Module 3 – Advanced Features: Part I - Structural Diagrams

3 basic building blocks of UML - Diagrams

Graphical representation of a set of elements.
Represented by a connected graph: Vertices are things; Arcs are relationships/behaviors.
5 most common views built from

UML 1.x: 9 diagram types.

Structural Diagrams

Represent the static aspects of a system.

- Class;
  Object
- Component
- Deployment

Behavioral Diagrams

Represent the dynamic aspects.

- Use case
- Sequence;
  Collaboration
- Statechart
- Activity

UML 2.0: 12 diagram types

Structural Diagrams

- Class;
  Object
- Component
- Deployment
- Composite Structure
- Package

Behavioral Diagrams

- Use case
- Statechart
- Activity

Interaction Diagrams

- Sequence;
  Communication
- Interaction Overvie
- Timing

Class Diagrams

Structural Diagrams

- Class;
  Object
- Component
- Deployment
- **Composite Structure**
- Package

Class Diagram

The basis for all object modeling
All things lead to this

- Most common diagram.
- Shows a set of classes, interfaces, and collaborations and their relationships (dependency, generalization, association and realization); notes too.
- Represents the static view of a system (With active classes, static process view)

Three modeling perspectives for Class Diagram

- ***Conceptual***: the diagram reflects the domain
- ***Specification***: focus on interfaces of the software (Java supports interfaces)
- ***Implementation***: class (logical database schema) definition to be implemented in code and database.

Most users of OO methods take an implementation perspective, which is a shame because the other perspectives are often more useful. -- Martin Fowler

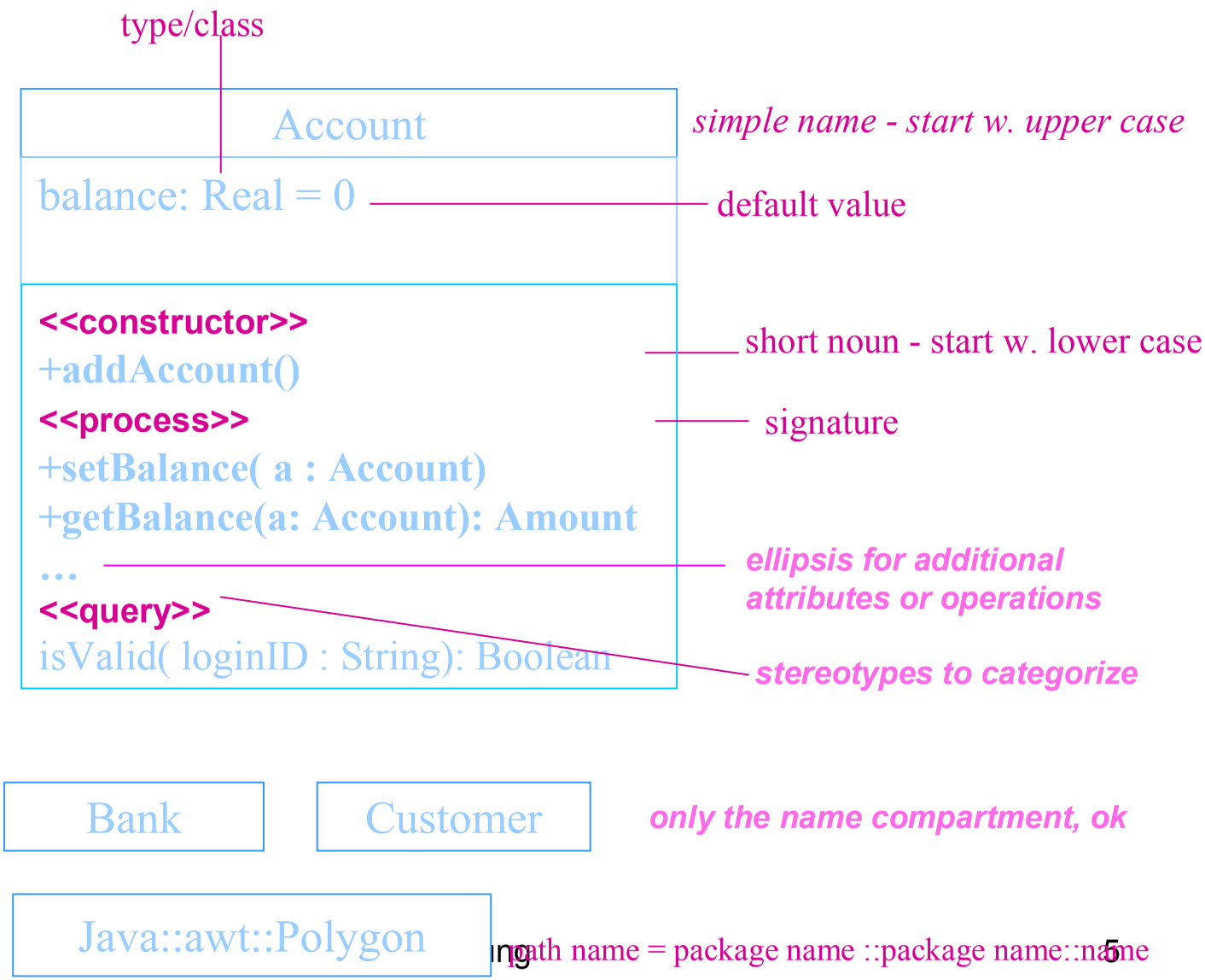
Classes

Names

Attributes

Operations

may cause object to change state



Responsibilities

Account
Responsibilities -- handles deposits -- reports fraud to managers

- anything that a class knows or does (Contract or obligation)

- An optional 4th item carried out by attributes and operations.
- Free-form text; one phrase per responsibility.
- Technique - CRC cards (Class-Responsibility-Collaborator); Kent Beck and Ward Cunningham'89

- A collaborator is also a class which the (current) class interacts with to fulfill a responsibility

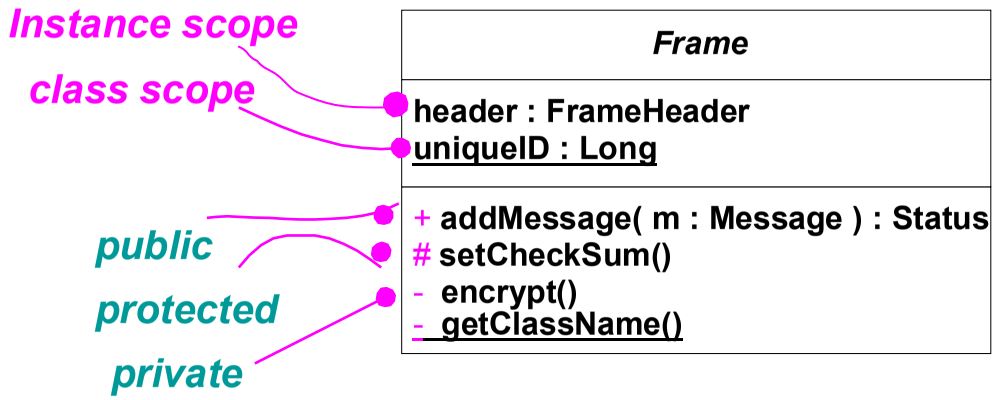
Class Name	
Responsibilities	Collaborators

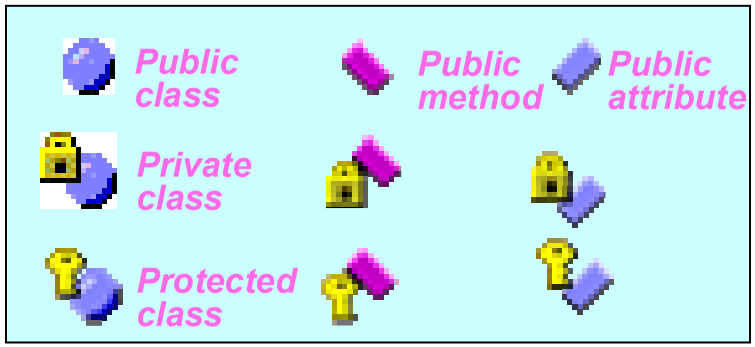
Customer	
Opens account Knows name Knows address	Account

Account	
Knows interest rate Knows balance Handles deposits Reports fraud to manager	Manager

Scope & Visibility

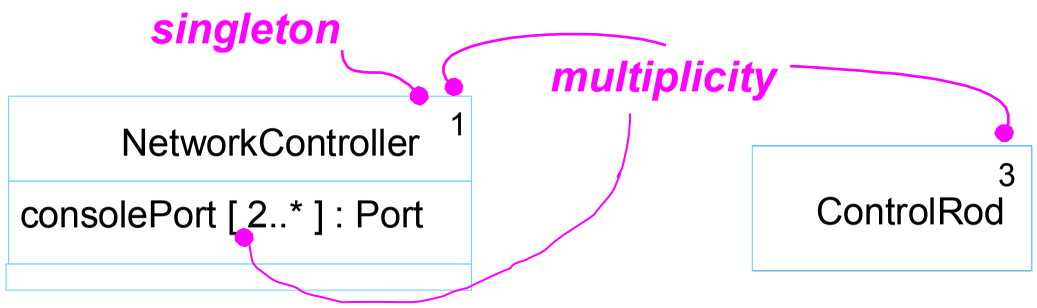
- *Instance* Scope — each instance of the classifier holds its own value.
- *Class* Scope — one value is held for all instances of the classifier (underlined).



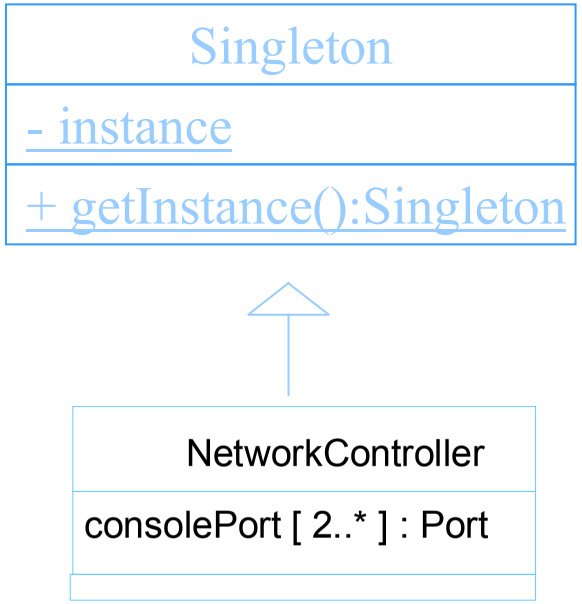


- Public - access allowed for any outside classifier (+).
- Protected - access allowed for any descendant of the classifier (#).
- Private - access restricted to the classifier itself (-).
- (using adornments in JBuilder)

Multiplicity



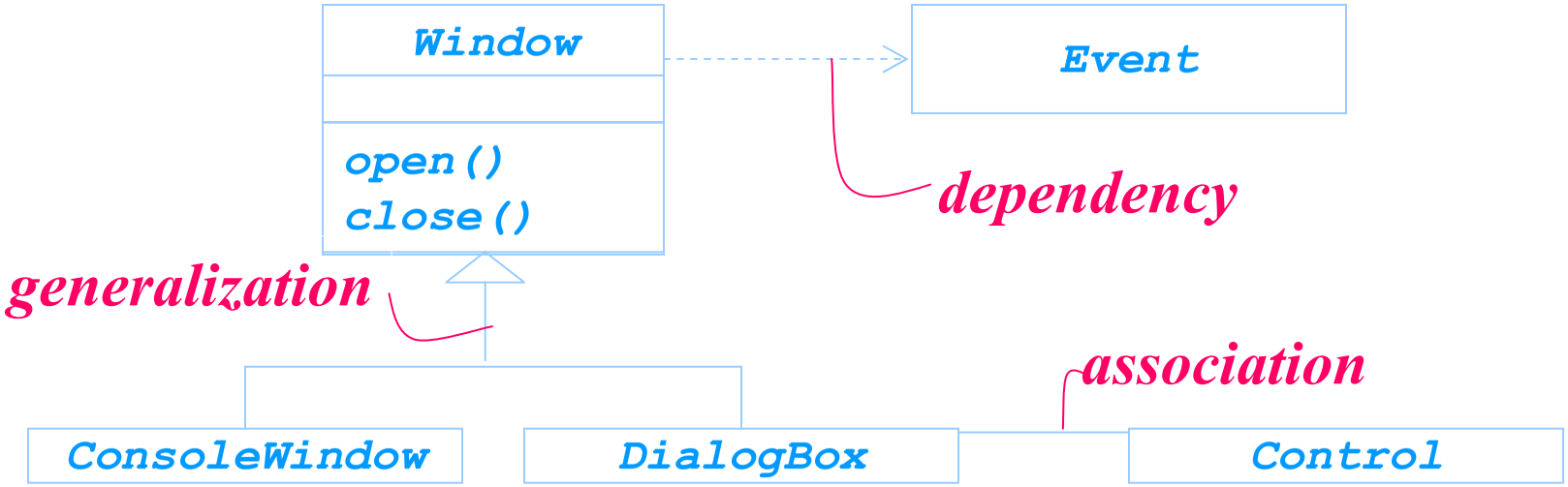
Using Design Pattern

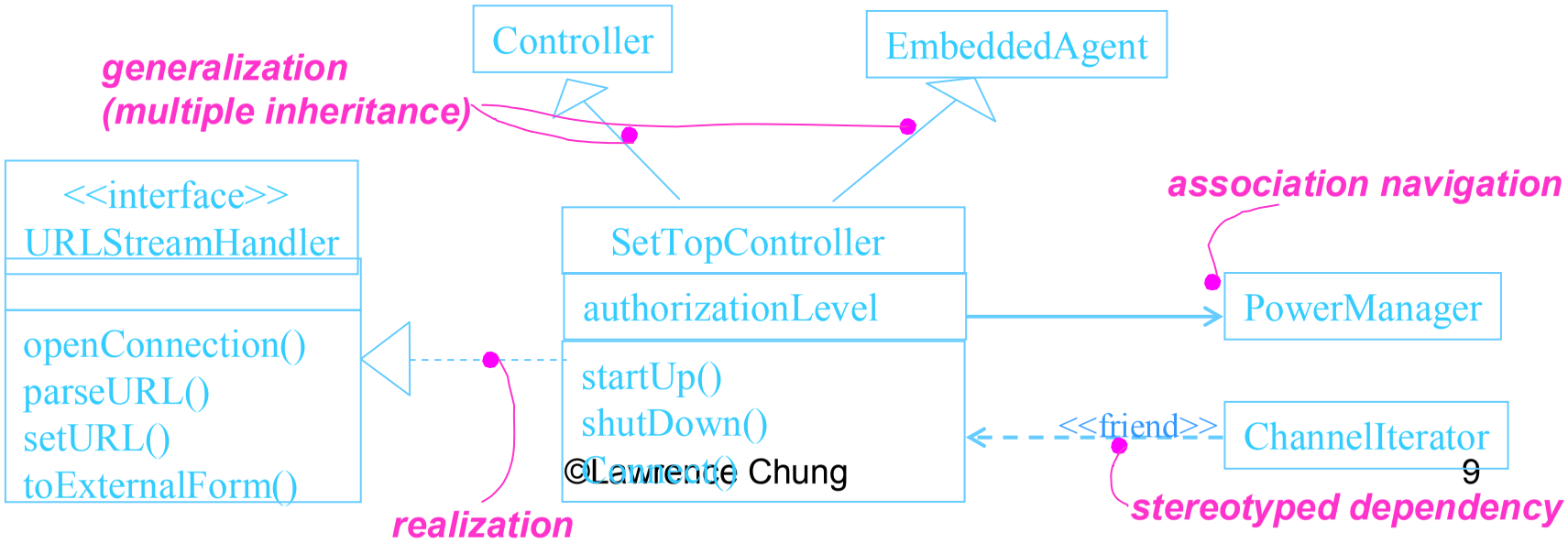



```
public class Singleton {
  private static Singleton instance = null;

  private Singleton() {}
  public static Singleton getInstance() {
    if (instance == null) {
      instance = new Singleton();
    }
    return instance;
  }
}
```

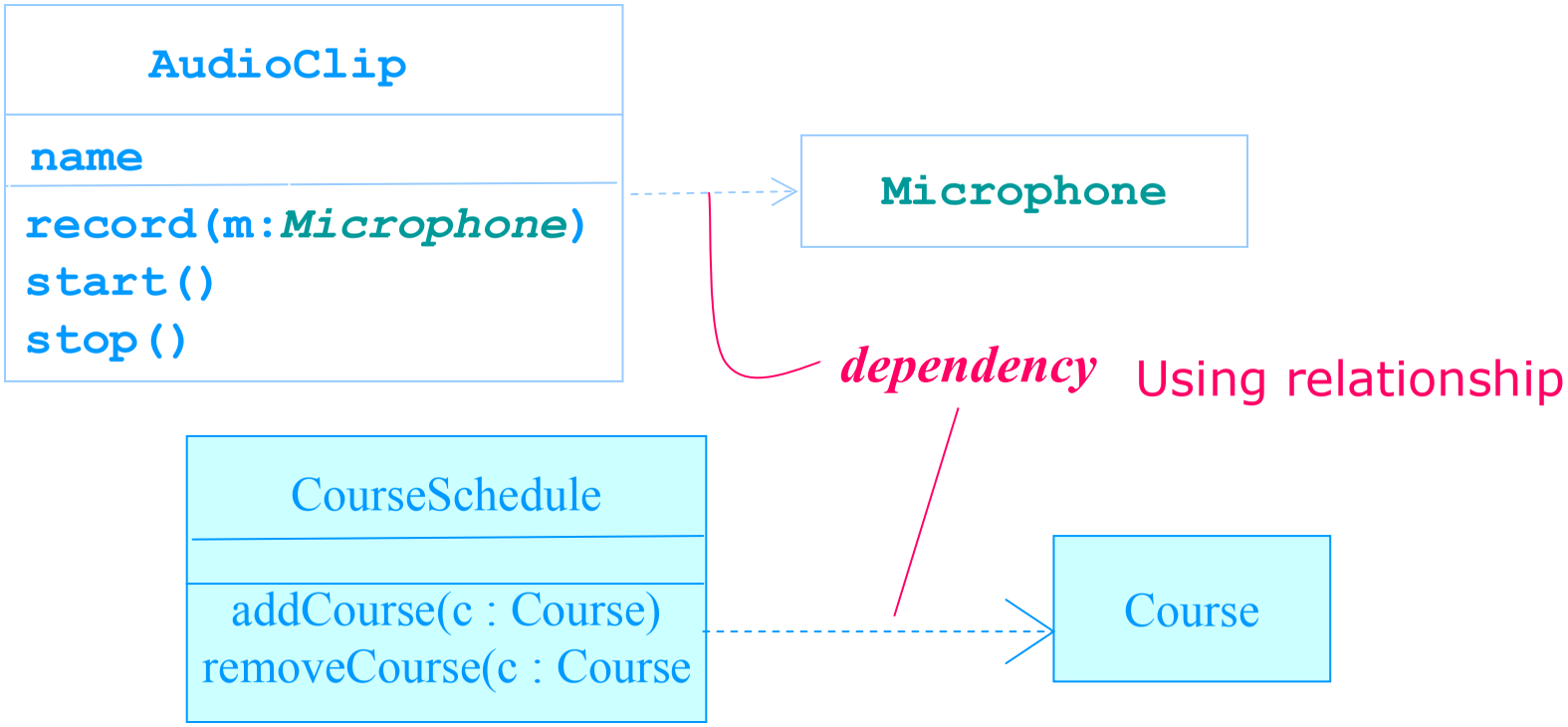
Relationships





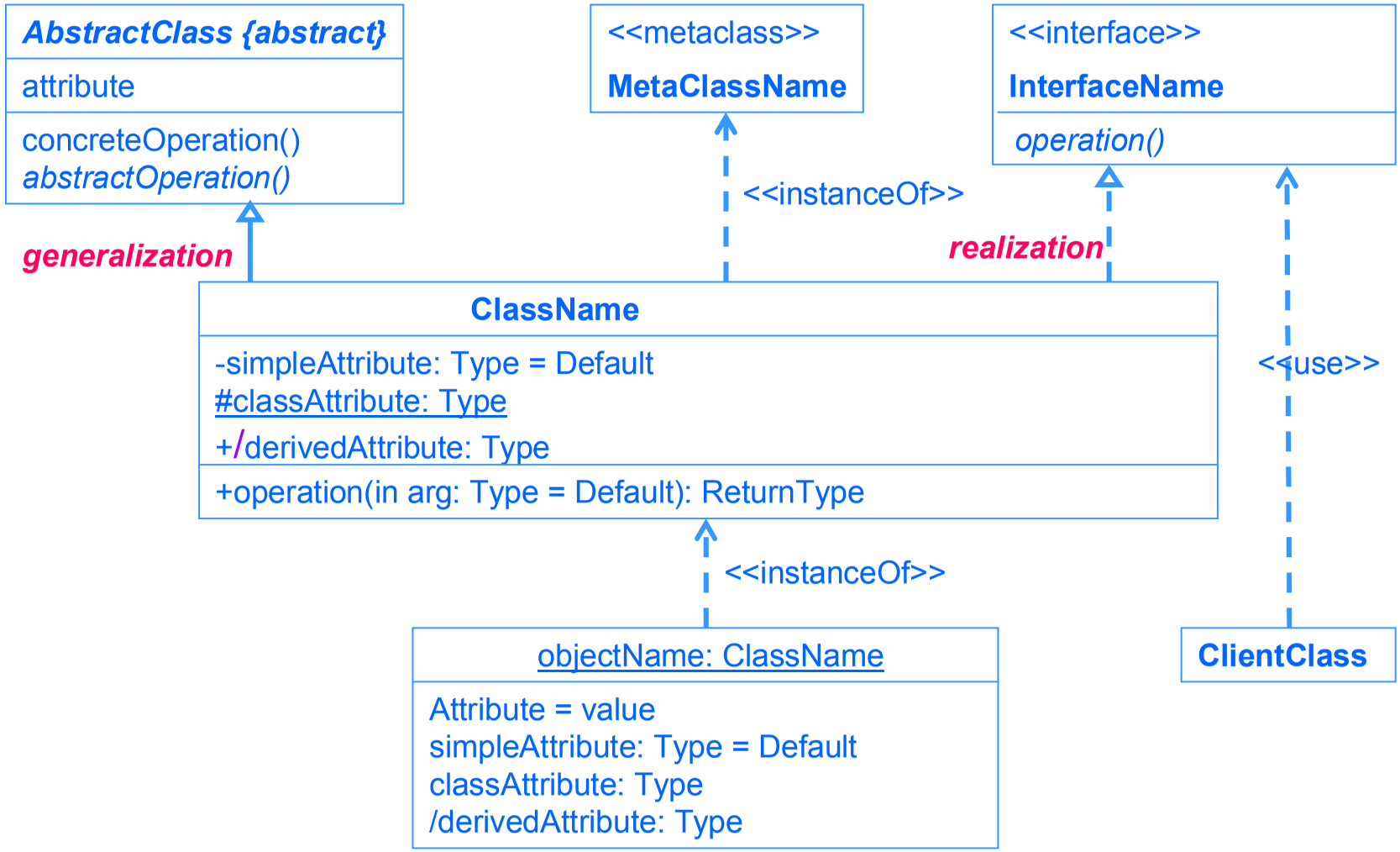
Dependency

- A change in one thing may affect another.
  - The most common dependency between two classes is one where one class <<use>>s another as a *parameter to an operation*.



Usually initial class diagrams will not have any significant number of dependencies in the beginning of analysis but will as more details are identified.

Dependency – Among Classes

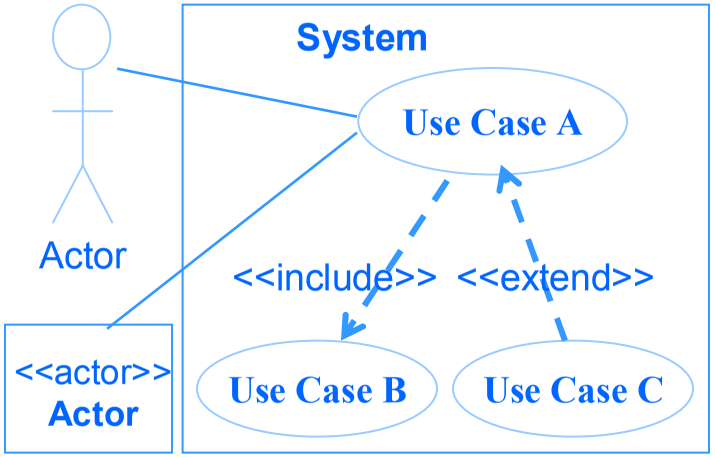


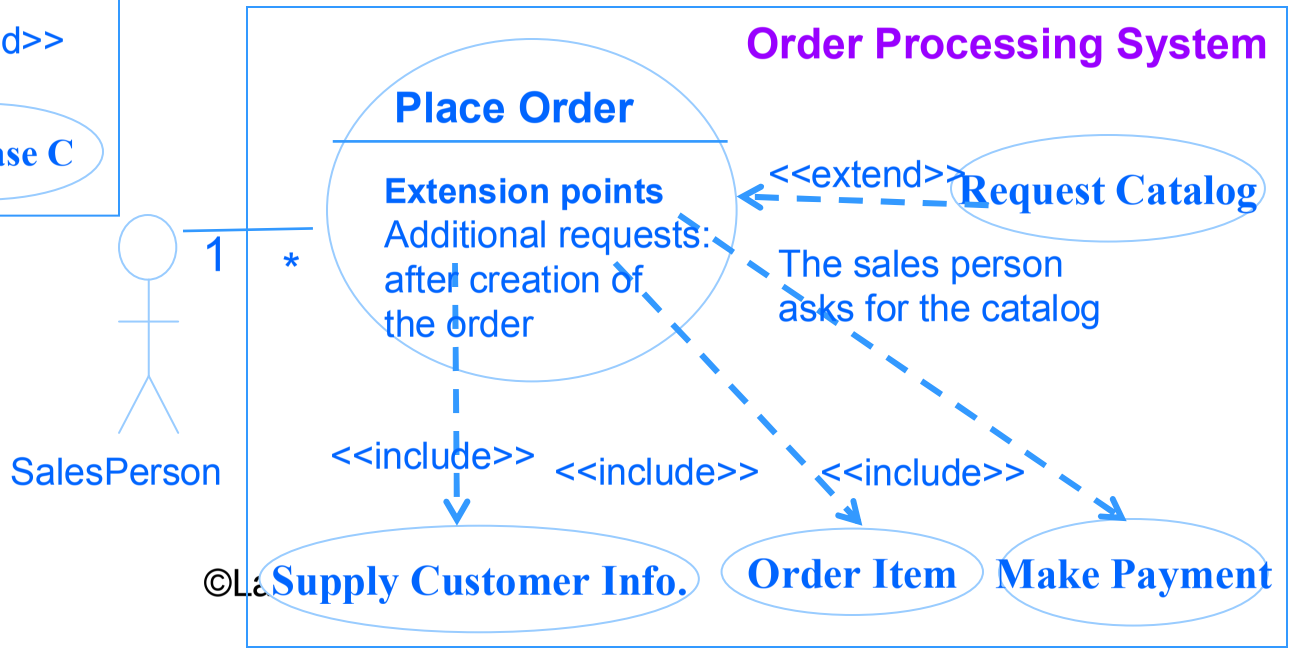
Dependency –Among Classes

- Eight Stereotypes of Dependency Among Classes
  - *bind*: the source instantiates the target template using the given actual parameters
  - *derive*: the source may be computed from the target
  - *friend*: the source is given special visibility into the target
  - ***instanceOf*** *:* the source object is an instance of the target classifier
  - *instantiate*: the source creates instances of the target
  - *powertype*: the target is a powertype of the source; a powertype is a classifier whose objects are all the children of a given parent
  - *refine*: the source is at a finer degree of abstraction than the target
  - *use*: the semantics of the source element depends on the semantics of the public part of the target

Dependency –Among Use Cases

- Two Stereotypes of Dependency Among Use Cases:
  - *extend*: the target use case extends the behavior of the source
  - *include*: the source use case explicitly incorporates the behavior of another use case *at a location* specified by the source



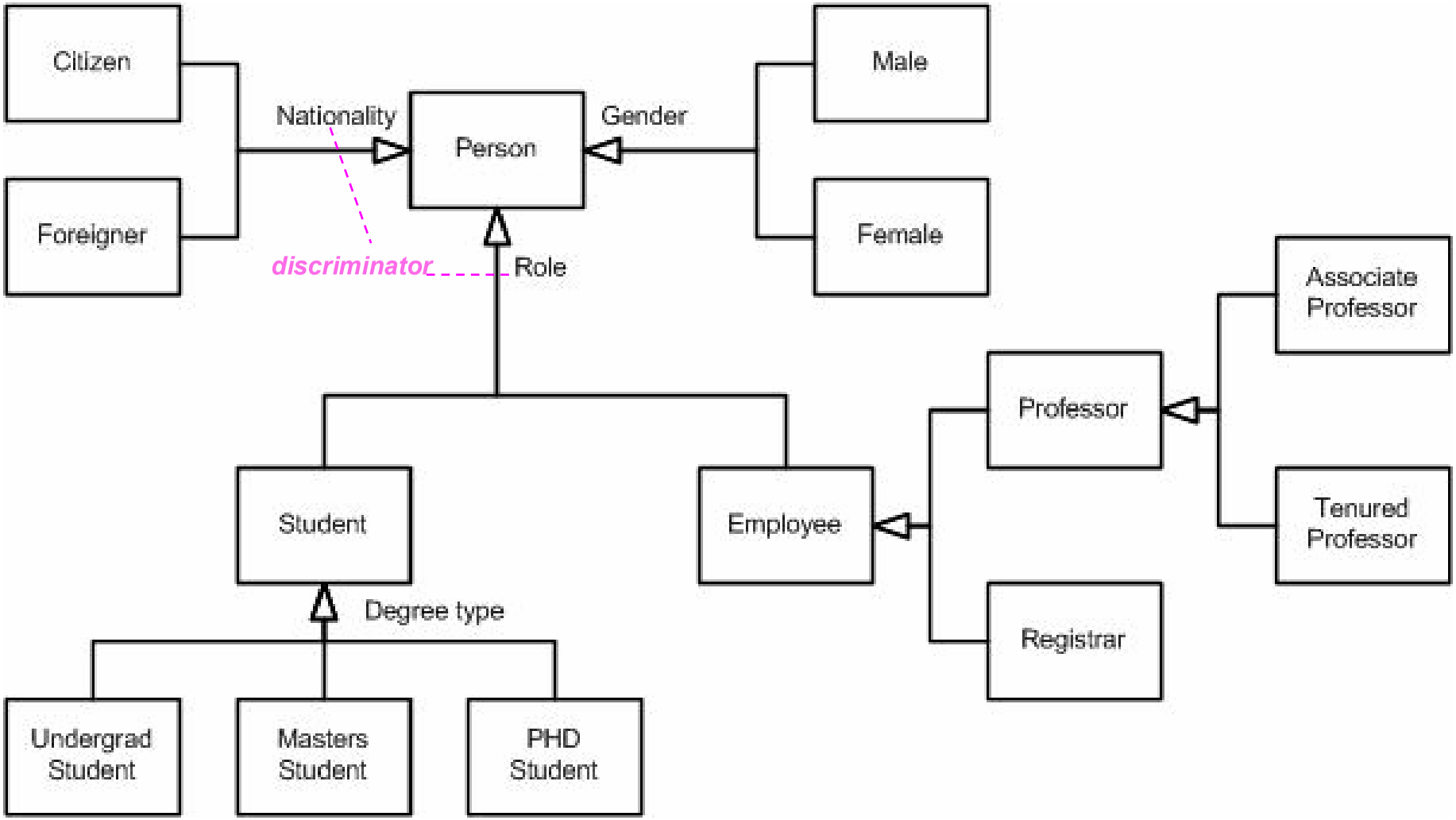


Generalization

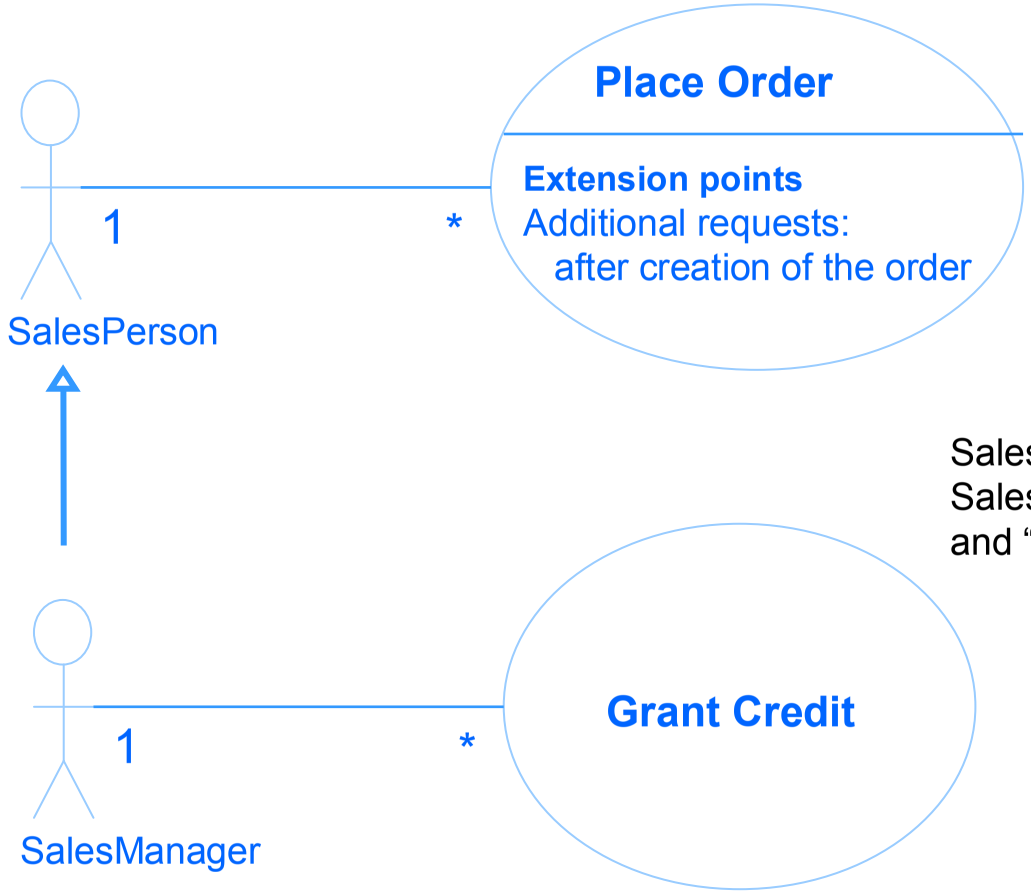
- Four Standard Constraints
  - *complete*: all children in the generalization have been specified; no more children are permitted
  - ***incomplete***: not all children have been specified; additional children are permitted
  - *disjoint*: objects of the parent have no more than one of the children as a type
  - ***overlapping***: objects of the parent may have more than one of the children as a type

- One Stereotype
  - *implementation*: the child inherits the implementation of the parent but does not make public nor support its interfaces

Generalization – Along Roles



Generalization –Among Actors

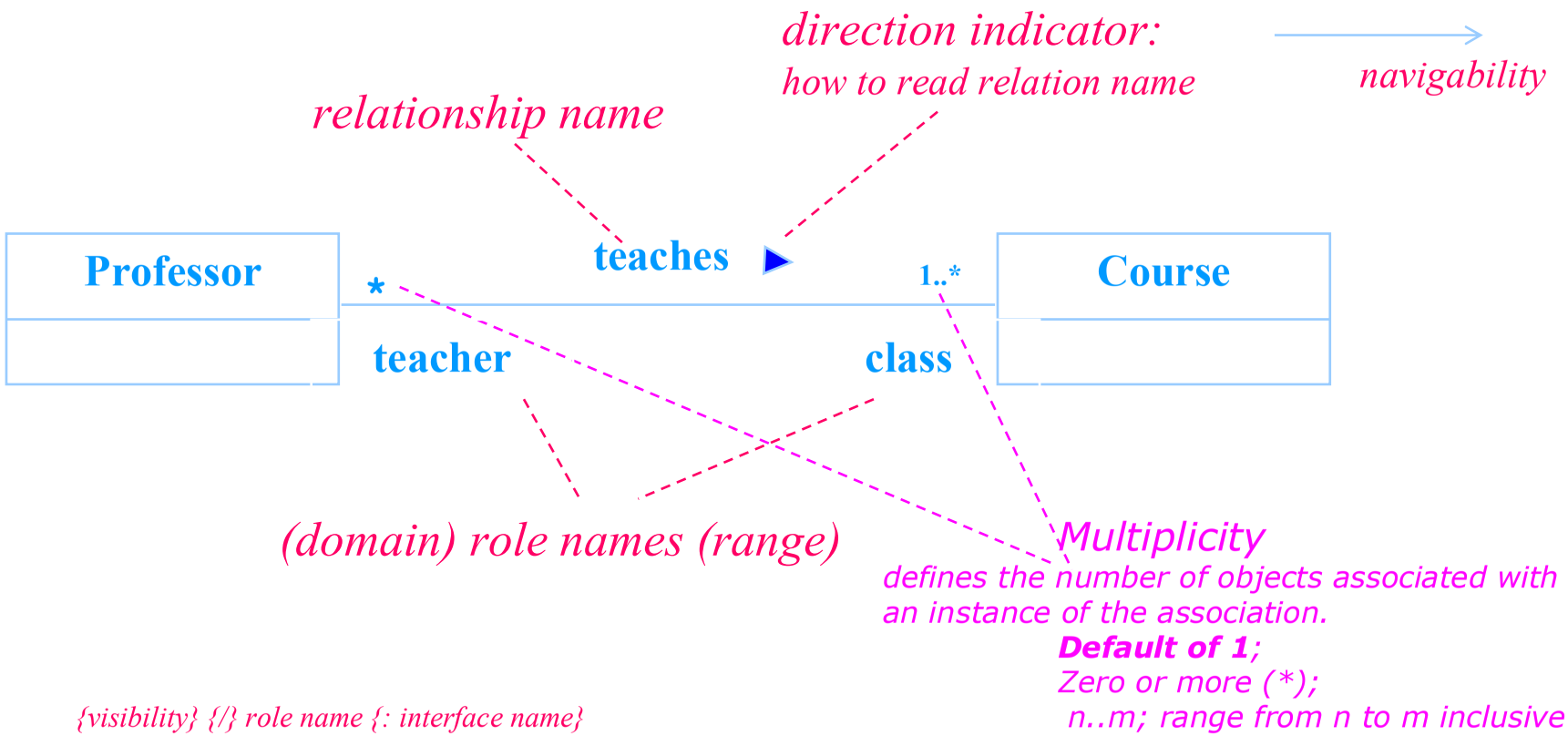


Sales person can do only “Place Order”;
Sales manager can do both “Place Order” and “Grant Credit”

Associations

- Represent conceptual relationships between classes

  (cf. dependency with no communication/message passing)



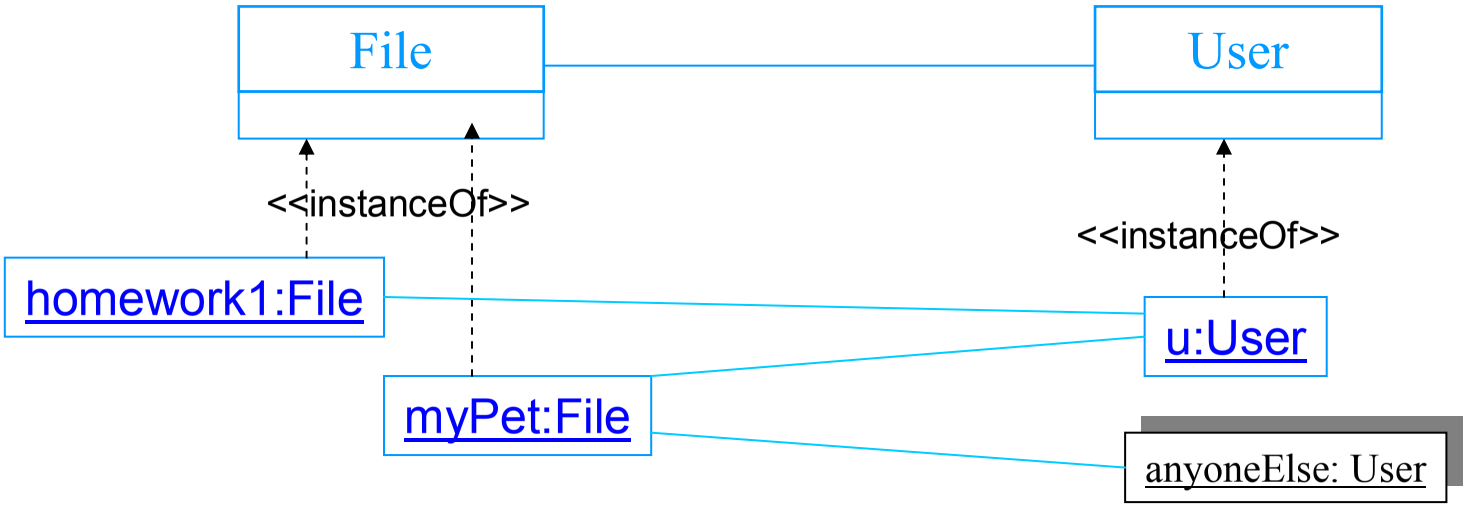
What's the difference between attributes and associations?

Associations – A Question

- How would you model the following situation?

"You have two files, say homework1 and myPet, where homework1 is read-accessible only by you, but myPet is write-accessible by anybody."

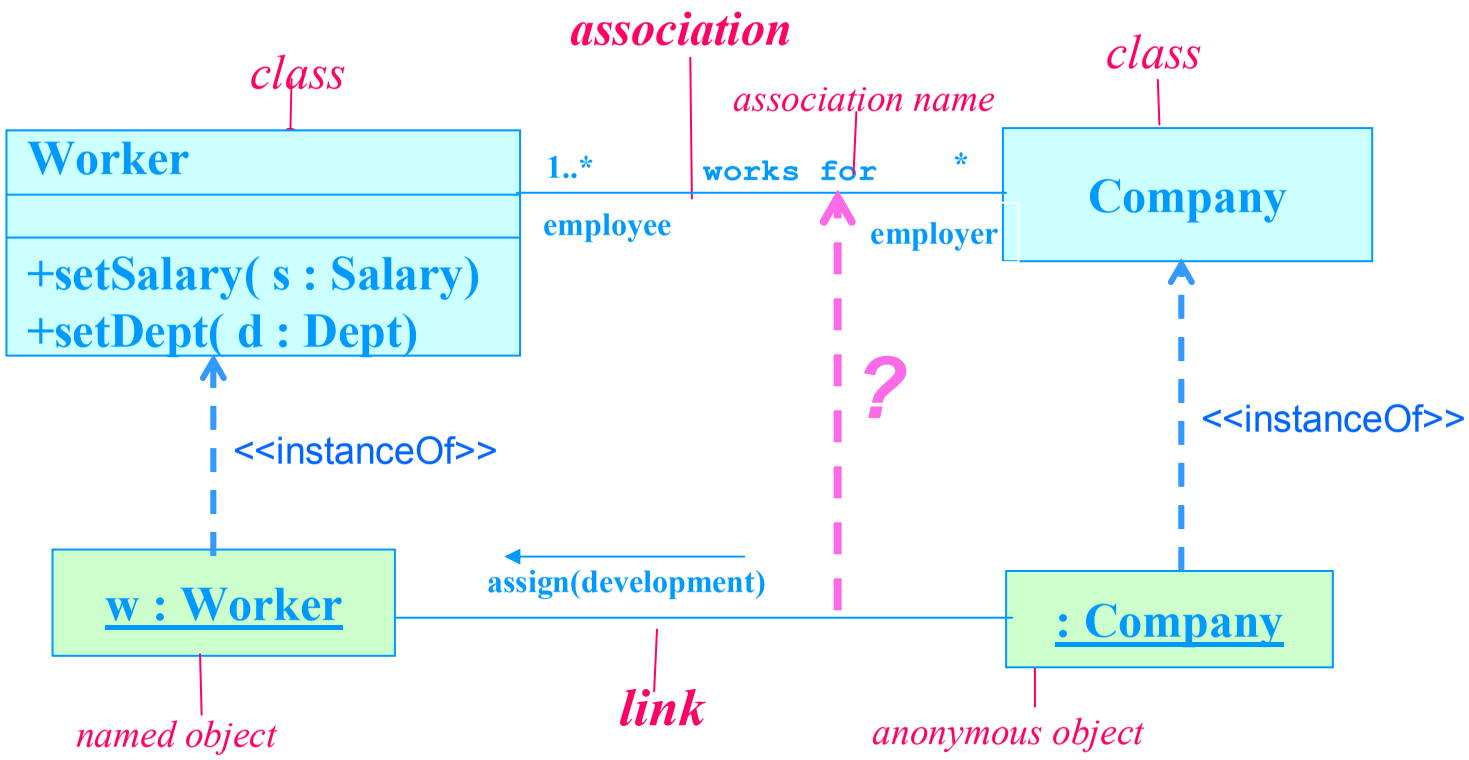
You could create two classes, File and User.
Homework1 and MyPet are files, and you are a user.



Approach 1: Now, would you associate the file access right with File?
Approach 2: Or, would you associate the file access right with User?

Associations – Links

- link is a semantic connection among objects.
- A link is an instance of an association.

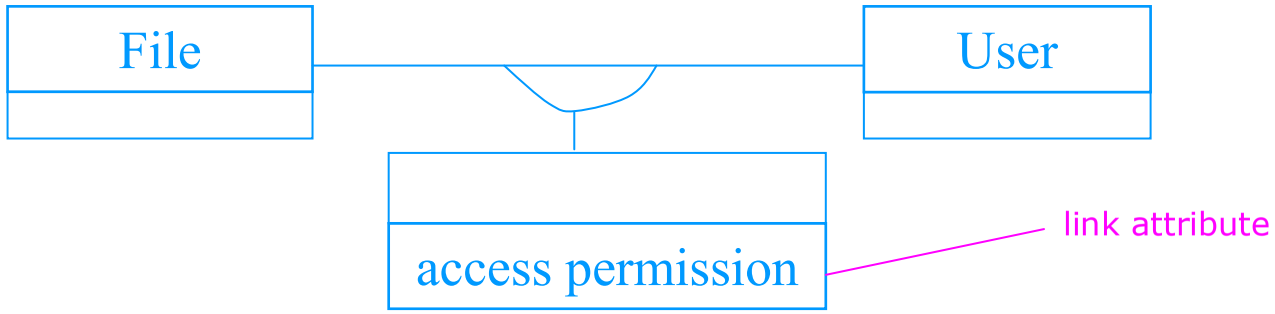


Association generalization is not automatic, but should be explicit in UML 1.x (not in UML2.0)

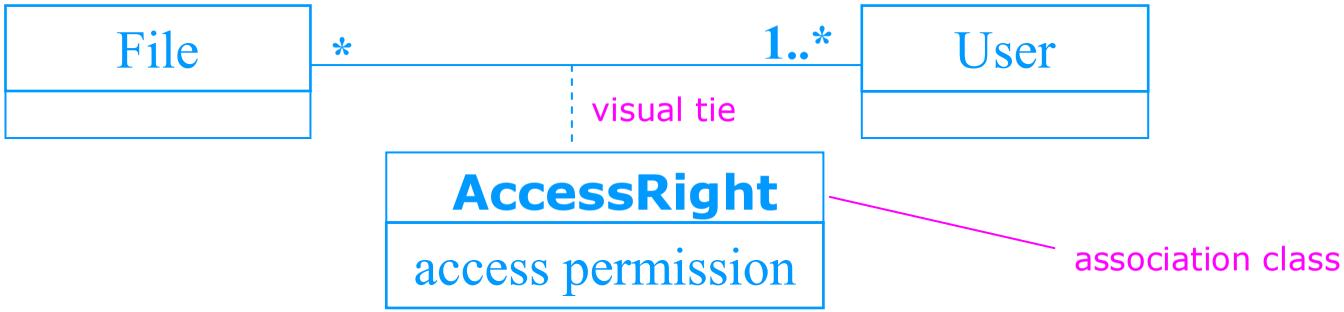
Associations – Link Attributes

- Link Attributes

The most compelling reason for having link attributes is for-many-to-many relationships



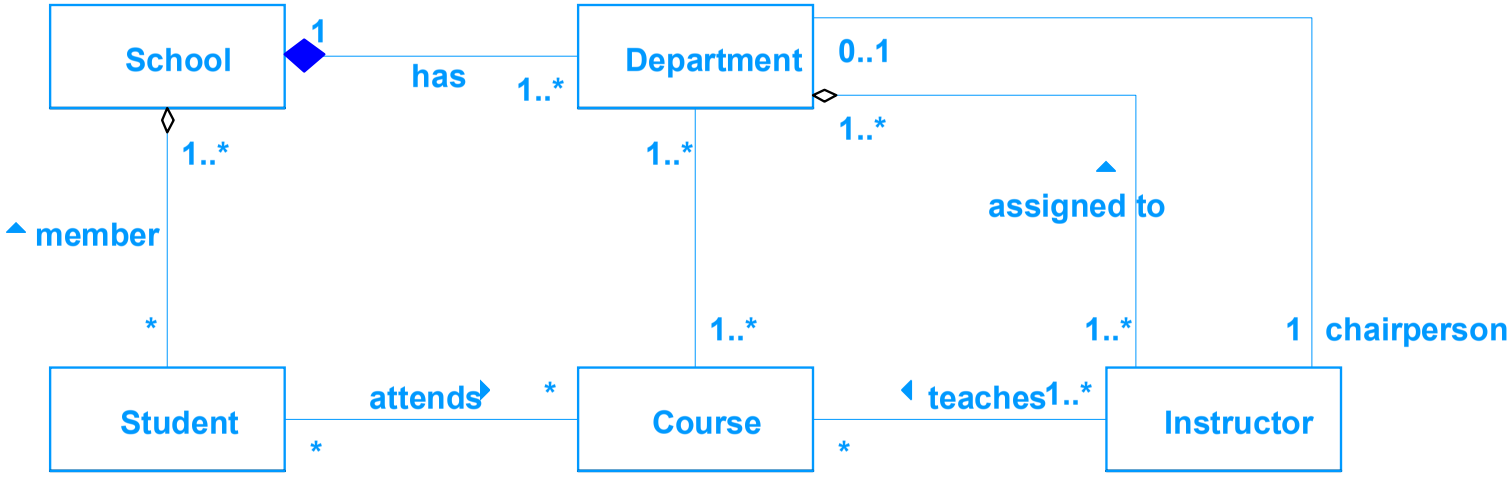
- Association Class



- With a refactoring ("reification")

Modeling Structural Relationships

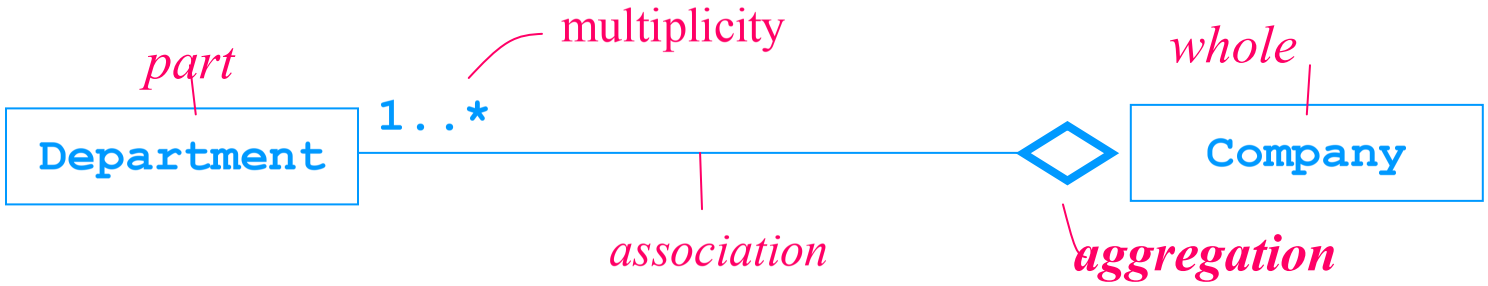
- Considering a bunch of classes and their association relationships



The model above is from Rational Rose. How did the composite symbol (◆)get loaded versus the aggregation? Use the Role Detail and select aggregation and then the "by value" radio button.

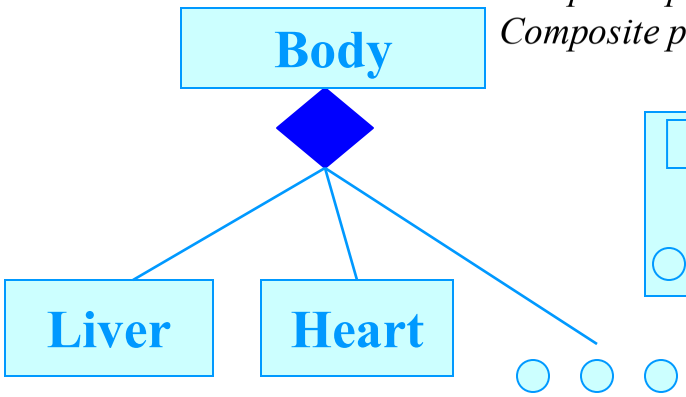
Modeling Structural Relationships

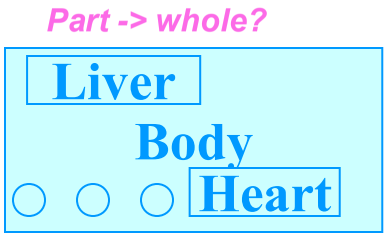
Aggregation - structural association representing "whole/part" relationship.
- "has-a" relationship.

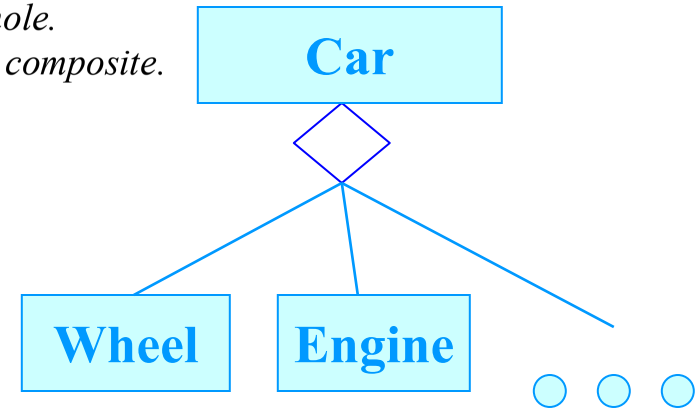


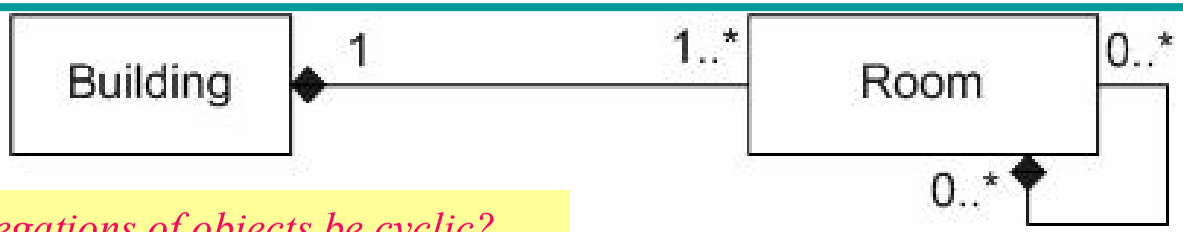
Composite

Composite is a stronger form of aggregation.
Composite parts live and die with the whole.
Composite parts may belong to only one composite.



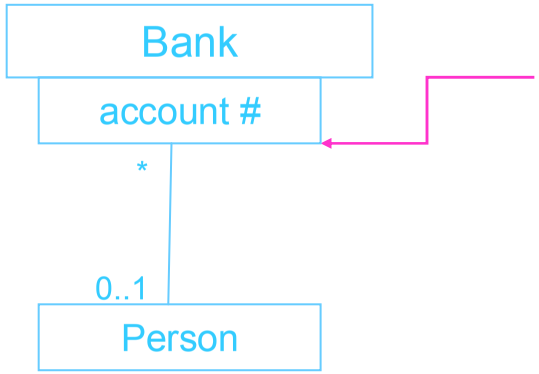




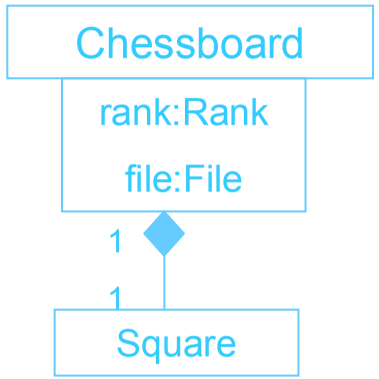


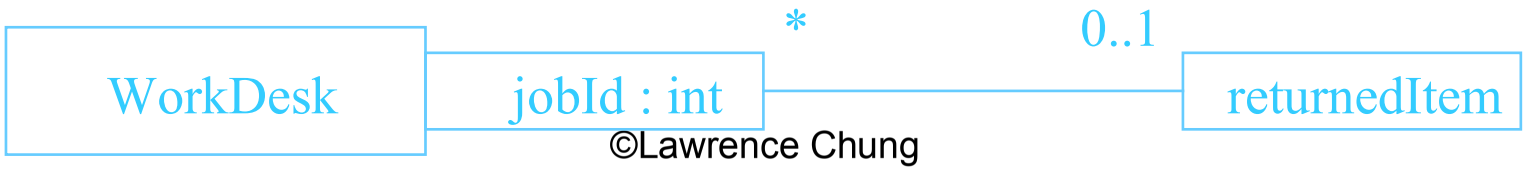
Can aggregations of objects be cyclic?

Association – Qualification

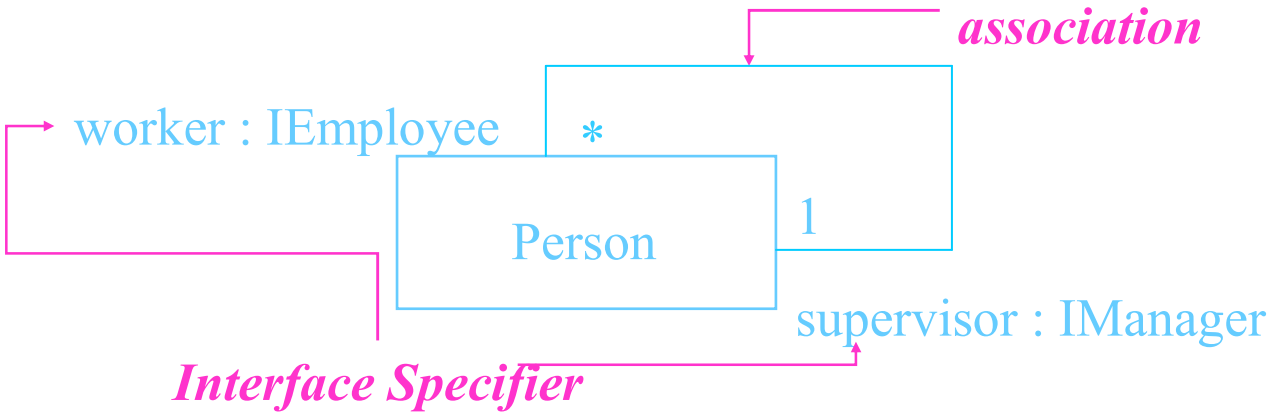


Qualifier,
cannot access person without knowing the account #





Association – Interface Specifier

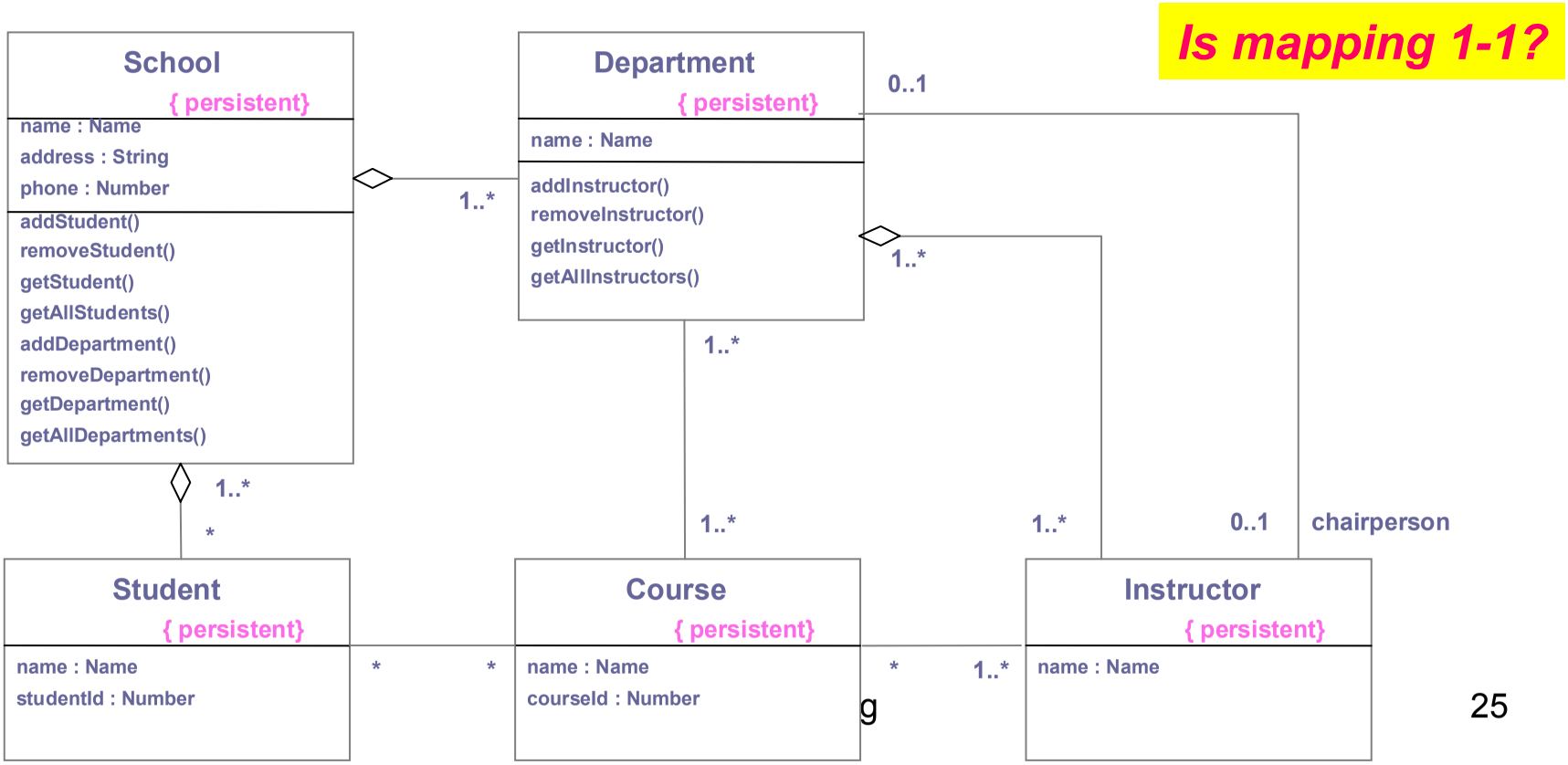


Realization

- A semantic relationship between classifiers in which one classifier specifies a contract that another guarantees to carry out.
- In the context of interfaces and collaborations
- **An interface can be realized by many classes/components**
- **A class/component may realize many interfaces**

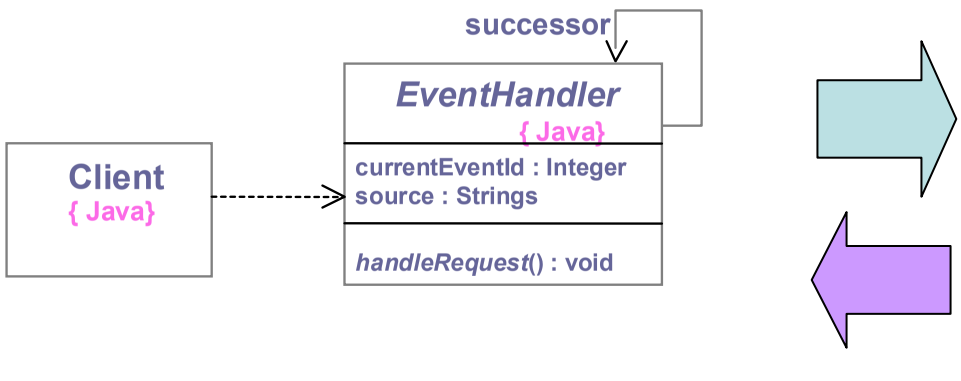
Modeling a Logical Database

- Class diagrams to provide more semantics
- From a general class diagram, first identify classes whose state must be persistent (e.g. after you turn off the computer, the data survives, although the program doesn't).
- Create a class diagram using standard tagged value, (e.g. {persistent}).
- Include attributes and associations.
- Use tools, if available, to transform logical design (e.g., tables and attributes) into physical design (e.g., layout of data on disk and indexing mechanisms for fast access to the data).



Forward/ Reverse Engineering

- translate a collaboration into a logical database schema/operations
- transform a model into code through a mapping to an implementation language.
- Steps
  - Selectively use UML to match language semantics (e.g. mapping multiple inheritance in a collaboration diagram into a programming language with only single inheritance mechanism).
  - Use **tagged values** to identify language..




```
public abstract class EventHandler
{
    private EventHandler successor;
    private Integer currentEventId;
    private String source;

    EventHandler() {}
    public void handleRequest() {}
}
```

- translate a logical database schema/operations into a collaboration
- transform code into a model through mapping from a specific implementation language.

Object Diagrams

Structural Diagrams

- Class;

  Object
- Component
- Deployment
- **Composite Structure**
- Package

Instances & Object Diagrams

- "instance" and "object" are largely synonymous; used interchangeably.

- difference:
  - instances of a **class** are called objects or instances; but
  - instances of other abstractions (components, nodes, use cases, and associations) are not called objects but only instances.

What is an instance of an association called?

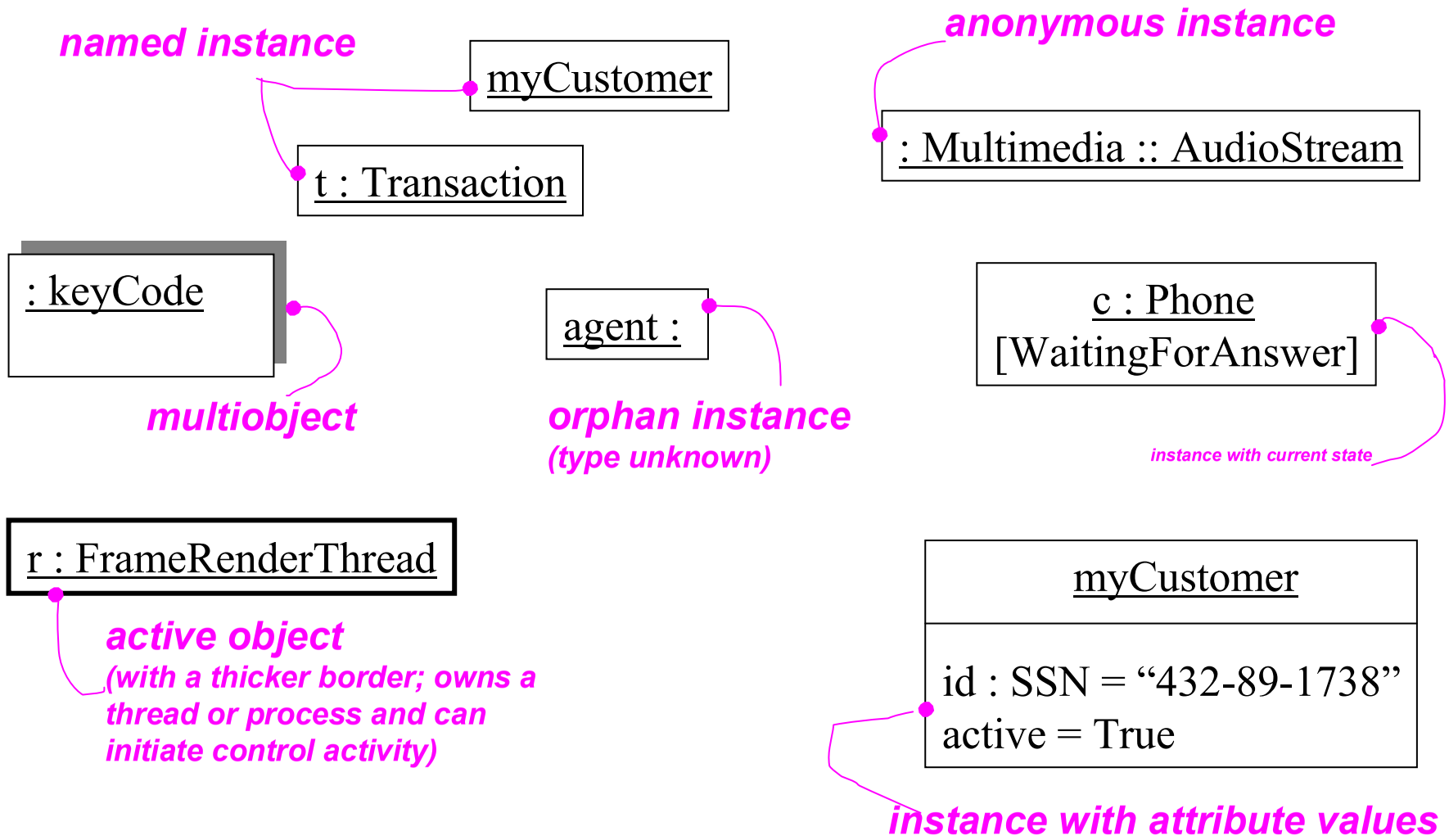
Are use cases objects?

Object Diagrams

- very useful in debugging process.
  - walk through a scenario (e.g., according to use case flows).
  - Identify the set of objects that collaborate in that scenario (e.g., from use case flows).
  - Expose these object's states, attribute values and links among these objects.

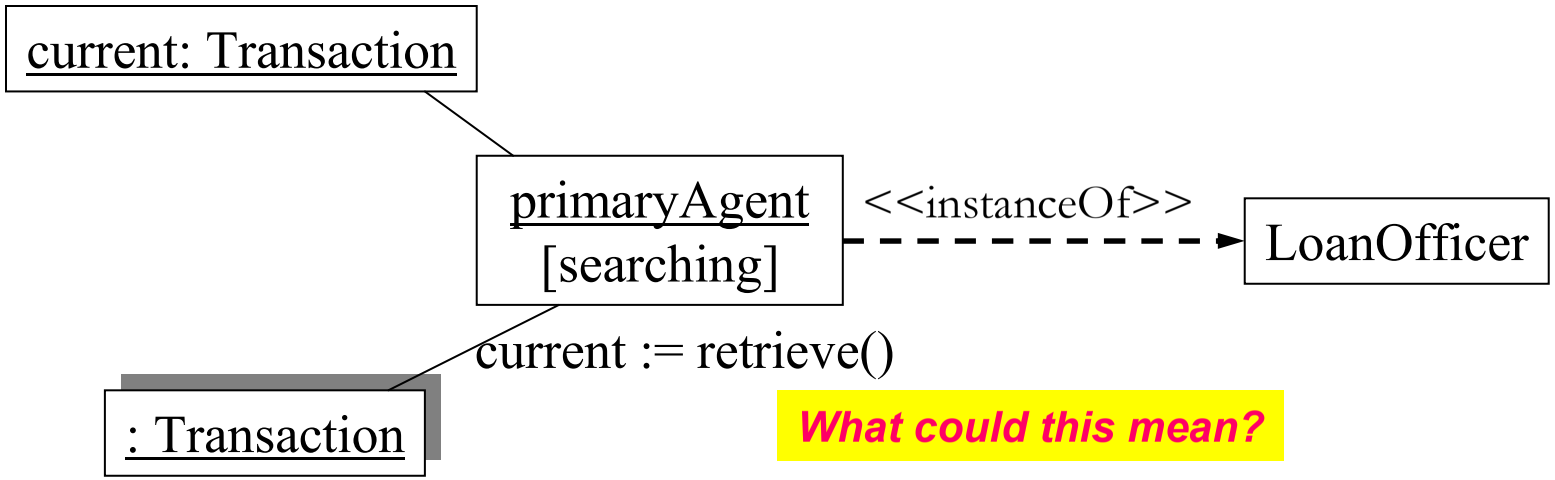
How in the "4+1"?

Instances & Objects - Visual Representation



Instances & Objects - Modeling Concrete Instances

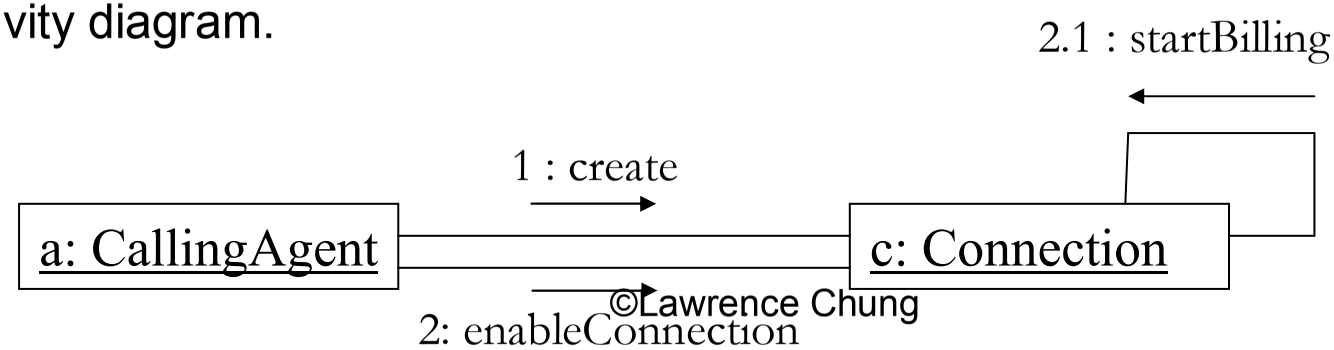
- Expose the stereotypes, tagged values, and attributes.
- Show these instances and their relationships in an object diagram.



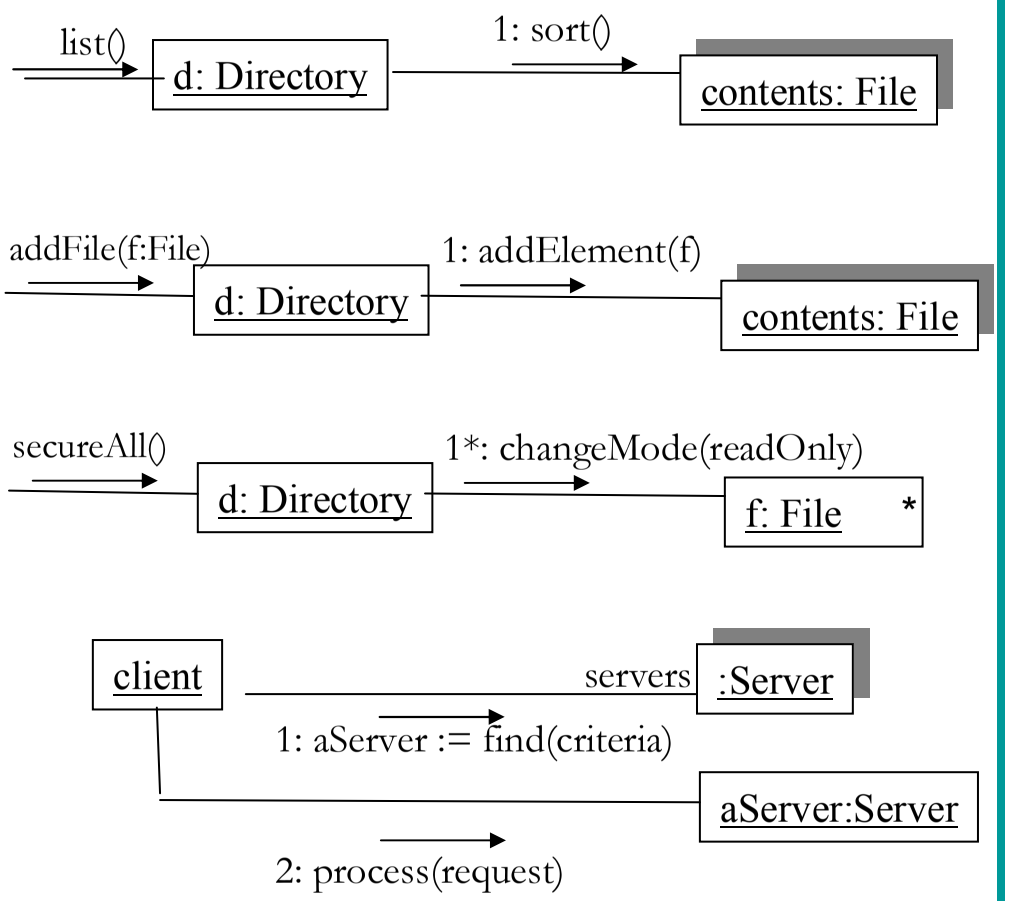
What could this mean?

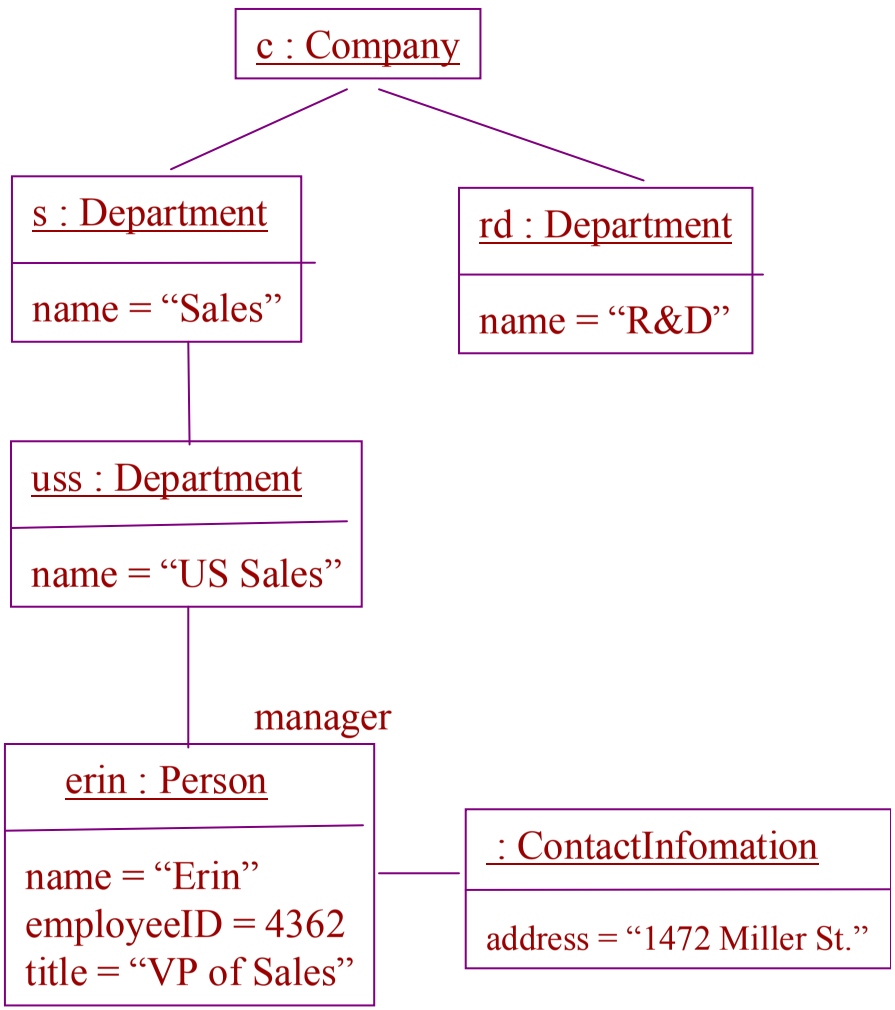
Instances & Objects - Modeling Prototypical Instances

- Show these instances and their relationships in an interaction diagram or an activity diagram.



Instances & Objects – More Examples





call ::= label [guard] ["*"] [return-val-list ":="] msg-name "(" arg-list ")"

Component Diagrams

Structural Diagrams

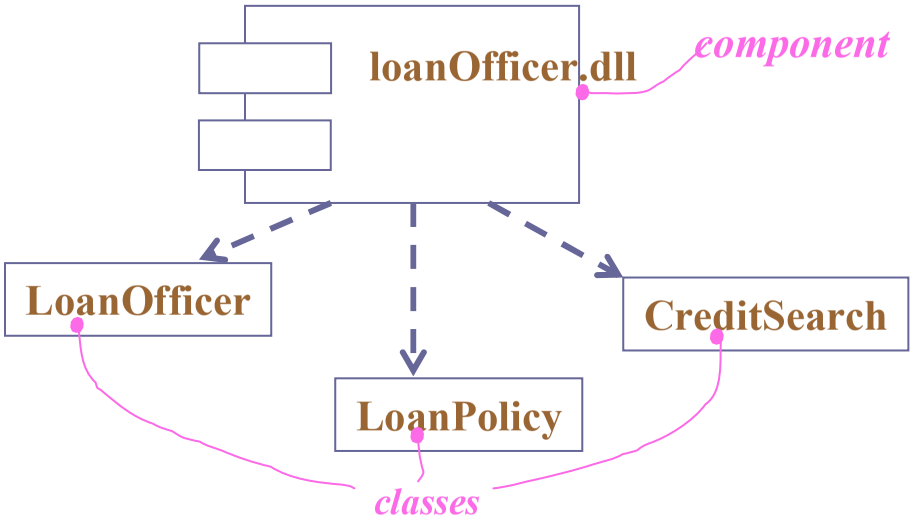
- Class;
  Object
- Component
- Deployment
- **Composite Structure**
- Package

Component Diagram

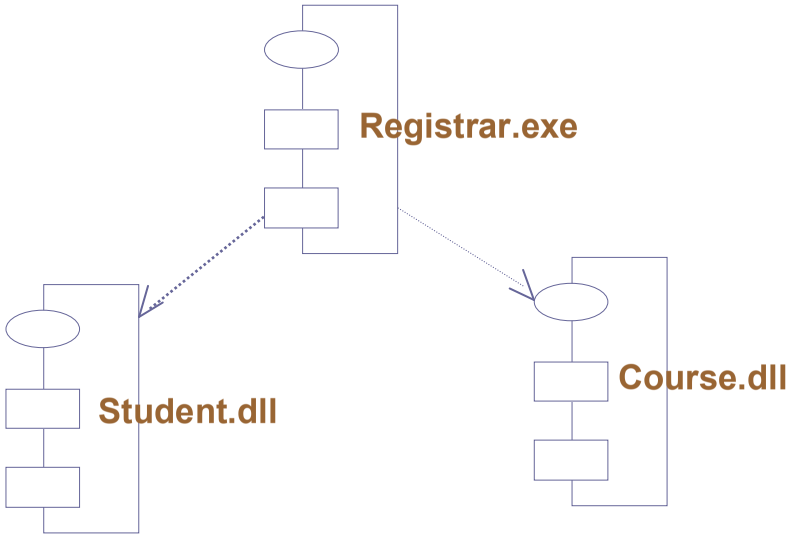
UML1.x – implementation view

- Shows a set of components and their relationships.
- Represents the static implementation view of a system.
- Components map to one or more classes, interfaces, or collaborations.

Mapping of Components into Classes



Components and their Relationships



Component Diagram UML2.0 – architectural view

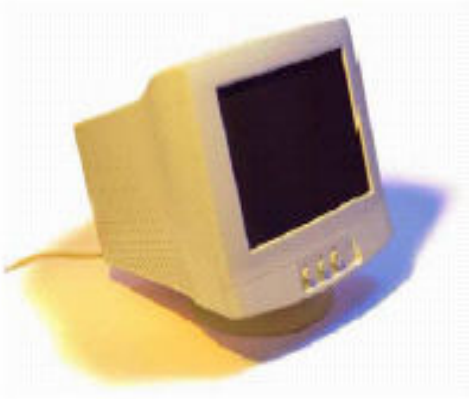
Big demand, hmm…

- Short history behind architecture
- Architecture still an emerging discipline
- Challenges, a bumpy road ahead

- UML and architecture evolving in parallel
- Component diagram in need of better formalization and experimentation

Component Diagram – another example

(www.cs.tut.fi/tapahtumat/olio2004/richardson.pdf)



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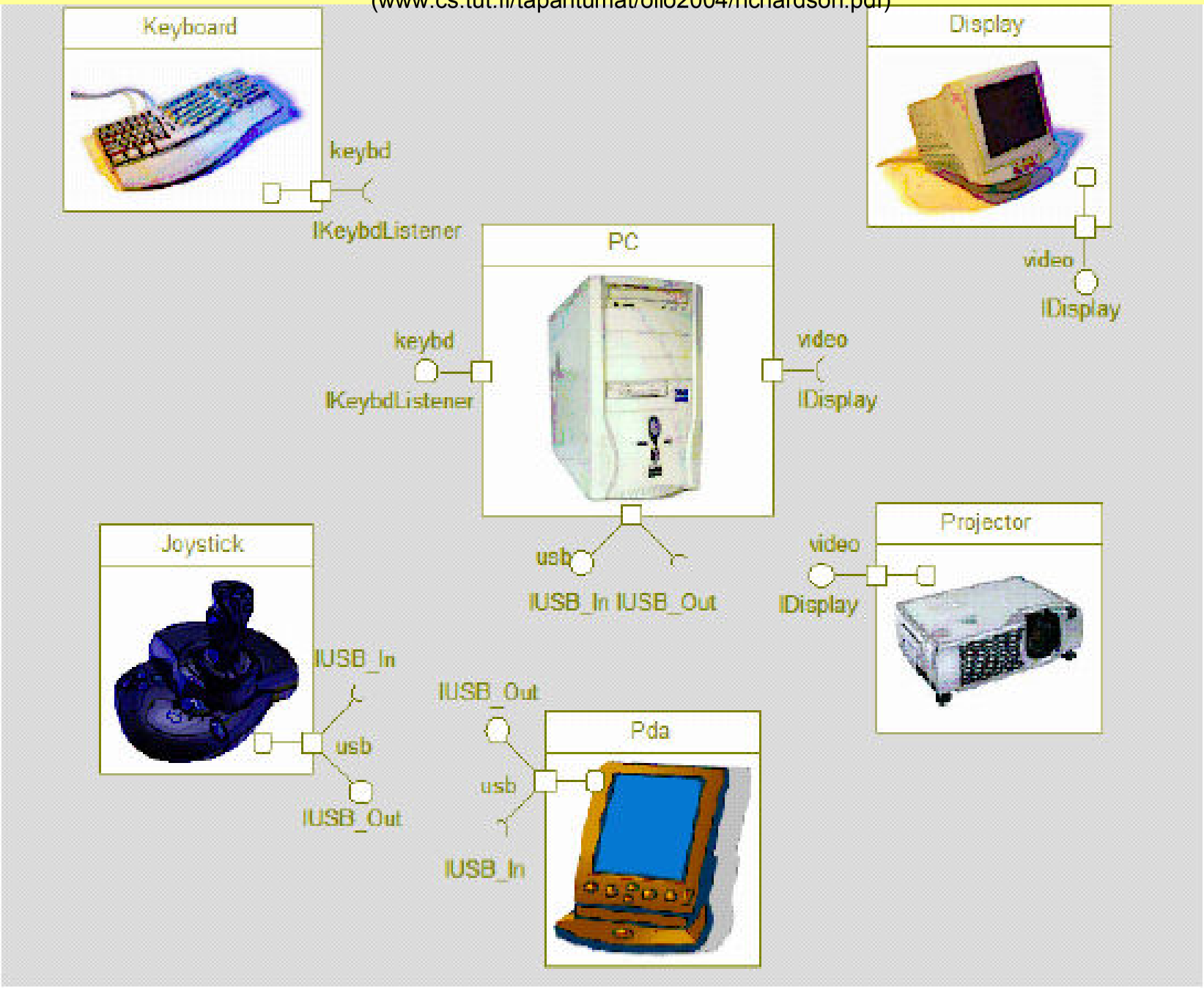

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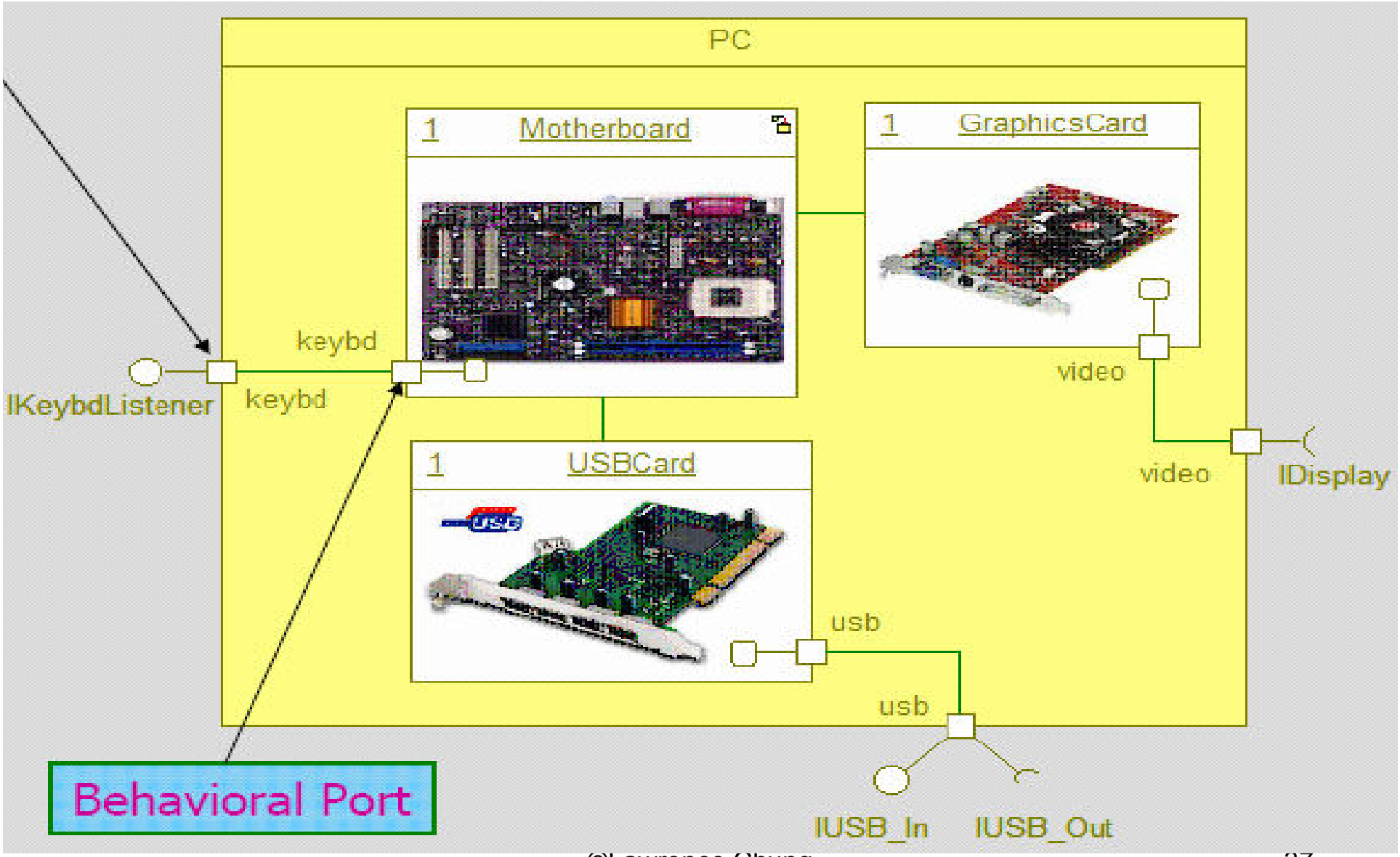
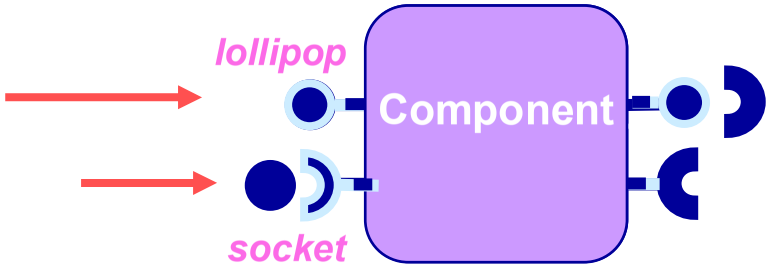


Component Diagram UML2.0 – architectural view

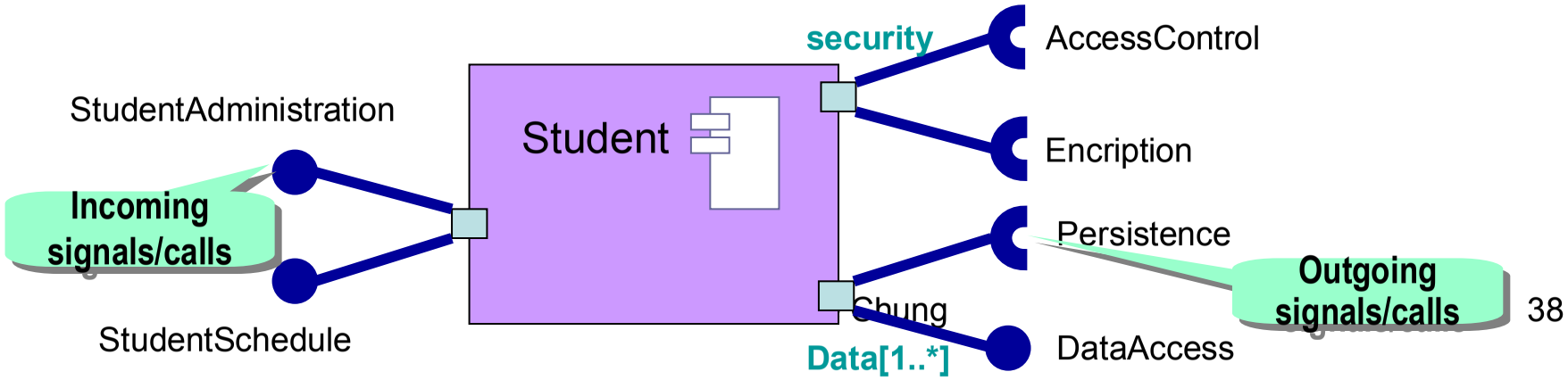
Explicit description of ***interfaces***:

- provided services to other components
- requested services from other components



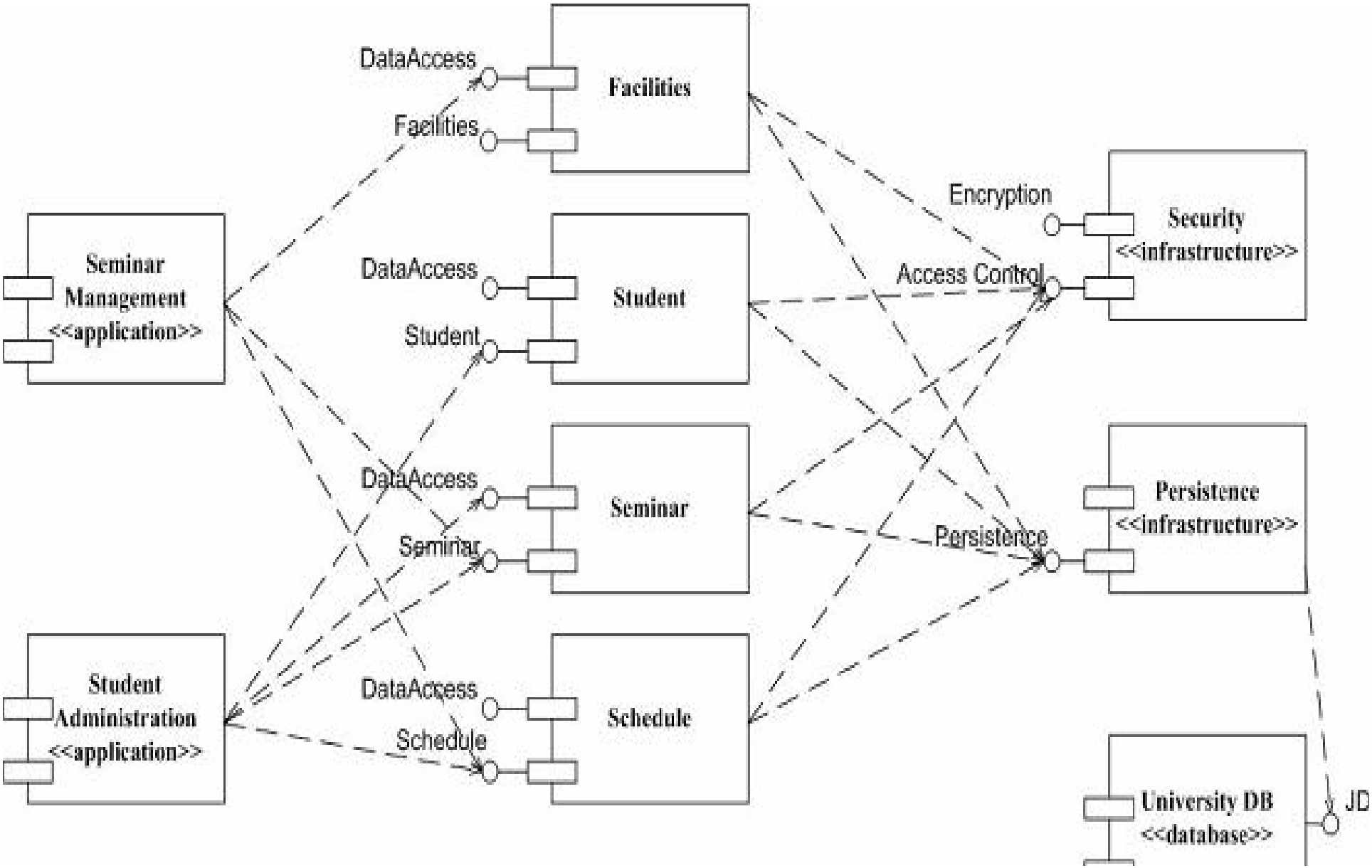
- An interface is a collection of 1..* methods, and 0..* attributes
- Interfaces can consist of synchronous and / or asynchronous operations
- A ***port*** (***square***) is an interaction point between the component and its environment.
- Can be named; Can support uni-directional (either provide or require) or bi-directional (both provide and require) communication; Can support multiple interfaces.
- possibly concurrent interactions
- fully isolate an object's internals from its environment

caller or callee?



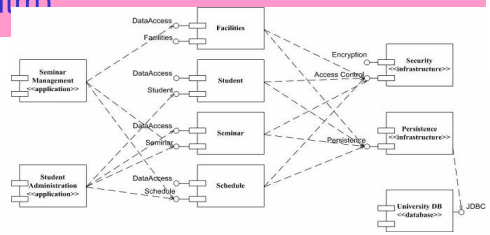
Component Diagram: UML 1.x and UML 2.0

(http://www.agilemodeling.com/artifacts/componentDiagram.htm)



Component Diagram: UML 1.x and UML 2.0

(http://www.agilemodeling.com/artifacts/componentDiagram.htm)



Seminar Management <<UI>>

Student Administration <<UI>>

DataAccess

Facilities

Facilities

DataAccess

Student

Student

DataAccess

Seminar

Seminar

DataAccess

Schedule

Schedule

<<component>>

Facilities

Student

Seminar

Schedule

Encryption

Access Control

Security <<infrastructure>>

Persistence

Persistence <<infrastructure>>

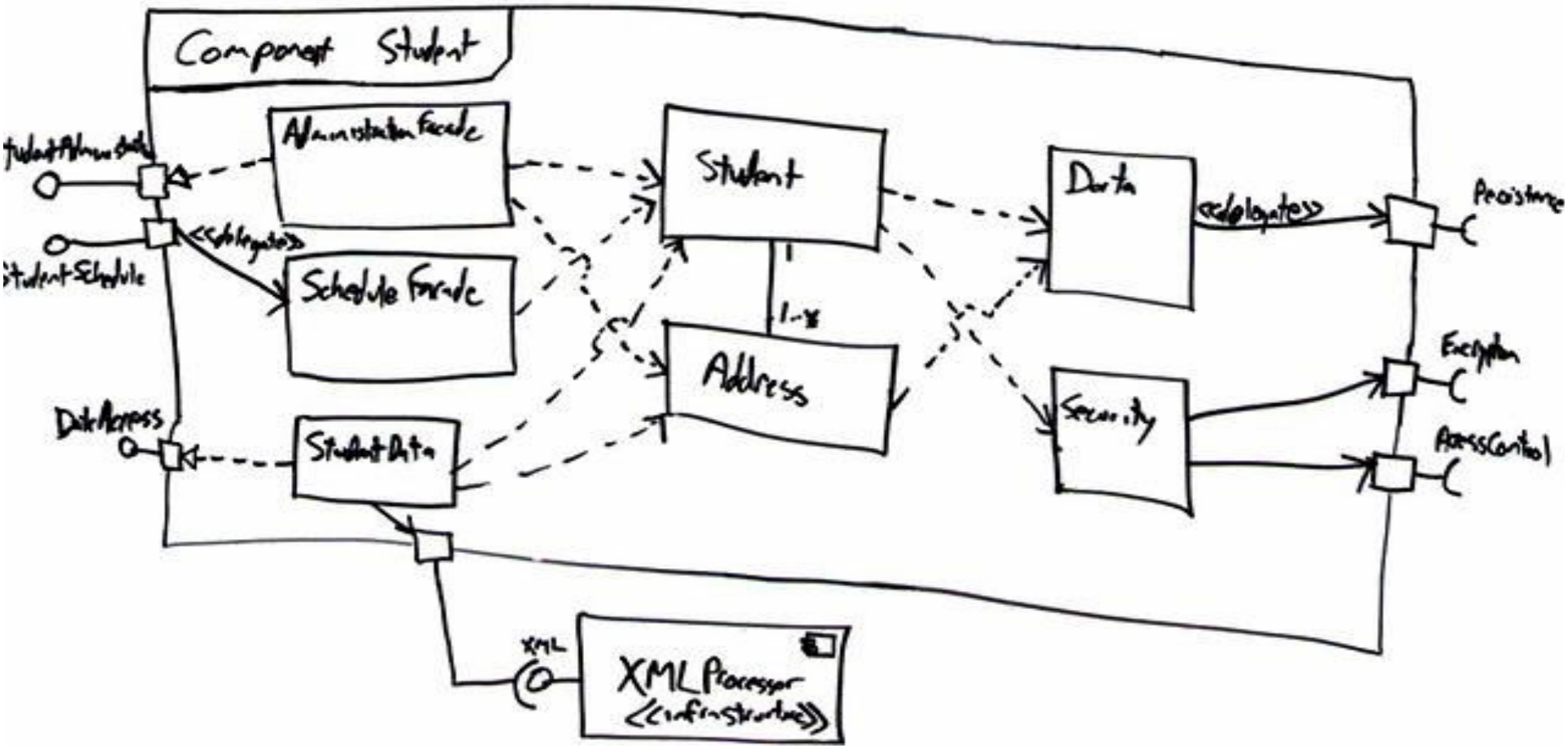
<<requires>>

University DB <<database>>

JDBC

So, how many different conventions for components in UML2.0?

Building a Component

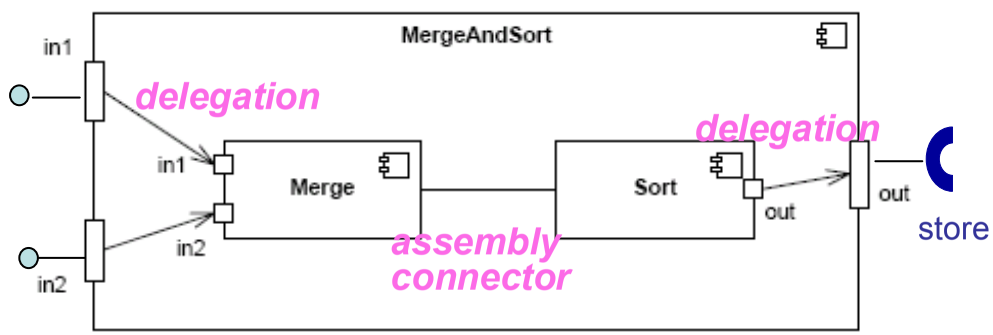


- simplified the ports to either provide or require a single interface
- relationships between ports and internal classes in three different ways:
  i) as ***stereotyped delegates*** (flow), as ***delegates***, and as ***realize***s (logical->physical) relationships
- Cohesive reuse and change of classes; acyclic component dependency ***???***

Component Diagram – Connector & Another Example

- a connector: just a link between two or more connectable elements (e.g., ports or interfaces)
- 2 kinds of connectors: *assembly* and *delegation*. For ***"wiring"***
  - An ***assembly*** connector: a binding between a provided interface and a required interface (or ports) that indicates that one component provides the services required by another; ***simple line/ball-and-socket/lollipop-socket notation***
  - A ***delegation*** connector binds a component's external behavior (as specified at a port) to an internal realization of that behavior by one of its parts *(provide-provide, request-request).*

External View of a Component with Ports



Internal View of a Component with Ports

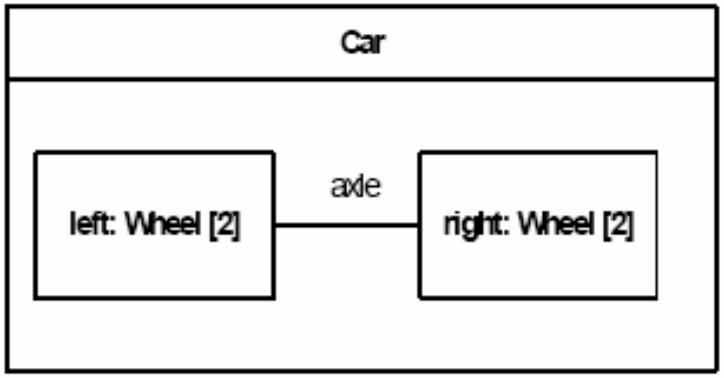
Left delegation: direction of arrowhead indicates "provides"

Right delegation: direction of arrowhead indicates "requests"

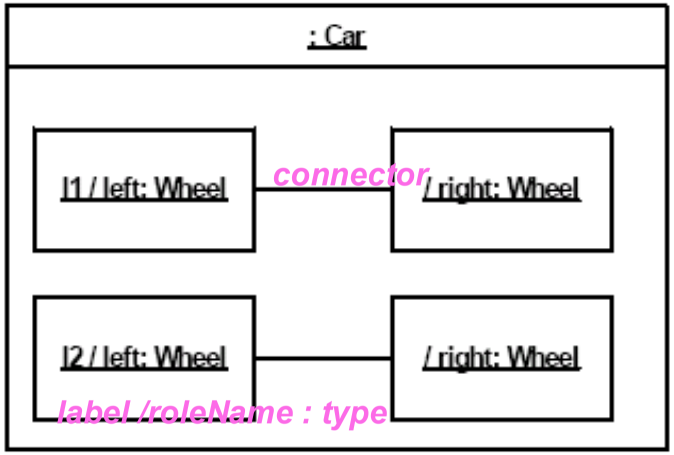
So, what levels of abstractions for connections?

Structured Class

- A *structured class(ifier)* is defined, in whole or in part, in terms of a number of *parts* - contained instances owned or referenced by the structured class(ifier).
- With a similar meaning to a **composition** relation ***Any difference?***
- A structured classifier's parts are created within the containing classifier (either when the structured classifier is created or later) and are destroyed when the containing classifier is destroyed.
- Like classes and components, combine the descriptive capabilities of structured classifiers with ***ports and interfaces***



component or class?



Components extend classes with additional features such as

- the ability to ***own more types of elements*** than classes can; e.g., packages, constraints, use cases, and artifacts
- deployment specifications that define the execution parameters of a component deployed to a node

Classifiers

- Classifier—mechanism that describes structural (e.g. class attributes) and behavioral (e.g. class operations) features. In general, those *modeling elements* that can have *instances* are called classifiers.
- *cf. Packages and generalization relationships do not have instances.*

an asynchronous stimulus communicated between instances

class

Shape
origin
move()
resize()
display()

interface

IUnknown

data type

<<type>>
Int
{ values range from
-2**31 to +2**31 - 1 }

signal

<<signal>>
OffHook

use case

Process loan

kernel32.dll

component

membership_server

node

<<subsystem>>
Customer Service

subsystem

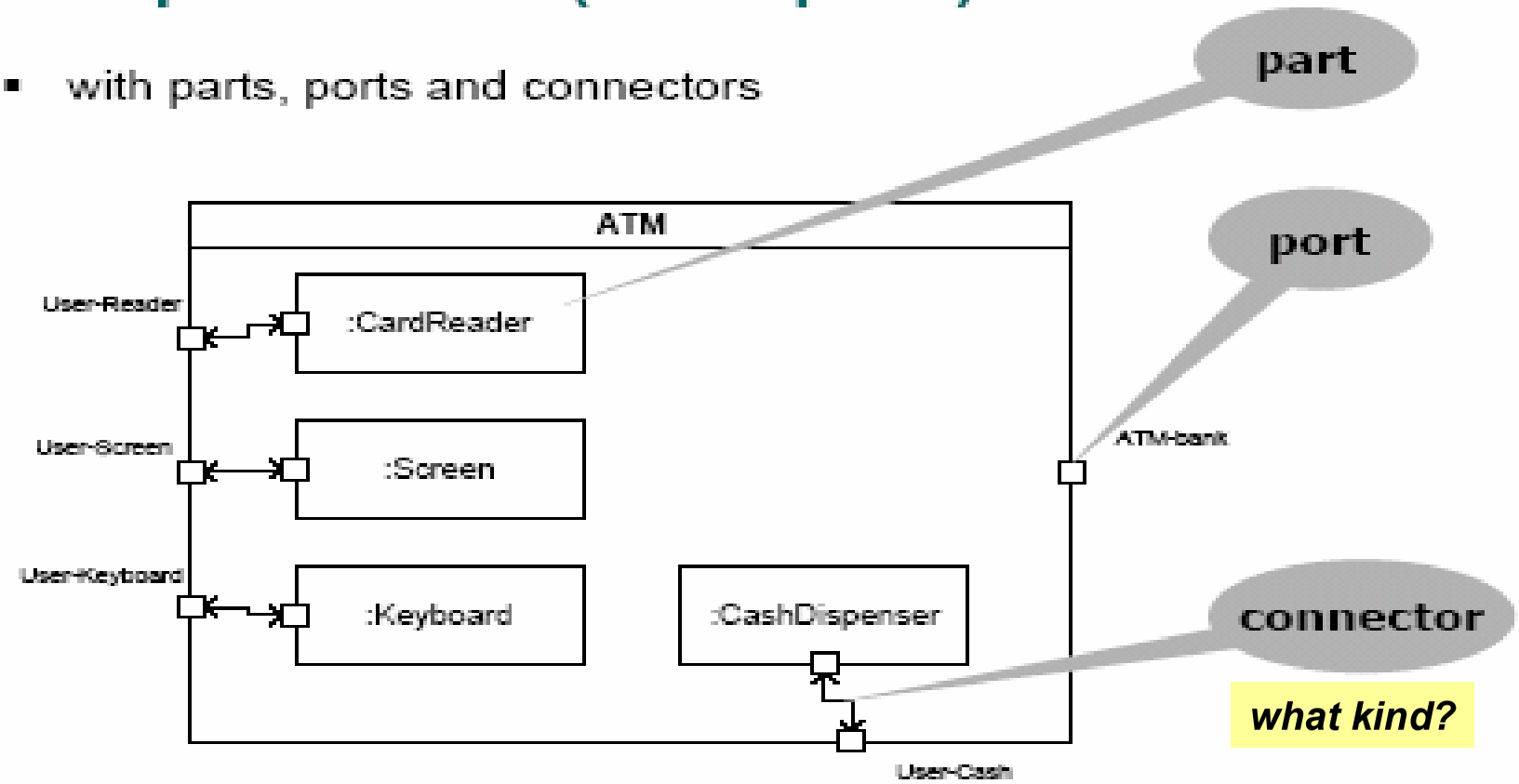
Generalizable Element, Classifier, Class, Component?

Structured Class – Another Example

UNIVERSITY OF OSLO

Composite class (incomplete)

- with parts, ports and connectors



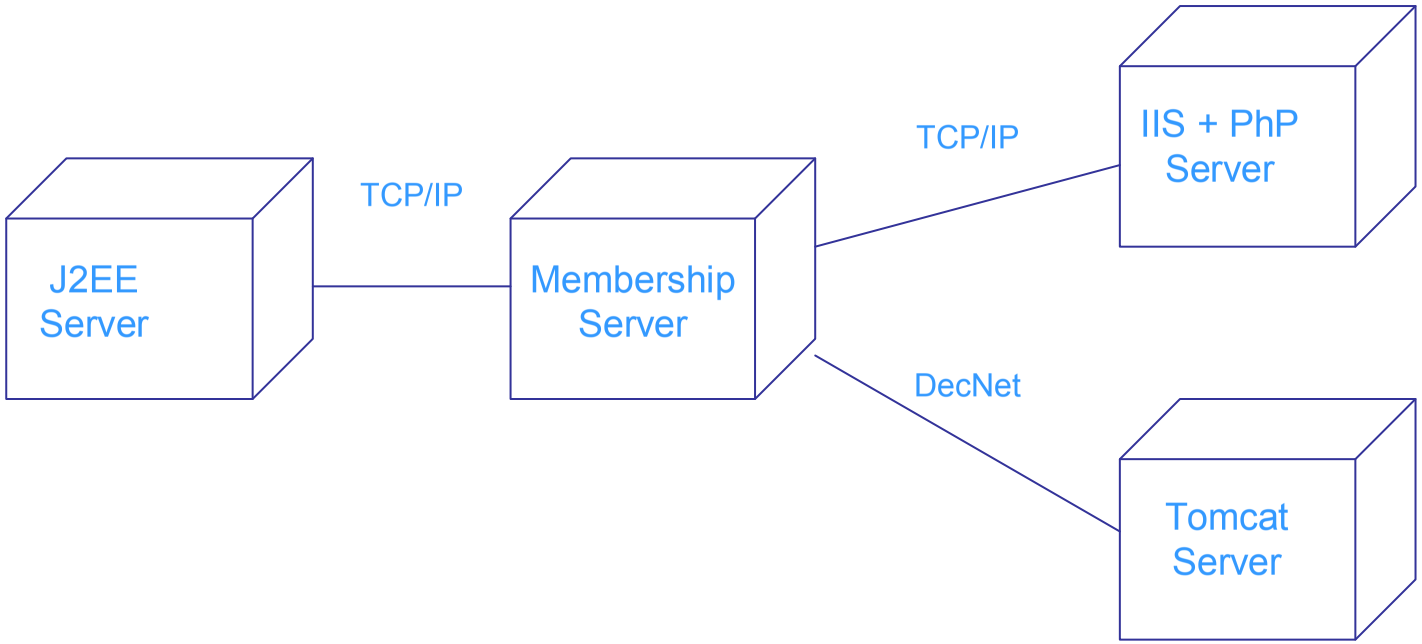
Deployment Diagrams

Structural Diagrams

- Class;
  Object
- Component
- Deployment
- **Composite Structure**
- Package

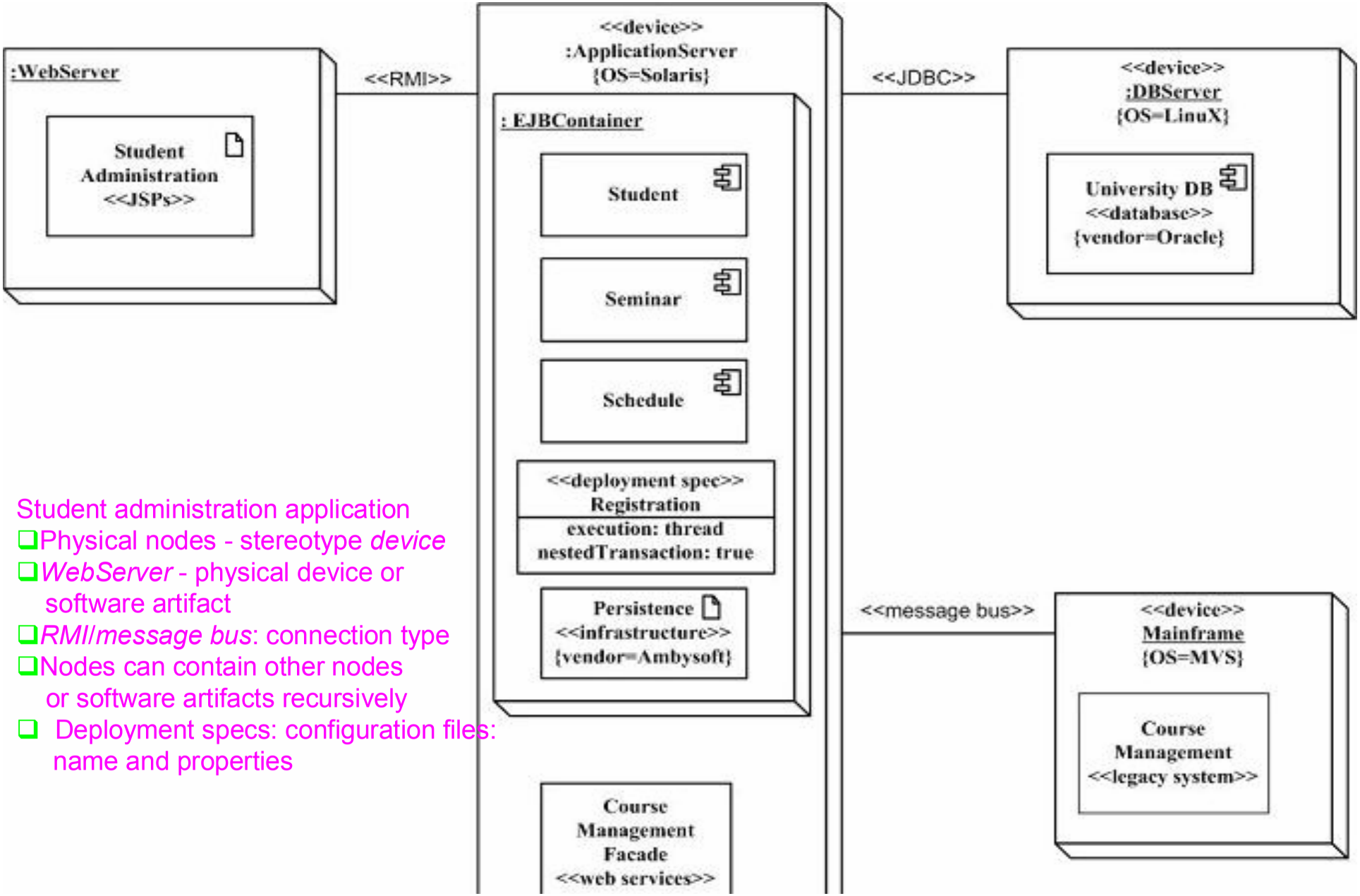
Deployment Diagram

- Shows a set of *processing* nodes and their relationships.
- Represents the static deployment view of an *architecture*.
- Nodes typically enclose one or more components.



Structural Diagrams - Deployment Diagram

(http://www.agilemodeling.com/artifacts/deploymentDiagram.htm)



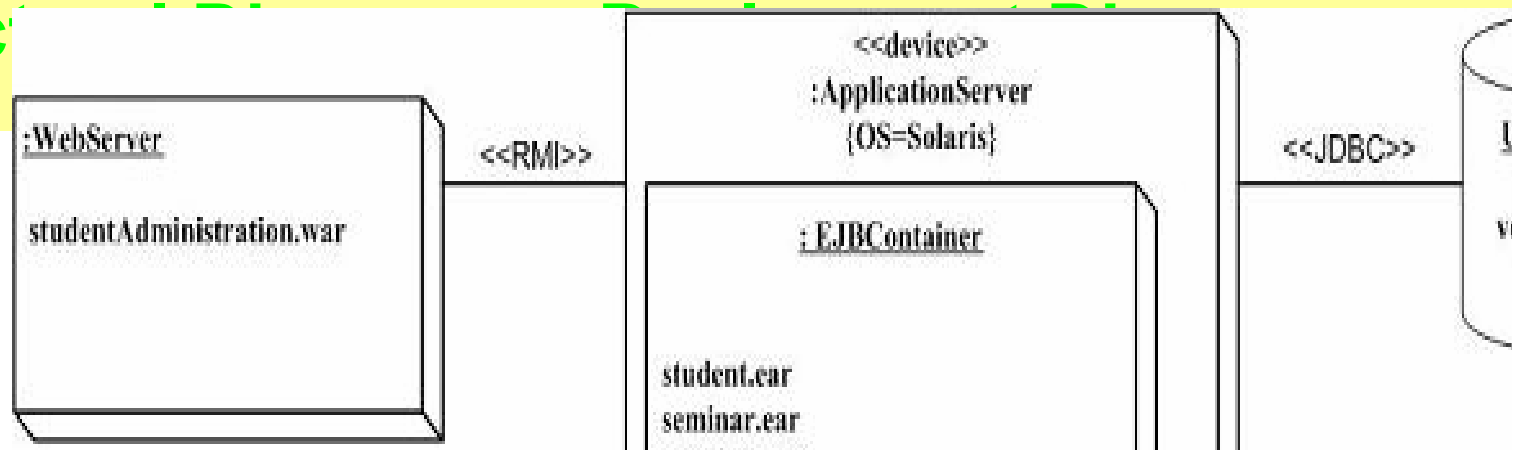
Student administration application

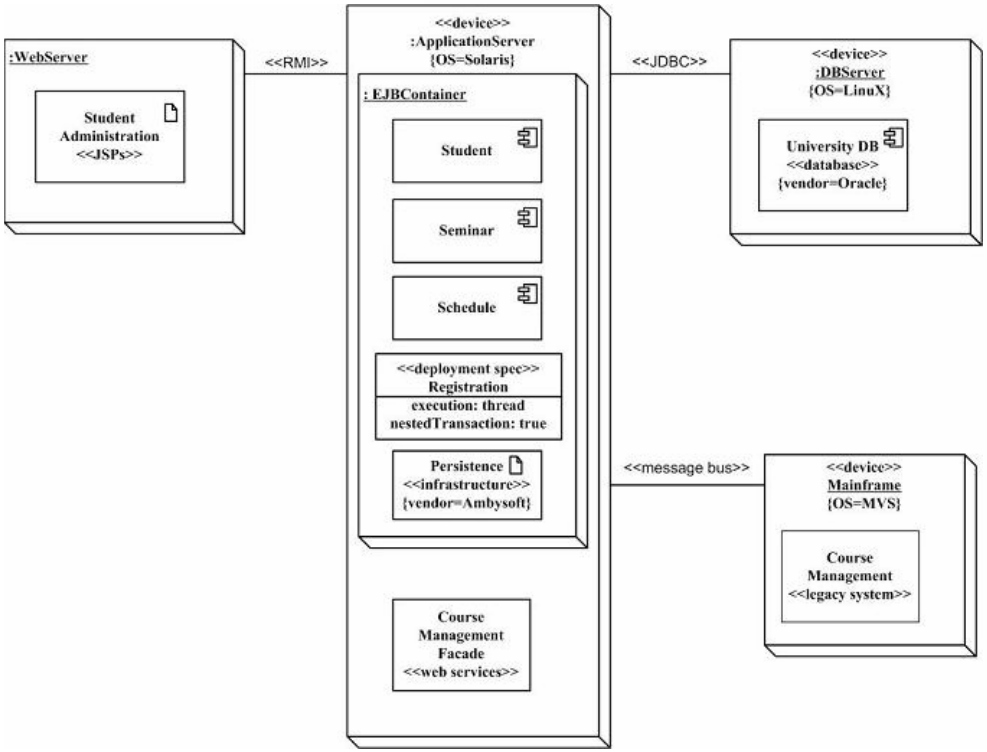
- Physical nodes - stereotype *device*
- *WebServer* - physical device or software artifact
- *RMI/message bus*: connection type
- Nodes can contain other nodes or software artifacts recursively
- Deployment specs: configuration files: name and properties

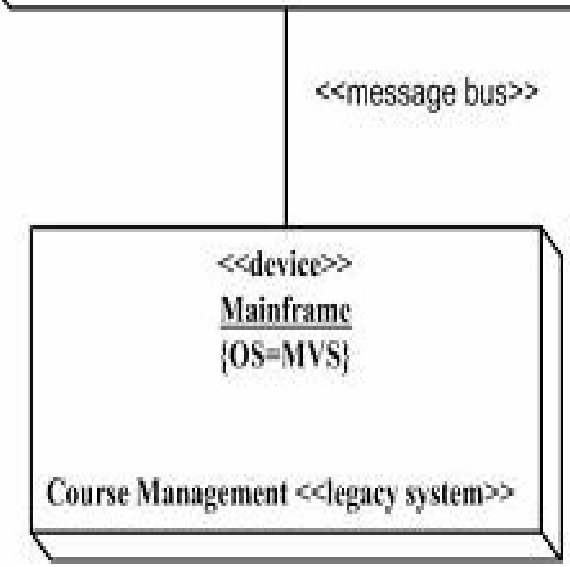
Struc

Is this better?

- More concrete
- Implementation-oriented







Composite Structure Diagrams

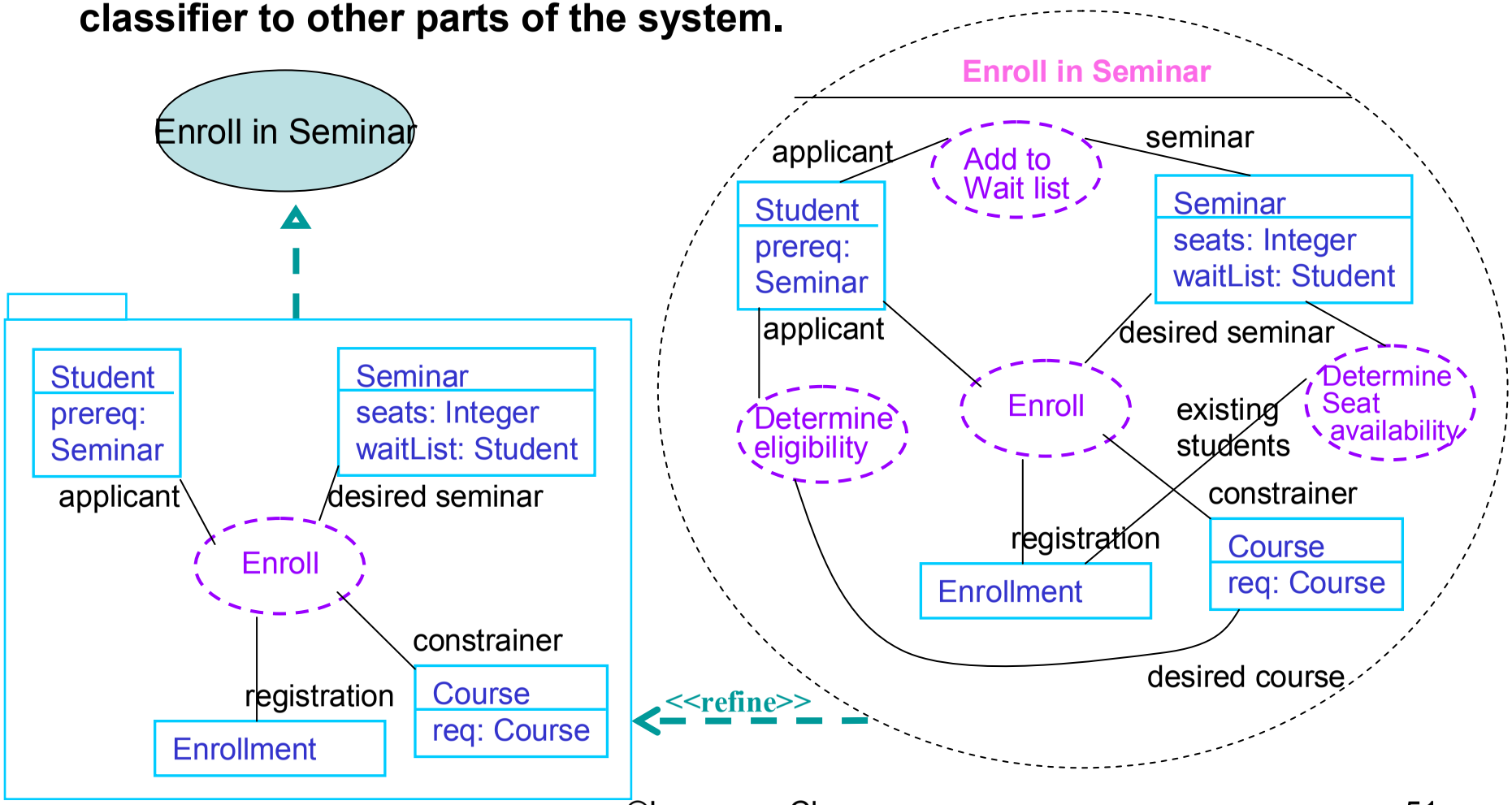
Structural Diagrams

- Class;
  Object
- Component
- Deployment
- **Composite Structure**
- Package

Composite Structure Diagrams

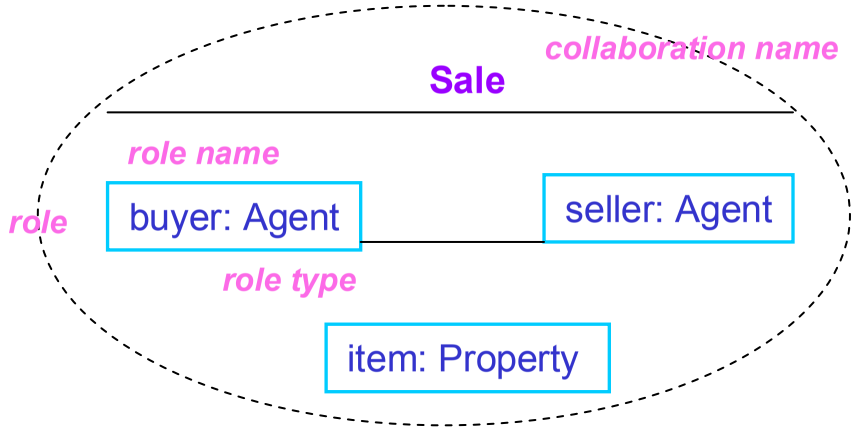
(http://www.agilemodeling.com/artifacts/compositeStructureDiagram.htm)

- **Depicts the internal structure of a classifier (such as a class, component, or collaboration), including the interaction points of the classifier to other parts of the system.**

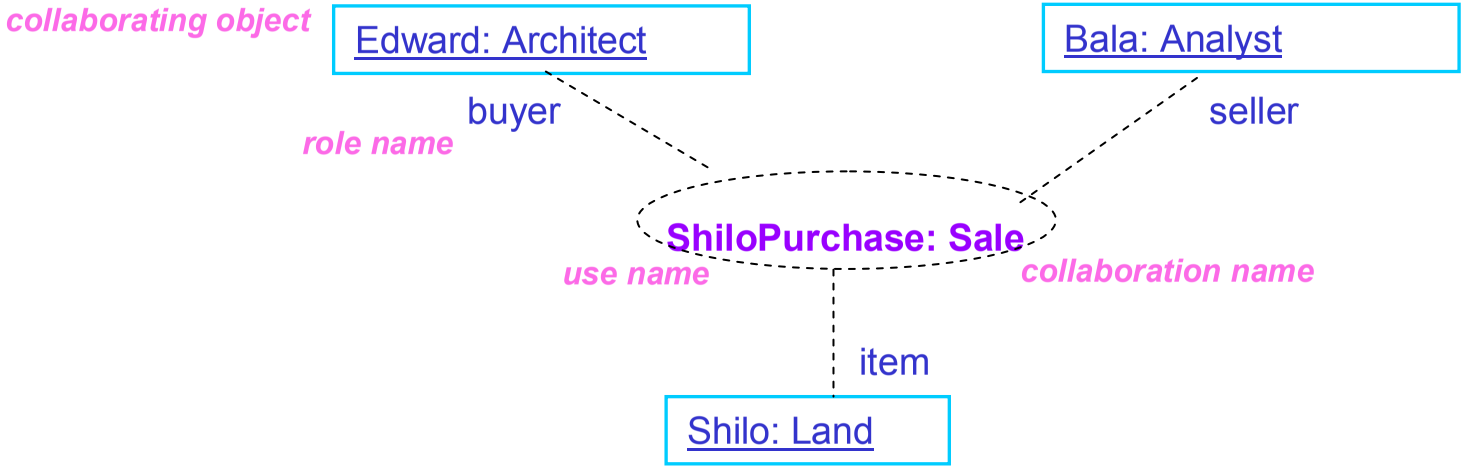


structured class, structured component, structured use case, structured node, structured interface, …

Variations [Rumbaugh – UML 2.0 Reference: p234]



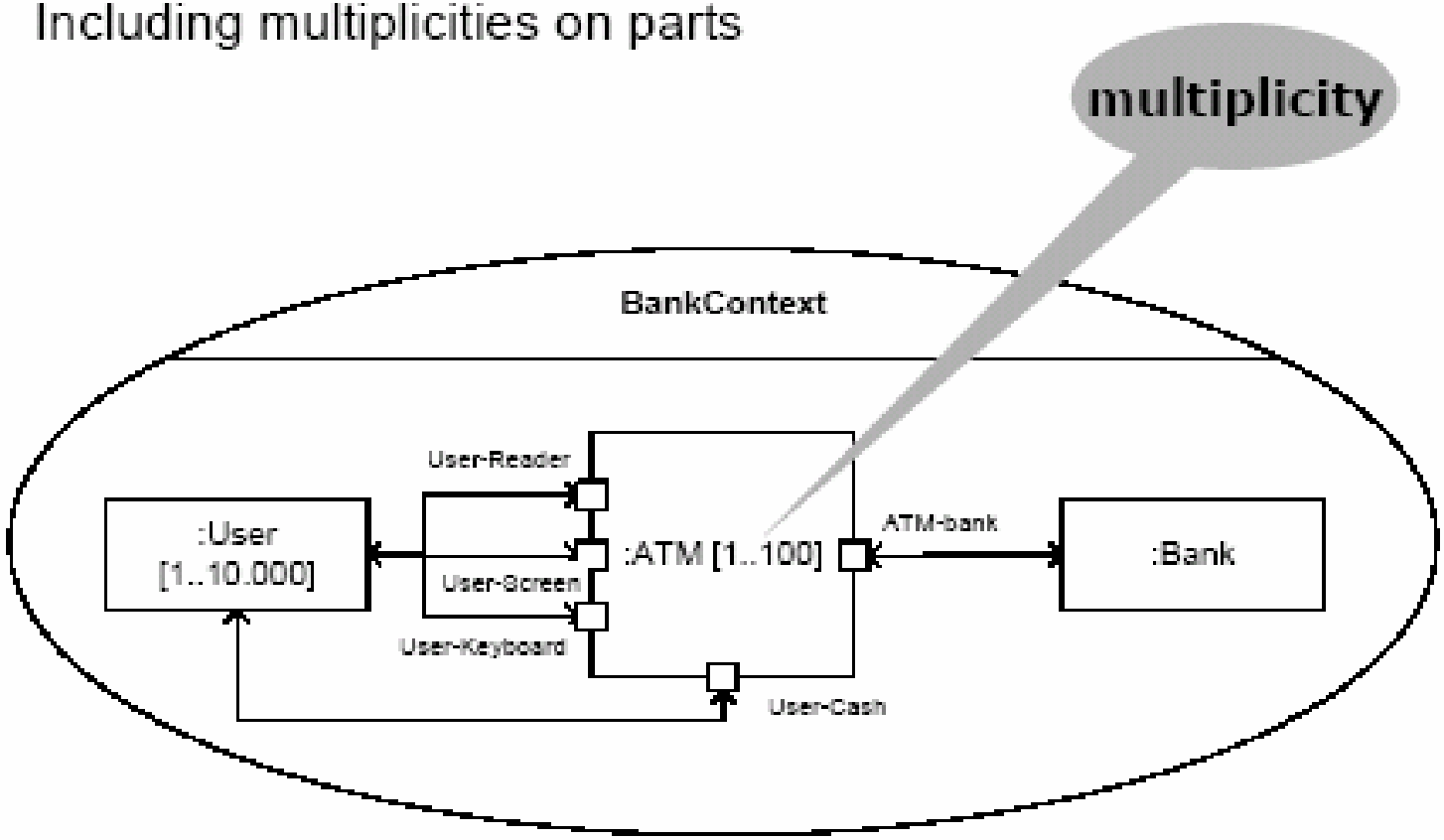
Collaboration definition



Collaboration use in object diagram

Context Model in UML2.0 - II

- Including multiplicities on parts

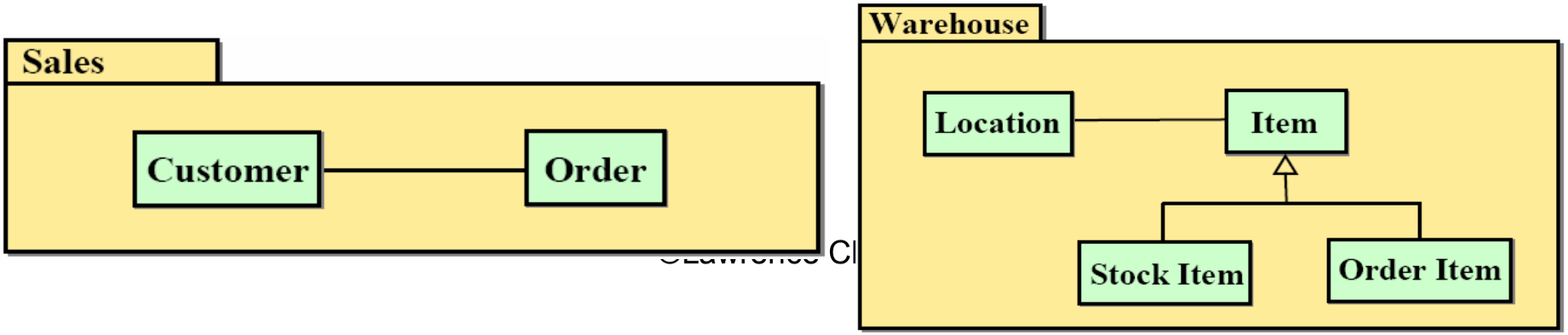


Structural Diagrams

- Class;
  Object
- Component
- Deployment
- Composite Structure
- **Package**

Packages

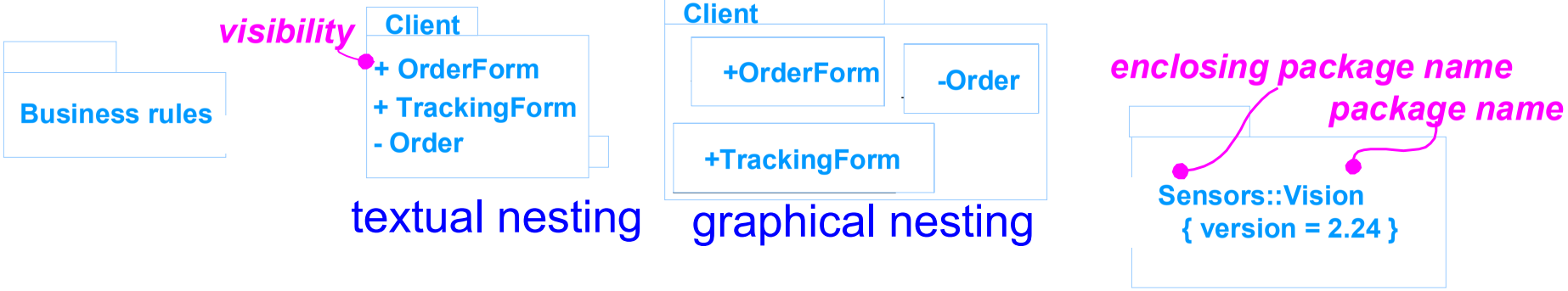
Construct	Description	Syntax
Package	A grouping of model elements.	Name
Import	A dependency indicating that the public contents of the target package are added to the namespace of the source package.	«import»
Access	A dependency indicating that the public contents of the target package are available in the namespace of the source package.	«access»



Packages

- Package — general-purpose mechanism for organizing elements into groups.
- Nested Elements: Composite relationship (When the whole dies, its parts die as well, but not necessarily vice versa)
- (C++ namespace; specialization means “derived”)

simple names



textual nesting

graphical nesting

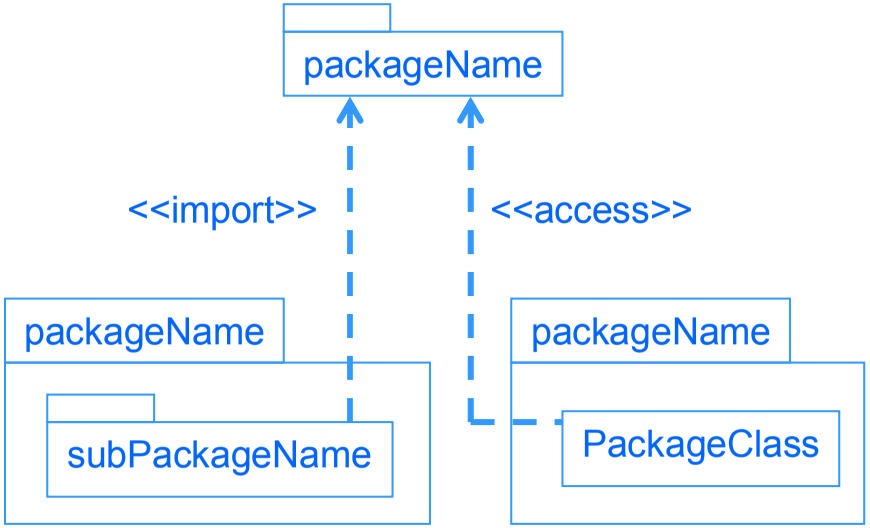
path names

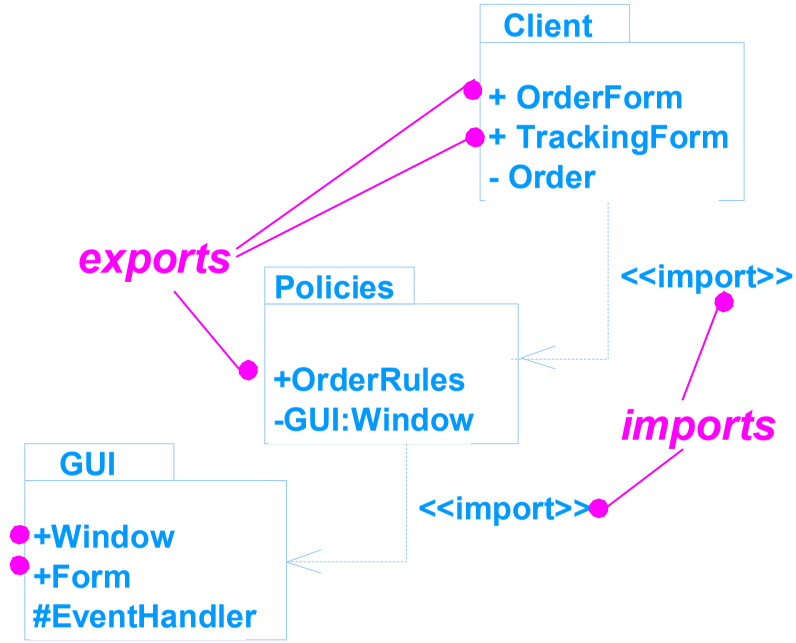
Visibility
+/-/#

- Packages that are friends to another may see all the elements of that package, no matter what their visibility.
- If an element is visible within a package, it is visible within all packages nested inside the package.

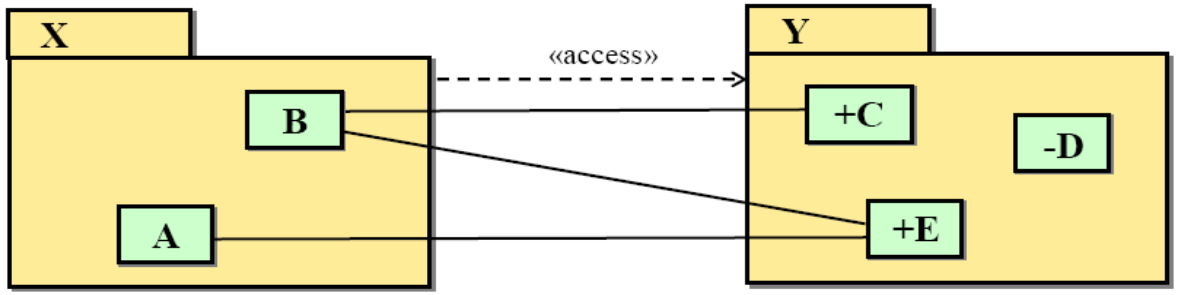
Dependency –Among Packages

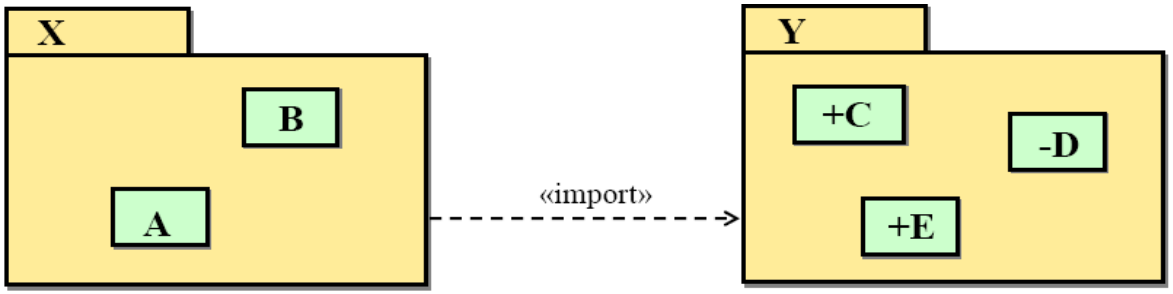
- Two Stereotypes of Dependency Among Packages:
  - *access*: the source package is granted the right to reference the elements of the target package *(:: convention)*
  - *import*: a kind of access; the ***public*** contents of the target package enter the flat namespace of the source as if they had been declared in the source



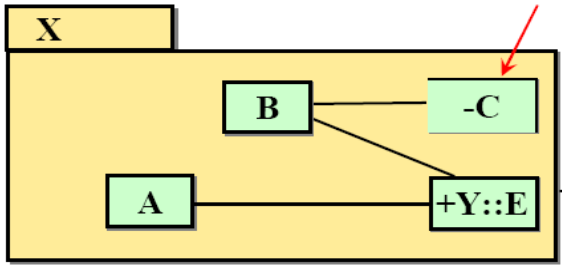


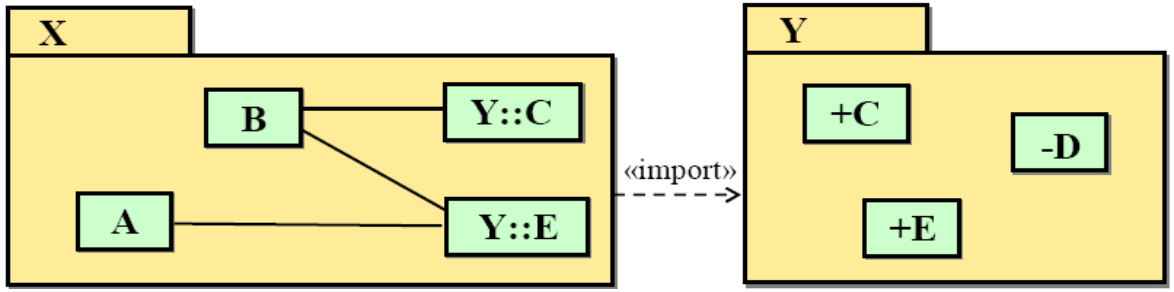
Access and Import





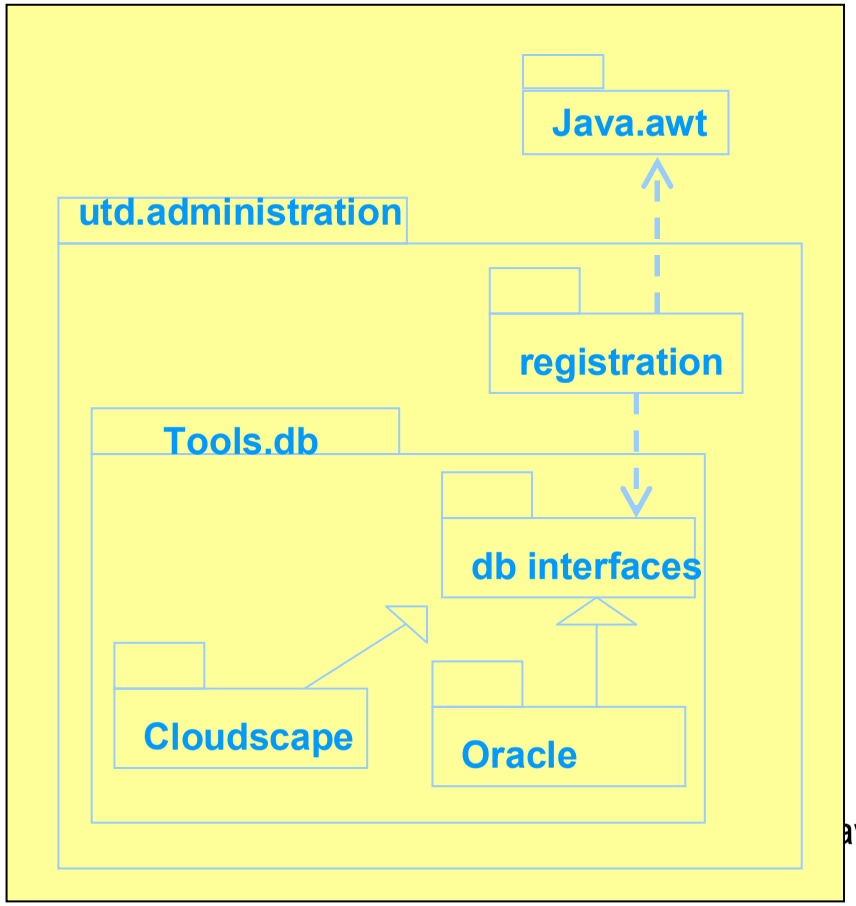
An imported element can be given a local alias and a local visibility





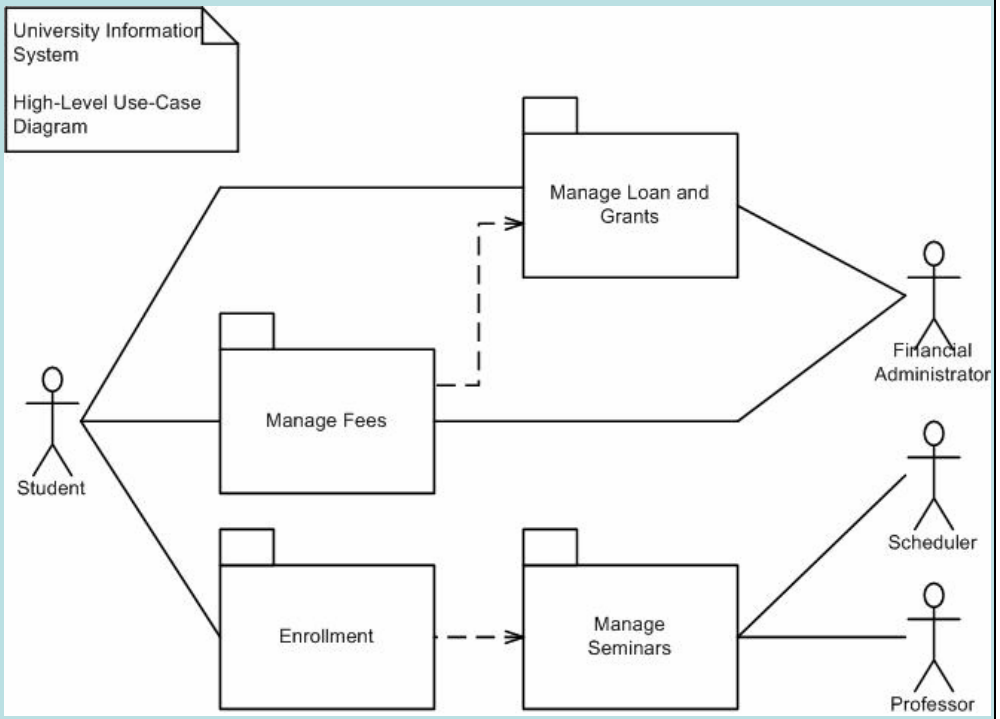
Modeling Groups of Elements

- Look for “clumps” of elements that are semantically close to one another.
- Surround “clumps” with a package. ***High cohesion & high coupling***
- Identify public elements of each package.
- Identify import dependencies.



Use Case package Diagram

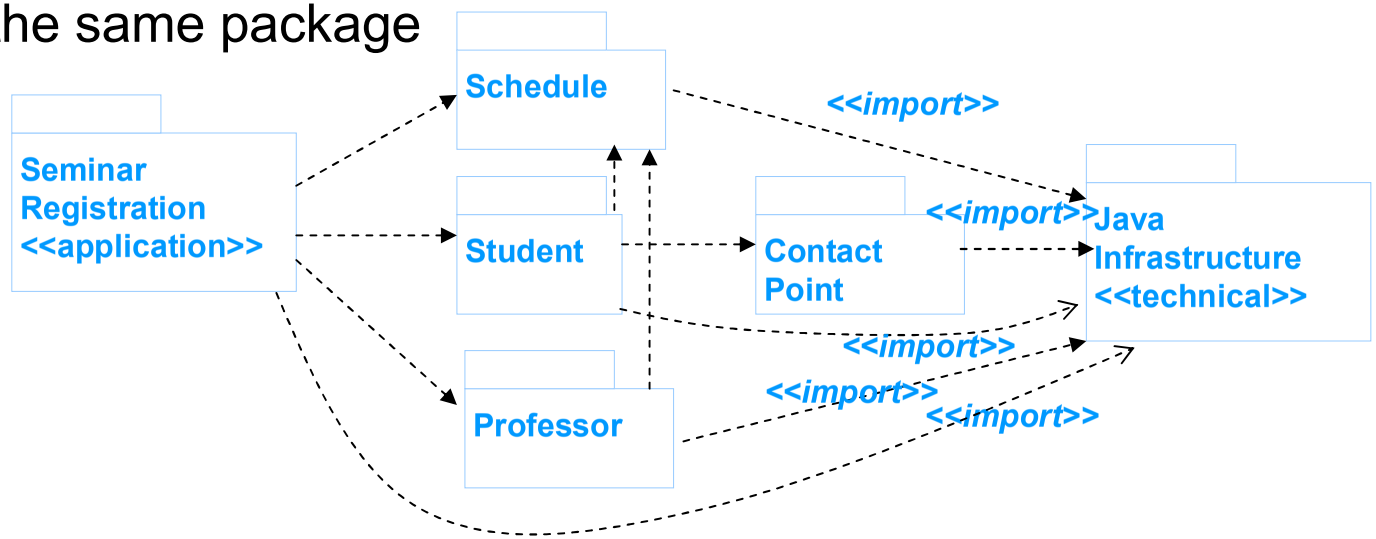
- Included and extending use cases belong in the same package as the parent/base use case
- Cohesive, and goal-oriented packaging
- Actors could be inside or outside each package



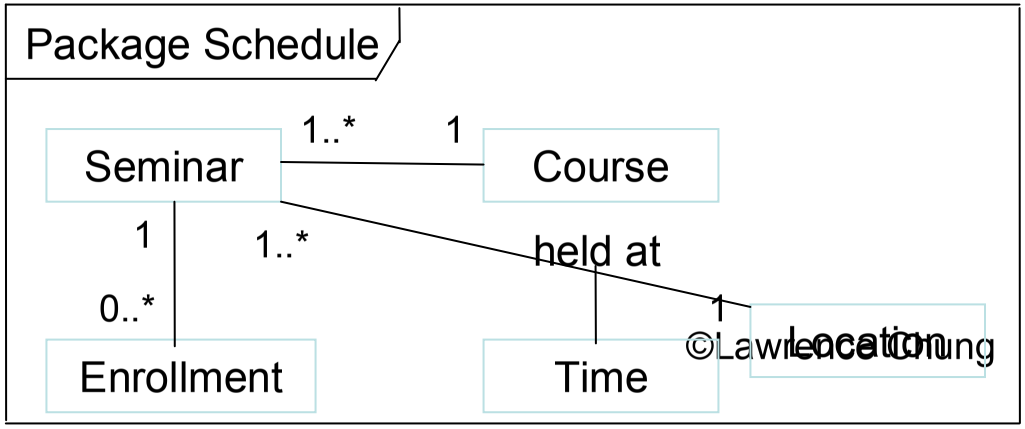
Class Package Diagrams

(http://www.agilemodeling.com/artifacts/packageDiagram.htm)

- Classes related through inheritance, composition or communication often belong in the same package



- A ***frame*** depicts the contents of a package (or components, classes, operations, etc.)
- Heading: rectangle with a cut-off bottom-right corner, [kind] name [parameter]



A frame encapsulates
a collection of collaborating instances or refers to another representation of such

Common Mechanisms

- Adornments

  Notes & Compartments

- Extensibility Mechanisms
  - Stereotypes - Extension of the UML metaclasses.
  - Tagged Values - Extension of the properties of a UML element.
  - Constraints - Extension of the semantics of a UML element.

Adornments

- Textual or graphical items added to an element's basic notation.
- Notes - Graphical symbol for rendering constraints or comments attached to an element or collection of elements; No Semantic Impact

Rendered as a rectangle with a dog-eared corner.

See smartCard.doc for details about this routine.

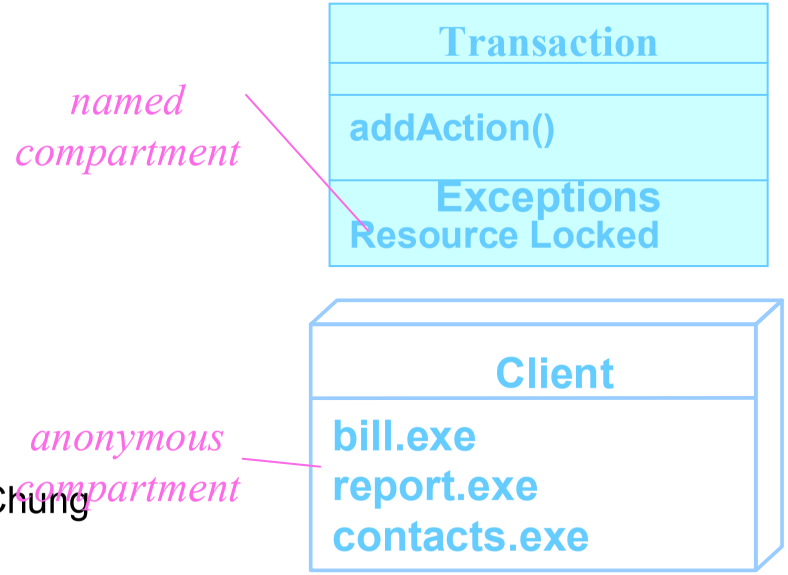
May contain combination of text and graphics.

See http://www.rational.com for related info.

May contain URLs linking to external documents.

Additional Adornments

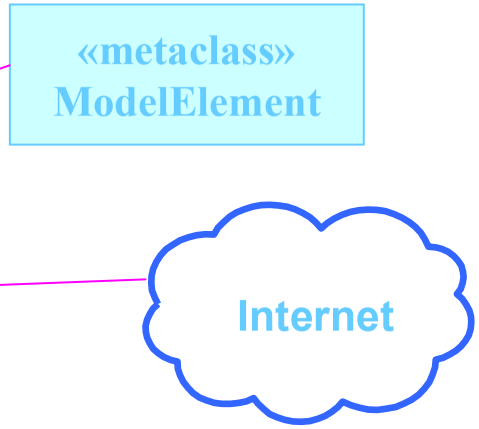
- Placed near the element as
  - Text
  - Graphic
- Special compartments for adornments in
  - Classes
  - Components
  - Nodes



Stereotypes

- Mechanisms for extending the UML vocabulary.
- Allows for new modeling building blocks or parts.

- Allow controlled extension of metamodel classes.
  [UML11_Metamodel_Diagrams.pdf]
- Graphically rendered as
  - Name enclosed in guillemets (<< >>)
    - <<stereotype>>
  - New icon



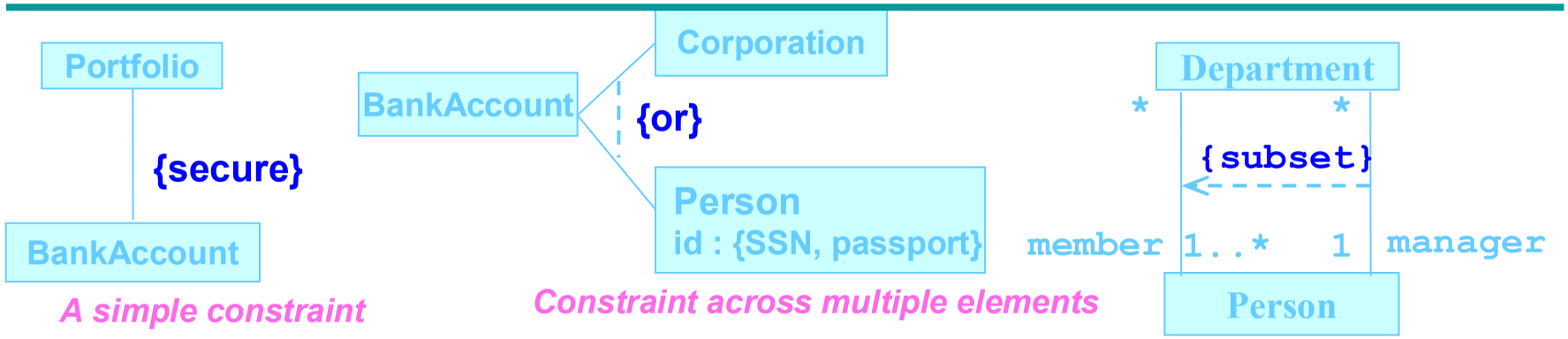
- The new building block can have
  - its own special properties through a set of tagged values
  - its own semantics through constraints

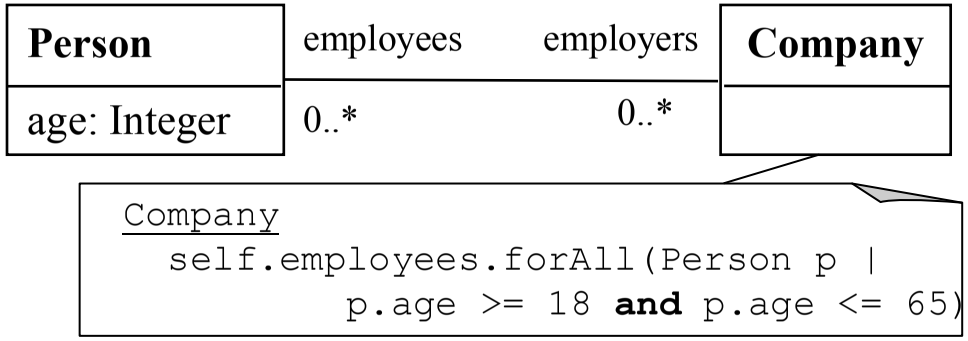
Tagged Values

- a (name, value) pair describes a property of a model element.
- Properties allow the extension of "***metamodel***" element attributes.
- modifies the semantics of the element to which it relates.
- Rendered as a text string enclosed in braces { }
- Placed below the name of another element.

Constraints

- Extension of the semantics of a UML element.
- Allows new or modified rules
- Rendered in braces {}.
  - Informally as free-form text, or
  - Formally in UML's Object Constraint Language (OCL):
    E.g., {self.wife.gender = female and self.husband.gender = male}





Appendix
Some Additional Material

Classes: Notation and Semantics

Class - Name
attribute-name-1 : data-type-1 = default-value-1 **attribute-name-2 : data-type-2 = default-value-2**
operation-name-1 (argument-list-1) : result-type-1 **operation-name-2 (argument-list-2) : result-type-2**
responsibilities

To model the <<semantics>> (meaning) of a class:

- Specify the body of each method (pre-/post-conditions and invariants)
- Specify the state machine for the class
- Specify the collaboration for the class
- Specify the responsibilities (contract)

Attributes

- Syntax
  [visibility] name [multiplicity] [: type] [= initial-value] [{property-string }]
- Visibility
  + public; - private; # protected; {default = +}
- type
  - There are several defined in Rational Rose.
  - You can define your own.

  Or you can define your own: e.g. {leaf}
- property-string
  Built-in property-strings:
  - *changeable*—no restrictions (default)
  - *addOnly*—values may not be removed or altered, but may be added
  - *frozen*—may not be changed after initialization

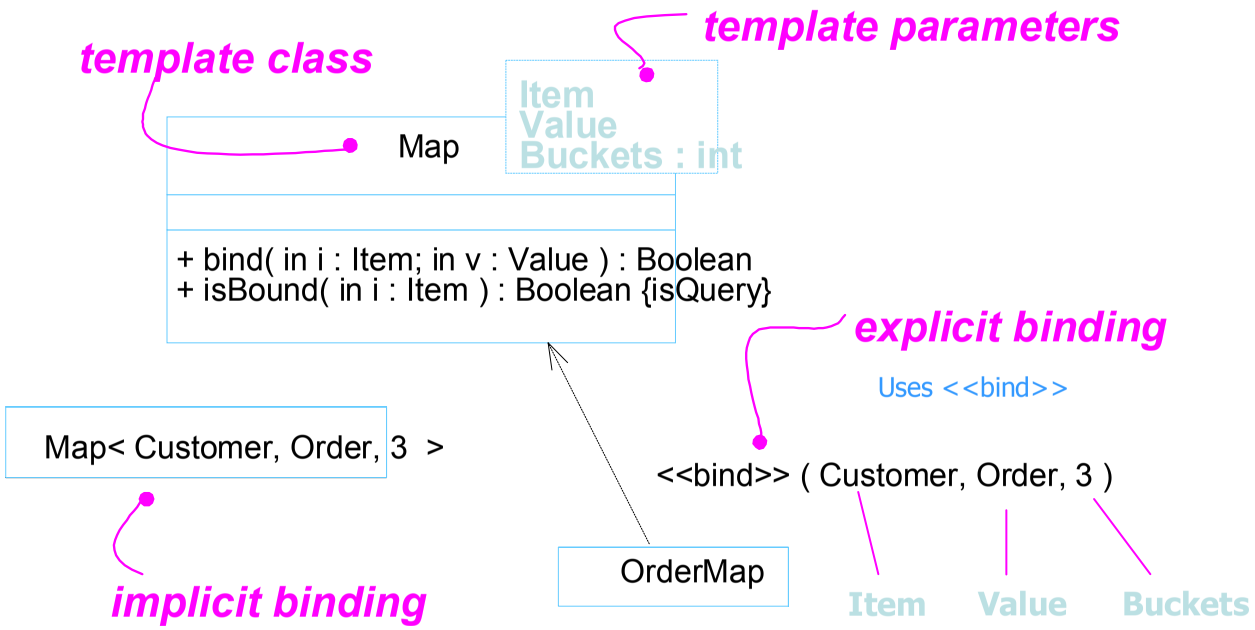
origin	Name only
+ origin	Visibility and name
origin : Point	Name and type
head : *Item	Name and complex type
name [0..1] : String	Name, multiplicity, and type
origin : Point = { 0, 0 }	Name, type, and initial value
id : Integer { frozen }	Name and property

Operations

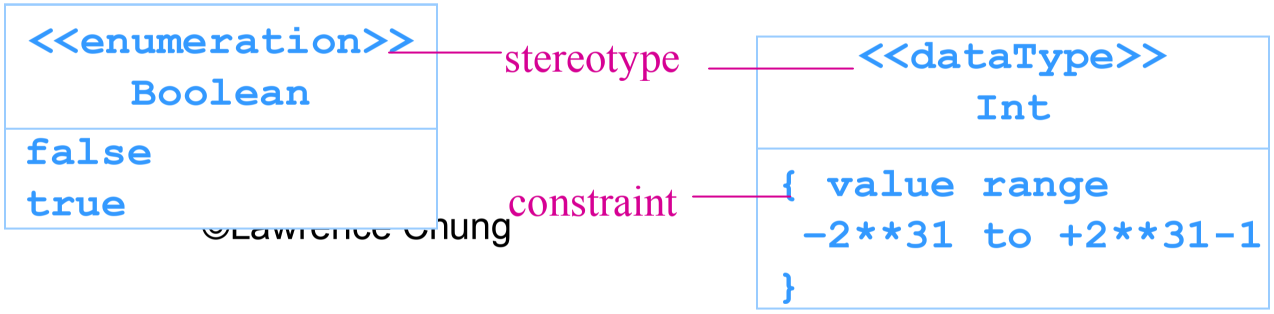
- Syntax
  [visibility] name [(parameter-list)] [: return-type] [(property-string)]
- Visibility
  + public; - private; # protected; {default = +}
- parameter-list syntax
  [direction] name : type [= default-value]
- direction
  - *in*—input parameter; may not be modified
  - *out*—output parameter; may be modified
  - *inout*—input parameter; may be modified
- property-string
  - *leaf*
  - *isQuery*—state is not affected
  - *sequential*—not thread safe
  - *guarded*—thread safe (Java synchronized)
  - *concurrent*—typically atomic; safe for multiple flows of control

Template Classes; Primitive Types

- A template class is a parameterized element and defines a family of classes
- In order to use a template class, it has to be instantiated
- Instantiation involves binding formal template parameters to actual ones, resulting in a concrete class



Primitive Types using a class notation



Interface: A Java Example

```
public interface SoundFromSpaceListener extends EventListener {
    void handleSoundFromSpace(SoundFromSpaceEventObject sfseo);
}

public class SpaceObservatory implements SoundFromSpaceListener
    public void handleSoundFromSpace(SoundFromSpaceEventObject sfseo) {
            soundDetected = true;
            callForPressConference();
    }
```

Can you draw a UML diagram corresponding to this?

Package Diagrams: Standard Elements

- *Façade* — only a view on some other package.
- *Framework* — package consisting mainly of patterns.
- *Stub* — a package that serves as a proxy for the public contents of another package.
- *Subsystem* — a package representing an independent part of the system being modeled.
- *System* — a package representing the entire system being modeled.

Is <<import>> transitive?
Is visibility transitive?
Does <<friend>> apply to all types of visibility: +, -, #?

Dependency –Among Objects

- 3 Stereotypes of Dependency in Interactions among Objects:
  - *become*: the target is the same object as the source but at a later point in time and with possibly different values, state, or roles
  - *call*: the source operation invokes the target operation
  - *copy*: the target object is an exact, but independent, copy of the source