University of Applied Sciences Northwestern Switzerland
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UML – Unified Modelling Language

Sources:

OMG Unified Modelling Language - UML, Current Standard Version 2.1.2
http://www.omg.org/spec/UML/2.1.2/

R. Miller: Practical UML: A Hands-On Introduction for Developers.
http://dn.codegear.com/article/31863

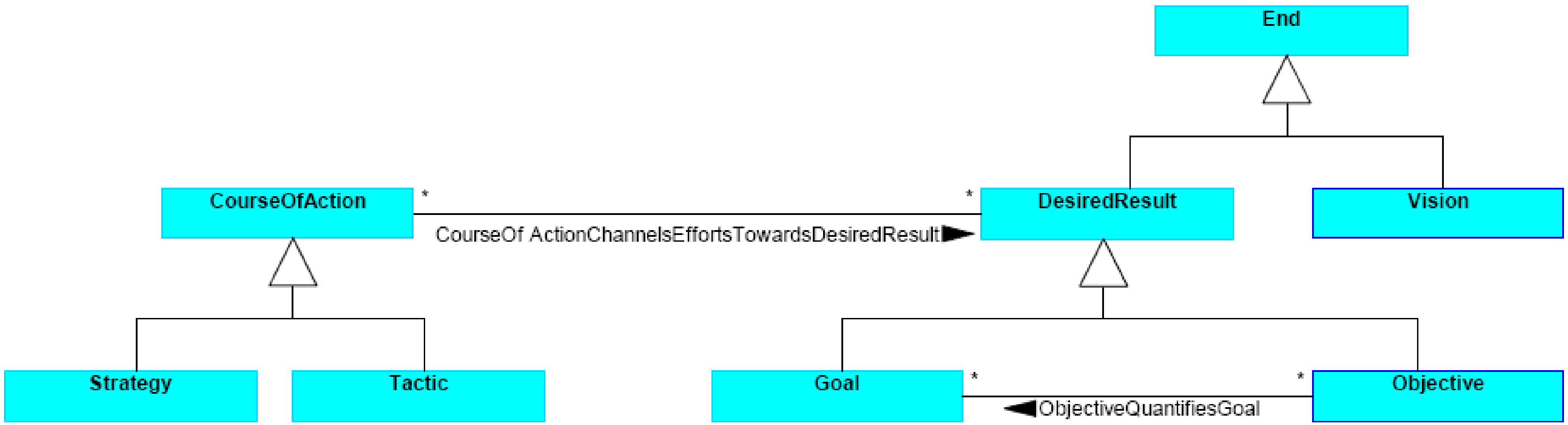
The Significance of UML

- UML helps you specify, visualize, and document models of software systems, including their structure and design
- In UML, you can model
  - any type of application,
  - running on any type and combination of hardware, operating system, programming language, and network
- UML forms a foundation of OMG's Model Driven Architecture (MDA)
  - a UML model can be either platform-independent or platform-specific,
- Standardized by the OMG: Definition driven by consensus rather than innovation
- Using XMI (XML Metadata Interchange, another OMG standard), you can transfer your UML model
  - from one tool into a repository, or
  - into another tool for refinement or the next step in your chosen development process.

Source: Introduction to OMG's Unified Modeling Language™ (UML®), http://www.omg.org/gettingstarted/what_is_uml.htm

Class Diagramm

- We already used UML class diagrams informally to describe BMM and SBVR
- Example: Class Diagramm



Types of UML Diagrams

Structure diagrams

1. Class diagram
2. Composite structure diagram (*)
3. Component diagram
4. Deployment diagram
5. Object diagram
6. Package diagram

Behavior diagrams

7. Use-case diagram
8. State machine diagram
9. Activity diagram

   Interaction diagrams

   10. Sequence diagram
   11. Communication diagram
   12. Interaction overview diagram (*)
   13. Timing diagram (*)

(*) not existing in UML 1.x, added in UML 2.0

Overview of this Section

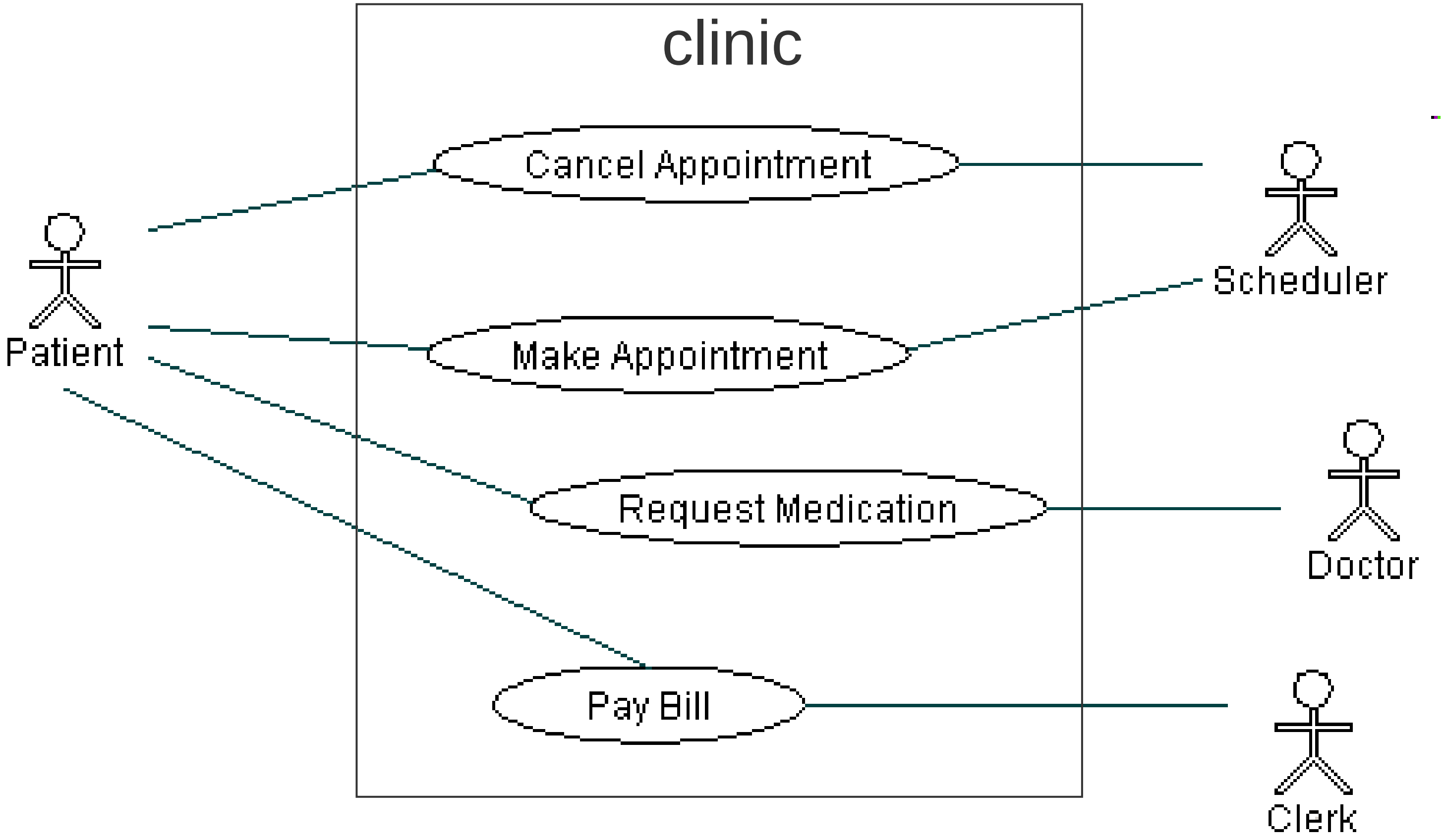
- A closer look at …
  - Use case diagram
  - Class diagram
- A short look at …
  - Object diagram
  - Deployment diagram
  - State machine diagram
  - Activity diagram

  and the
  - OCL Object Constraint Language

Use Case Diagrams

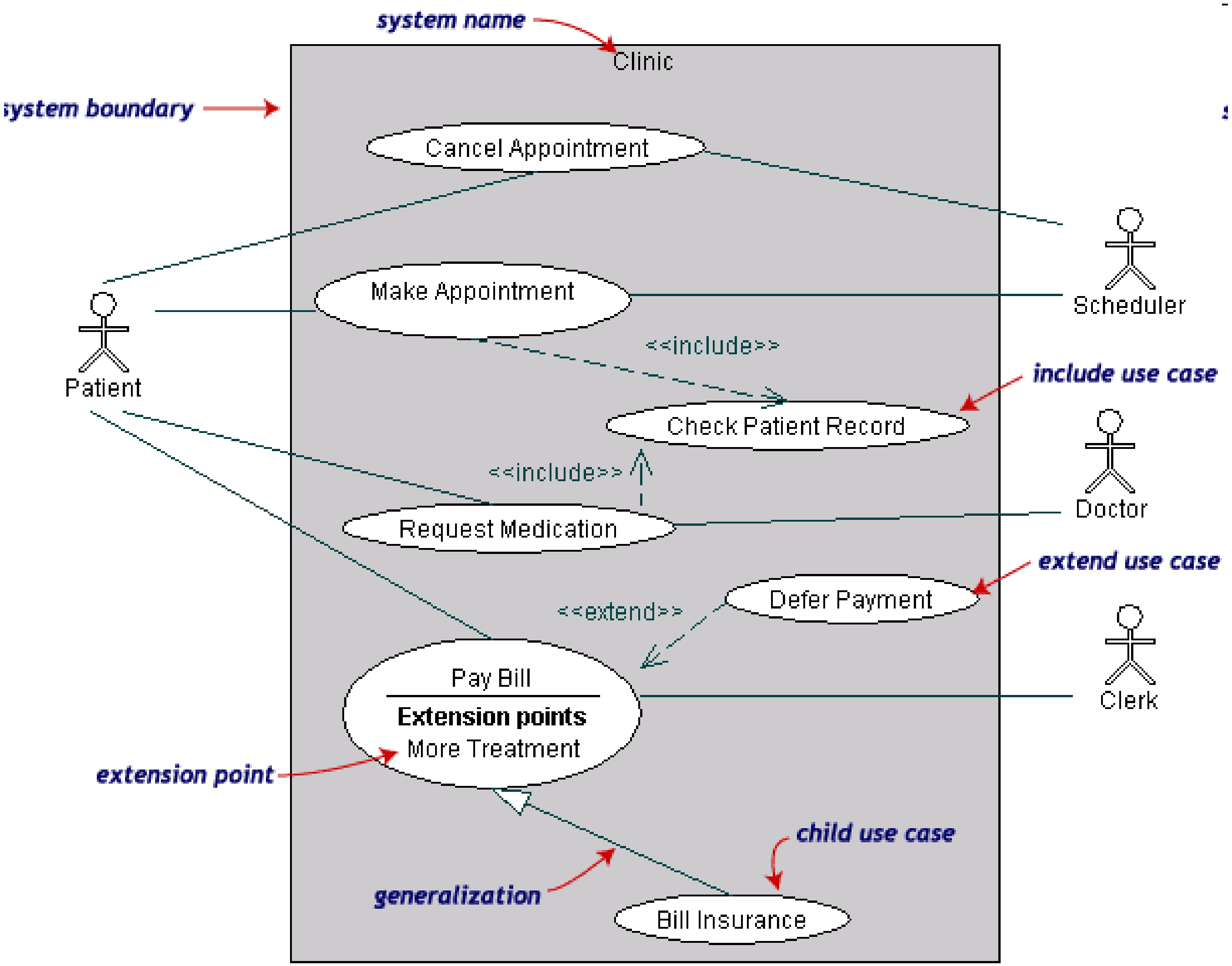
- **Use case diagrams** describe what a system does from the standpoint of an external observer. The emphasis is on *what* a system does rather than *how.*
- Main concepts:
  - System: the system under modeling
  - Actor: external "user" of the system: who or what initiates the events involved in that task. Actors are simply roles that people or objects play.
  - Use case: execution scenario, observable by an actor:
  - Communication: The connection between actor and use case is a communication association (or communication for short).
- Use Case diagrams are widely used in real-life projects, e.g. for
  - Exposing requirements
  - Communicate with clients
  - Planning the project
- Additional textual notes are often used/required

Use Case Diagram Example



A **system boundary** rectangle separates the clinic system from the external actors.

Use Case Diagram extended



Use Case Example - Explanations

- A use case **generalization** shows that one use case is simply a special kind of another.
  - **Pay Bill** is a parent use case and **Bill Insurance** is the child.

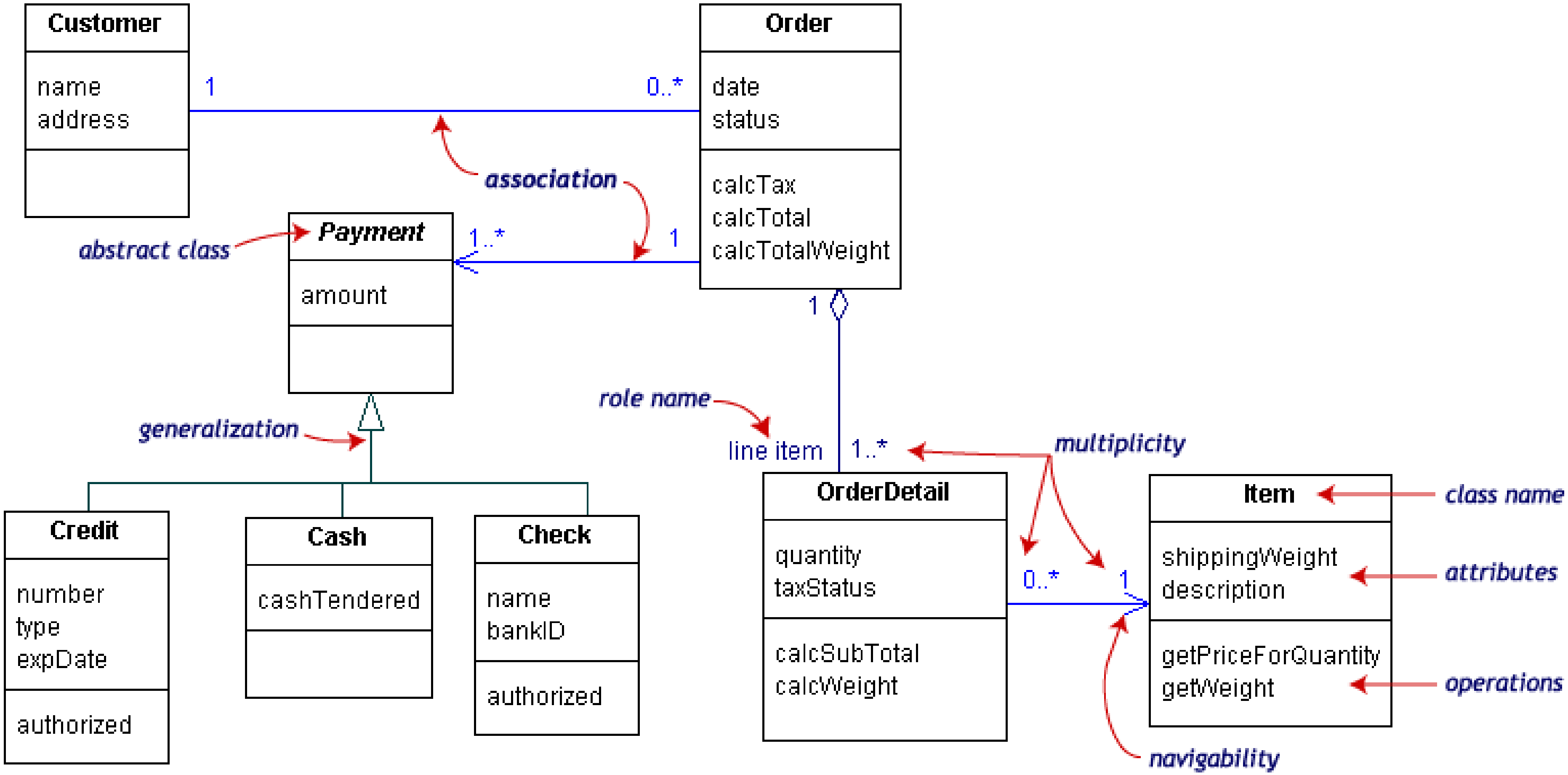
  A child can be substituted for its parent whenever necessary. Generalization appears as a line with a triangular arrow head toward the parent use case.
- **Include** relationships factor use cases into additional ones. Includes are especially helpful when the same use case can be factored out of two different use cases.
  - **Make Appointment** and **Request Medication** include **Check Patient Record** as a subtask.

  In the diagram, include notation is a dotted line beginning at base use case ending with an arrows pointing to the include use case. The dotted line is labeled <<include>>.
- An **extend** relationship indicates that one use case is a variation of another. Extend notation is a dotted line, labeled <<extend>>, and with an arrow toward the base case. The **extension point**, which determines when the extended case is appropriate, is written inside the base case.

Class Diagrams

- **A Class diagram** gives an overview of a system by showing its classes and the relationships among them.
- Class diagrams are static -- they display what interacts but not what happens when they do interact.
- Main concepts involved
  - Class - Object
  - Inheritance
  - (various kinds of) Associations

Class Diagram Example

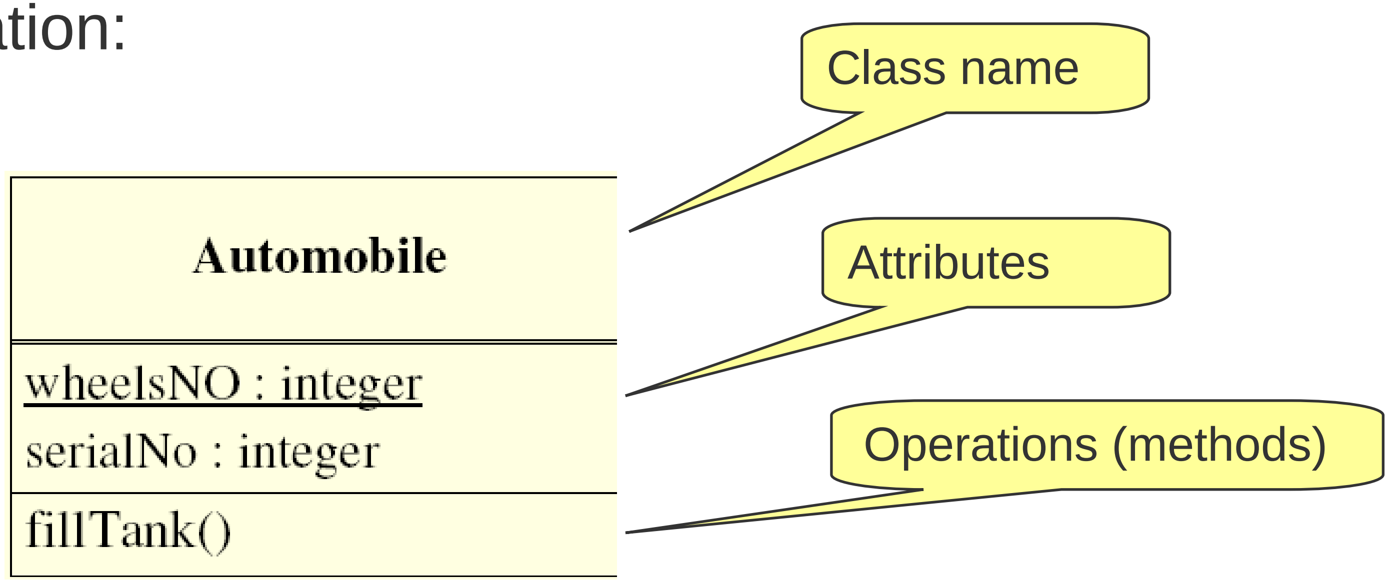


Object Orientation

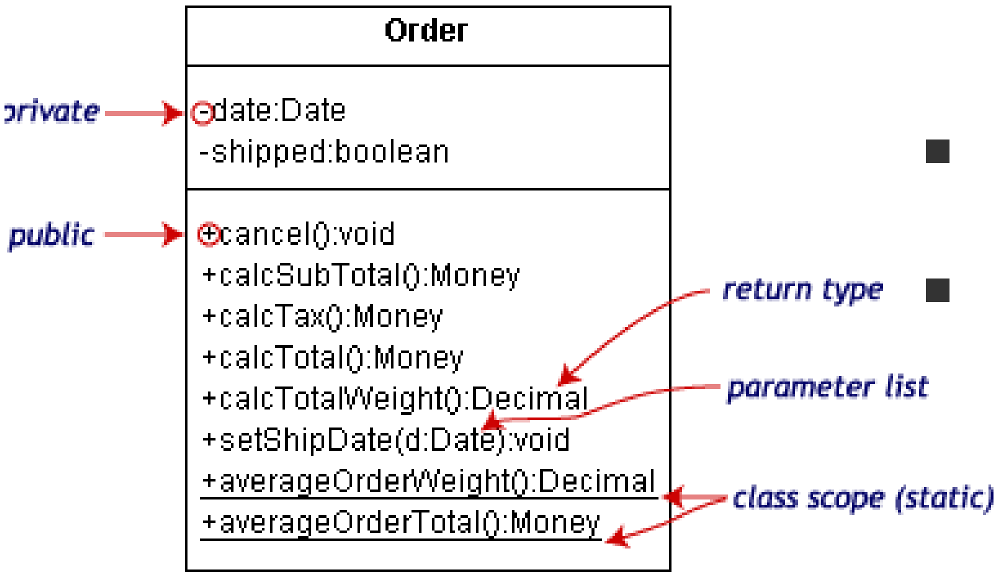
- In the first versions, UML was described as addressing the needs of modeling systems in a OO manner
- Object orientation still is the inspiration for some key concepts
- Main concepts:
  - Object – individual unit capable of *receiving/sending messages*, processing data
  - Class – pattern giving an abstraction for a set of objects
  - Inheritance – technique for reusability and extendibility

UML Class

- Gives the type of a set of objects existing at run-time
- Declares a collection of methods and attributes that describe the structure and behavior of its objects
- Basic notation:



Class Information



Access specifiers:

Symbol	Access
+	public: they are visible to all
–	private: not visible to callers outside the class
#	protected: only visible to children of the class

- The class notation is a 3-piece rectangle with the class name, attributes, and operations.
- Attributes and operations can be labeled according to access and scope.
- The illustration uses the following UML™ conventions.
  - Static members are underlined. Instance members are not.
  - The operations follow this form: *<access specifier> <name>* (*<parameter list>*) : *<return type>*
  - The parameter list shows each parameter type preceded by a colon.
  - Access specifiers appear in front of each member.

Class Diagram Elements

- **Association** -- a relationship between instances of the two classes. In a diagram, an association is a link connecting two classes.
- **Aggregation** -- an association in which one class belongs to a collection. An aggregation has a diamond end pointing to the part containing the whole.
  - **Order** has a collection of **OrderDetails**.
- **Generalization** -- an inheritance link indicating one class is a superclass of the other. A generalization has a triangle pointing to the superclass.
  - ***Payment*** is a superclass of **Cash**, **Check**, and **Credit**.
- An end of an assiciation may have a **role name** to clarify the nature of the association.
  - **OrderDetail** is a line item of each **Order**
- A **navigability** arrow on an association shows which direction the association can be traversed or queried. The arrow also indicates who "owns" the association's implementation
  - **OrderDetail** has an **Item**..
  - An **OrderDetail** can be queried about its **Item**, but not the other way around

Associations with no navigability arrows are bi-directional

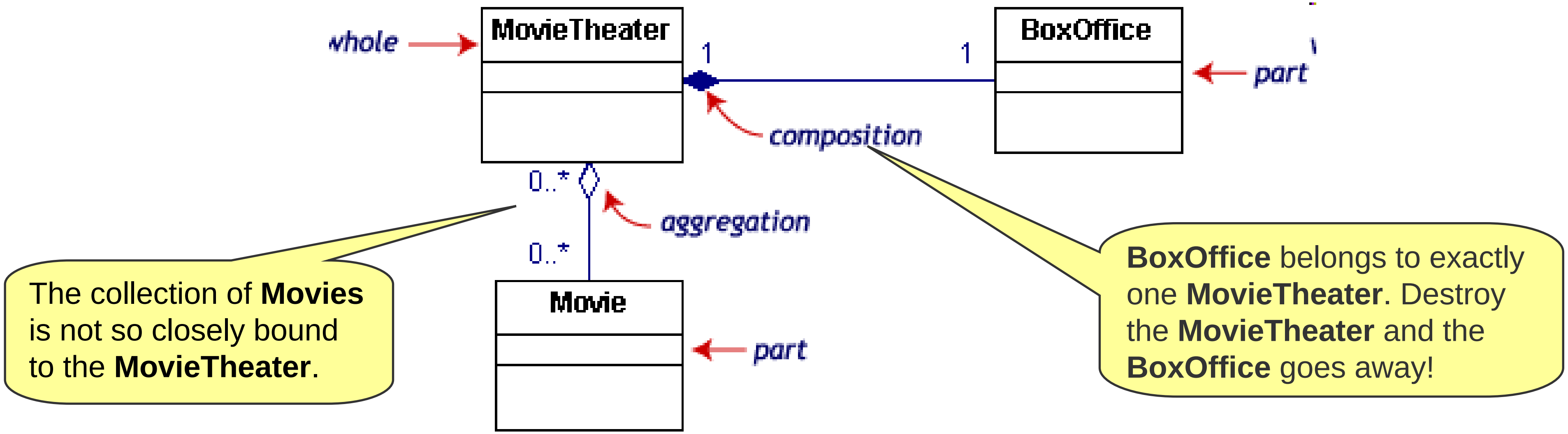
Class Diagram Elements (cont.)

- The **multiplicity** of an association end is the number of possible instances of the class associated with a single instance of the other end. Multiplicities are single numbers or ranges of numbers.
  - In our example, there can be only one **Customer** for each **Order**, but a **Customer** can have any number of **Orders**.
- This table gives the most common multiplicities.

Multiplicities	Meaning
0..1	zero or one instance. The notation ***n . . m*** indicates ***n*** to ***m*** instances.
0..* *or* *****	no limit on the number of instances (including none).
1	exactly one instance
1..*	at least one instance

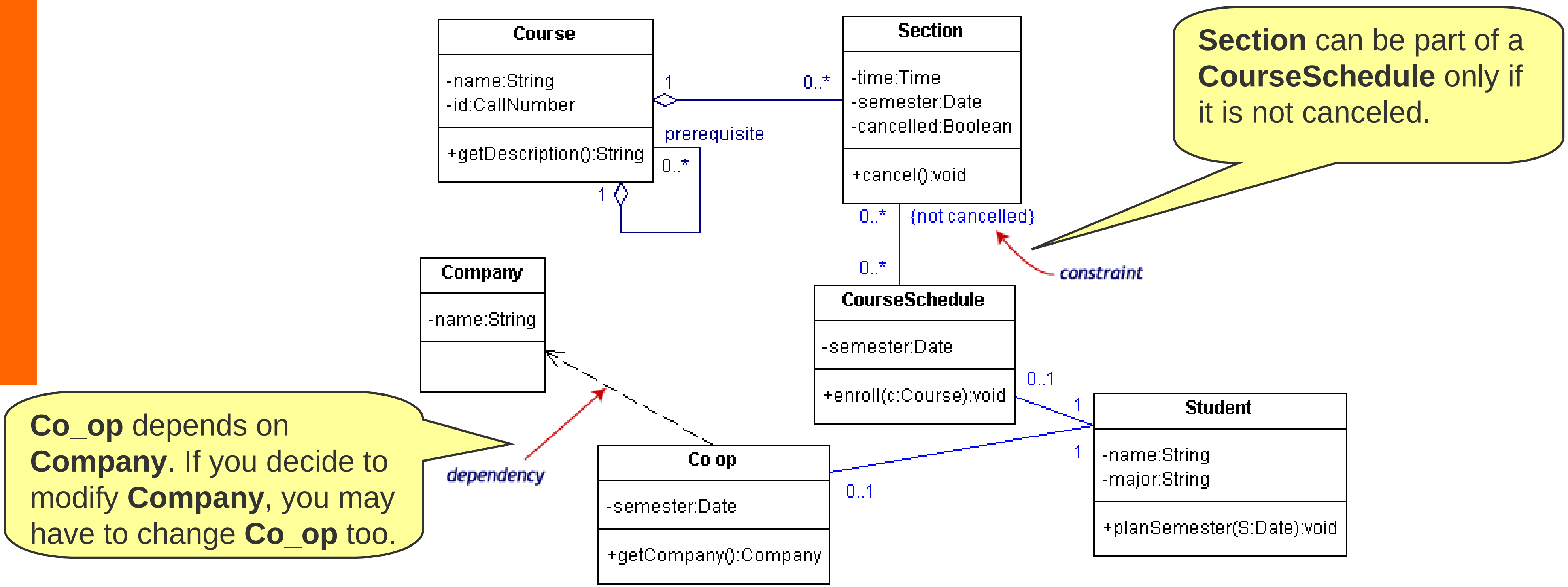
Composition and Aggregation

- **Composition** is a strong association in which the part can belong to only one whole -- the part cannot exist without the whole.
  - Composition is denoted by a filled diamond at the whole end.
- **Aggregation** is a kind of "light" composition (semantics open, to be accommodated to user needs)
  - Aggregation is denoted by a empty diamond at the whole end.



Dependencies and Constraints

- A **dependency** is a relation between two classes in which a change in one may force changes in the other. Dependencies are drawn as dotted lines.
- A **constraint** is a condition that every implementation of the design must satisfy. Constraints are written in curly braces { }.



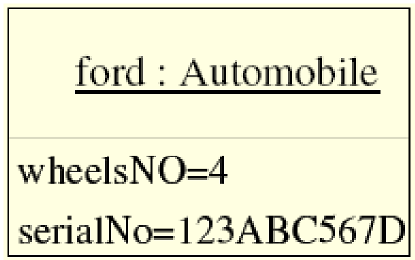
Other Elements of Class Diagrams

There are other elements of class diagrams

- Association Classes
- Interfaces
- Stereotypes
- Templates
- Comments

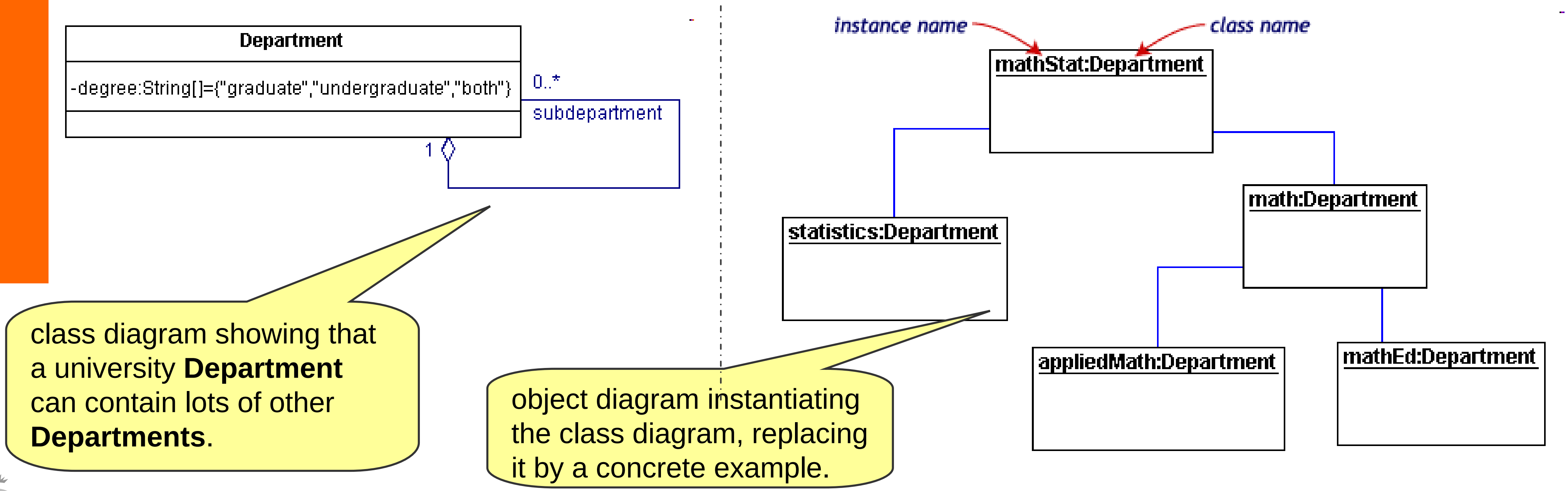
UML Object

- Instance of a class
- Can be shown in a class and object diagram
- Notation

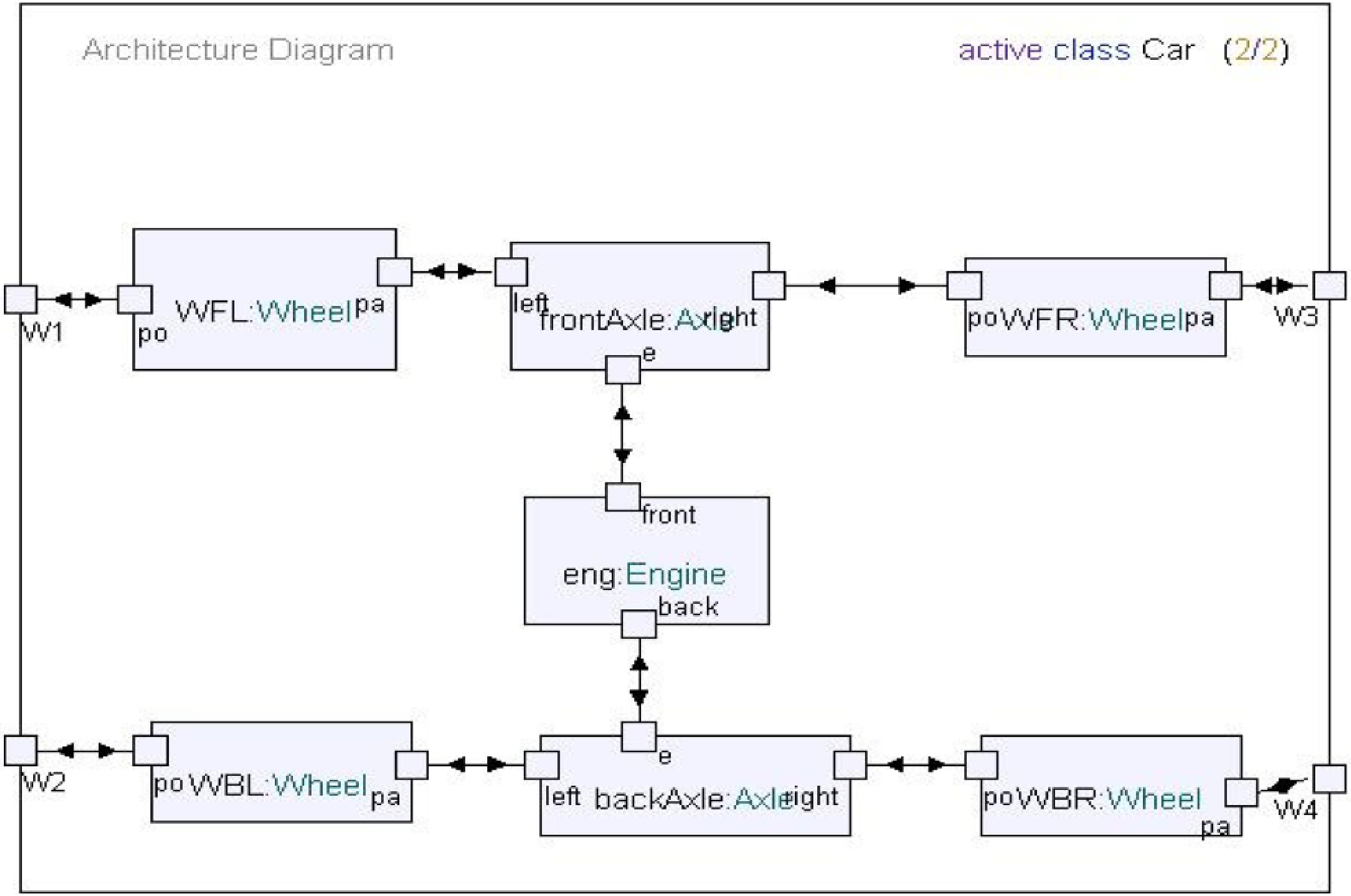


Object Diagram

- **Object diagrams** show instances instead of classes. They are useful for explaining small pieces with complicated relationships, especially recursive relationships.
- Each rectangle in the object diagram corresponds to a single instance.
- Instance names are underlined in UML diagrams.
- Class or instance names may be omitted from object diagrams as long as the diagram meaning is still clear.

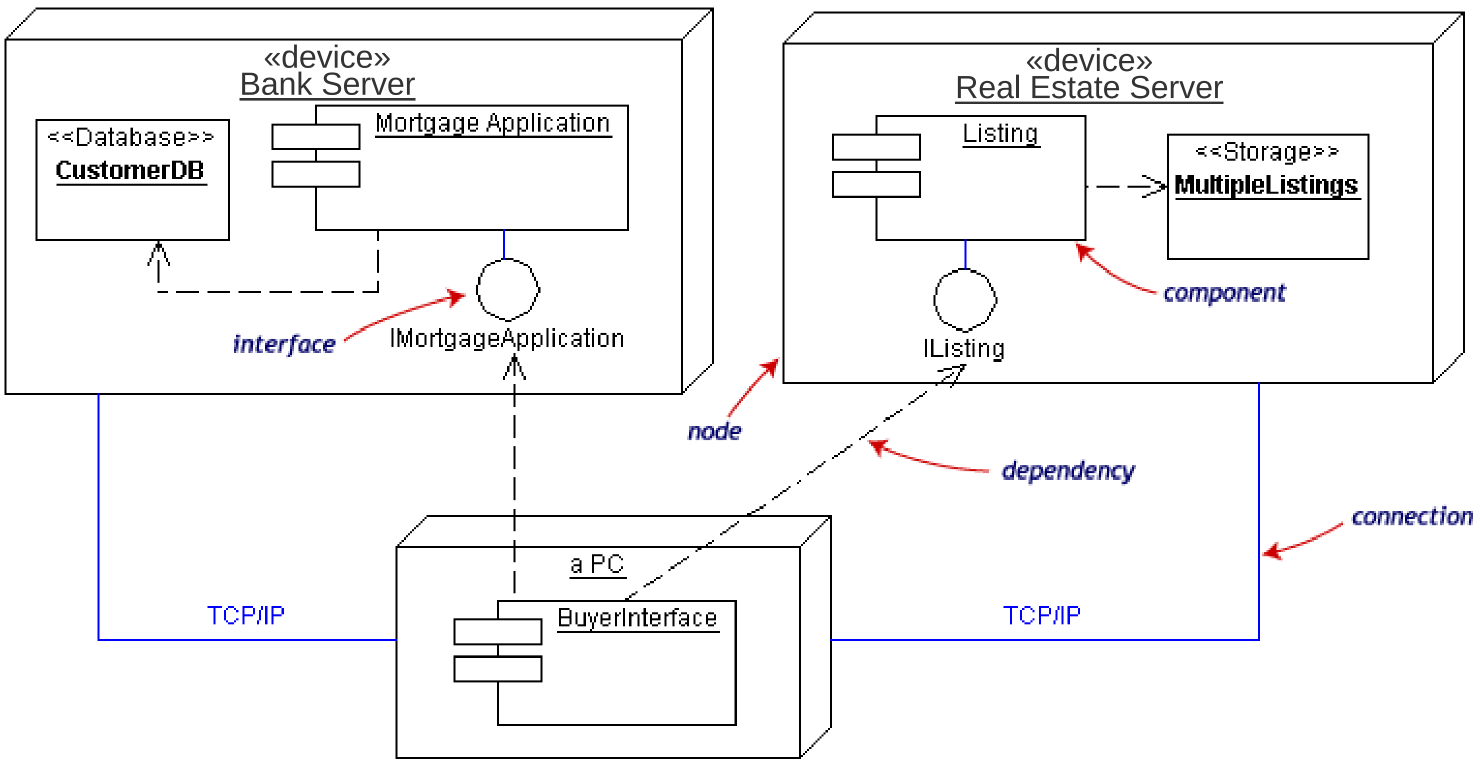


Composite Structure Diagram



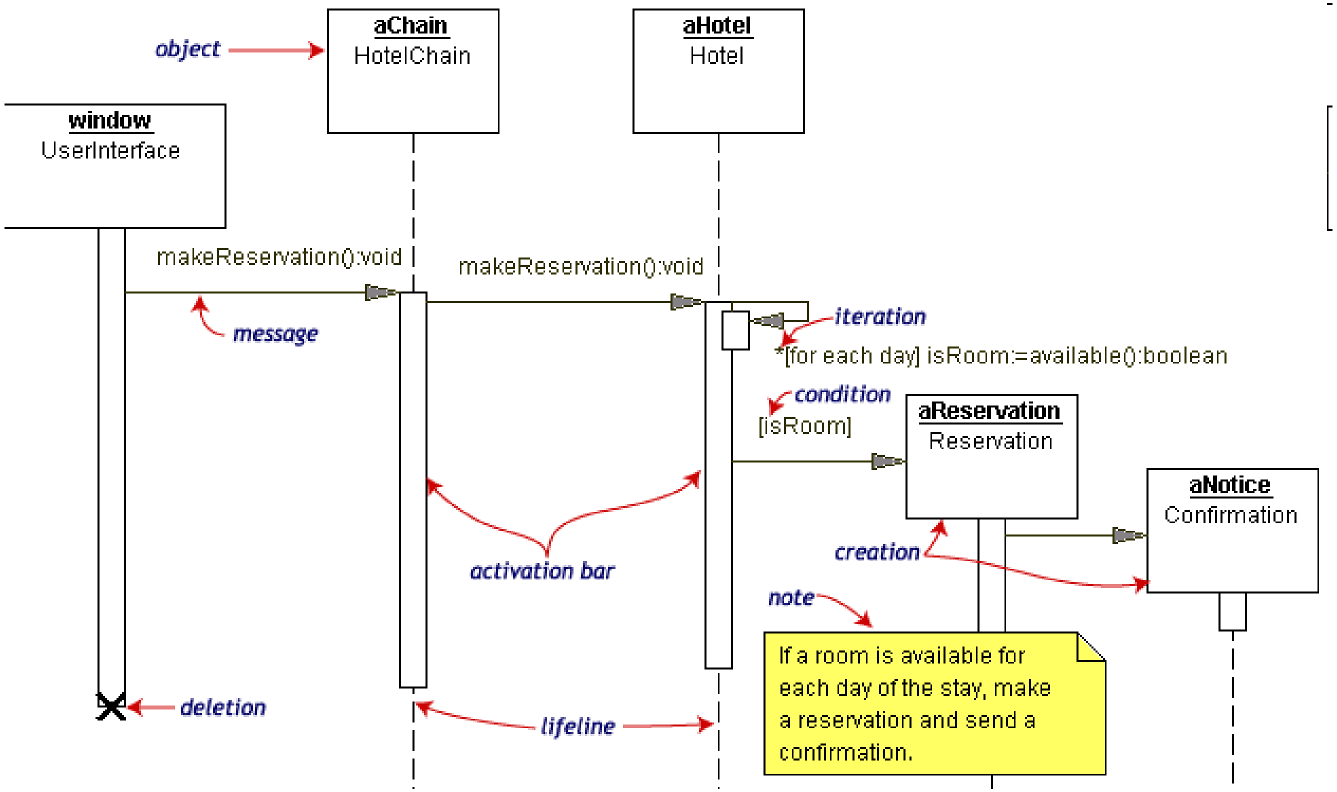
Deployment Diagrams

- **Deployment diagrams** show the physical configurations of software and hardware.
  - **Nodes** represent either physical hardware (keyword «device») or software (<<executionEnvironment>>)
  - Nodes are connected by communication relations
  - A **component** is a code module. Components are shown as rectangles with two tabs at the upper left. Each component belongs on a node.



Sequence Diagram

- A **sequence diagram** is an interaction diagram that details how operations are carried out -- what messages are sent and when.
  - Sequence diagrams are organized according to time. The time progresses as you go down the page.
  - The objects involved in the operation are listed from left to right according to when they take part in the message sequence.



Collaboration Diagram

- **Collaboration diagrams** are also interaction diagrams. They convey the same information as sequence diagrams, but they focus on object roles instead of the times that messages are sent.

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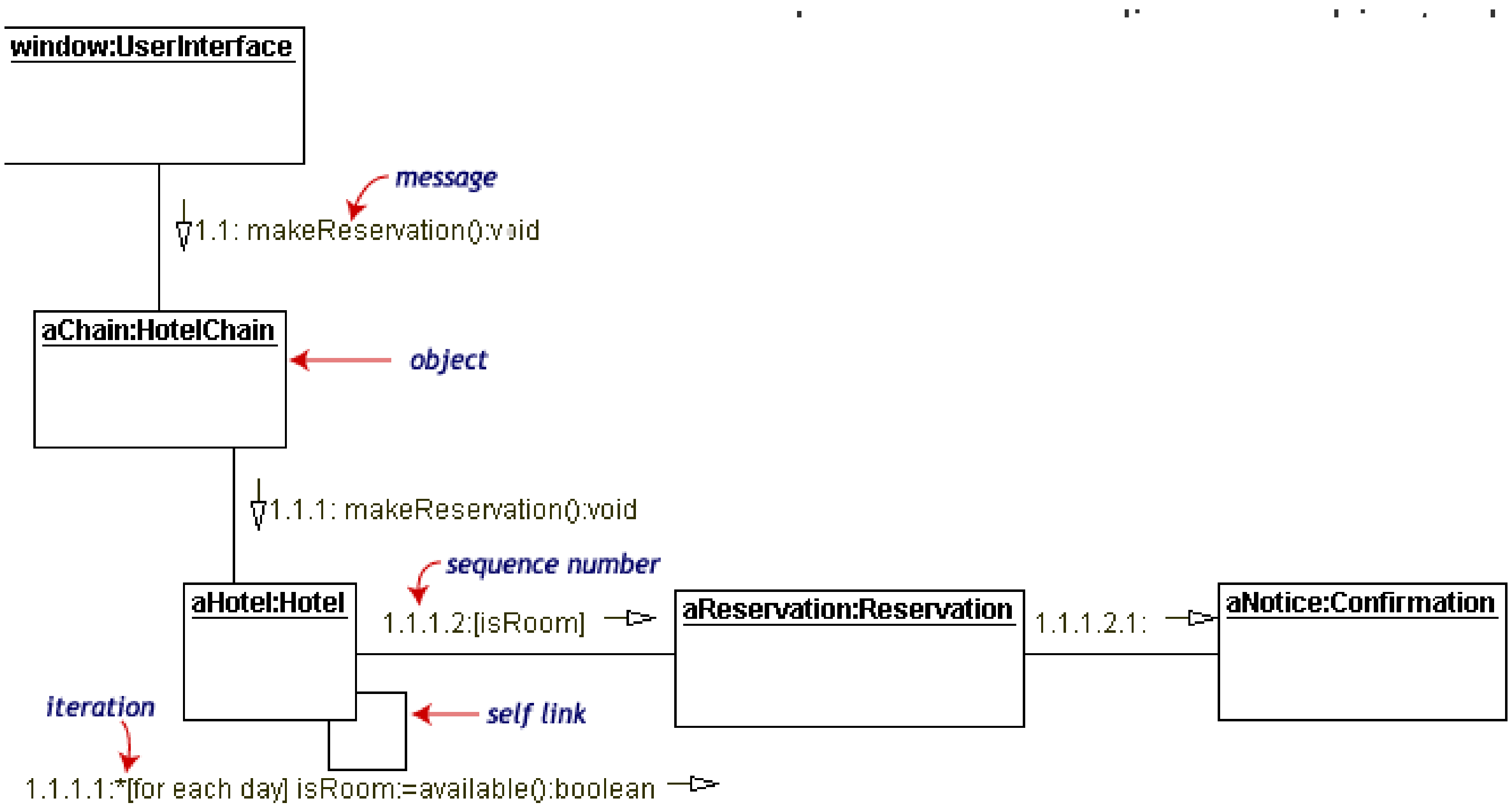
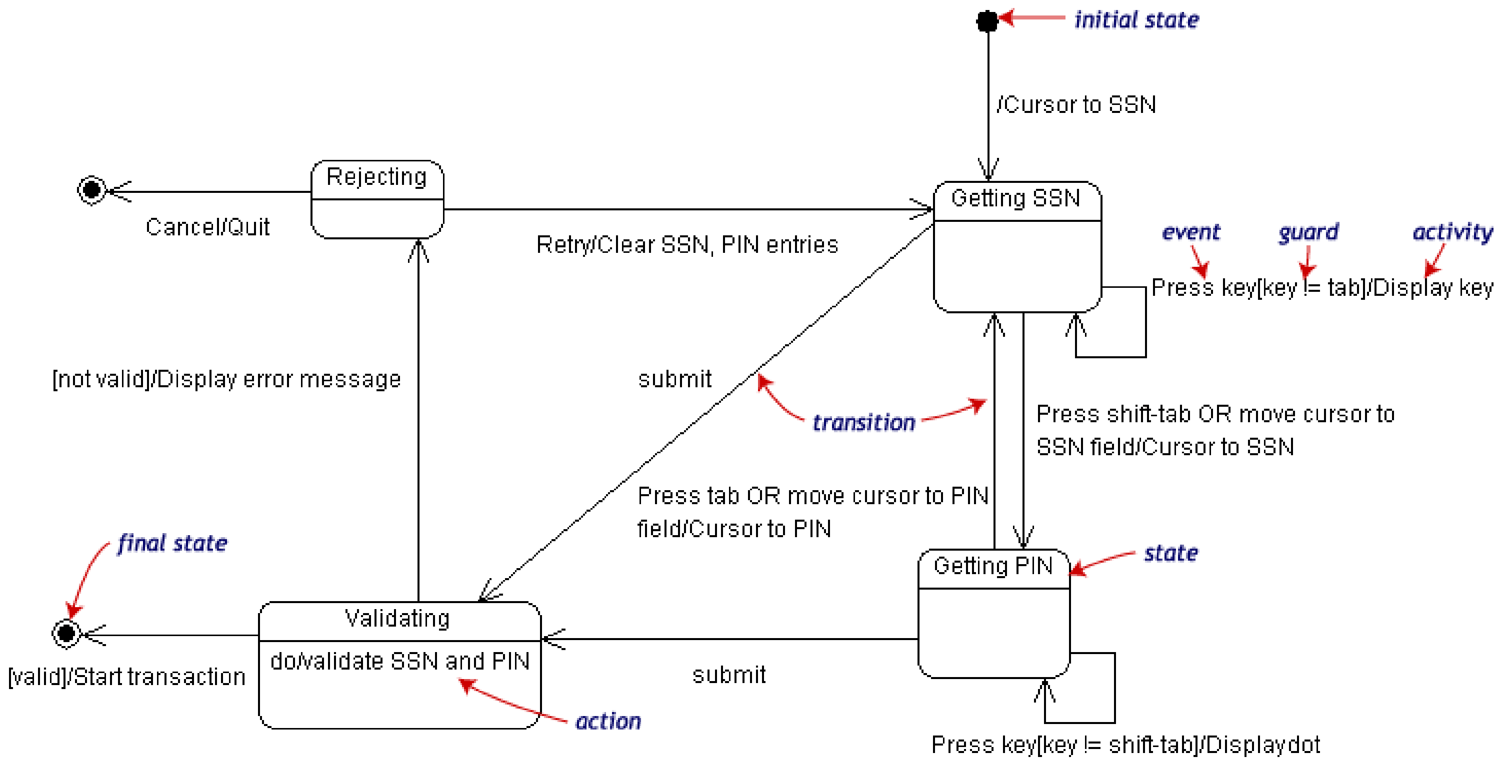


Activity Diagram

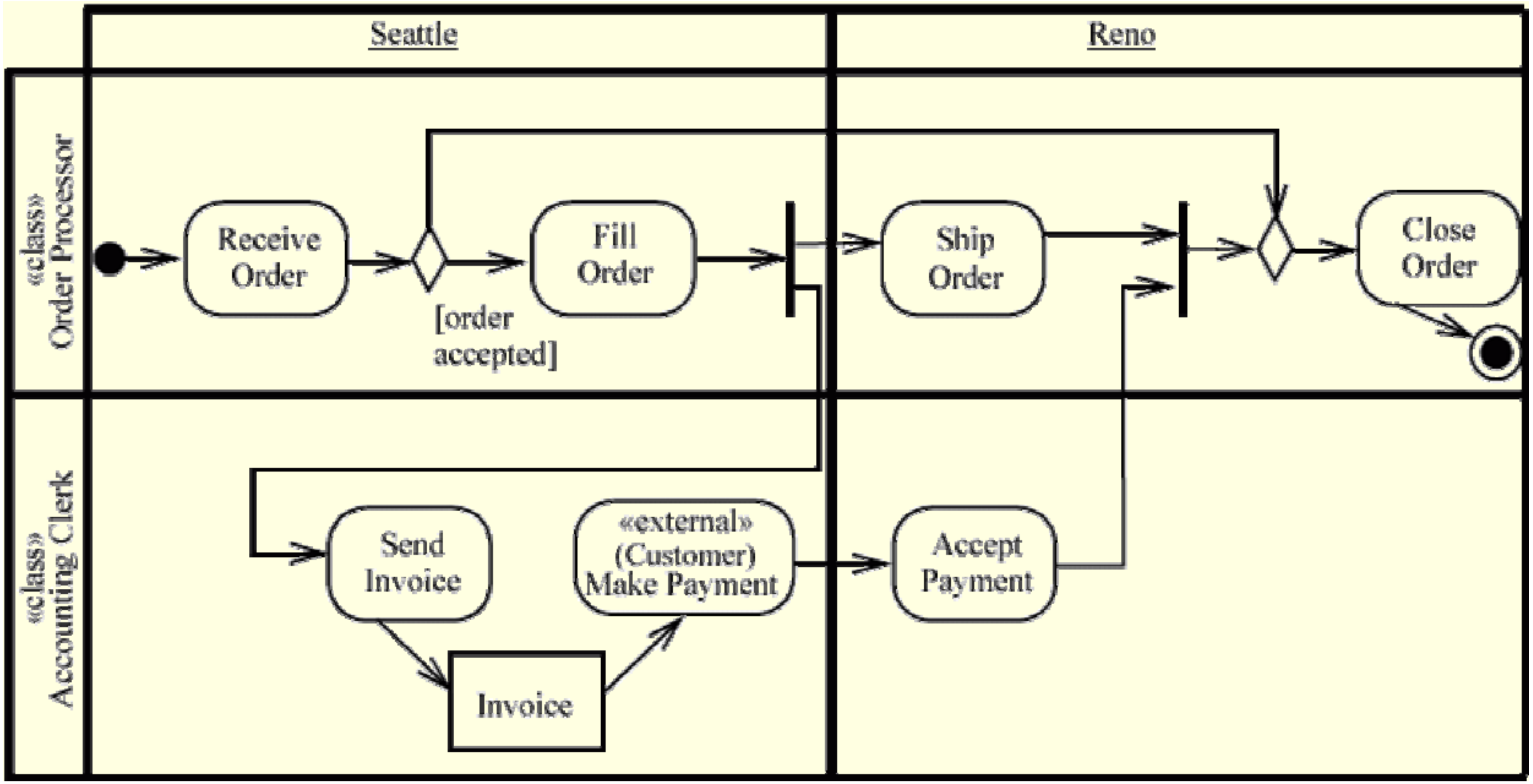
- An **activity diagram** is essentially a fancy flowchart. Activity diagrams can be divided into object **swimlanes** that determine which object is responsible for which activity.
- A single **transition** comes out of each activity, connecting it to the next activity.
- A transition may **branch** into two or more mutually exclusive transitions. **Guard expressions** (inside [ ]) label the transitions coming out of a branch.
- A branch and its subsequent **merge** marking the end of the branch appear in the diagram as hollow diamonds.
- A transition may **fork** into two or more parallel activities. The fork and the subsequent **join** of the threads coming out of the fork appear in the diagram as solid bars.

State Chart Diagram

- A **statechart diagram** shows the possible states of the object and the transitions that cause a change in state.
  - States are rounded rectangles.
  - Transitions are arrows from one state to another.
  - Events or conditions that trigger transitions are written beside the arrows.



Activity Diagram - Example



OCL – Object Constraint Language

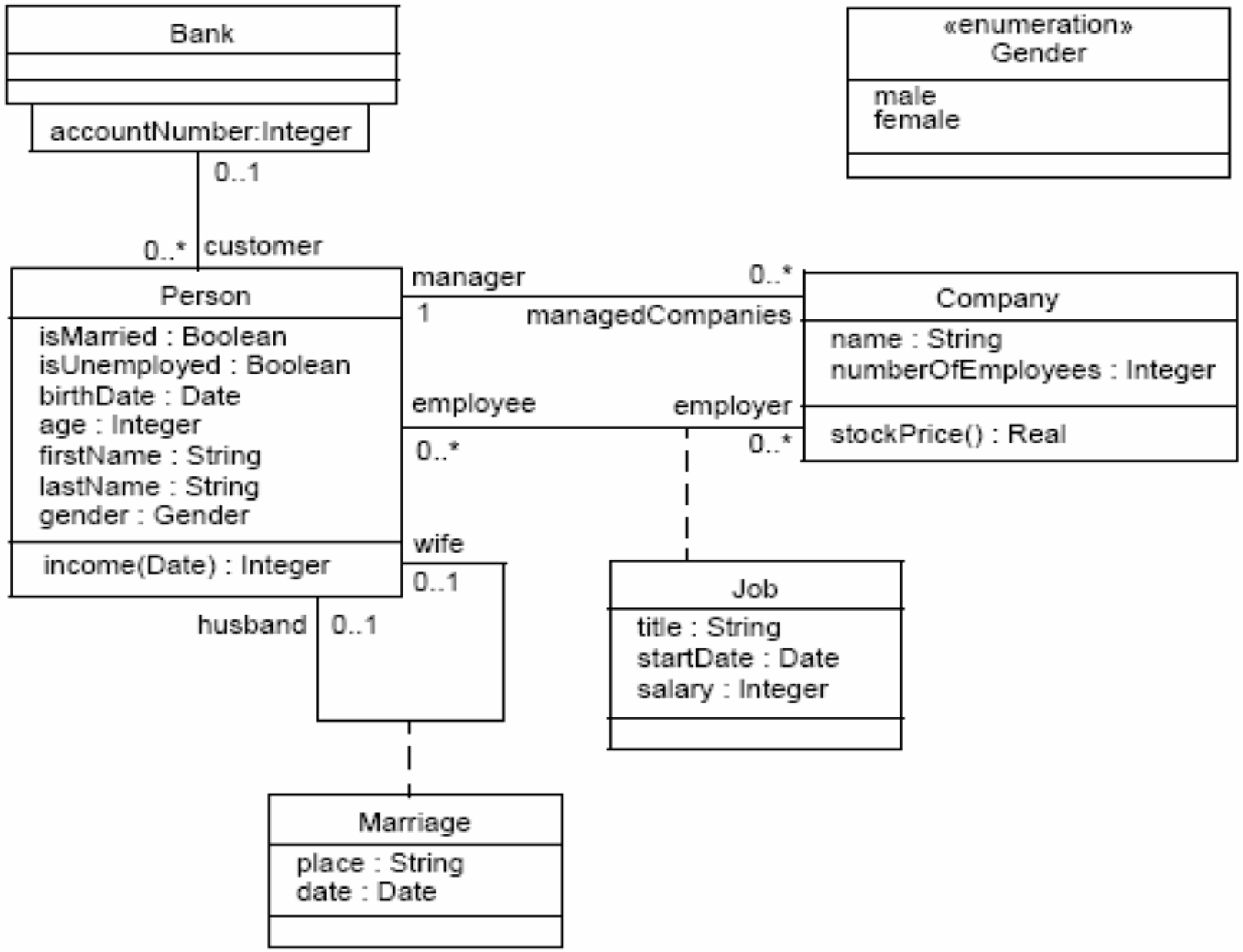
- OCL is a constraint language integrated in the UML standard
- OCL aims to fill the gap between mathematical rigor and business modeling
  - formal language with precise semantics for expression but
  - easy to read and write
- It is recommended in UML for:
  - Constraints: pre and post conditions, invariants
  - Boolean expressions: guards, query body specification
  - Defining initial and derived values of features

  and
  - to specify queries on the UML model, which are completely programming language independent.
- OCL is a pure specification/modeling language; therefore, an OCL expression is guaranteed to be without side effects – it simply returns a value
- OCL is not a programming language; therefore, it is not possible to write program logic or flow control in OCL. You cannot invoke processes or activate non-query operations within OCL.

Where to use OCL

- OCL can be used for a number of different purposes:
  - As a query language
  - To specify invariants on classes and types in the class model
  - To specify type invariant for Stereotypes
  - To describe pre- and post conditions on Operations and Methods
  - To describe Guards
  - To specify target (sets) for messages and actions
  - To specify constraints on operations
  - To specify derivation rules for attributes for any expression over a UML model.

Example Diagram



Relation to the UML Metamodel

- Context
  - Each OCL expression is written in the context of an instance of a specific type.
  - In an OCL expression, the reserved word *self* is used to refer to the contextual instance
  - The context of an OCL expression within a UML model can be specified through a so-called context declaration at the beginning of an OCL expression
- Invariant
  - The OCL expression can be part of an Invariant, a condition that must be true for all instances at any time

context Company **inv**:

self.numberOfEmployees > 50

Relation to the UML Metamodel

- Preconditions and Postconditions
  - The stereotype of constraint is shown by putting the labels ‘pre:’ and ‘post:’ before the actual Preconditions and Postconditions. For example:
  - The OCL expression can be part of an Invariant, a condition that must be true for all instances at any time

```
context Typename::operationName(param1 : Type1, ... ): ReturnType
    pre : param1 > ...
    post: result = ...
```

- In an example diagram, we can write:

```
context Person::income(d : Date) : Integer
    post: result = 5000
```