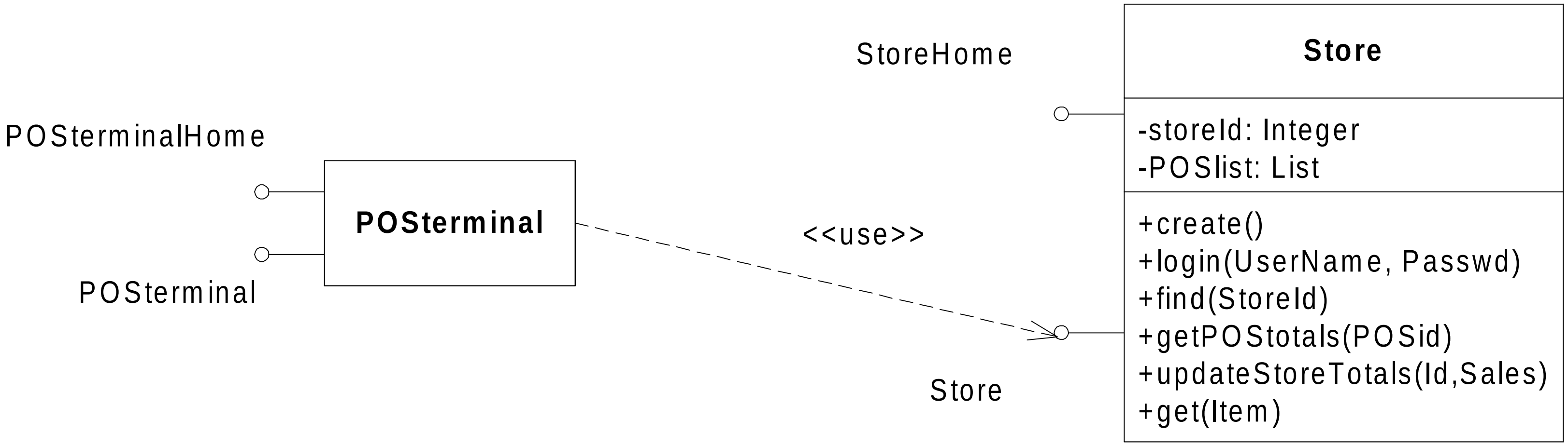



Fig. 3-29, *UML Notation Guide*

# Interfaces: Longhand Notation

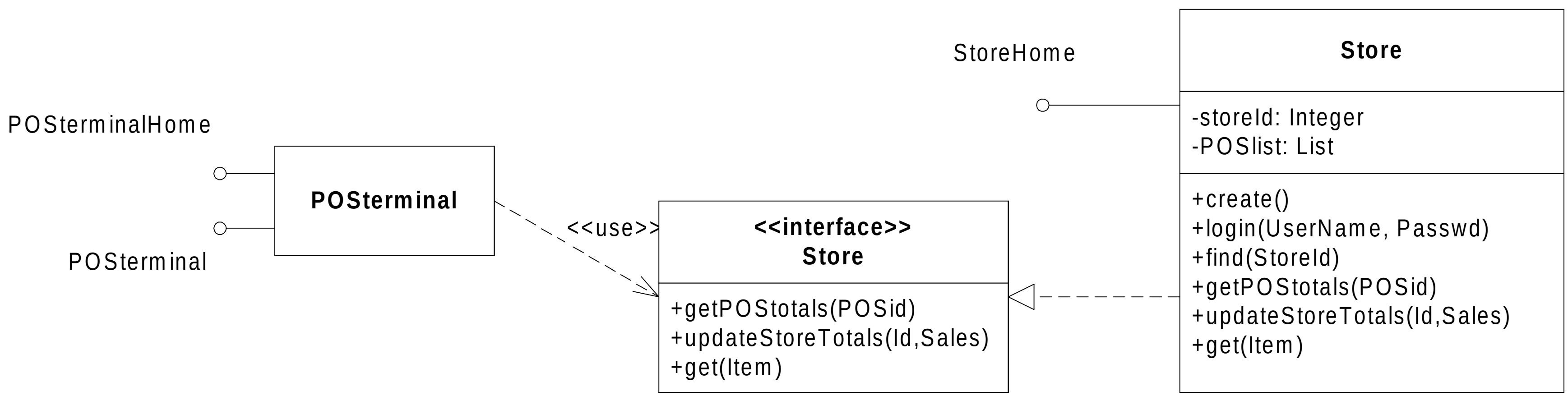
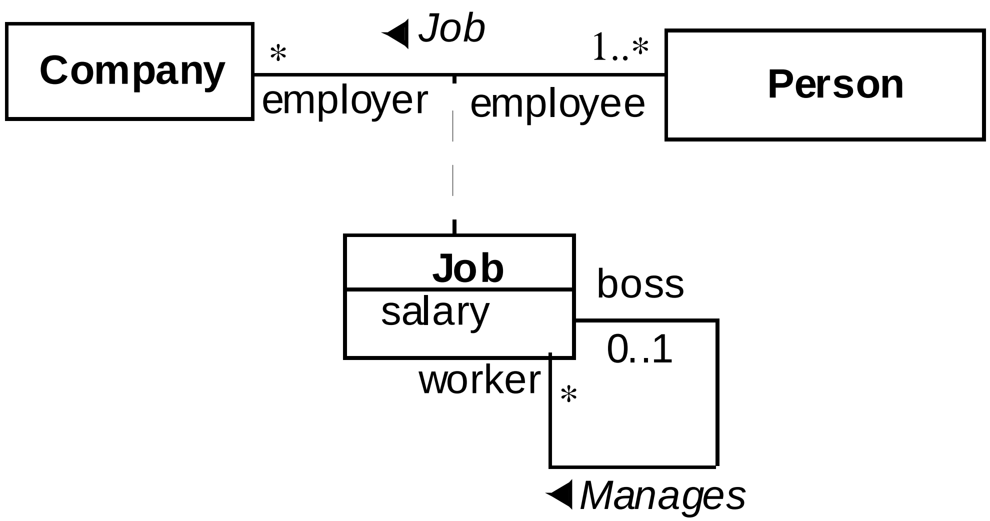



Fig. 3-29, *UML Notation Guide*

# Associations



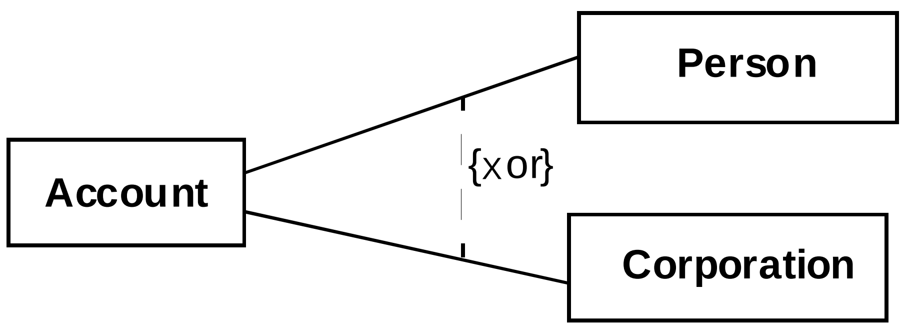




Fig. 3-40, *UML Notation Guide*

# Association Ends

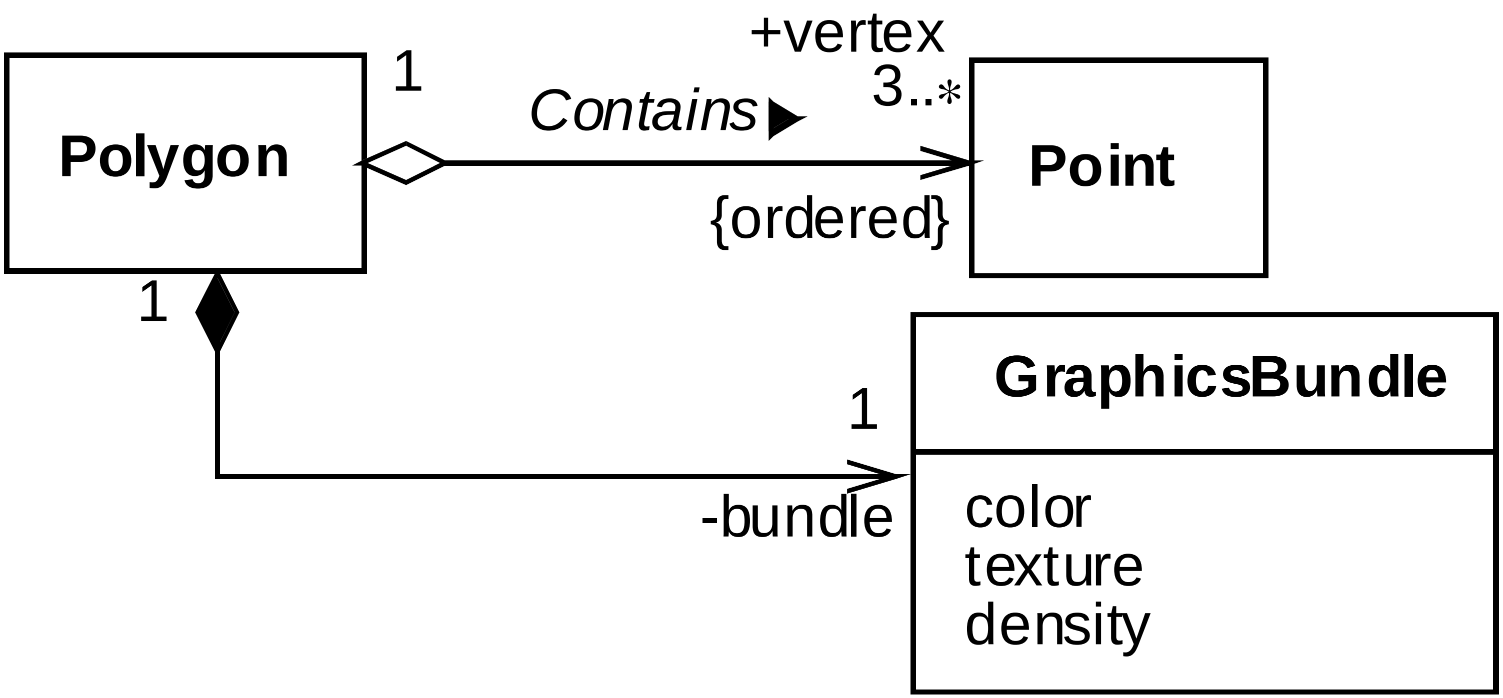



Fig. 3-41, *UML Notation Guide*

# Ternary Associations

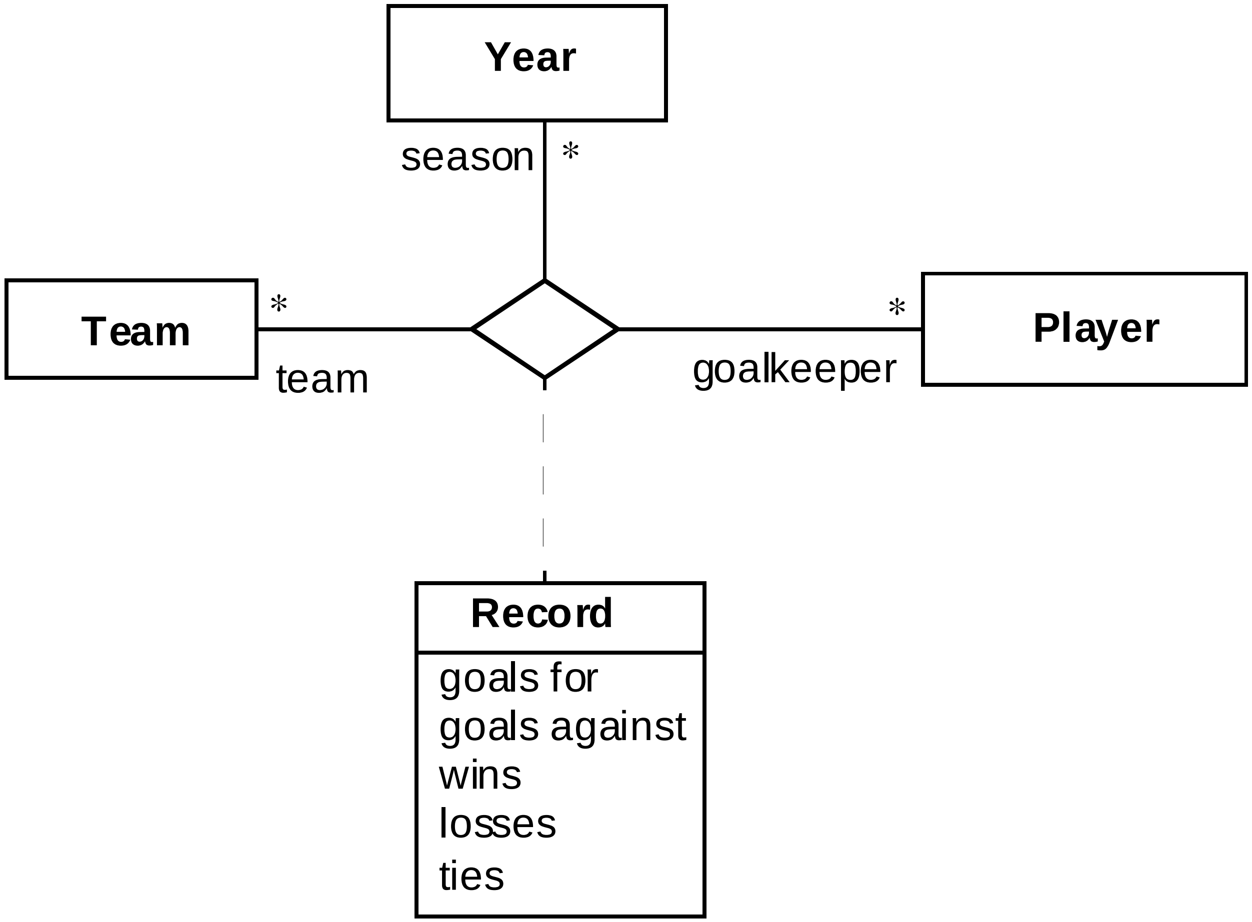



Fig. 3-44, *UML Notation Guide*

# Composition

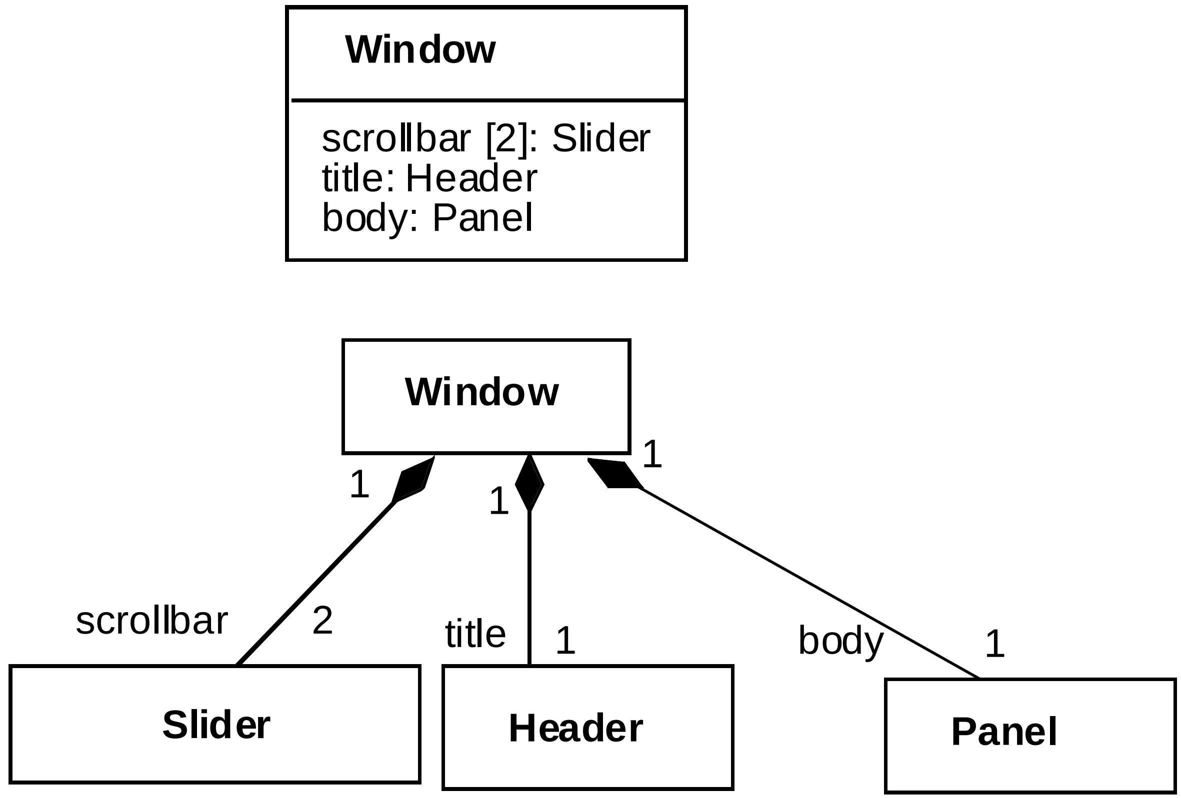



Fig. 3-45, *UML Notation Guide*

# Composition (cont'd)

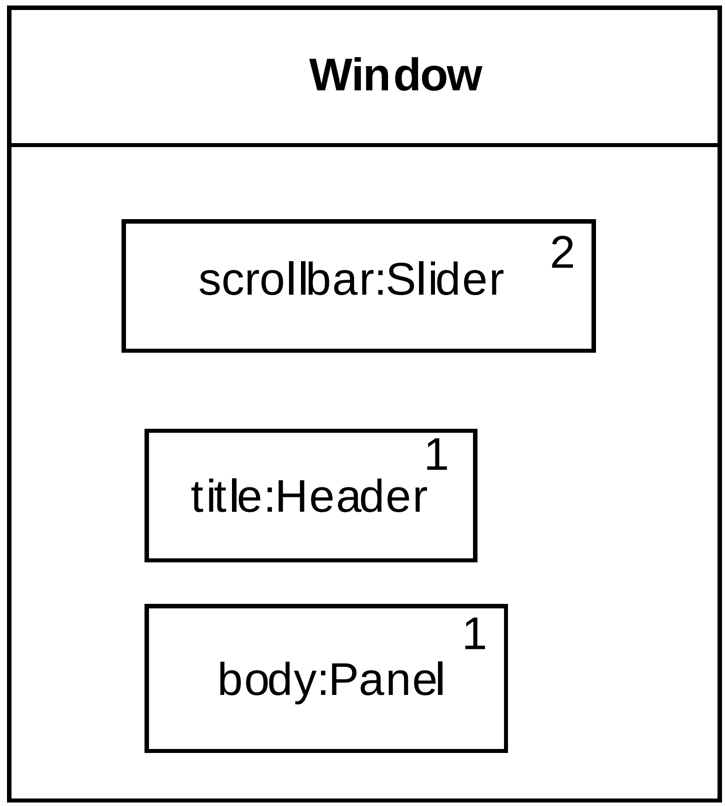



Fig. 3-45, *UML Notation Guide*

# Generalization

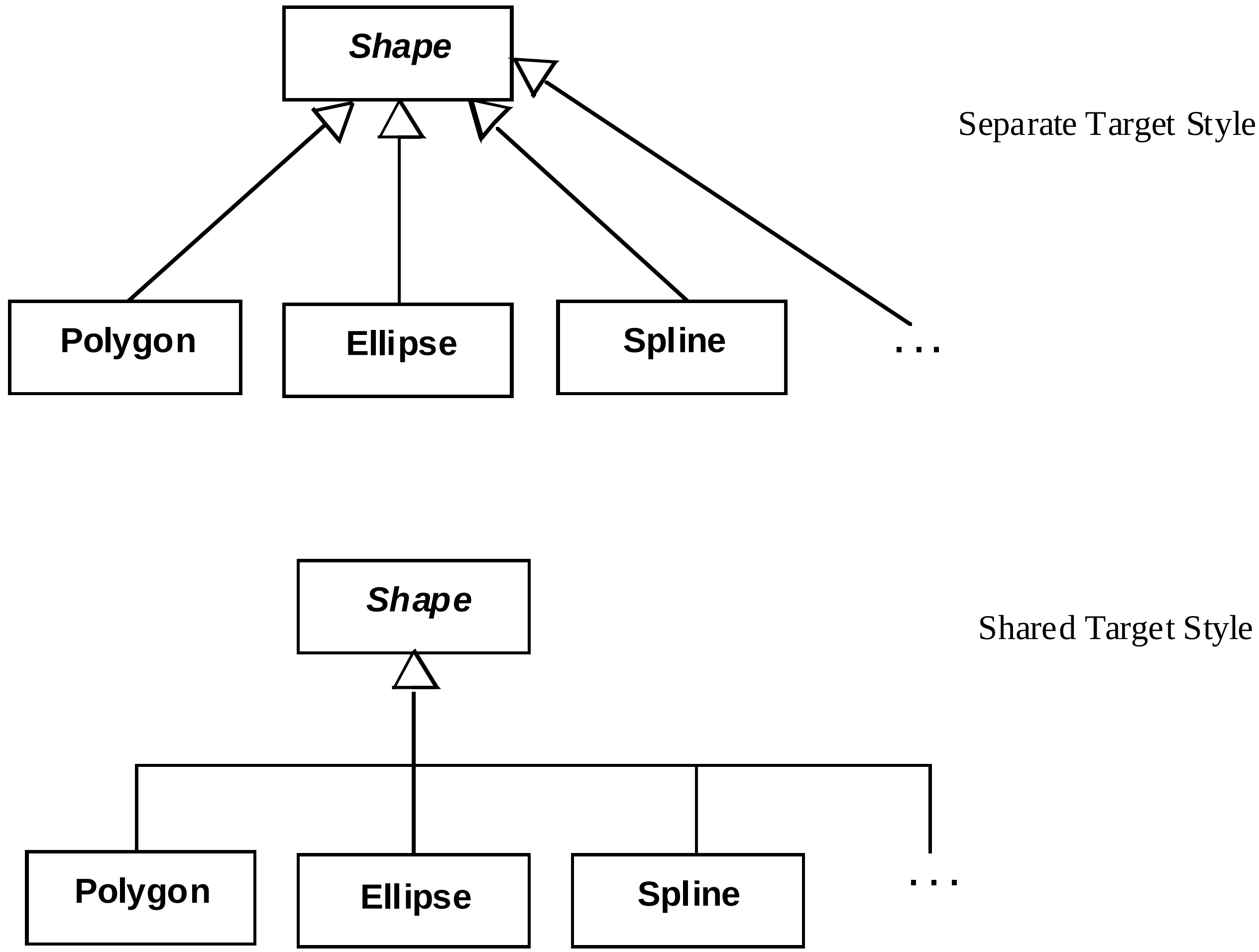



Fig. 3-47, *UML Notation Guide*

# Generalization

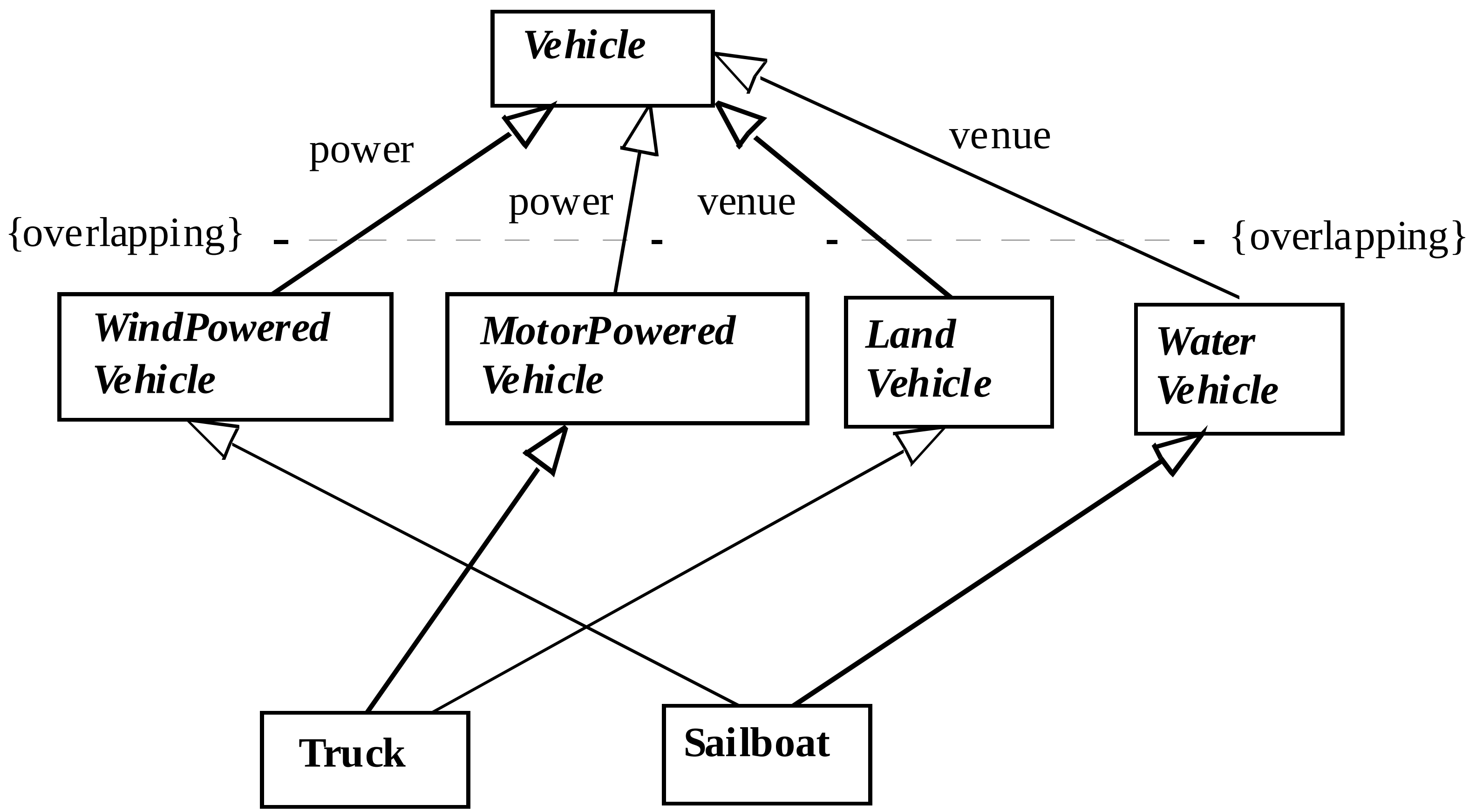



Fig. 3-48, *UML Notation Guide*

# Dependencies

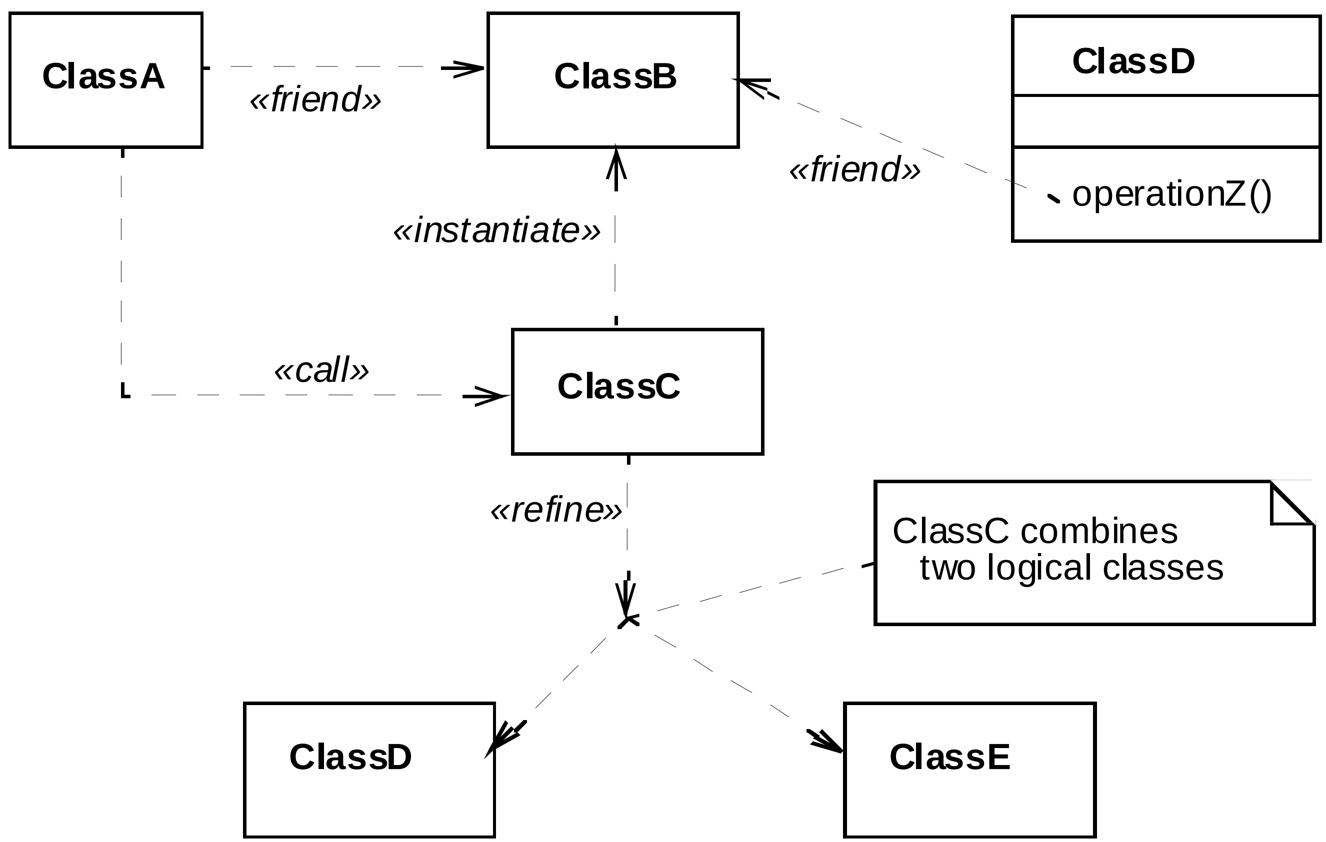



Fig. 3-50, *UML Notation Guide*

# Dependencies

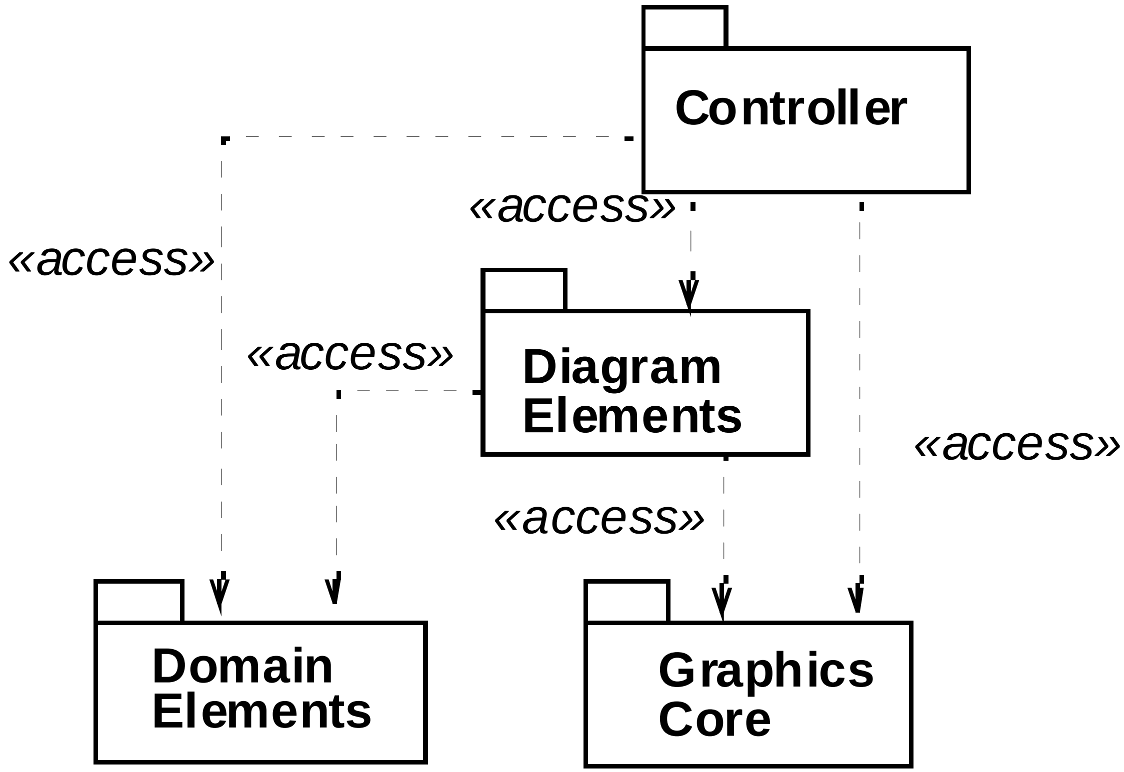
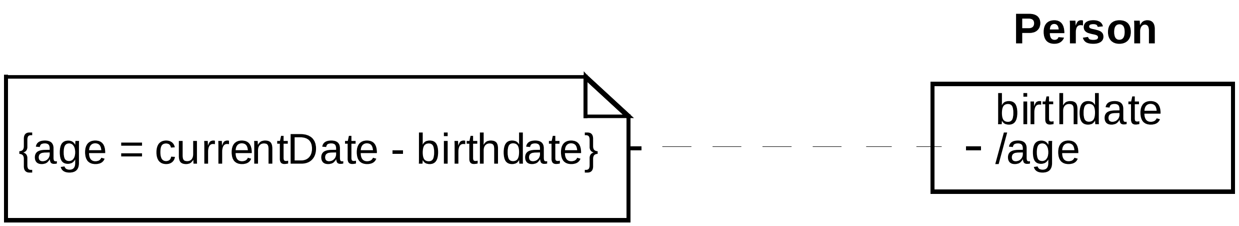



Fig. 3-51, *UML Notation Guide*

# Derived Attributes and Associations



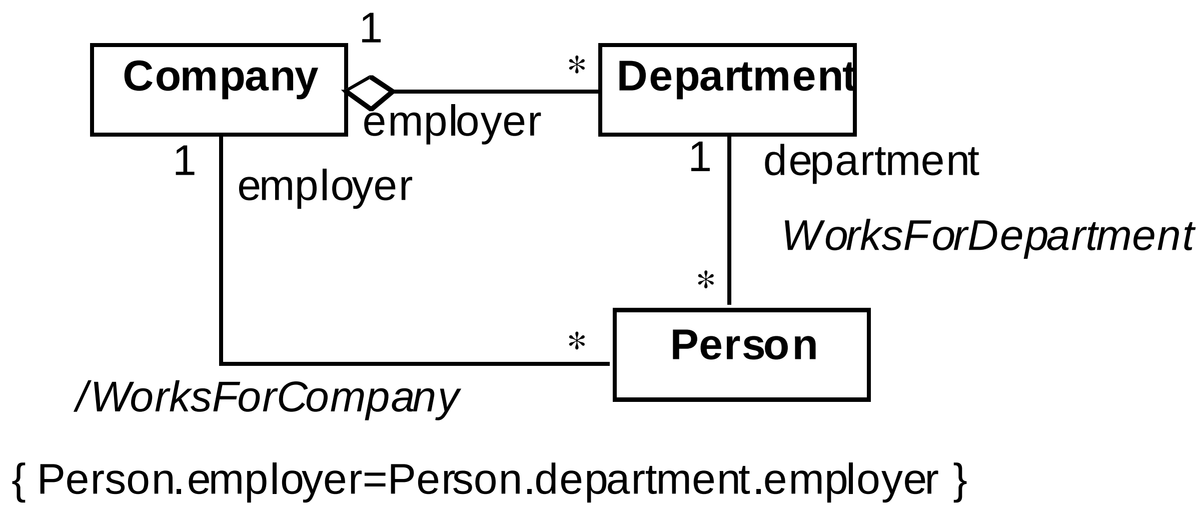




Fig. 3-52, *UML Notation Guide*

# Objects

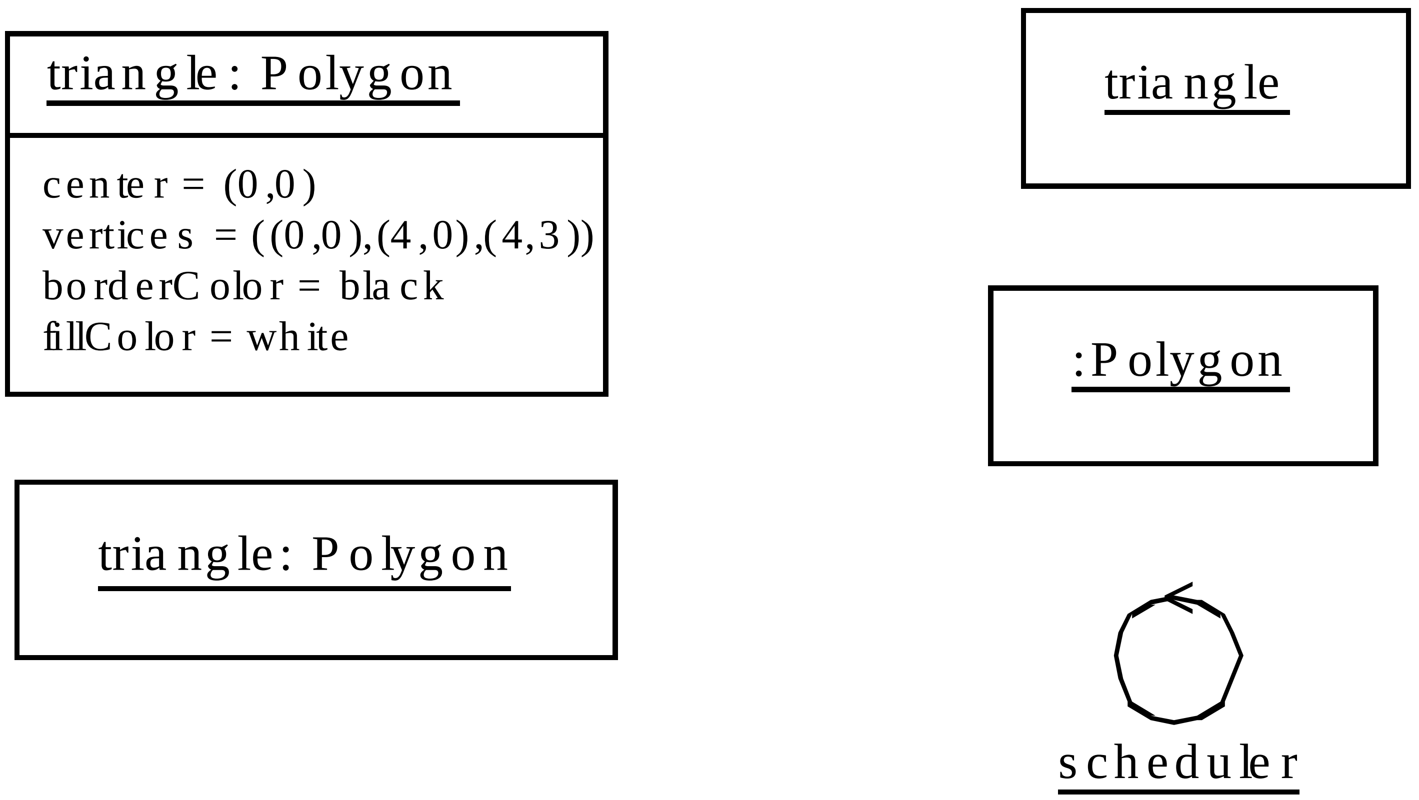



Fig. 3-38, *UML Notation Guide*

# Composite objects

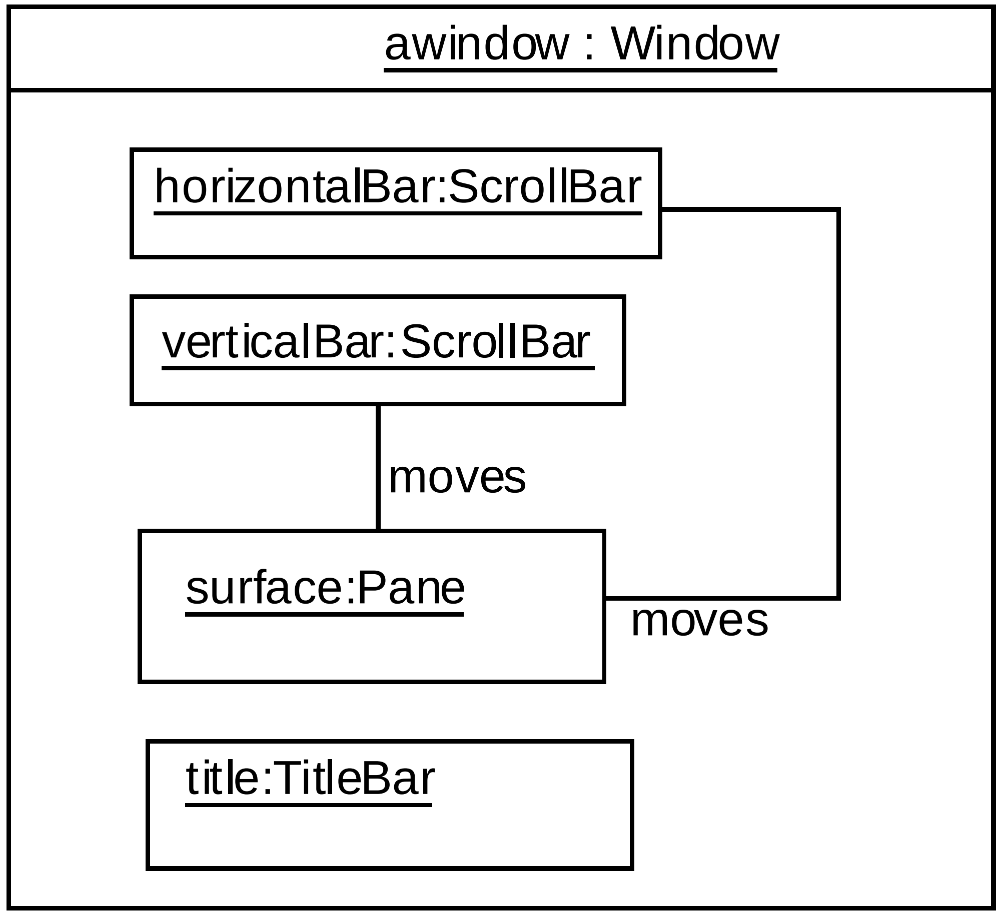



Fig. 3-39, *UML Notation Guide*

# Links

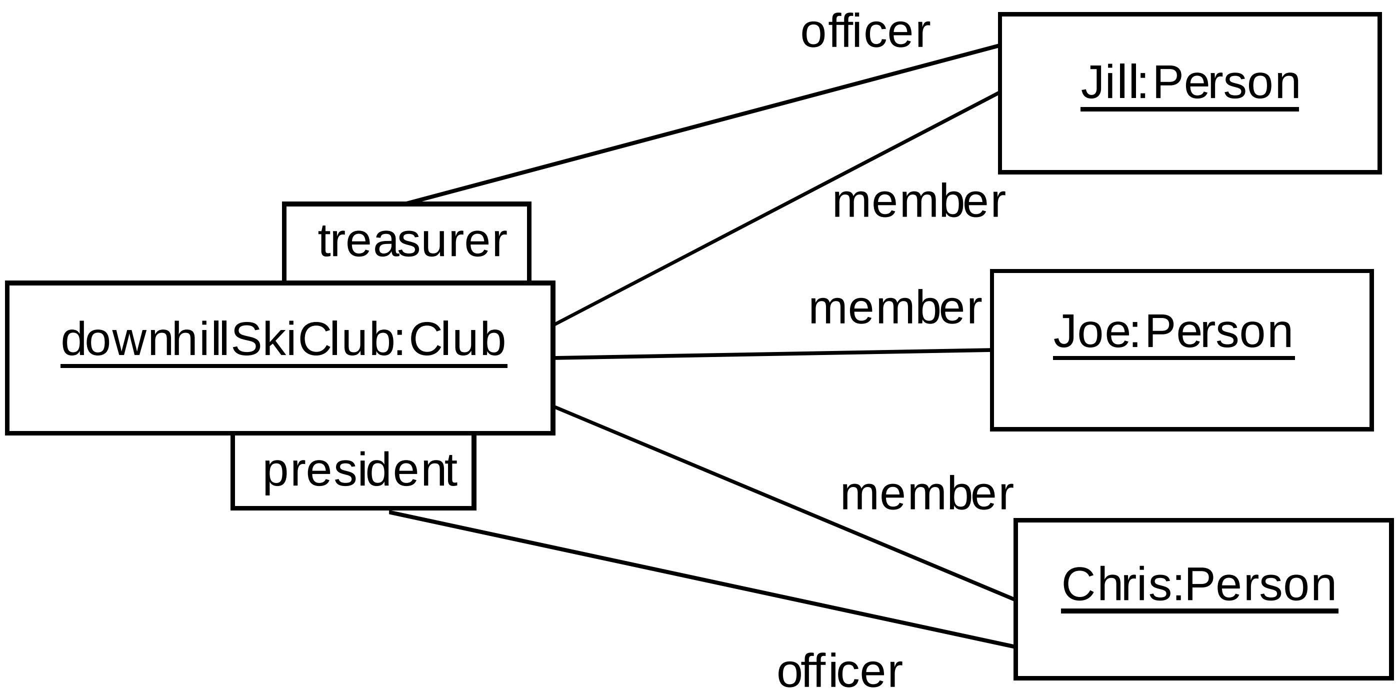



Fig. 3-46, *UML Notation Guide*

# Constraints and Comments

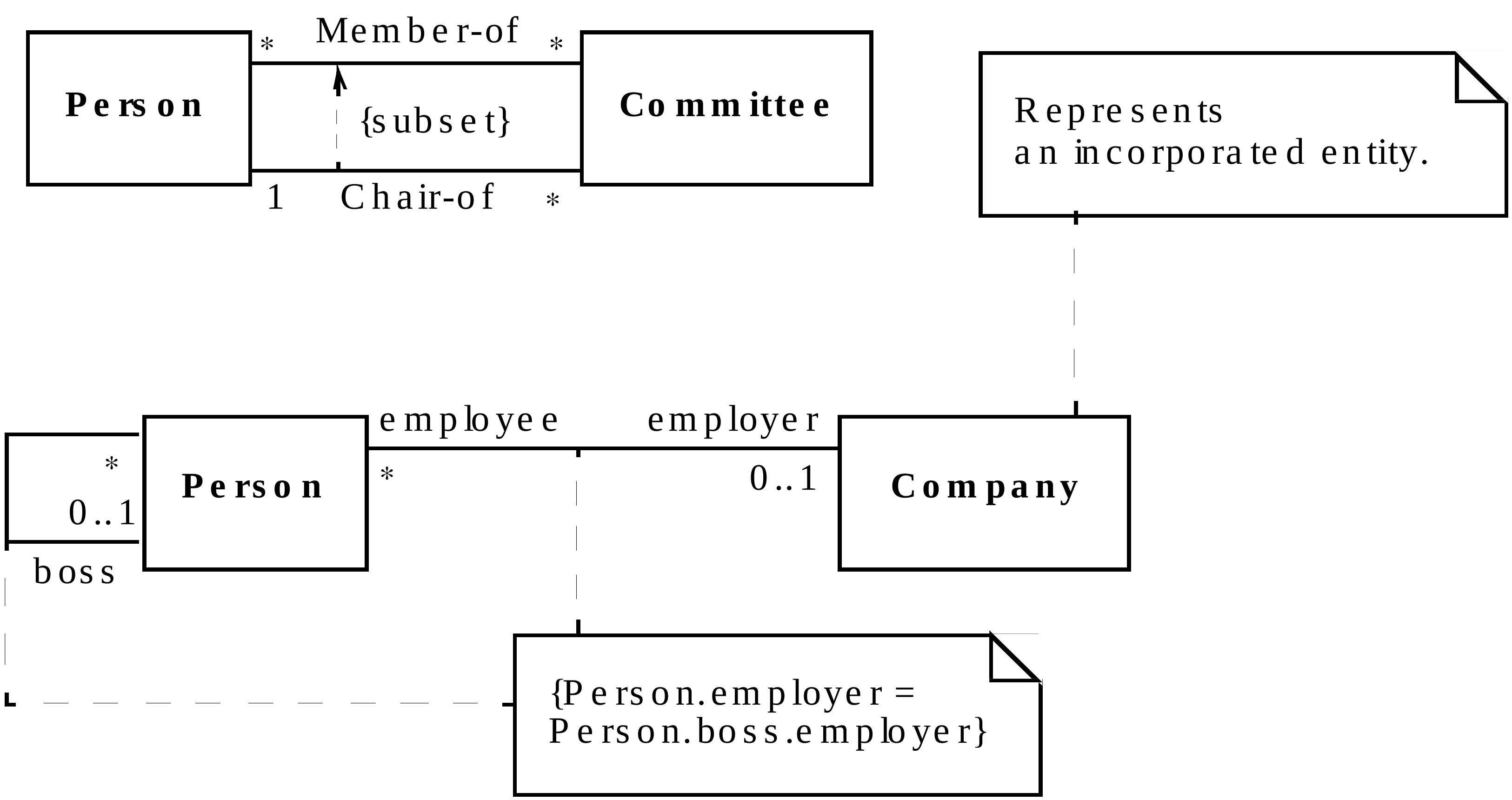
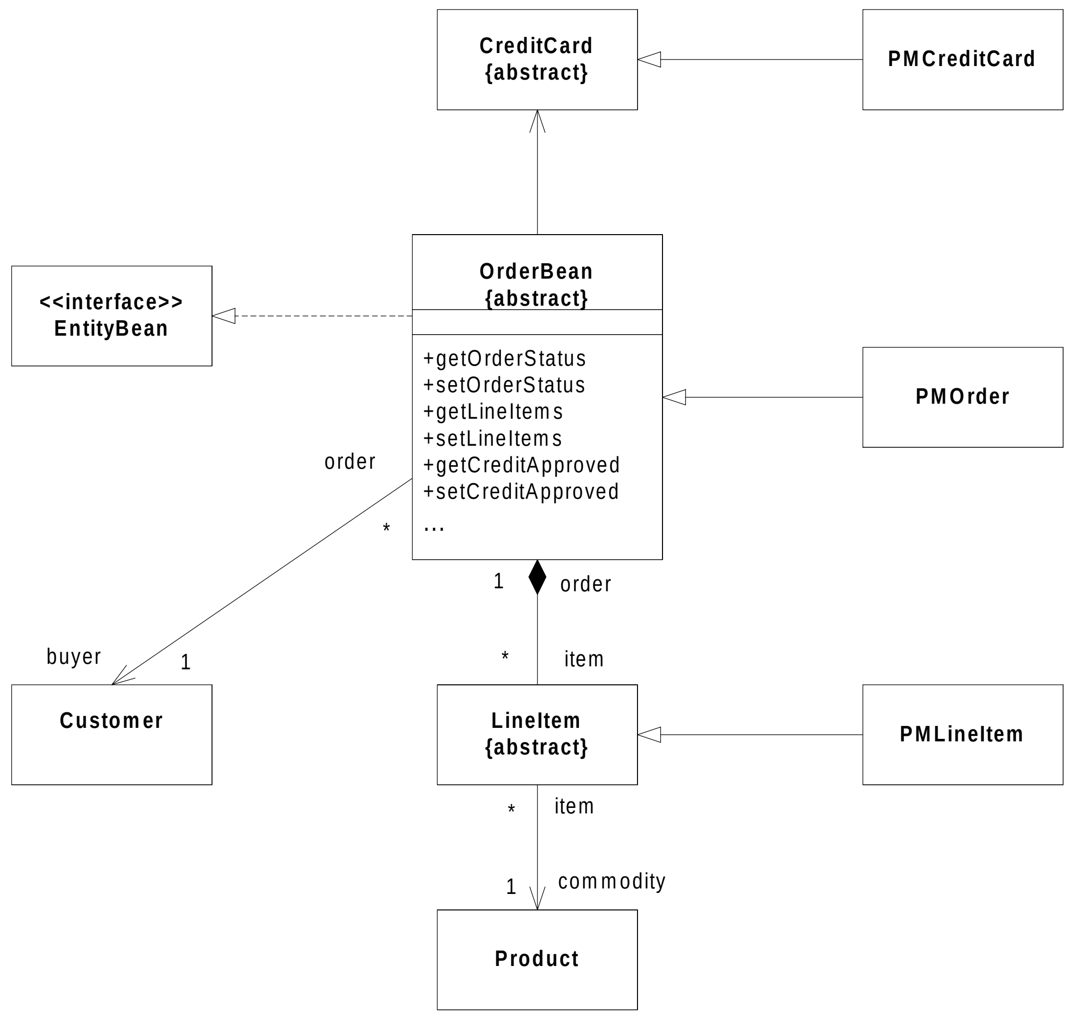



Fig. 3-17, *UML Notation Guide*

# Class Diagram Example




Adapted from Fig. 23 [EJB 2.0].

# Implementation Diagrams

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

# Component Diagram

- Shows the organizations and dependencies among software components
- Components may be
  - specified by classifiers (e.g., implementation classes)
  - implemented by artifacts (e.g., binary, executable, or script files)

# Components

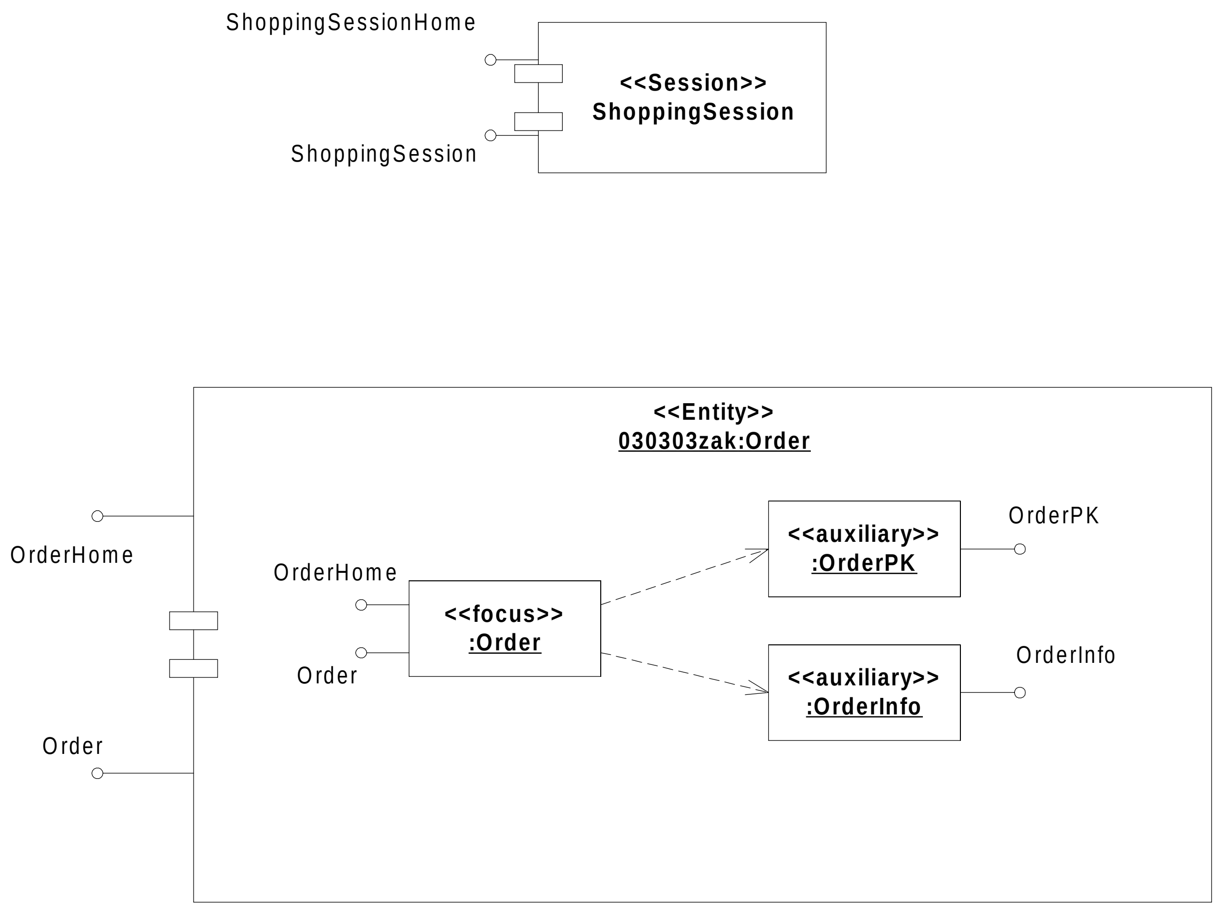



Fig. 3-99, *UML Notation Guide*

# Component Diagram

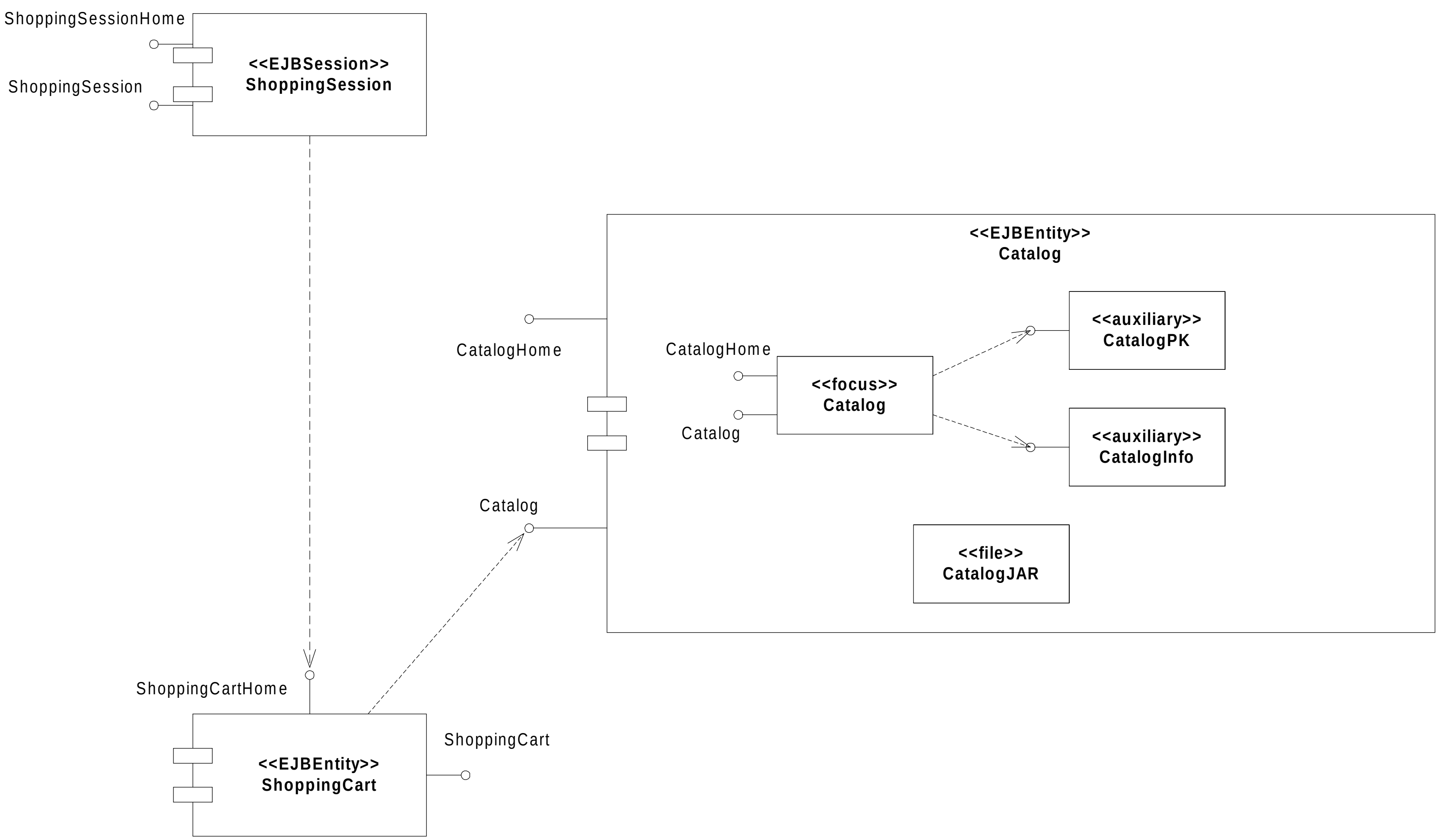



Fig. 3-95, *UML Notation Guide*

# Component Diagram with Relationships

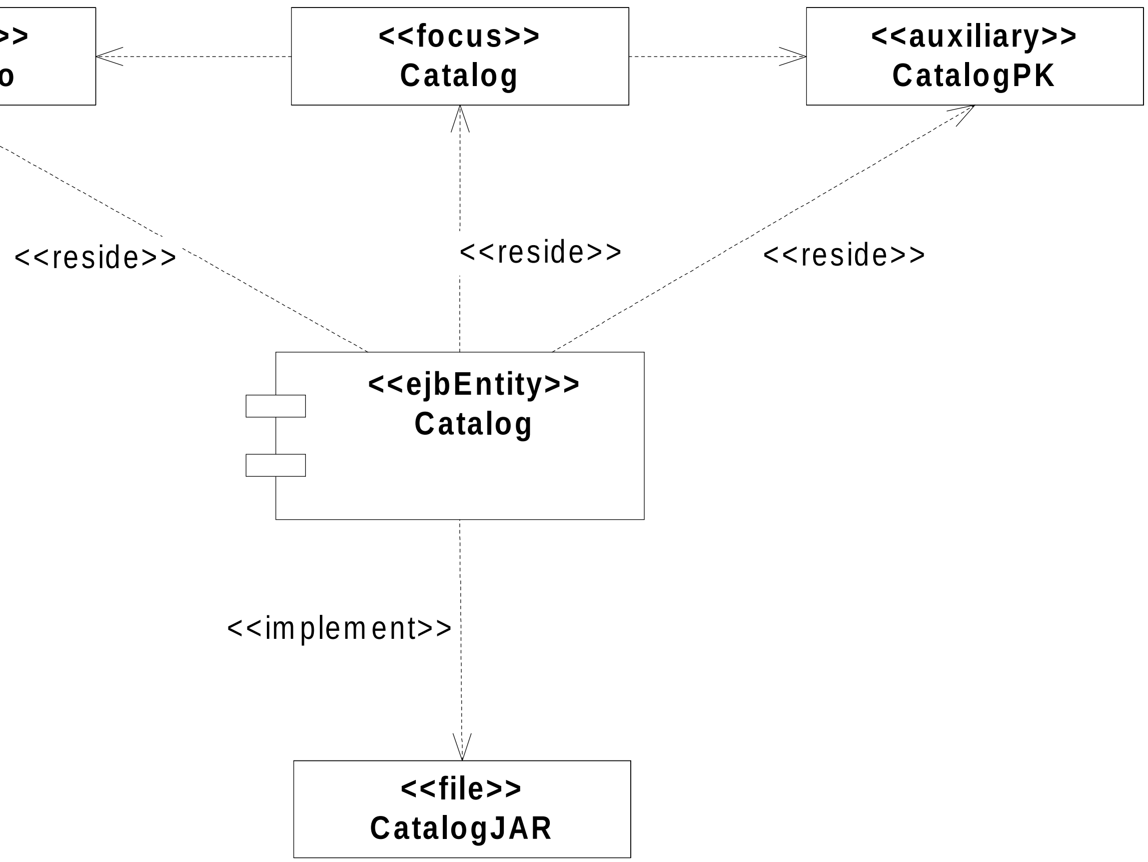



Fig. 3-96, *UML Notation Guide*

# Deployment Diagram

- 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 (1/2)

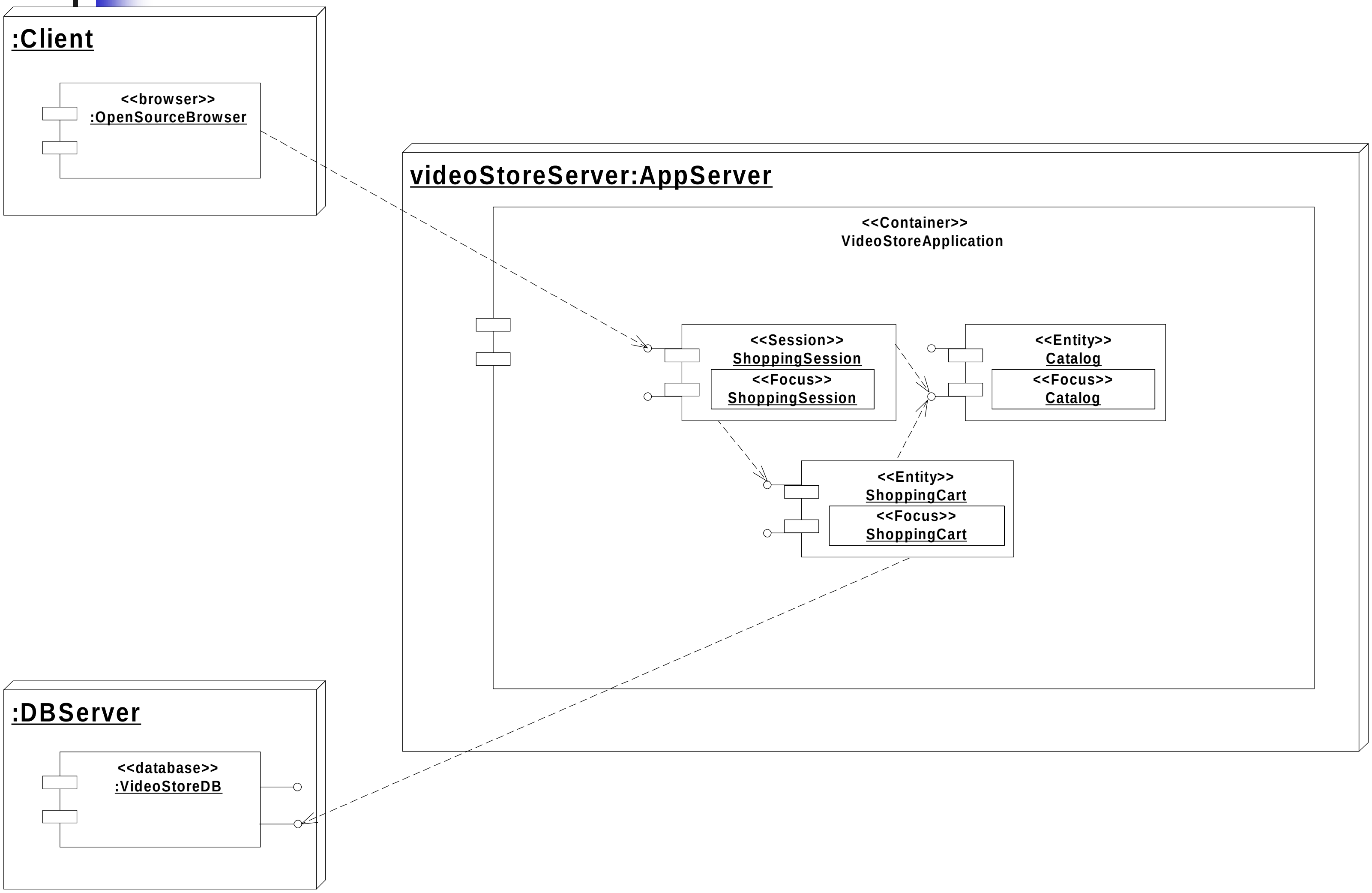



Fig. 3-97, *UML Notation Guide*

# Deployment Diagram (2/2)

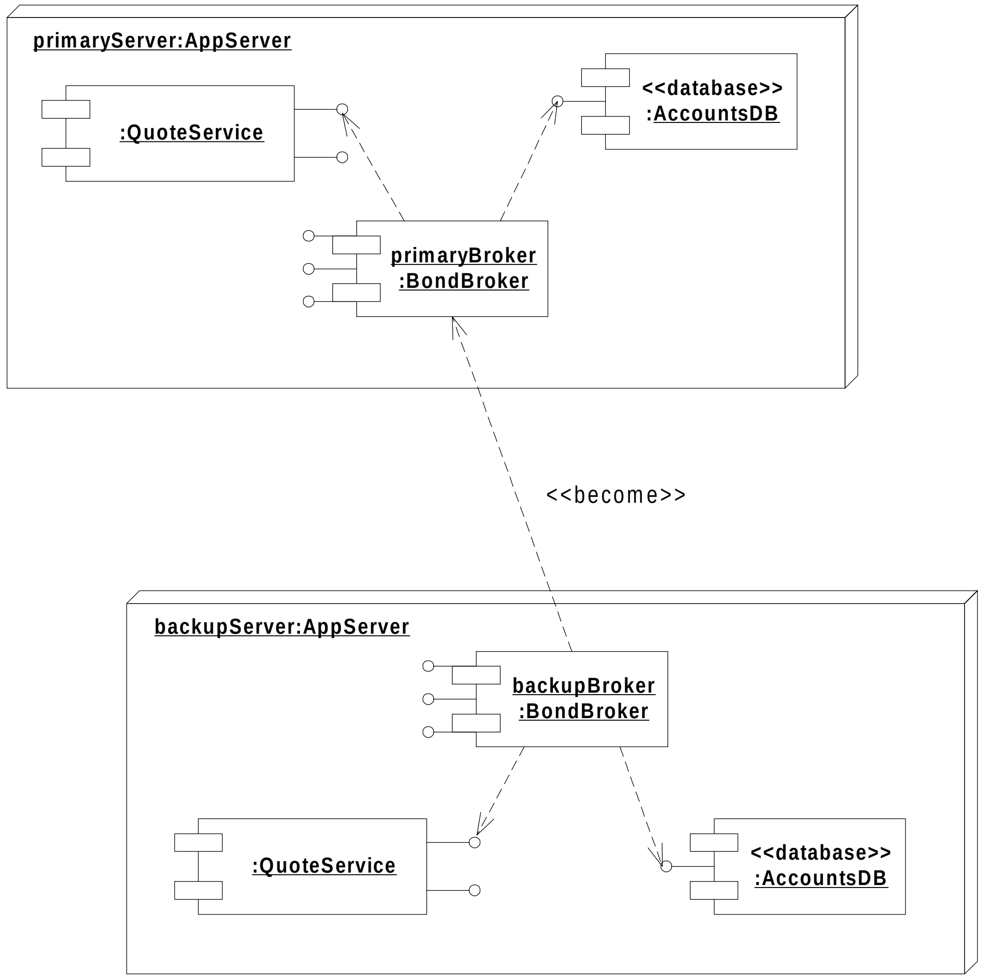



Fig. 3-98, *UML Notation Guide*

# When to model structure

- 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

- 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)

# Interface-Based Design

- Interface-based design is a design approach that
  - emphasizes the specification of system interfaces
  - separates the specification of service operations (interfaces) from their realization (implementation)
- CORBA IDL is typically used for interface-based design of CORBA applications
  - defines interfaces for business and system objects without constraining their implementations
  - defines the structure of an distributed application
  - doesn’t allow you to specify object behavior or class relationships other than generalization

# Interface-Based Design (cont'd)

- The following example shows how UML can model the interfaces for a Point of Sale application originally specified in CORBA IDL. From [Kobryn 2000].

# Example: Interface-based design

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

    interface InputMedia
    {
        typedef string OperatorCmd;

        void         barcode_input(in Barcode     item);
        void         keypad_input( in OperatorCmd cmd);
    };

    interface OutputMedia
    {
        boolean      output_text(  in string
   string_to_print );
    };
…..
```

Generic IDL Point of Sale (POS) example. [Siegel 00]

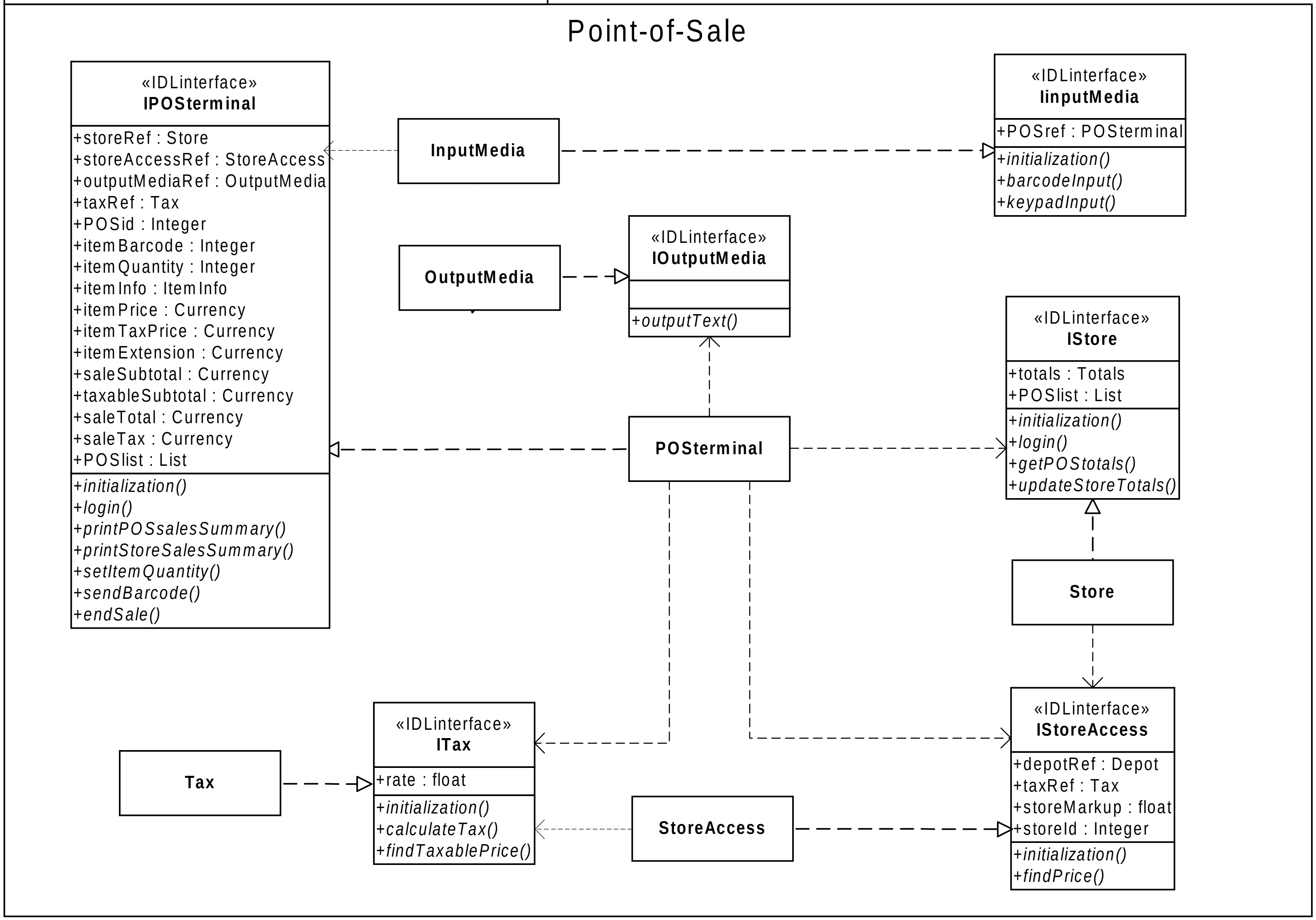
# Example: Interface-based design

```
…..
    interface POSTerminal
    {
        void  login();
        void  print_POS_sales_summary();
        void  print_store_sales_summary();
        void  send_barcode(        in Barcode     item);
        void  item_quantity(       in long
   quantity);
        void  end_of_sale();
    };

};

#endif /* _POS_IDL_ */
```

From [Kobryn 00].



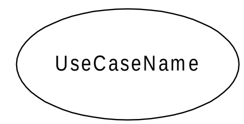
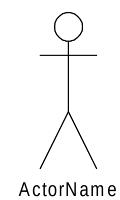
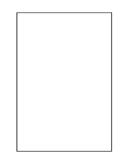
# Use Case Modeling

- 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?

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

# *Use Case Modeling:* Core Relationships

| Construct | Description | Syntax |
|---|---|---|
| **association** | 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. | |
| **generalization** | A taxonomic relationship between a more general use case and a more specific use case. | |
| **extend** | A relationship from an *extension* use case to a *base* use case, specifying how the behavior for the extension use case can be inserted into the behavior defined for the base use case. | <<extend>> |

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

| Construct | Description | Syntax |
| --- | --- | --- |
| **include** | An relationship from a *base* use case to an *inclusion* use case, specifying how the behavior for the inclusion use case is inserted into the behavior defined for the base use case. | <<include>><br>----------> |

# Use Case Diagram Tour

- 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

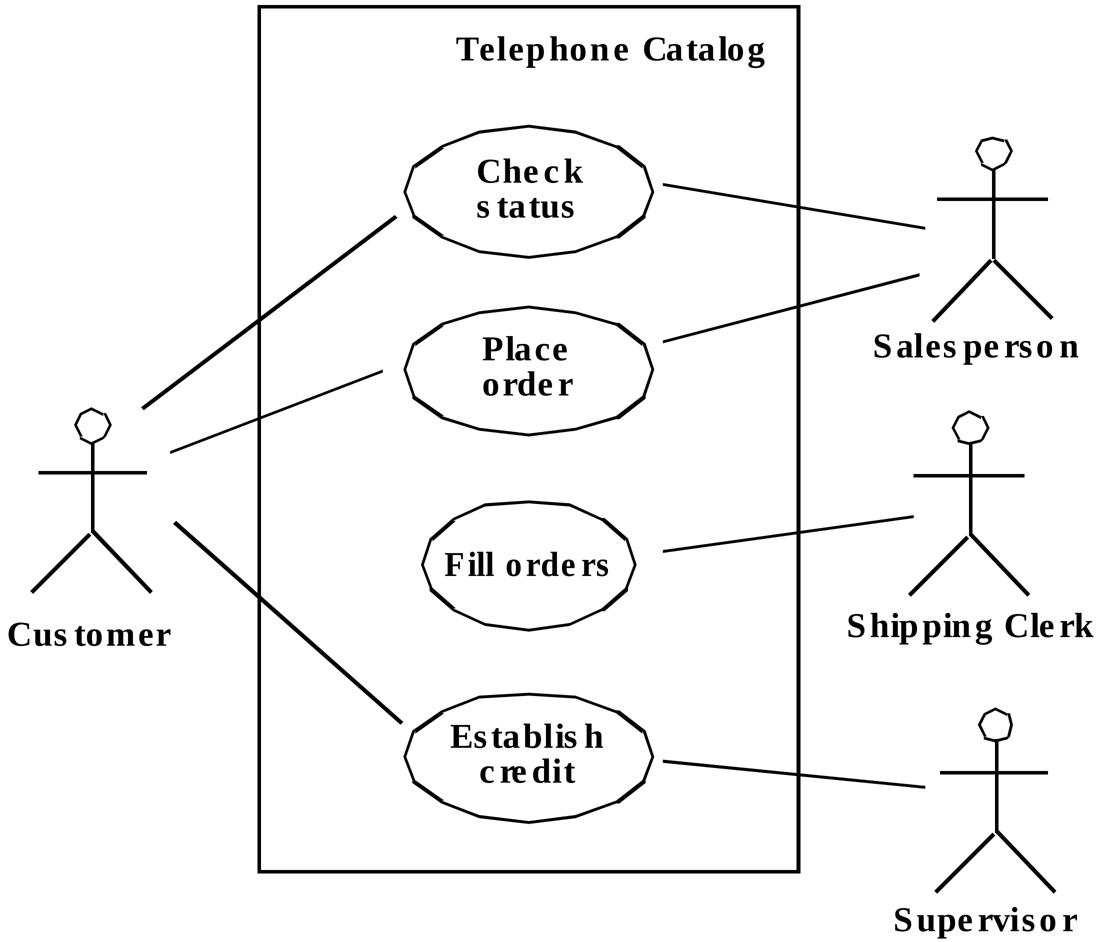



Fig. 3-53, *UML Notation Guide*

# Use Case Relationships

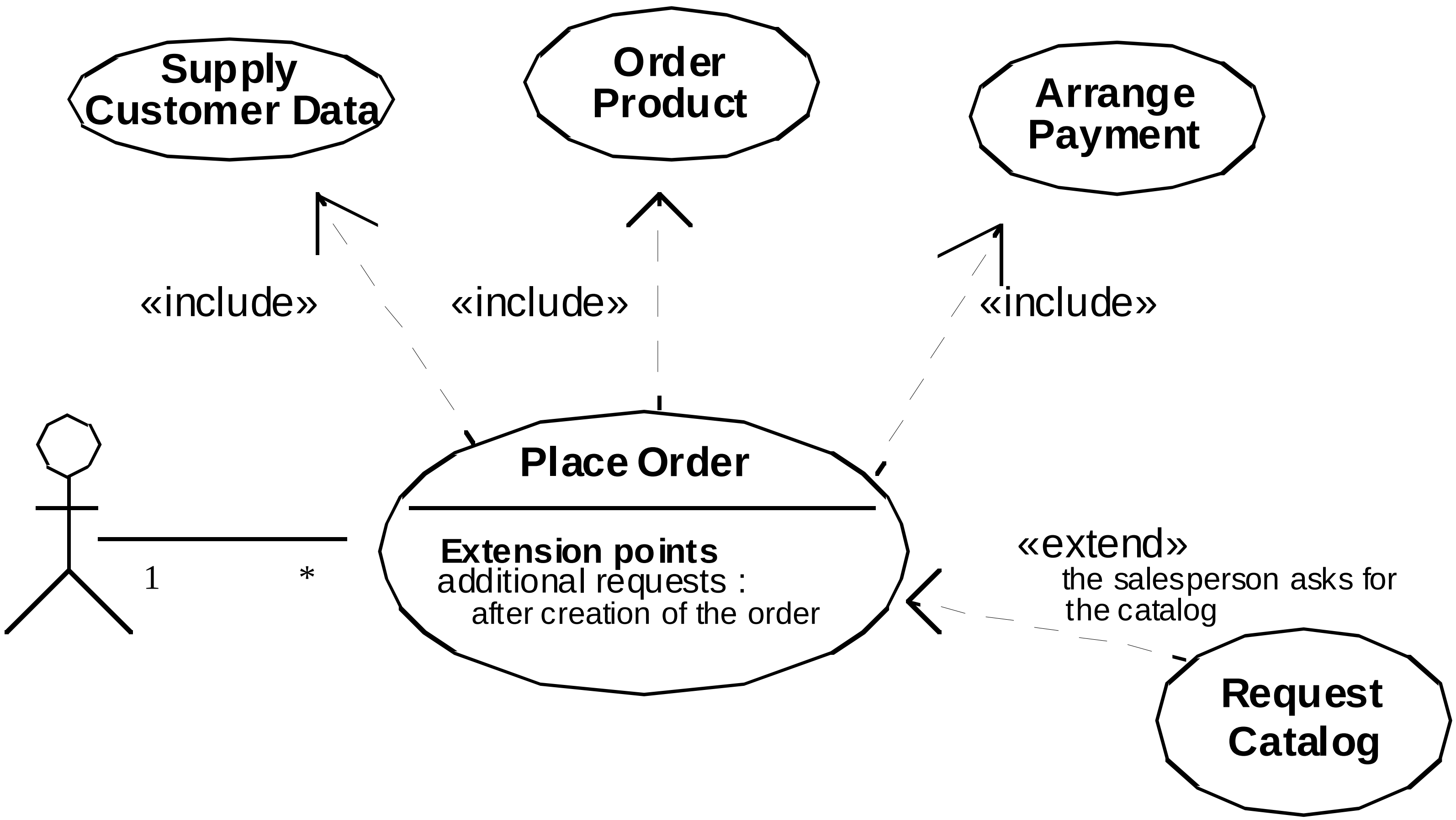



Fig. 3-54, *UML Notation Guide*

# Actor Relationships

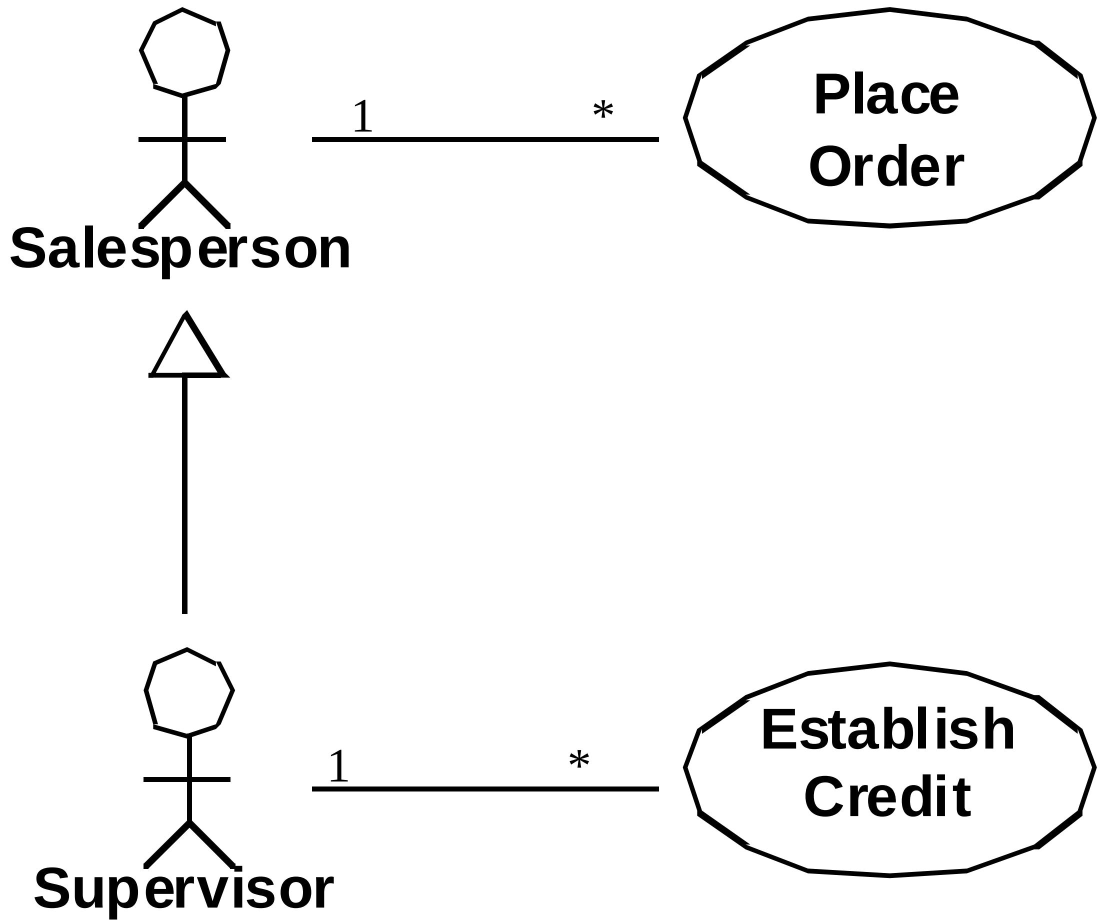



Fig. 3-55, *UML Notation Guide*

# Use Case Description: Change Flight

- **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 …

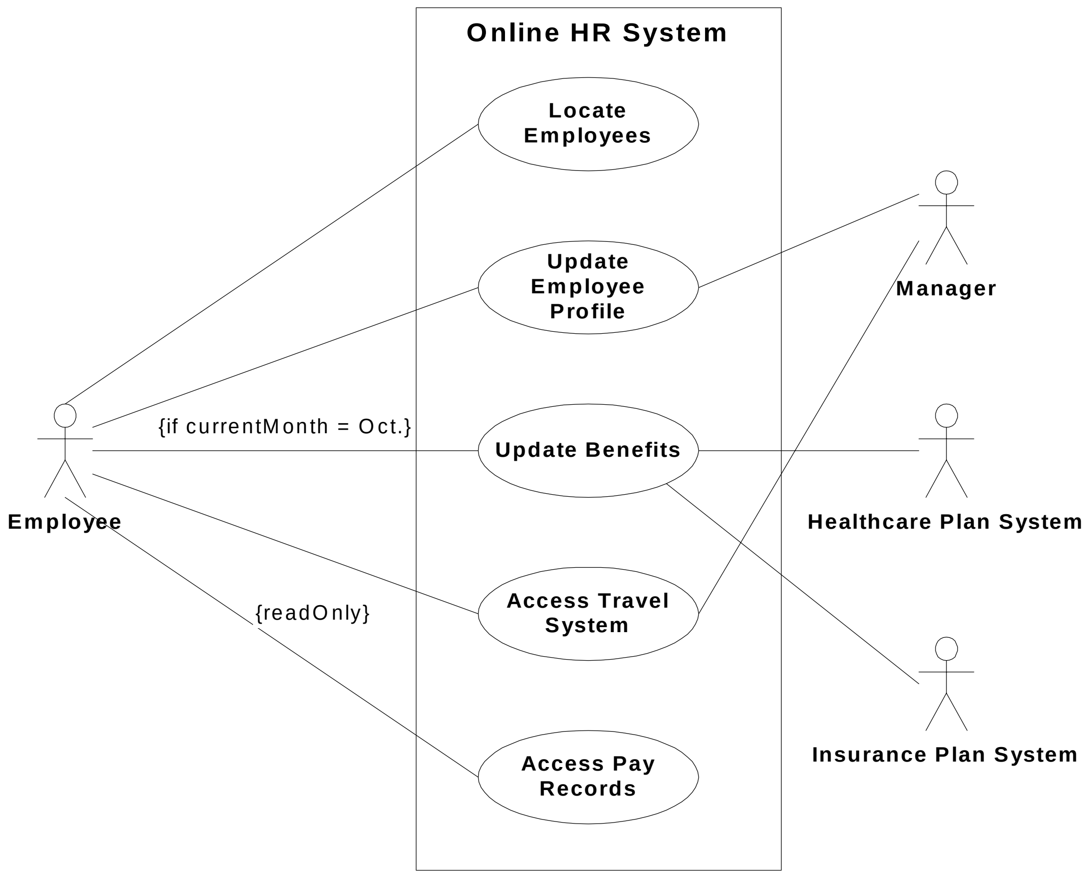
# When to model use cases

- 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.

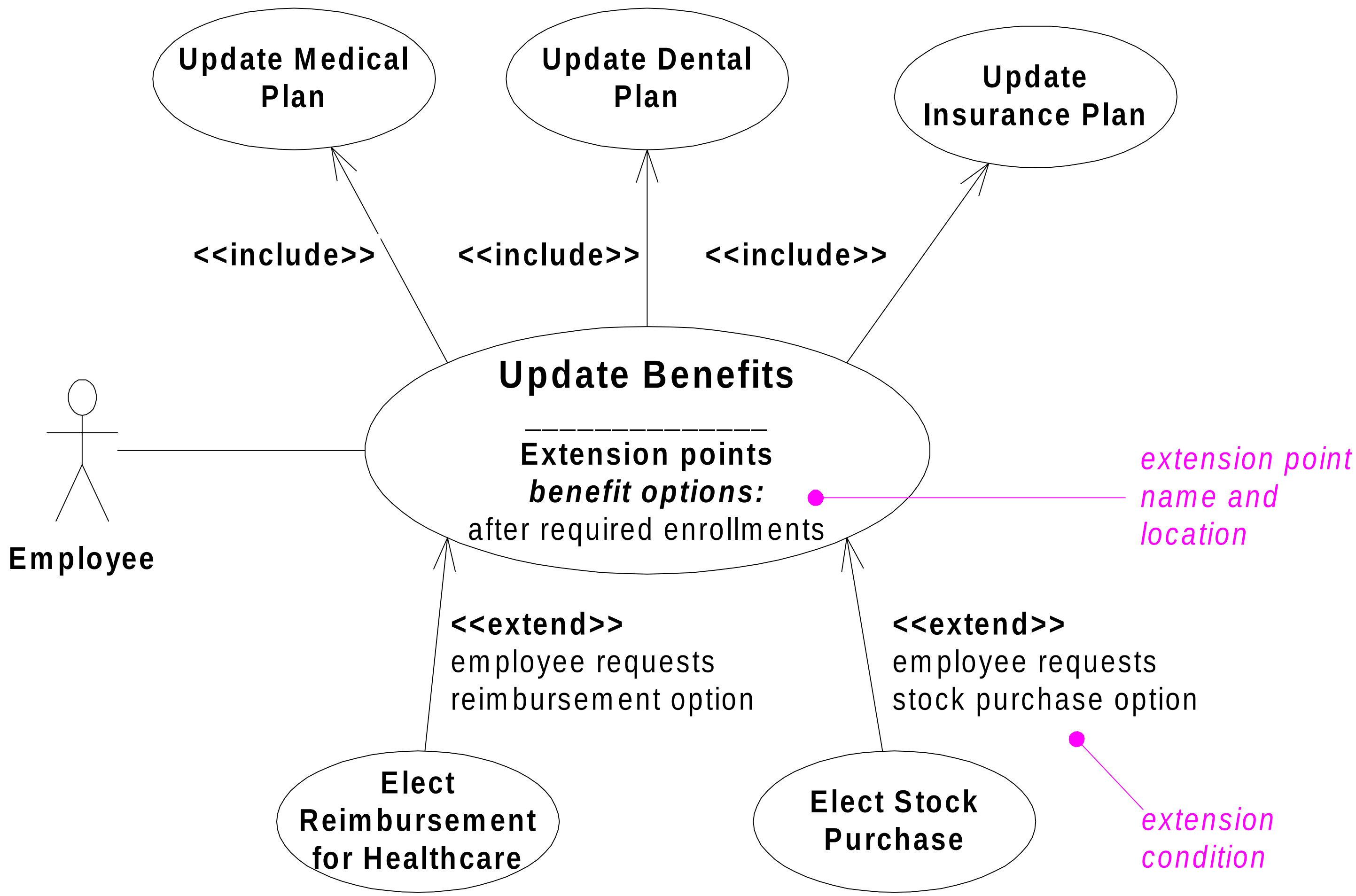
# Use Case Modeling Tips

- 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

- **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

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

# Ideas to Take Away

- 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

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

# References


- [UML 1.3] *OMG UML Specification v. 1.3*, OMG doc# ad/06-08-99
- [UML 1.4] *OMG UML Specification* v. 1.4, UML Revision Task Force recommended final draft, OMG doc# ad/01-02-13.
- [Kobryn 01a] C. Kobryn, "UML 2.0 Roadmap: Fast Track or Detours? ," *Software Development*, April 2001. To appear.
- [Kobryn 01b] C. Kobryn, "Modeling Distributed Applications with UML," chapter in [Siegel 01] *Quick CORBA 3*, Wiley, 2001. To be published.
- [Kobryn 00] "Modeling CORBA Applications with UML," chapter 21 in [Siegel 00] *CORBA 3 Fundamentals and Programming* (2nd ed.), Wiley, 2000.
- [Kobryn 99] *UML 2001: A Standardization Odyssey*, Communications of the ACM, Oct. 1999.
- [EJB 2.0] *Enterprise JavaBeans Specification* v. 2.0, Sun Microsystems, March 31, 2000.

# Further Info

- Web:
  - UML 1.4 RTF: www.celigent.com/omg/umlrtf
  - OMG UML Tutorials: www.celigent.com/omg/umlrtf/tutorials.htm
  - UML 2.0 Working Group: www.celigent.com/omg/adptf/wgs/uml2wg.htm
  - OMG UML Resources: www.omg.org/uml/
- Email
  - uml-rtf@omg.org
  - ckobryn@acm.org
- Conferences & workshops
  - UML World 2001, New York, June 11-14, 2001
  - UML 2001, Toronto, Canada, Oct. 1-5, 2001
  - OMG UML Workshop 2001, San Francisco, Dec. 3-6, 2001