ITEC 4010: Systems Analysis and Design II.

Lecture 9

Advanced Analysis

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Topics

- *Advanced Class Modeling*
- *Class Layers*
- *Advanced Generalization and Inheritance Modeling*
- *Advanced Aggregation and Delegation Modeling*

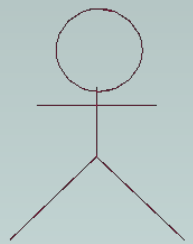
Advanced class modeling

- *Stereotypes*
- *Constraints*
- *Derived information*
- *Visibility*
- *Qualified associations*
- *Association class*
- *Parameterized class*
- *and few other concepts…*

Stereotype

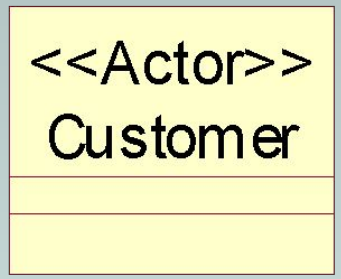
- *Extends (varies the semantics) of an existing UML element*
- ***Labeled** in the models with a name within matched quotation symbols, such as «global», «PK», «include»*
- *An **iconic** presentation of stereotypes is also possible*
- *Some popular stereotypes are **built-in** – they are pre-defined in UML*
- *A purposeful set of stereotypes to address a design modeling issue is called a **profile***

Stereotype examples

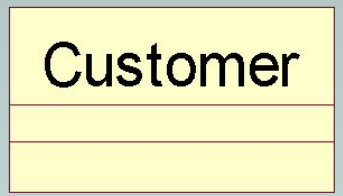


Customer

"icon" stereotype



"label" stereotype



no stereotype

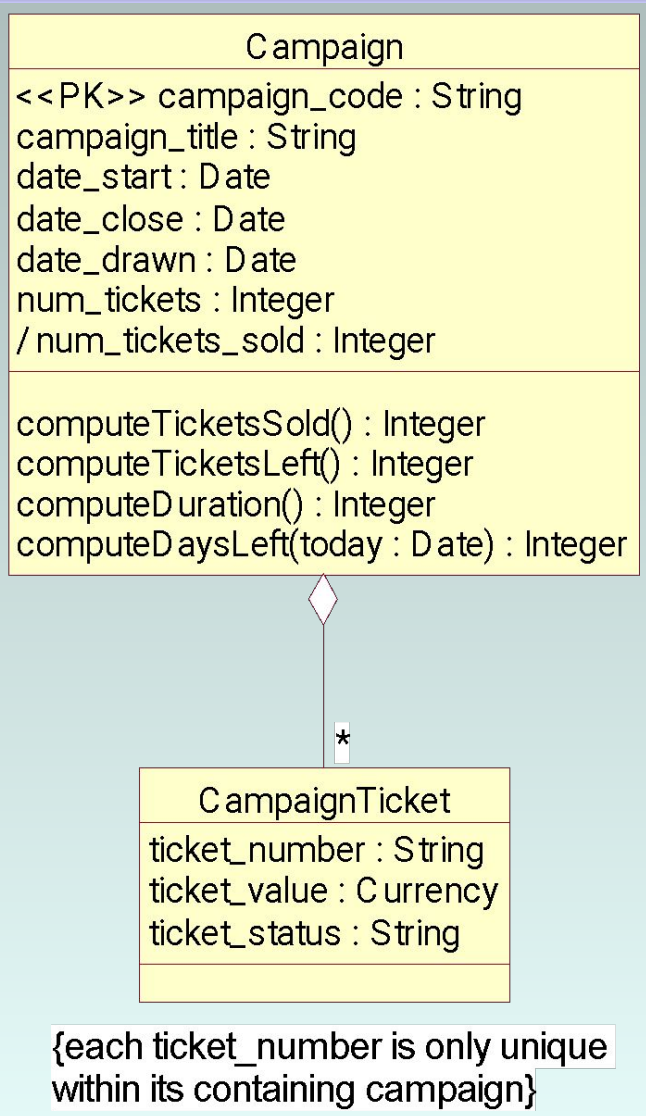
Constraint

- *Not to be confused with a stereotype*
- *However,a **stereotype** can be used to introduce a new **constraint** to the model*
- *Simple constraints can be shown on a UML diagram in curly brackets*
- *More elaborate constraints are just stored in the repository in text documents*

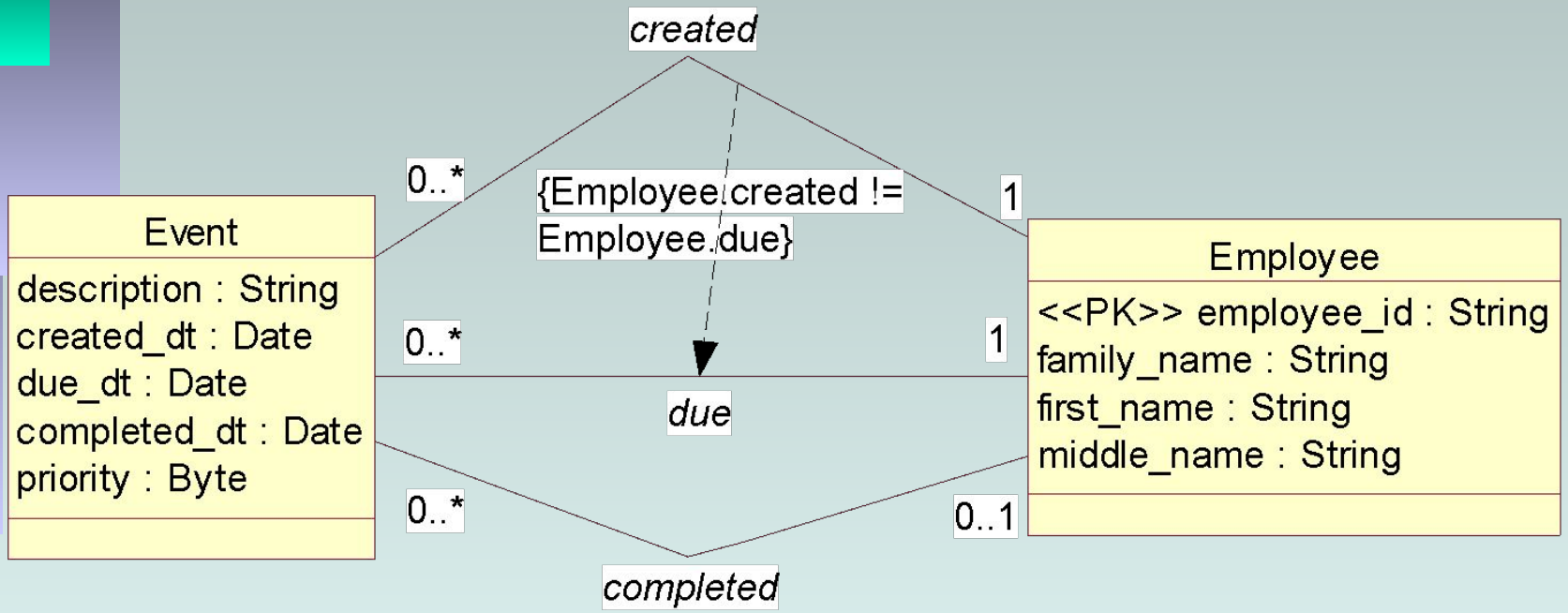
Example 9.1 – Telemarketing

- *Refer to Telemarketing example (Lecture7, slide 22) and add the following requirement*
- *All tickets are numbered. The numbers are unique across all tickets in a campaign*
- *Our task is to model the constraint on the class diagram*

Constraint on a class



Constraint on associations



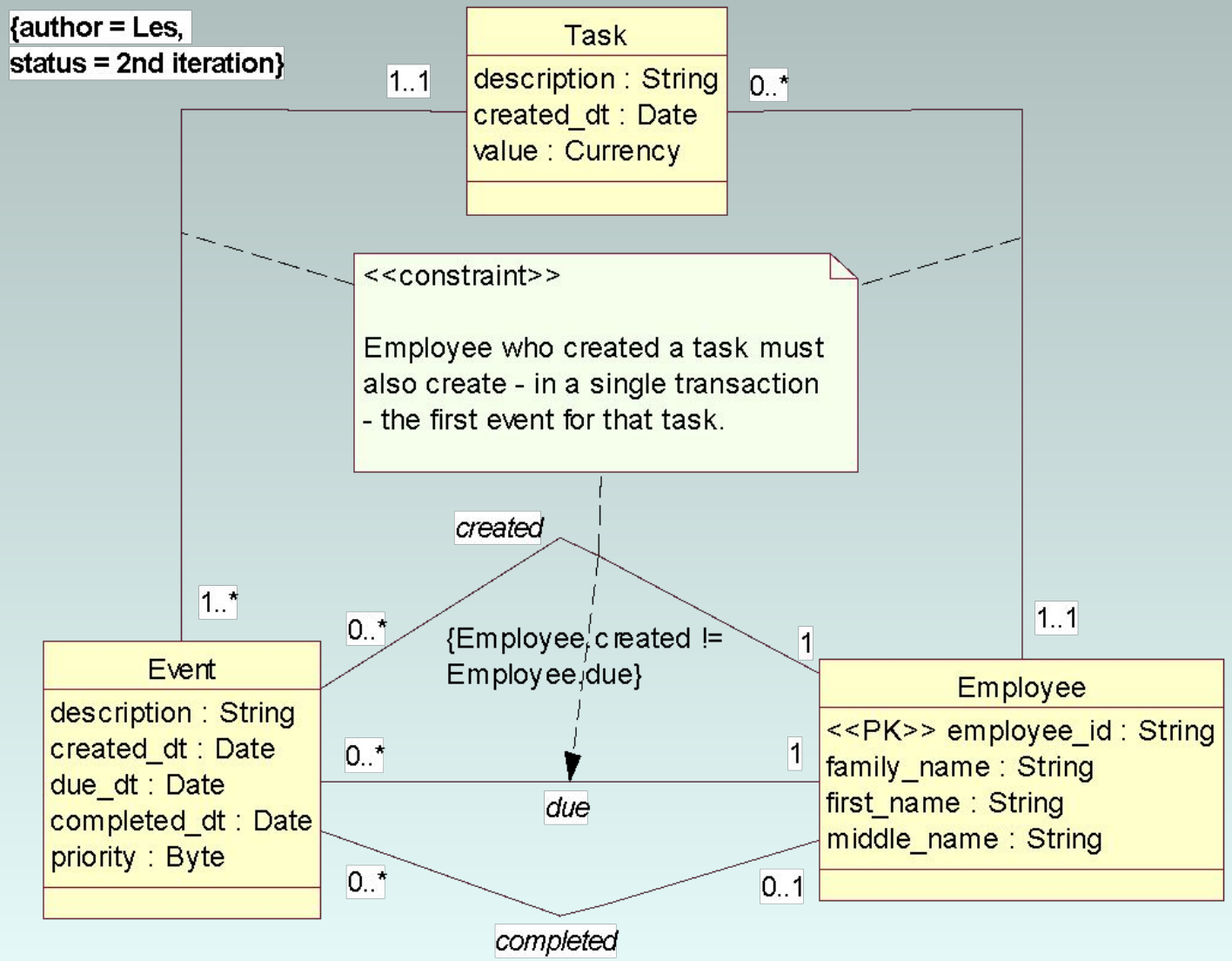
Note and tag

- ***Note*** *- frequently a special kind of (more complex) constraint*
- *A rectangle with its upper-right corner bent over*
- *Like notes,* ***tags*** *represent arbitrary textual information in the model, possibly a constraint*
- *Like constraints,* ***tags*** *are written inside curly brackets and take the form:*

  `tag = value`

- *A typical use of tags is in providing project management information*

Constraint note and tag



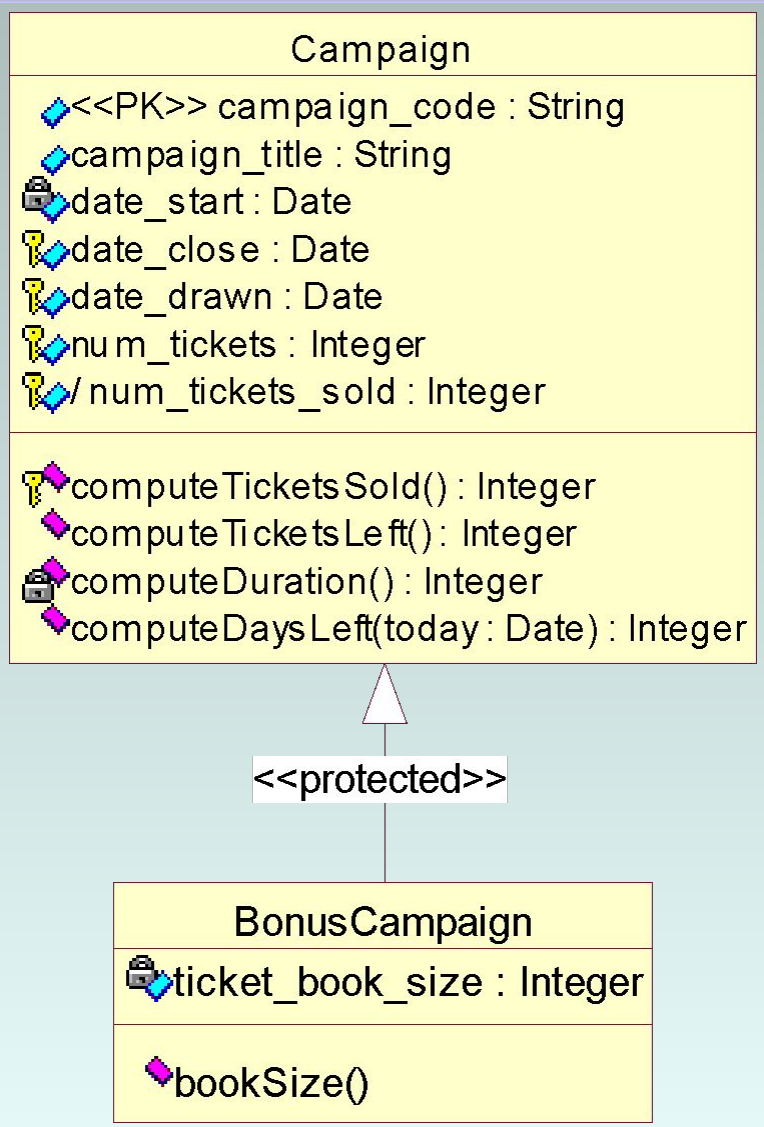
Visibility and encapsulation

- *UML notation for **visibility** are the signs*
  - *+ (for public),*
  - *# (for protected)*
  - *– (for private)*
- *CASE tools frequently replace this rather dull notation*

Protected visibility

- *There are many situations in which objects of a derived class (a subclass of the base class) should be allowed to access the private properties of the base class*
- *If* `Joe` *is an object of* `Employee`*, then – by definition of generalization –* `Joe` *must have access to (at least some) properties of* `Person` *(e.g. to the attribute* `date_of_birth`*)*
- ***Protected property*** *is visible to a derived class*

Visibility of class properties



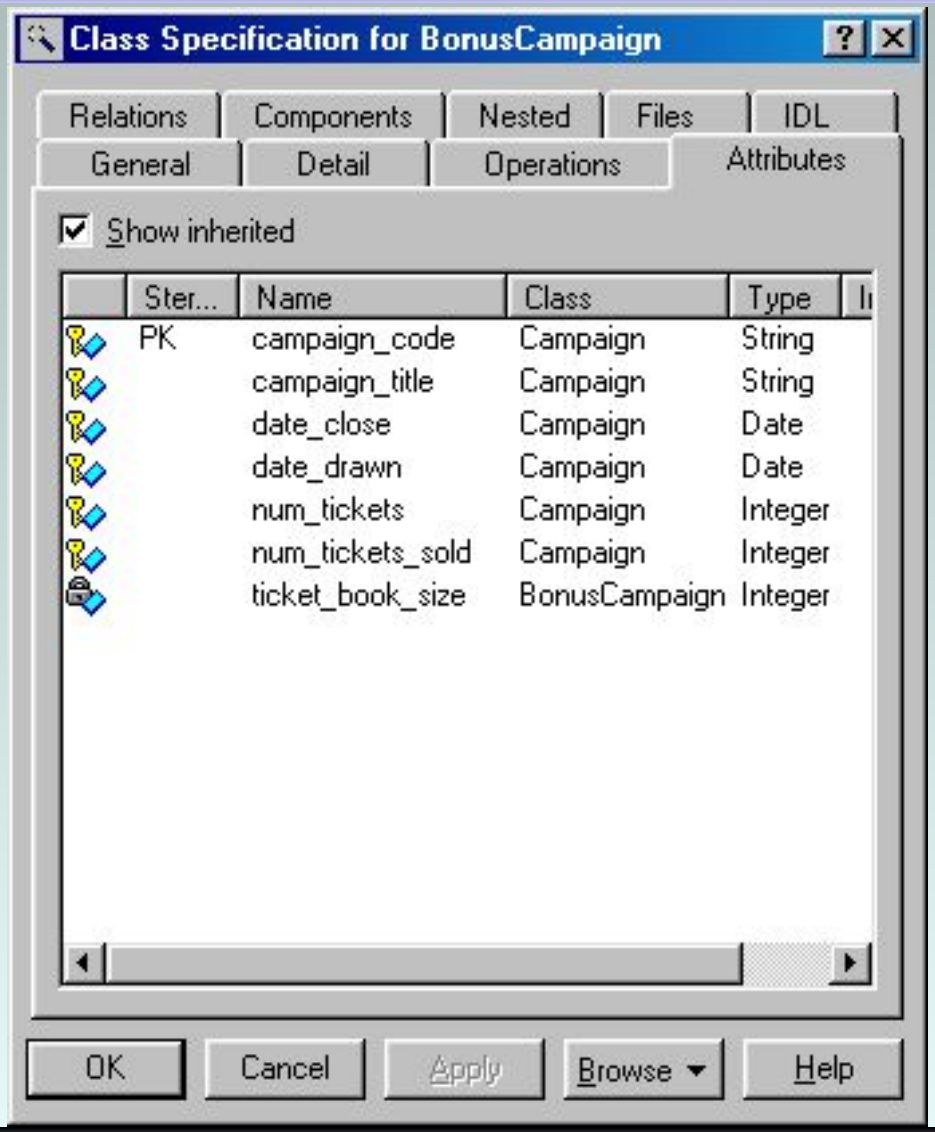
Visibility of inherited class properties

- *Visibility applies to **primitive** objects – attributes and operations*
- *Visibility can also be specified with regard to other "containers":*
  - *Visibility can be defined in the inheritance hierarchy at the level of the base class and at the level of properties of the base class*
  - *Let's say, a `class B` is a subclass of `class A`. The class A contains the mixture of attributes and operations – some public, others private, yet others protected*
  - *The question is: "What is the visibility of inherited properties in the `class B`?"*
  - *The answer depends on the **visibility level given to the base class** `A` when declaring it in the derived `class B`*

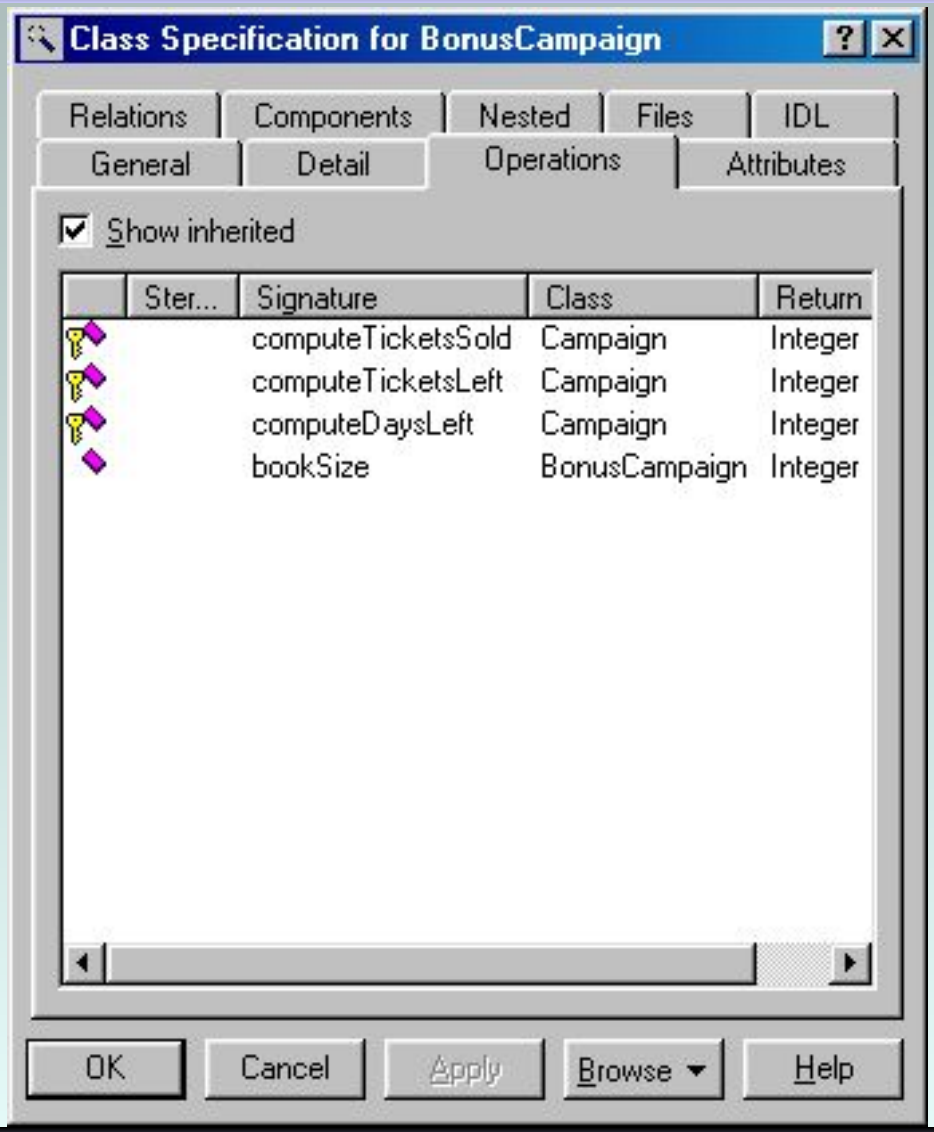
Visibility of inherited class properties

- The base class could have been defined **public** (`class B: public A`), or **protected** (`class B: protected A`), or **private** (`class B: private A`)
- Solutions:
  - The `private` properties (attributes and operations) of the base class `A` are not visible to the class `B` objects, no matter how the base class A is defined in B
  - If the base class `A` is defined as `public`, the visibility of inherited properties does not change in the derived class B (`public` are still public and `protected` are still protected)
  - If the base class `A` is defined as `protected`, the visibility of inherited `public` properties changes in the derived class B to `protected`
  - If the base class `A` is defined as `private`, the visibility of inherited `public` and `protected` properties changes in the derived class B to `private`

Visibility of inherited attributes



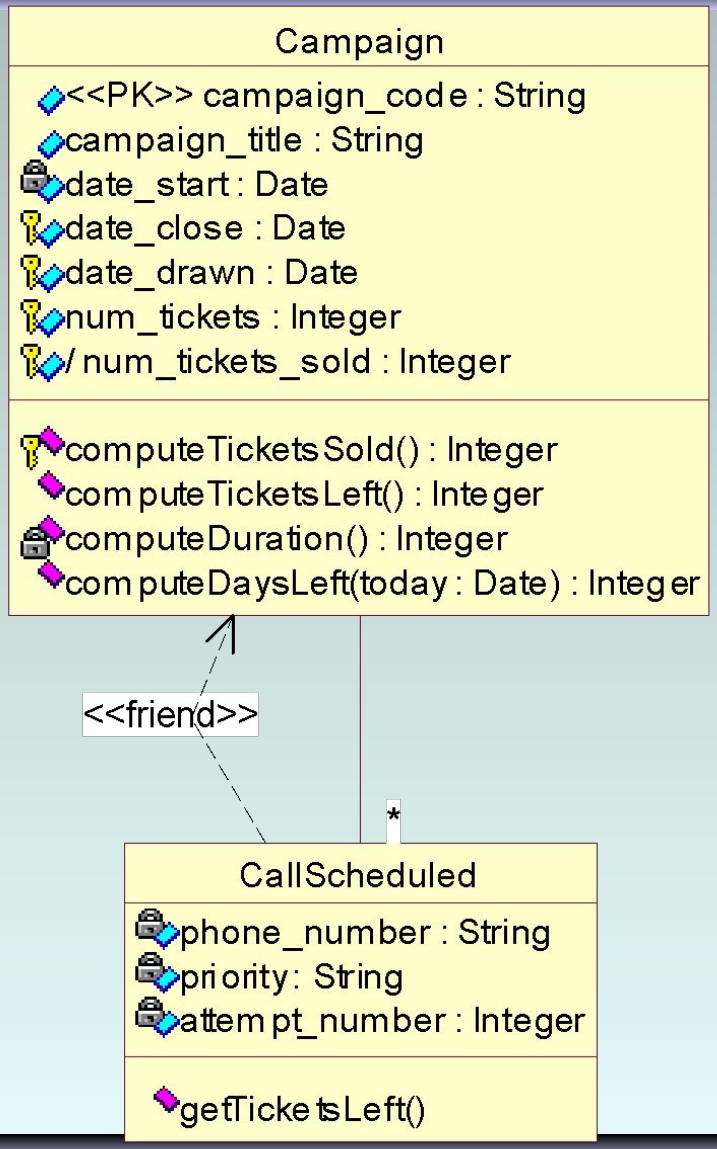
Visibility of inherited operations



Friend

- *Consider two classes* `Book` *and* `BookShelf` *and an operation in* `Book` *called* `putOnBookShelf`
- *We can declare (in the class* `BookShelf`*) the operation* `putOnBookShelf` *as a* ***friend****– something like:*
  `friend void Book::putOnBookShelf()`
- *A friend can be another class or an operation of another class*
- *Friendship is not reciprocal*
- *In UML, a friendship is shown as a dashed dependency relationship (stereotype* «`friend`»*) from a friend class or operation to the class that granted the friendship*

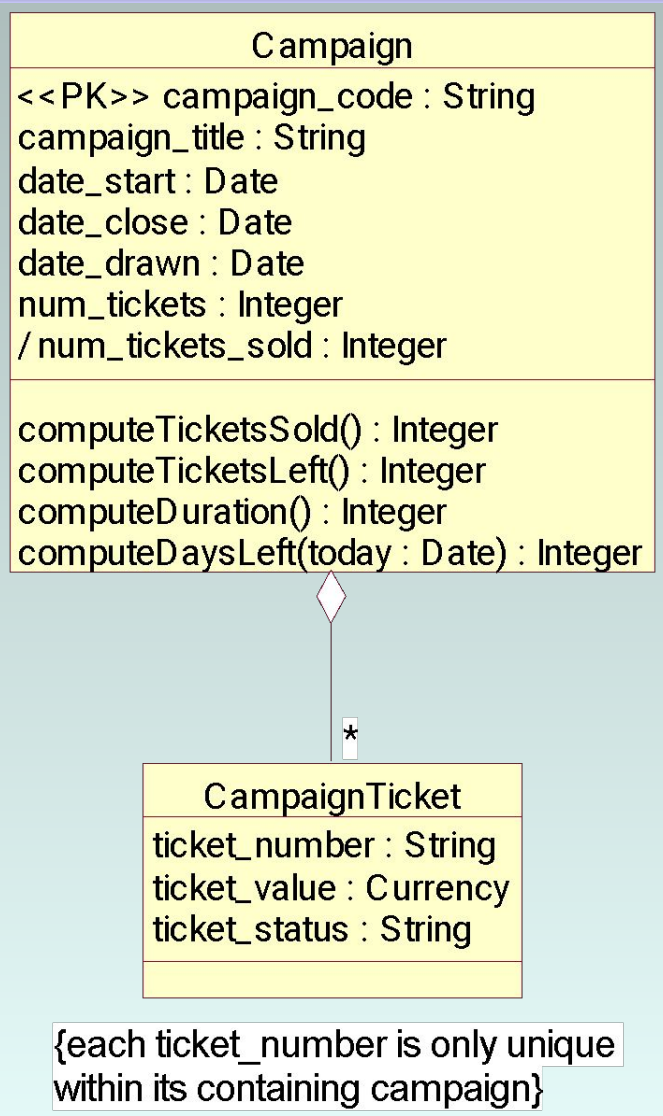
Friend


Campaign
<<PK>> campaign_code : String
campaign_title : String
date_start : Date
date_close : Date
date_drawn : Date
num_tickets : Integer
/ num_tickets_sold : Integer
computeTicketsSold() : Integer
computeTicketsLeft() : Integer
computeDuration() : Integer
computeDaysLeft(today : Date) : Integer
<<friend>>
*
CallScheduled
phone_number : String
priority: String
attempt_number : Integer
getTicketsLeft()

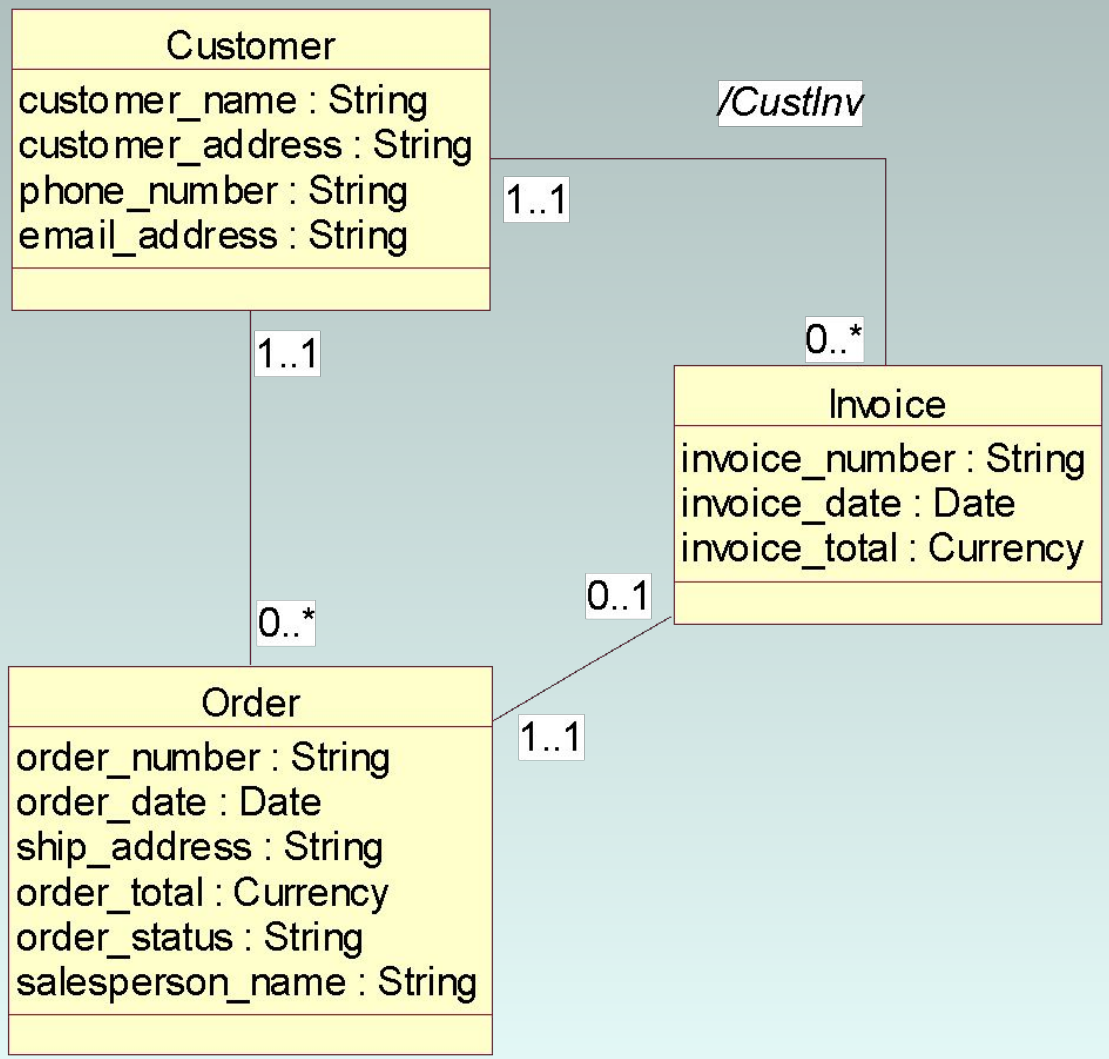
Derived information

- *A kind of constraint that applies (most frequently) to an attribute or an association*
- *Computed from other model elements*
- *More important in **design models***
  - *actual (stored)*
  - *virtual*
- *The UML notation for derived information is a slash (/) in front of the name of the derived attribute or association*

Derived attribute

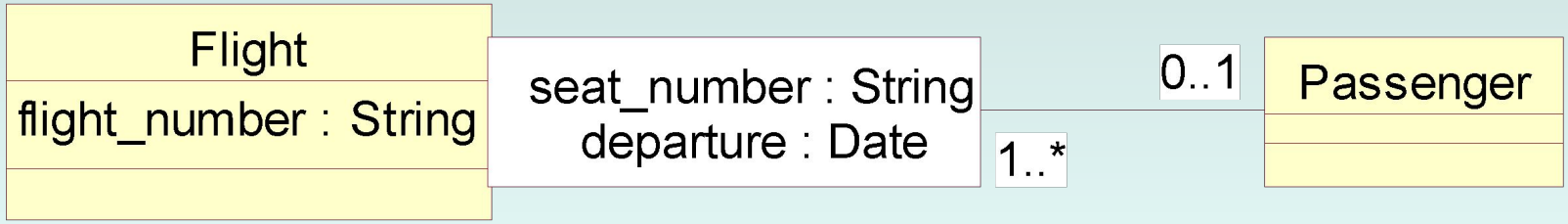


Derived association

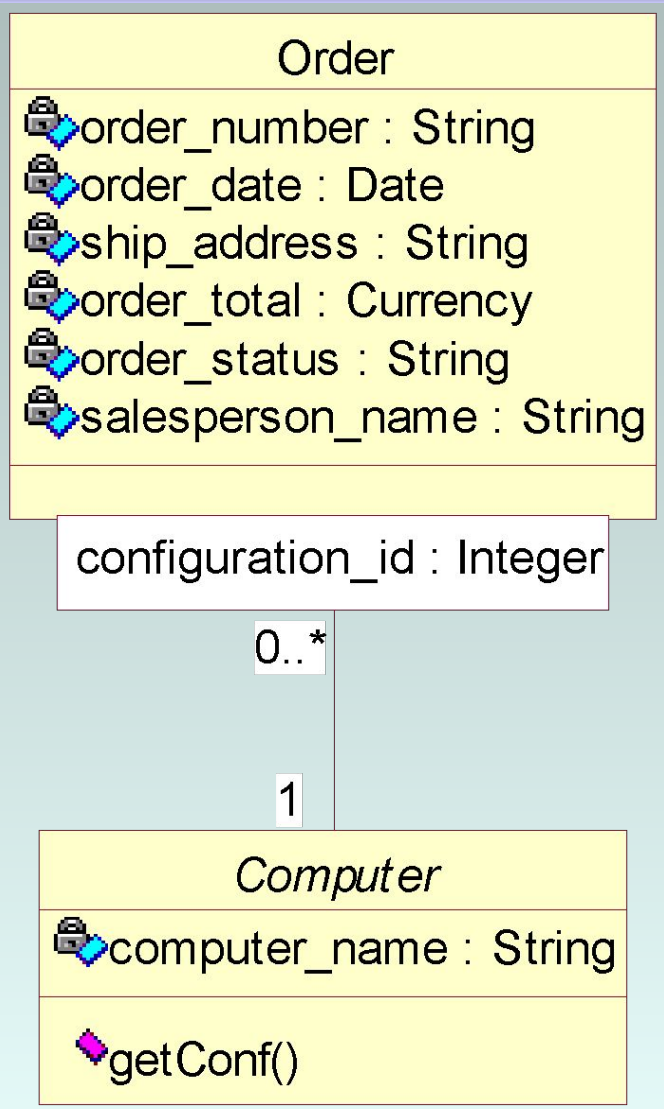


Qualified association

- *A qualified association has an attribute compartment (a **qualifier**) on one end of a binary association (an association can be qualified on both ends but this is rare)*
- *The compartment contains one or more attributes that can serve as an index key for traversing the association from the **qualified class** via qualifier to the **target class** on the opposite association end*



Qualified association



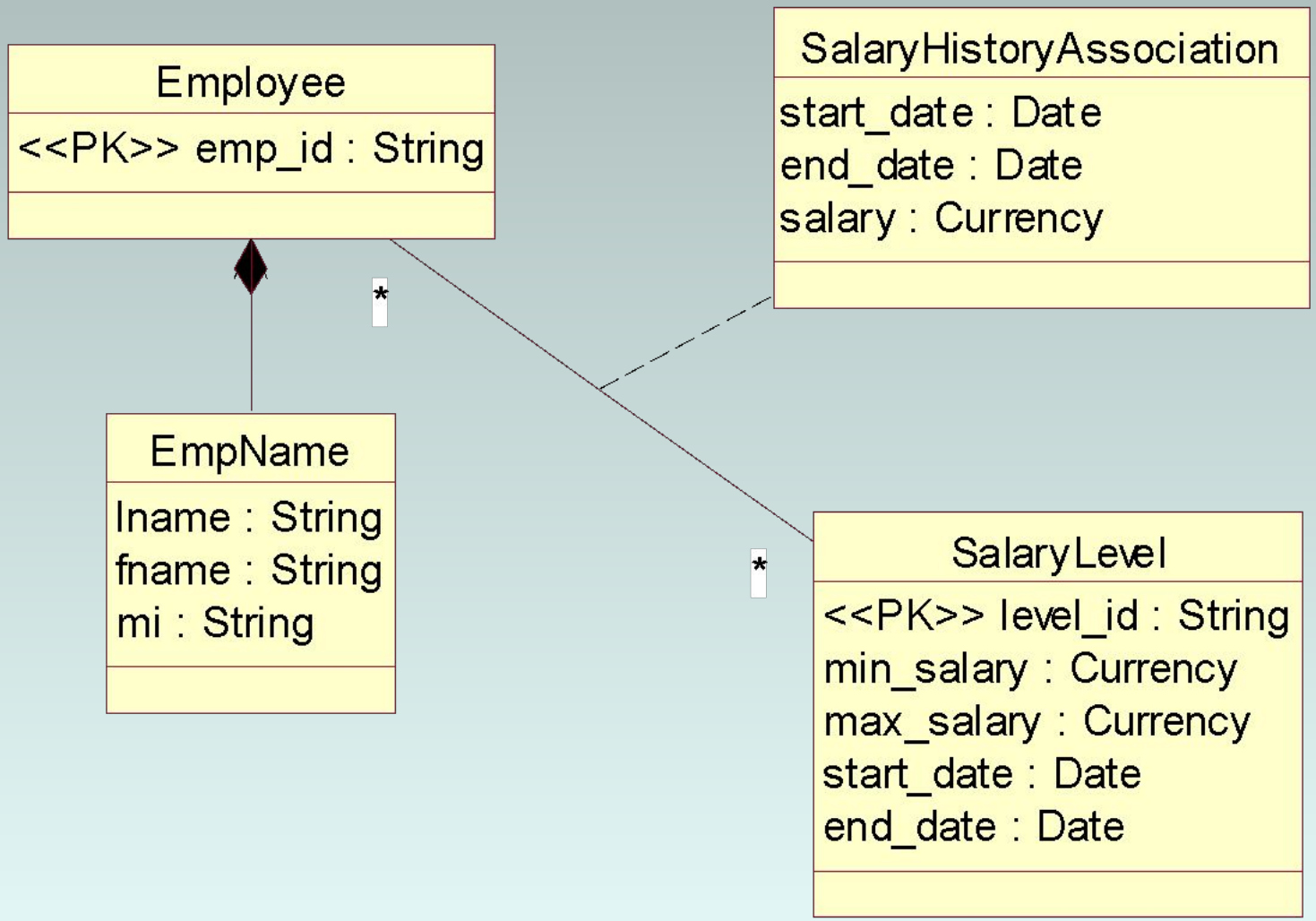
Association and reified class

- **Association class** – an association that is also a class
  - Typically used if there is a many-to-many association between two classes and each association instance (a link) has its own attribute values
  - Consider an association class C between the classes A and B - there can only be one instance of C for each pair of linked instances of A and B
  - If such a constraint is not acceptable then the modeller has to reify the association by replacing the class C with an ordinary class D
- **Reified class** D would have two binary associations to A and B
  - D is independent of classes A and B
  - Each instance of D has its own identity so that multiple instances of it can be created

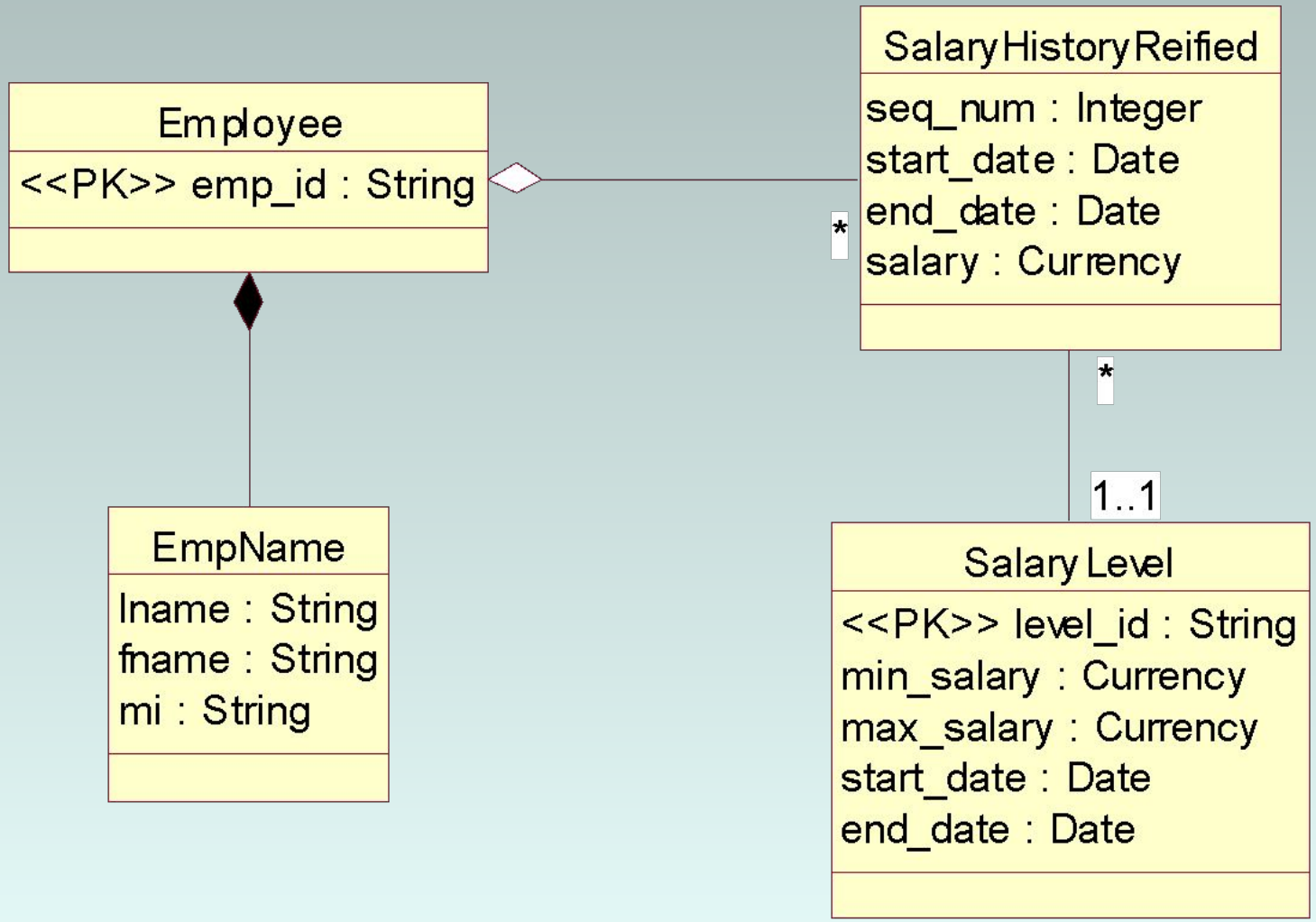
Example 9.2 - Employee Database

- *Each employee in an organization is assigned a unique emp_id. The name of the employee is maintained and consists of the last name, first name and middle initial*
- *Each employee is employed at a certain salary level. There is a salary range for each level, i.e. the minimum and maximum salary. The salary ranges for a level never change. If there is a need to change the minimum or maximum salary, a new salary level is created. The start and end dates, for each salary level, are also kept.*
- *Previous salaries of each employee are kept, including the start date and finish date at each level. Any changes of the employee's salary within the same level are also recorded*

Inadequate use of association class



Model with reified class

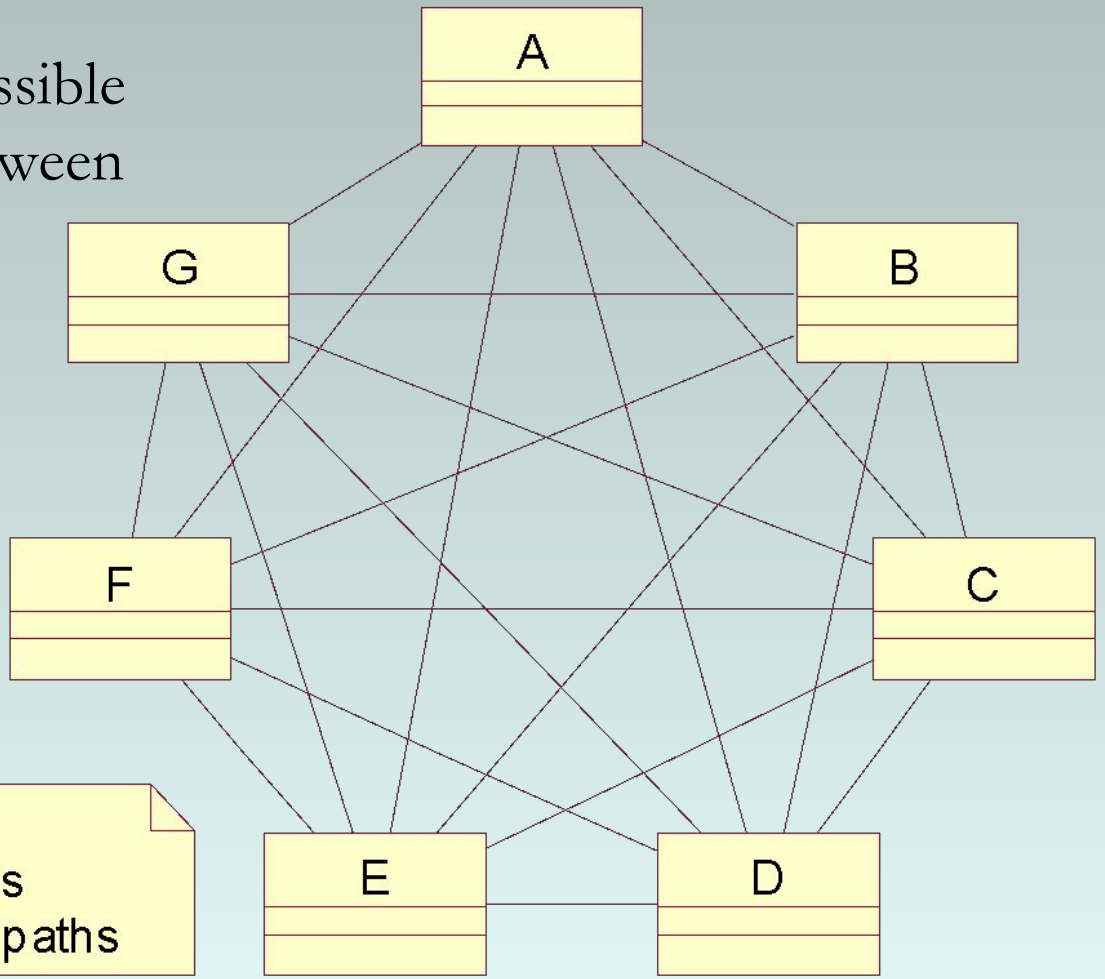


Class layers

- *Large object solution is a complex network of intercommunicating objects*
- *Clear architectural design needed to handle complexity*
- *In **networks**, the number of communication paths between objects grows exponentially with addition of new objects*
- ***Hierarchies** reduce the complexity from exponential to polynomial*
  - *introduce layers of objects and constrain intercommunication between layers*
  - *only objects in adjacent layers communicate directly*

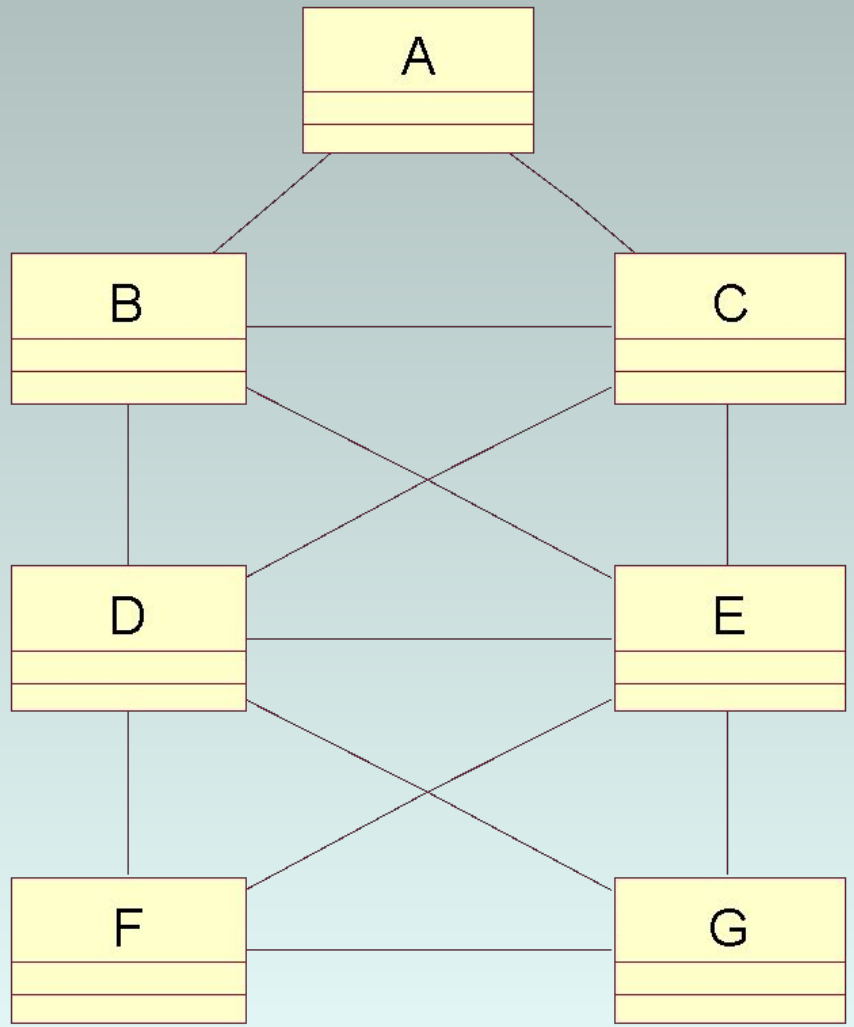
Complexity of networks

There are
`n(n-1)/2` possible
connections between
n classes



no layers
21 connections
42 interaction paths

Complexity of hierarchies

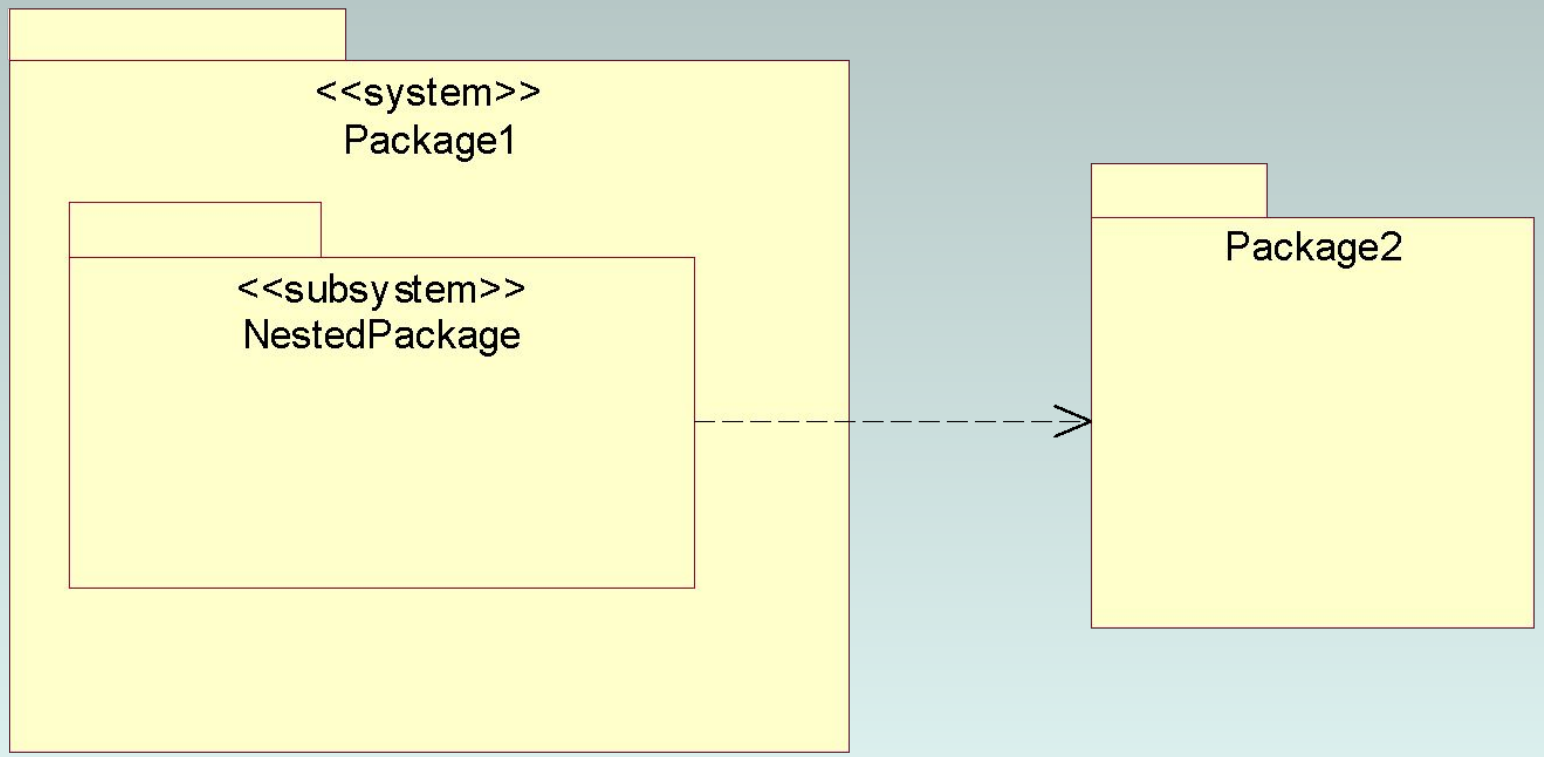


4 layers
13 connections
26 interaction paths

Package

- *Represent a group of classes (or other modeling elements, e.g. use cases)*
- *Packages can be **nested***
  - *An outer package has access to any classes directly contained in its nested packages*
- *A class can only be owned by one package*
  - *This does not inhibit the class from appearing in other packages or from communicating with classes in other packages*
  - *By declaring a class within a package to be private, protected, or public, we can control the communication and dependencies between classes in different packages*

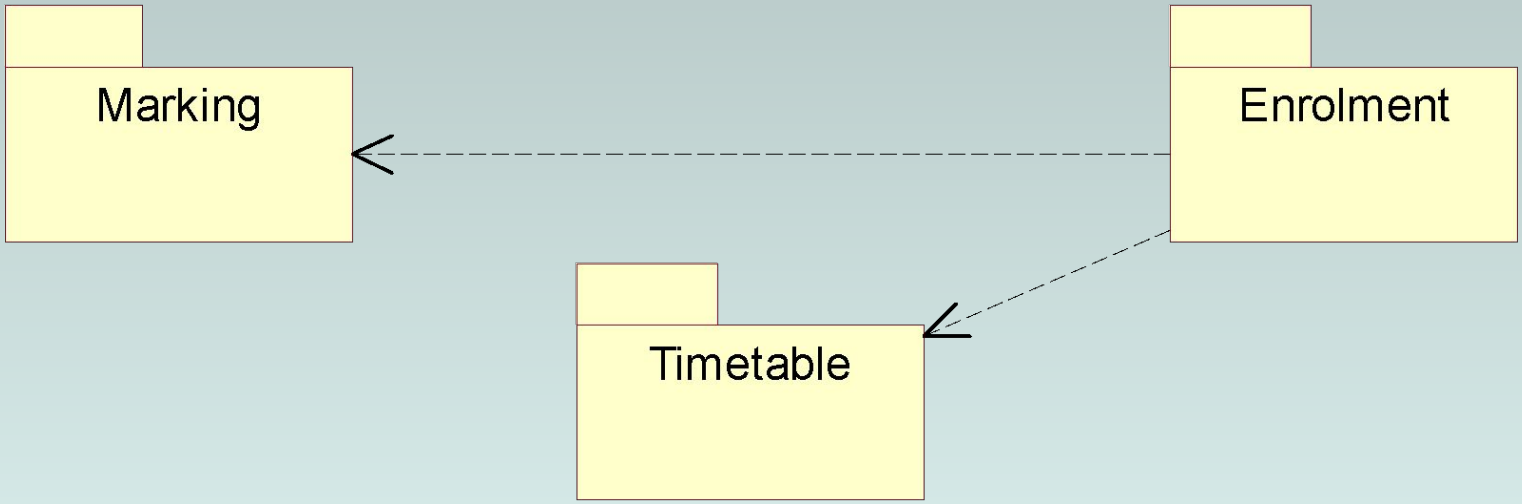
Packages and dependencies



Package diagram

- *Packages can be related with two kinds of relationships:*
  - ***Generalization***
  - ***Dependency***
- *The concept of a Package Diagram as such does not exist in UML*
  - *Packages are created in*
    - *Class Diagram or*
    - *Use Case Diagram*

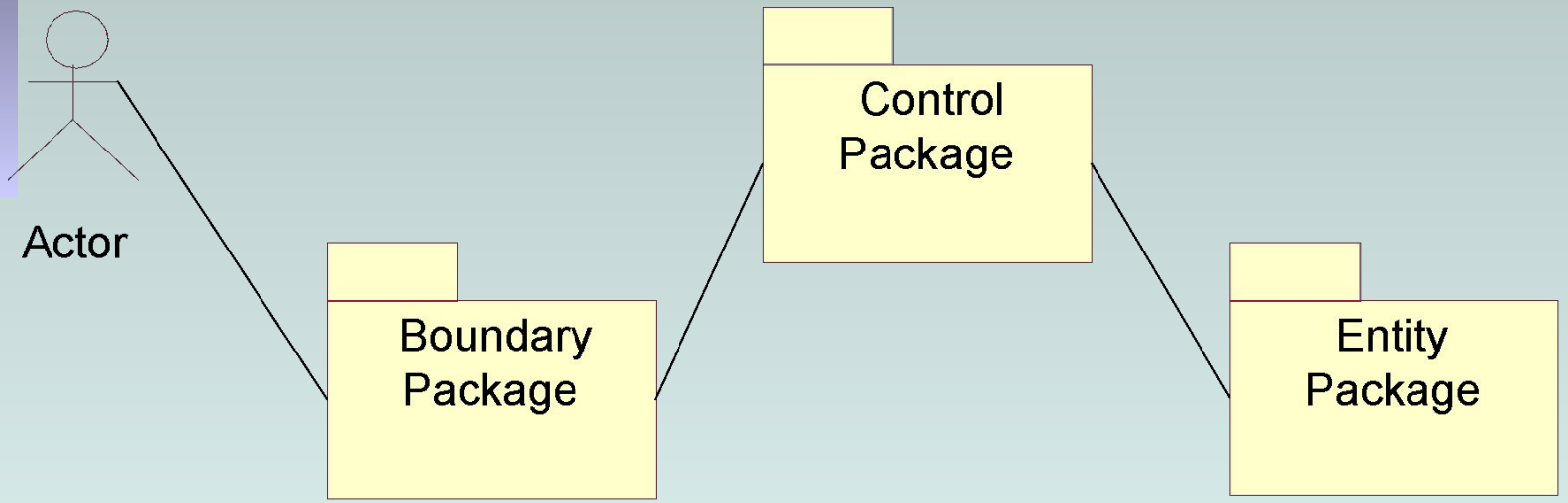
Packages



BCE approach

- *Boundary-Control-Entity (**BCE**) ≈ Model-View-Controller (**MVC**)*
- ***Boundary class***
  - *Describes objects that represent the interface between an actor and the system*
  - *Visual display or sound effect*
  - *Often persist beyond a single execution of the program*
- ***Control class***
  - *Describes objects that intercept user input events and control the execution of a business process*
  - *Represents actions and activities of a use case*
  - *Frequently do not persist beyond the program's execution*
- ***Entity class***
  - *Describes objects that represent the semantics of entities in an application*
  - *Corresponds to a data structure in the system's database*
  - *Always persist beyond the program's execution*

BCE package hierarchy



Advanced generalization

- ***Generalization***
  - *Useful and powerful concept but many problems due to intricacies of **inheritance***
  - *States that the interface of the subclass must include all (public and protected) properties of the superclass*
- ***Inheritance** is "the mechanism by which more specific elements incorporate structure and behavior defined by more general elements"*
- *Benefits of generalization arise from the **substitutability** principle*
  - *Subclass object can be used in place of a superclass object in any part of the code where the superclass object is accessed*
- *However, and unfortunately, the inheritance mechanism may be used in a way that defeats the benefits of the substitutability principle*

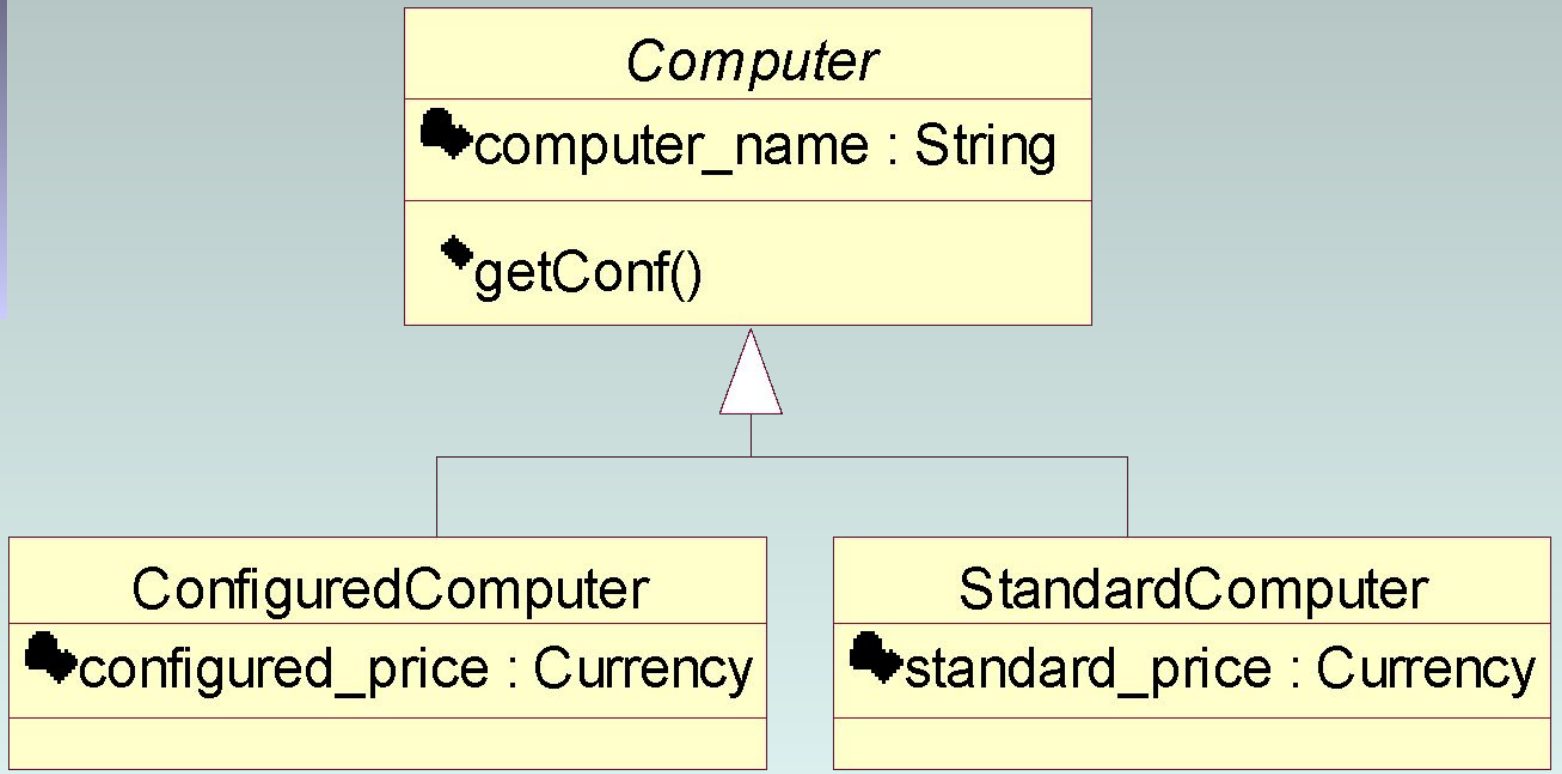
Inheritance vs. encapsulation

- ***Encapsulation***
  - *Demands that object's attributes are only accessible through the operations in the object's interface*
  - *Is orthogonal to inheritance and query capabilities*
- ***Inheritance** compromises encapsulation by allowing subclasses to directly access protected attributes*
  - *Also friends, static properties*
- *Users of **ad-hoc query language** want to directly refer to attributes in the queries*
  - *OnLine Analytical Processing (OLAP) queries*

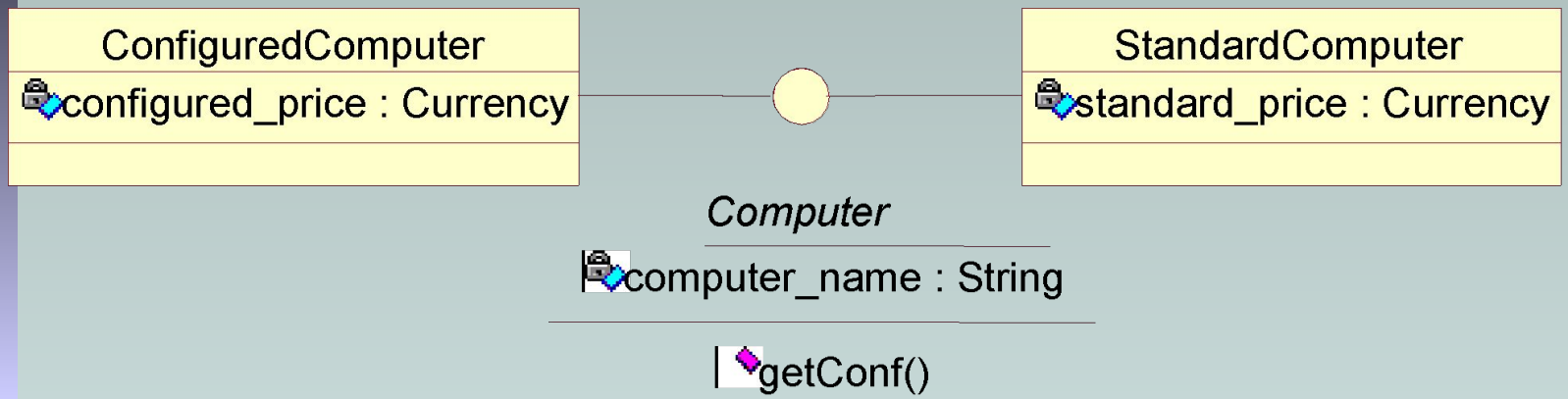
Interface inheritance

- *When generalization is used with the aim of substitutability then it means **interface inheritance** (**subtyping, type inheritance**)*
  - *A subclass inherits attribute types and operation signatures (operation names plus formal arguments)*
  - *A subclass is said to support a superclass interface*
  - *The implementation of inherited operations is deferred until later*
  - *The **interfaces** are normally declared through an **abstract class***
    - *We can say that an interface is an abstract class*

Interface inheritance



Realization relationship

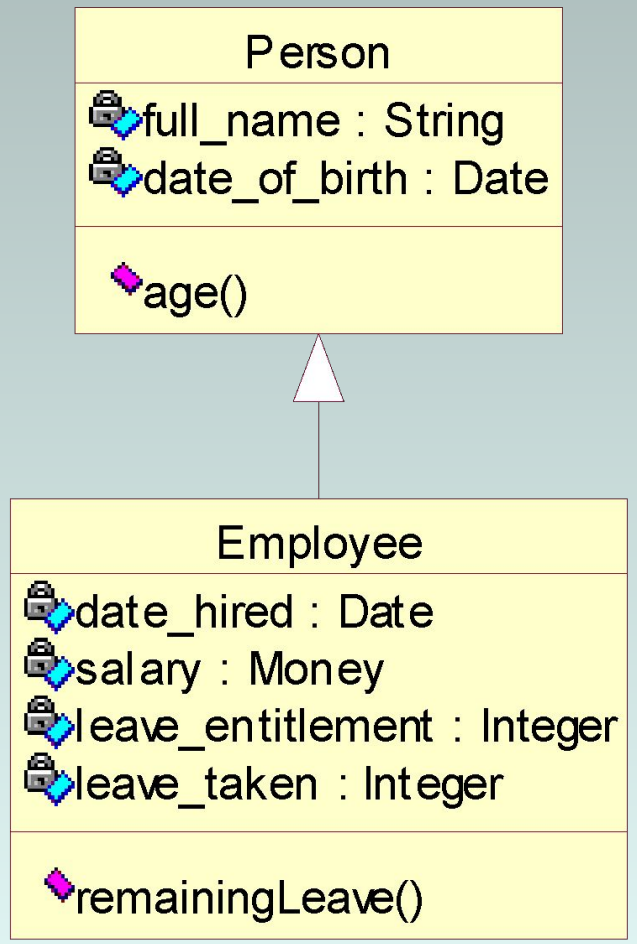


An alternative way of representing the interface inheritance - with a "lollypop" symbol to indicate the supported interface.
The "lollypop" relationship from a subclass (concrete class) to an abstract class is formally called the ***realization relationship.***

Implementation inheritance

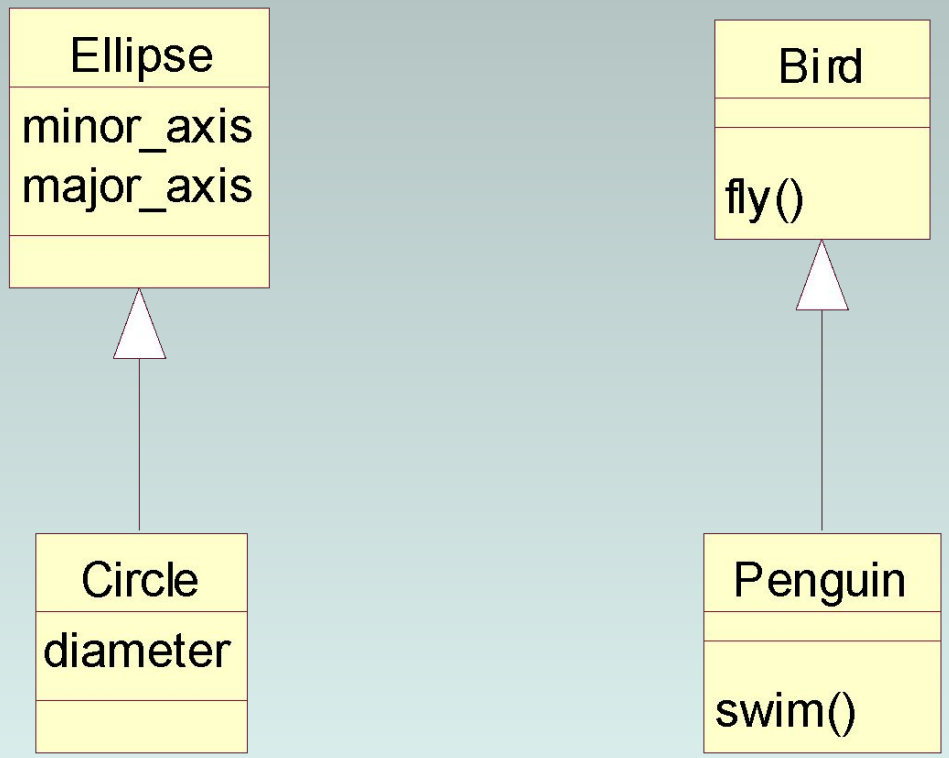
- *Generalization can be used (deliberately or not) to imply the code reuse and it is then realized by an **implementation inheritance (subclassing, code inheritance** or **class inheritance)***
  - *A very powerful, sometimes dangerously powerful, interpretation of generalization*
  - *It is also the "default" interpretation of generalization*
  - *Combines the superclass properties in the subclasses and allows **overriding** them with new implementations, when necessary*
  - *Allows sharing of property descriptions, code reuse, and polymorphism*

Extension inheritance



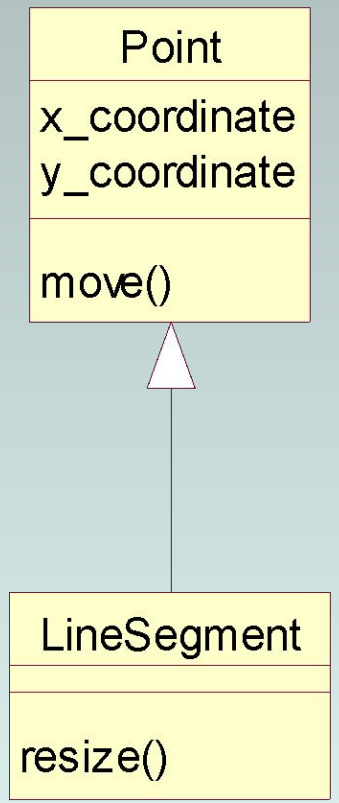
- *Inheritance as an **incremental definition** of a class*
- *A subclass **is-kind-of** superclass*
- *This is a **proper use** of inheritance*
- *The **overriding** of properties should be used with care. It should only be allowed to make properties **more specific** (e.g. to constrain values or to make implementations of operations more efficient), not to change the meaning of a property.*

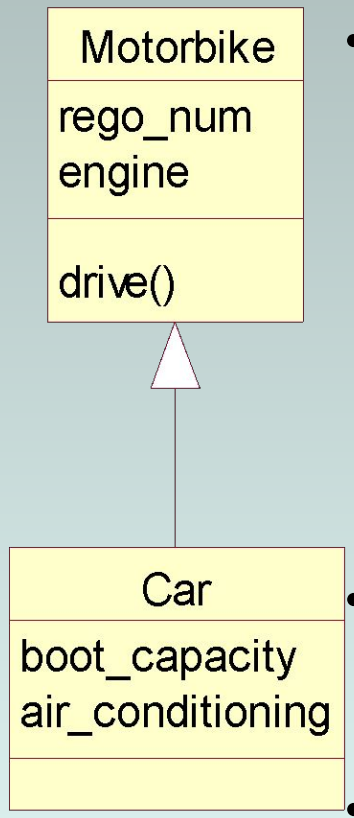
Restriction inheritance



- *Inheritance as a **restriction** mechanism whereby some inherited properties are suppressed (overridden) in the subclass*
- *This is a **problematic use** of inheritance*
- *A superclass object can still be substituted by a subclass object provided that whoever is using the object is aware of the overridden (suppressed) properties*

Convenience inheritance





- *When two or more classes have similar implementations, but there is **no taxonomic relationship** between the concepts represented by the classes*
- *One class is selected arbitrarily as an ancestor of the others*
- *This is an **improper use** of inheritance*

Evils of implementation inheritance

- *Fragile base class problem*
- *Overriding and callbacks*
- *Multiple implementation inheritance*

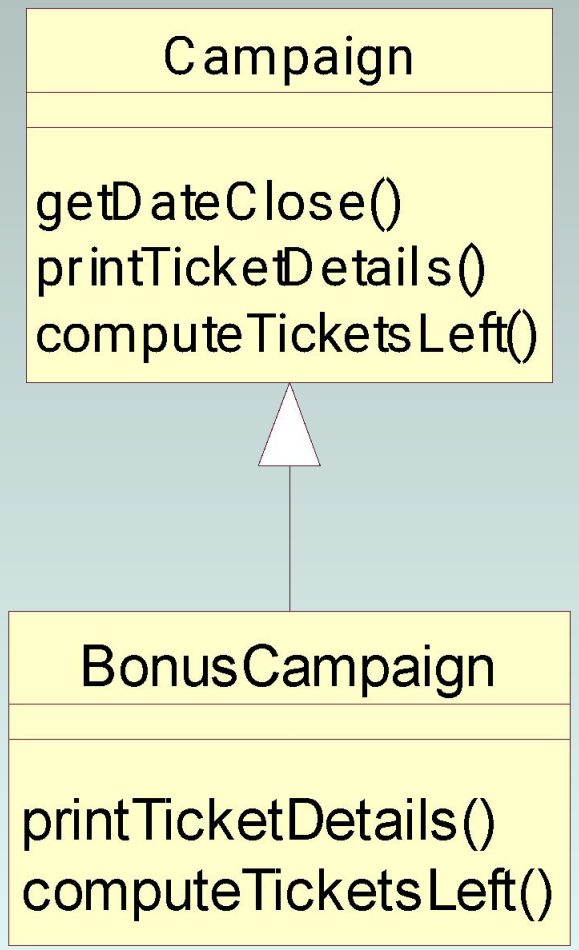
Fragile base class problem

- *How to make the sublasses valid and operational while allowing the **evolution** of the implementation of their superclass (or superclasses, if the multiple inheritance applies)?*
- ***Difficult to harness** short of declaring the public interfaces immutable or, at least, short of avoiding the implementation inheritance from the superclasses outside our control*
- *"Madness is inherited, you get it from your children"*

Overriding and callbacks

- *Subclass can inherit the*
  - *Method interface and implementation and introduce no changes to the implementation*
  - *Code and include it (call it) in its own method with the same signature*
  - *Code and then completely override it with a new implementation with the same signature*
  - *Code that is empty (i.e. the method declaration is empty) and then provide the implementation for the method*
  - *Method interface only (i.e. the interface inheritance) and then provide the implementation for the method*

Inheritance and overriding



BonusCampaign.printTicketDetails() calls the inherited Campaign.printTicketDetails() to print, say, the total number of tickets in the campaign. It then prints specific information about bonus tickets, such as the number of ticket books and book sizes.

computeTicketsLeft()inherits (because it has to) from Campaign. computeTicketsLeft()and it then completely overrides the inherited code.

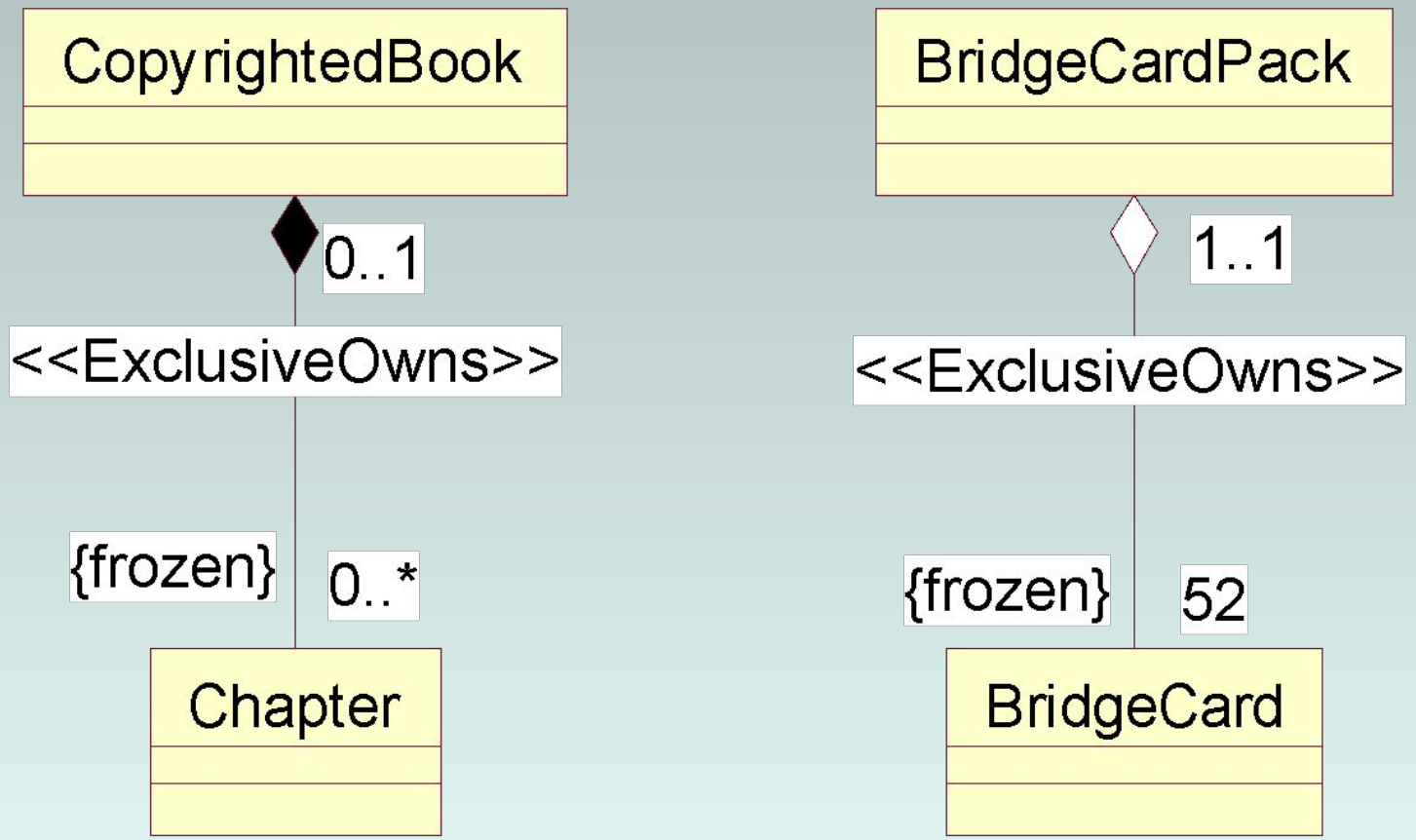
Multiple implementation inheritance

- ***Multiple interface inheritance*** *allows for merging of interface contracts*
- ***Multiple implementation inheritance*** *permits merging of implementation fragments*
- ***Complexity*** *growth due to excessive multiple inheritance related to the lack of support in object systems for multiple classification*

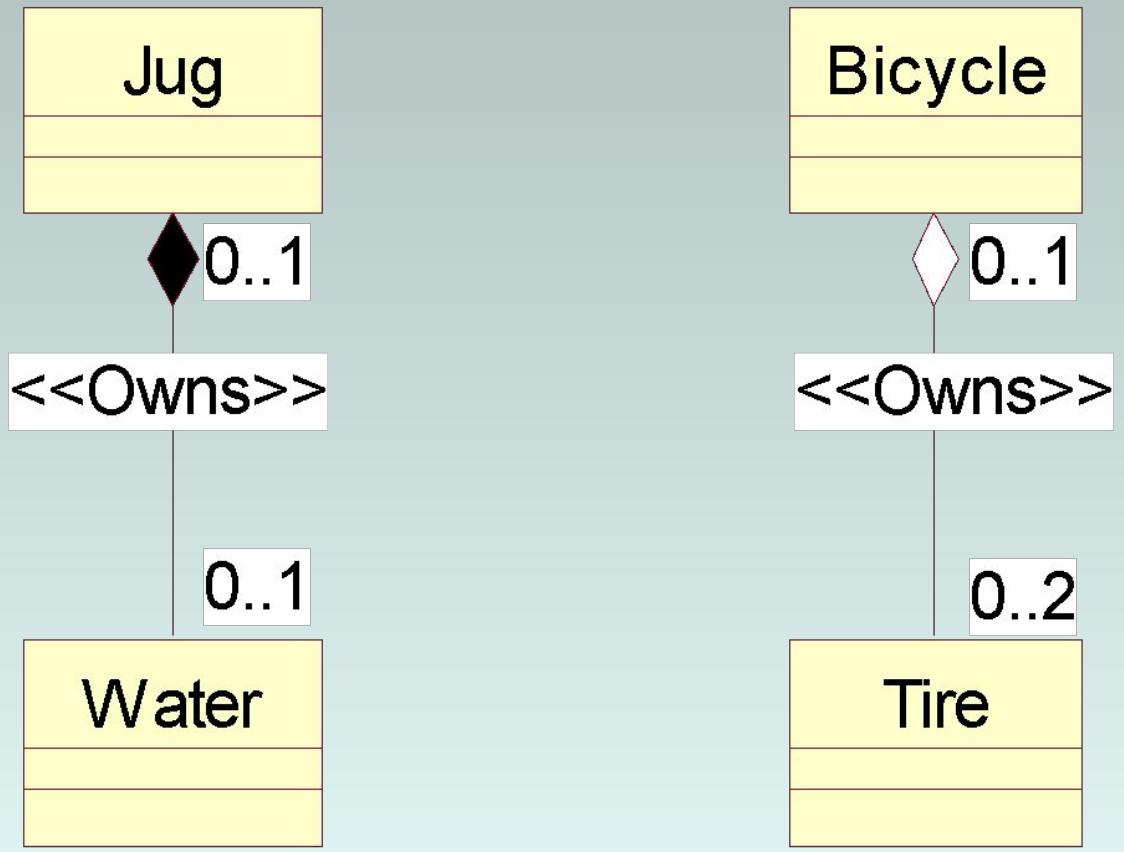
Putting more semantics in aggregation

- *"ExclusiveOwns" aggregation*
- *"Owns" aggregation*
- *"Has" aggregation*
- *"Member" aggregation*

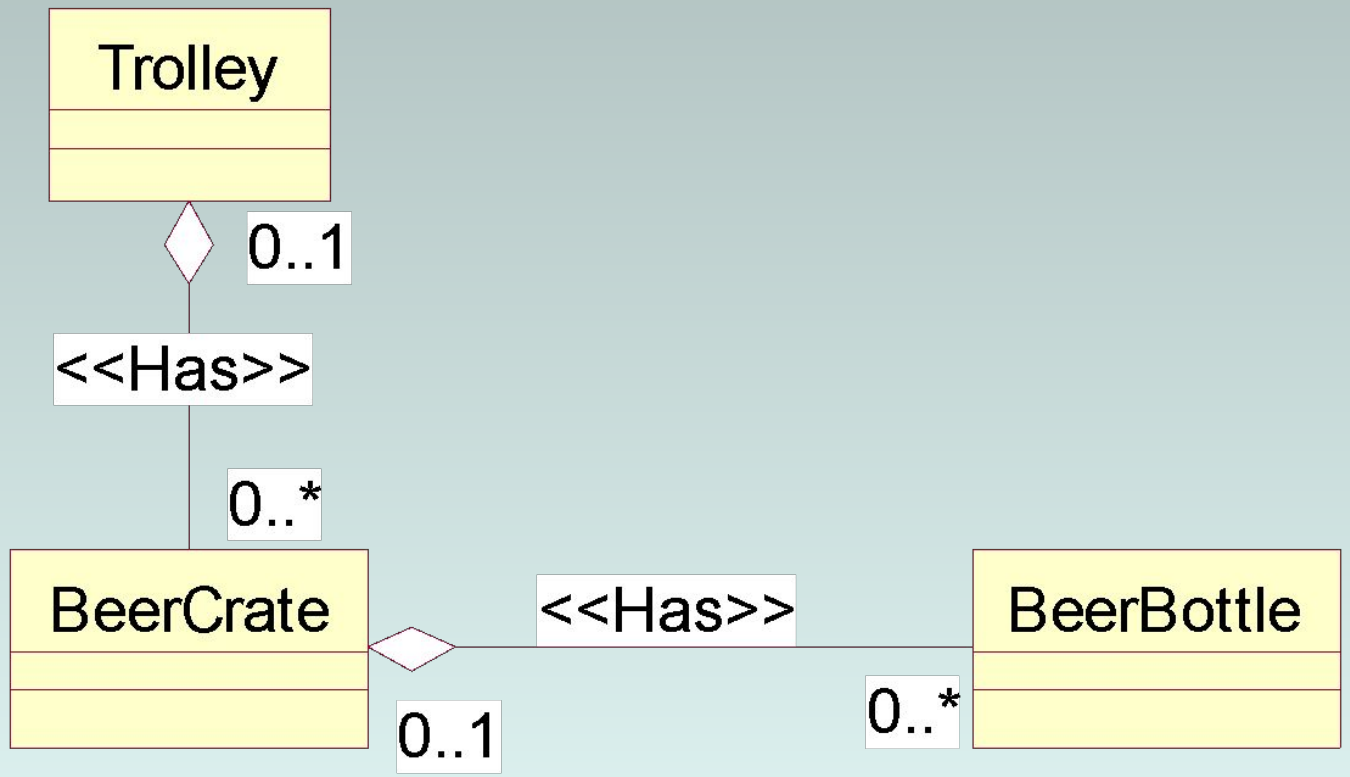
ExclusiveOwns aggregation



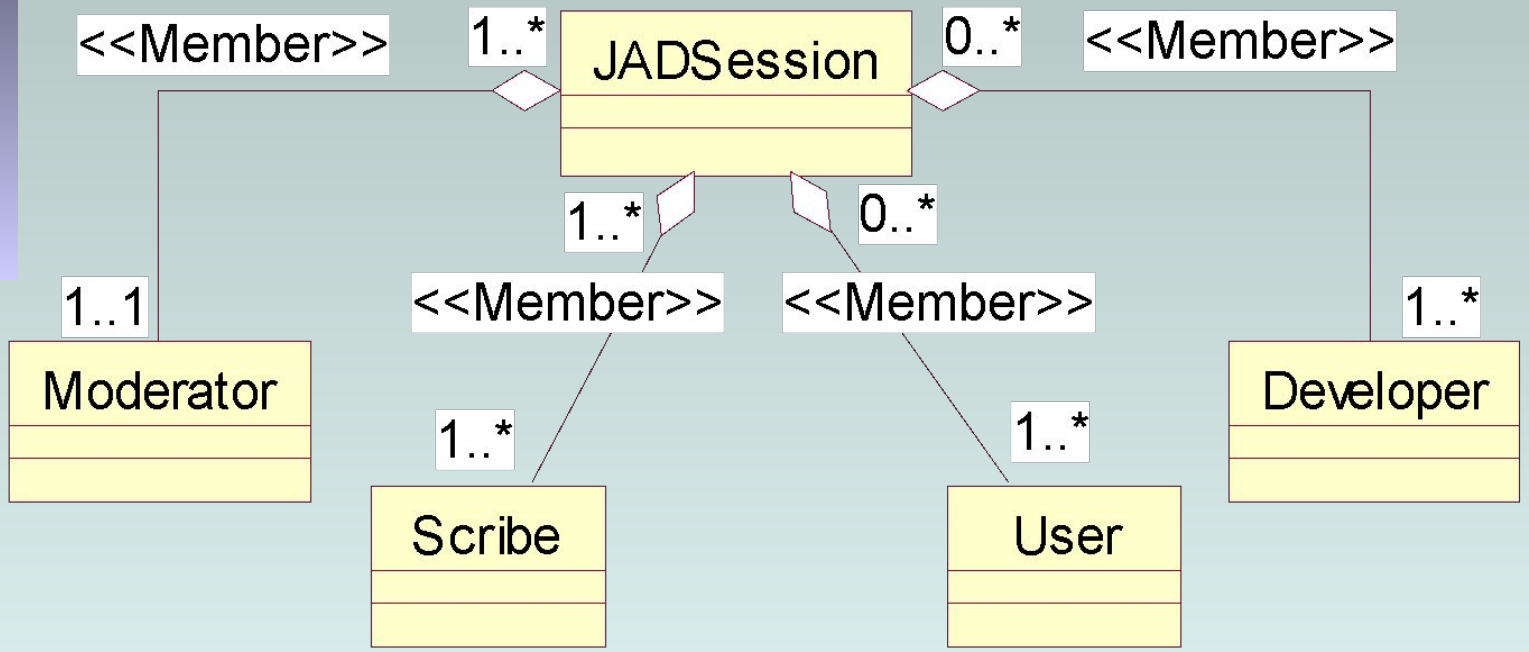
Owns aggregation



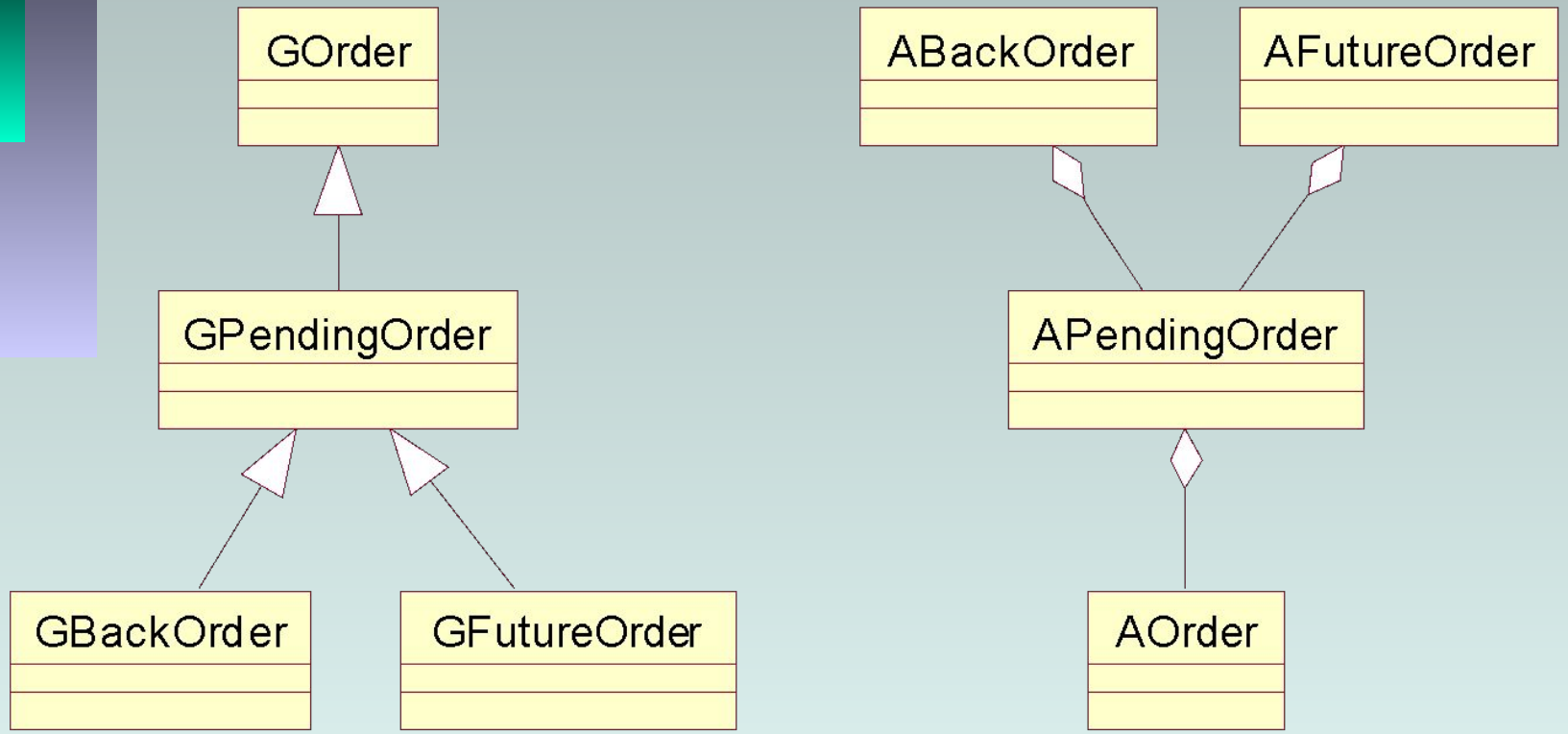
Has aggregation



Member aggregation



Generalization versus aggregation



*The generalization uses **inheritance** to implement its semantics. The aggregation uses **delegation** to reuse the implementation of the component objects.*

Delegation and prototypical systems

- *The computational model of inheritance is based on **the notion of a class***
- *However, it is possible to base the computational model on **the notion of an object***
  - ***Delegation***
    - *Whenever a composite object (**outer object**) cannot complete a task by itself it can call on the methods in one of its component objects (**inner objects**)*
    - *The functionality of the system is implemented by including (cloning) the functionality of existing objects*
    - *An (outer) object may have a **delegation relationship** to any other (inner) identifiable and visible object in the system*
    - *The inner object's interfaces may or may not be **visible** to objects other than the outer object*
    - *The four kinds of **aggregation** can be used for controlling the level of visibility of inner objects*

Delegation vs. inheritance

- *Delegation can model the inheritance and vice versa (Treaty of Orlando)*
- *From the **reuse** point of view, the delegation comes very close to inheritance*
  - *In the **inheritance** case, the object that receives the original message (request for service) is always returned the control after the service is accomplished **fragile base class** problem is a side-effect*
  - *In the **delegation** case, once the control has been passed from an outer to an inner object, it stays there any self-recursion has to be explicitly planned and designed into the delegation*
  - *In the **delegation** case, the sharing and reuse can be determined dynamically at run time - **unanticipatory sharing***

Summary

- ***Stereotypes*** *are the main extensibility technique of UML; not to be confused with UML constraints, notes and tags*
- *Visibility (including class-level visibility) allows to control the level of encapsulation*
- *UML offers a number of additional modeling concepts - derived attributes, derived associations, qualified associations, the choice between association class and reified class*
- ***Hierarchical layering*** *of system architectures to handle software complexity (BCE approach)*
- *The concept of* ***generalization and inheritance*** *is a double-edged sword in system modeling*
- *The concept of* ***aggregation and delegation*** *is an important modeling alternative to the generalization and inheritance*