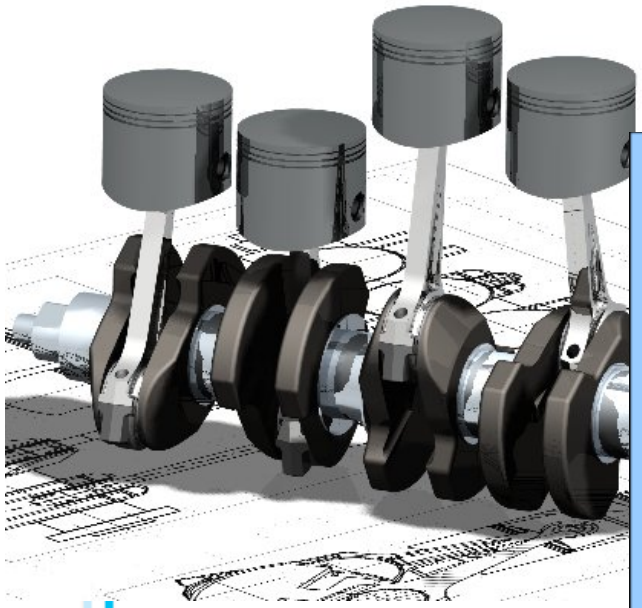
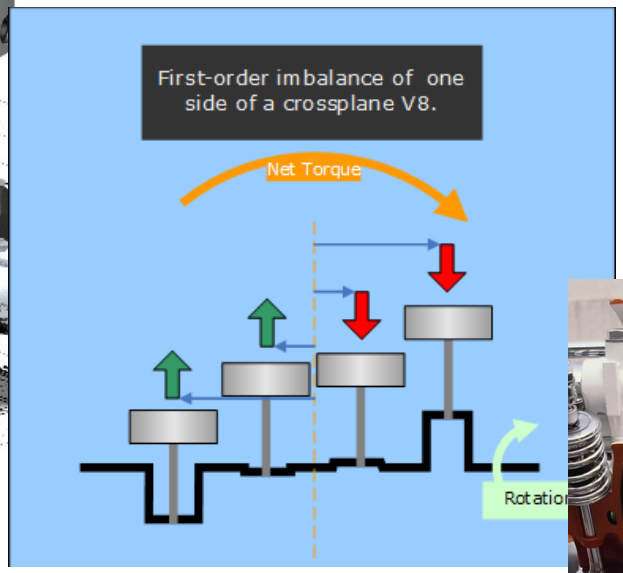
Anyone know what type of planes these are?

What is this?




First-order imbalance of one side of a crossplane V8.
Net Torque

Before beginning any "Large" undertaking, you should ALWAYS build a *model* first!

Question: Before building a house what kind of modeling occurs?

Object-Oriented Software Engineering

Practical Software Development using UML and Java

Chapter 5:

Modelling with Classes

Timing: 120-150 minutes

5.1 What is UML?

The Unified Modelling Language is a standard graphical language for modelling object oriented software

- At the end of the 1980s and the beginning of 1990s, the first object-oriented development processes appeared
- The proliferation of methods and notations tended to cause considerable confusion
- Two important methodologists Rumbaugh and Booch decided to merge their approaches in 1994.
  - —They worked together at the Rational Software Corporation
- In 1995, another methodologist, Jacobson, joined the team
  - —His work focused on use cases
- In 1997 the Object Management Group (OMG) started the process of UML standardization

UML diagrams

- Class diagrams
  - —describe classes and their relationships
- Interaction diagrams
  - —show the behaviour of systems in terms of how objects interact with each other
- State diagrams and activity diagrams
  - —show how systems behave internally
- Component and deployment diagrams
  - —show how the various components of systems are arranged logically and physically

UML features

- It has detailed *semantics*
- It has *extension* mechanisms
- It has an associated textual language
  - —*Object Constraint Language* (OCL) (not covered in cs2212)

The objective of UML is to assist in software development

- —It is not a *methodology*

What constitutes a good model?

A model should

- use a standard notation
- be understandable by clients and users
- lead software engineers to have insights about the system
- provide abstraction

Models are used:

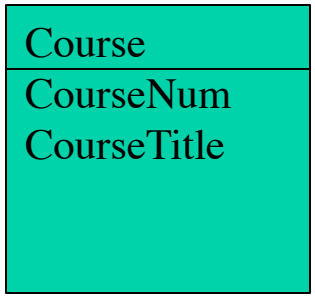
- to help create designs
- to permit analysis and review of those designs.
- as the core documentation describing the system.

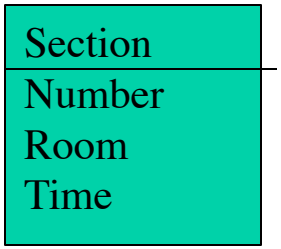
IMPORTANT

Do NOT confuse what we are learning today with the classes that you actually end up building (the class that you write in Java).

The classes we learn about today will be the BASIS for those classes but the first class diagram you draw/ model for your project will NOT be exactly like what you end up coding.

E.G.





How would you code it to see the sections of a course?

5.2 Essentials of UML Class Diagrams

The main symbols shown on class diagrams are:

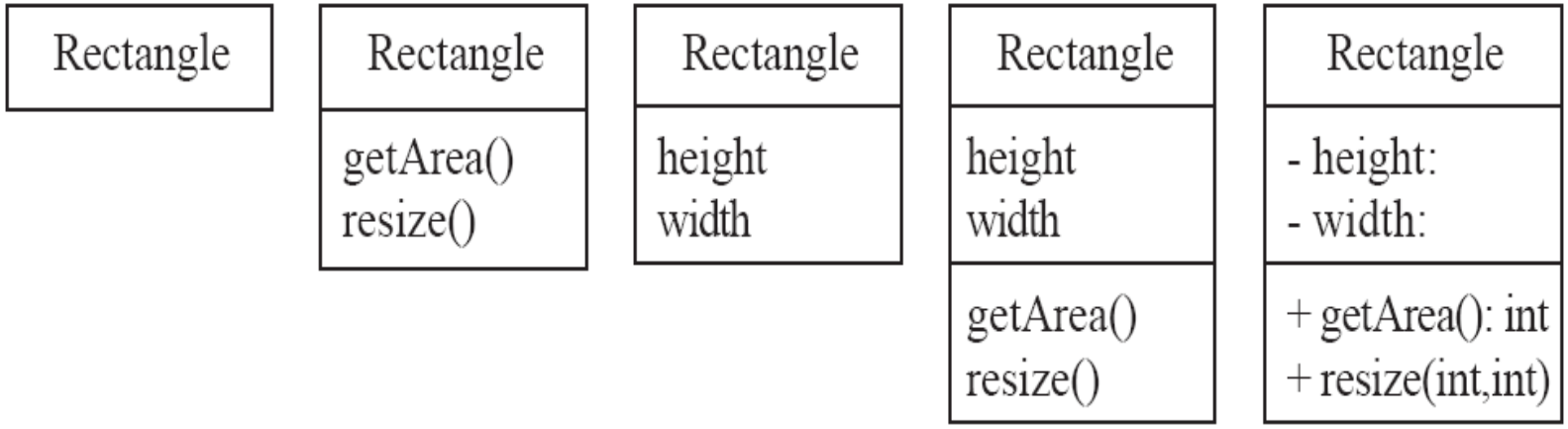
- *Classes*
  - represent the types of data themselves
- *Associations*
  - represent linkages between instances of classes
- *Attributes*
  - are simple data found in classes and their instances
- *Operations*
  - represent the functions performed by the classes and their instances
- *Generalizations*
  - group classes into inheritance hierarchies

Classes

A class is simply represented as a box with the name of the class inside

- The diagram may also show the attributes and operations
- The complete signature of an operation is:

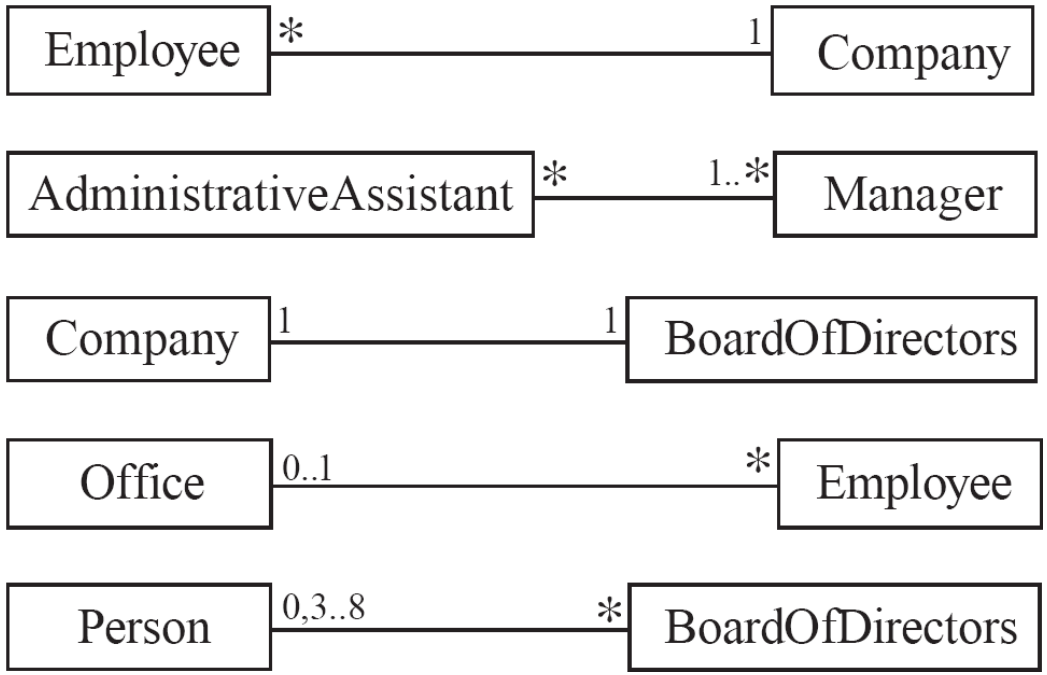
  operationName(parameterName: parameterType …): returnType



5.3 Associations and Multiplicity

An *association* is used to show how two classes are related to each other

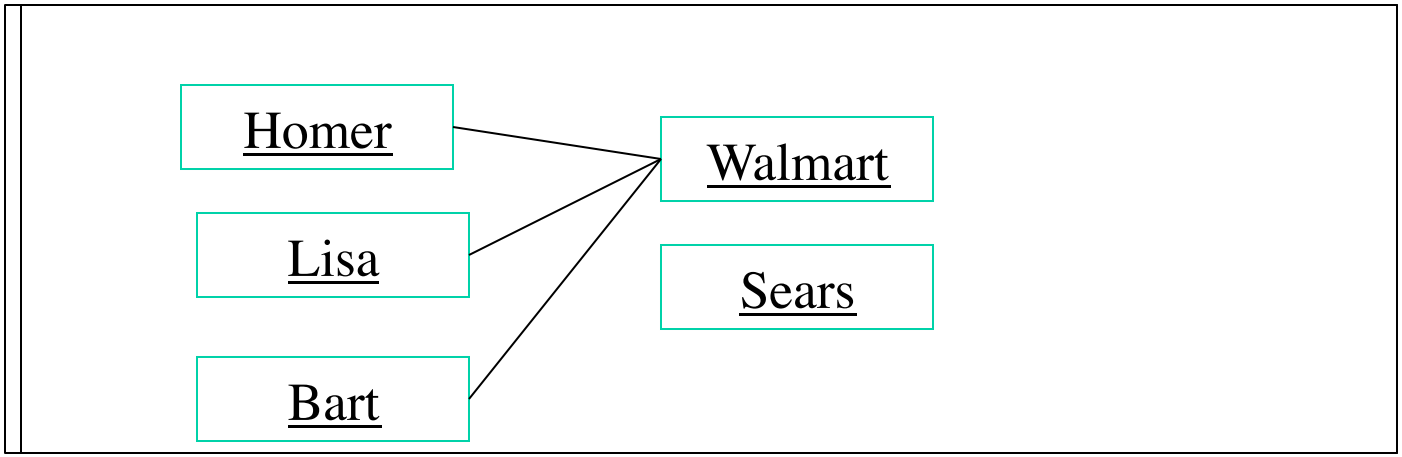
- Symbols indicating *multiplicity* are shown at each end of the association



Object Diagrams

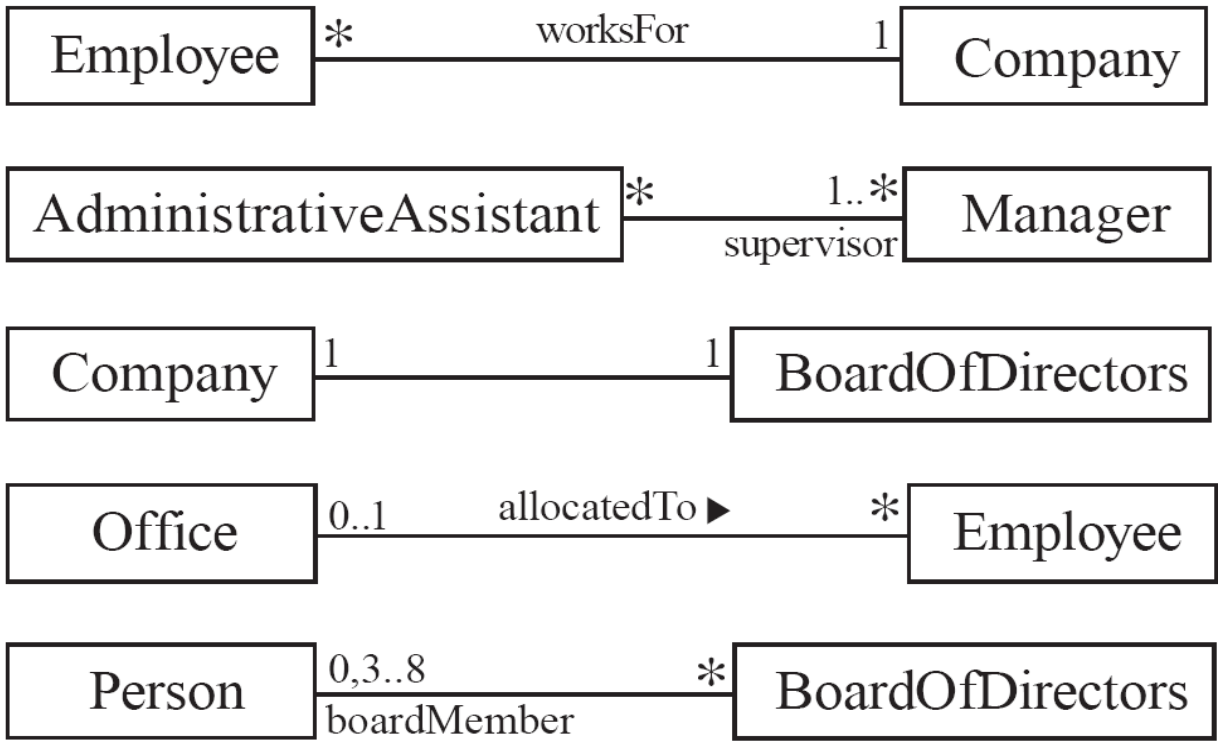
Object (Instant) Diagrams give a representation of a class diagram using actual objects in the system. For example if this is our class diagram:

Which of the following object diagrams are valid?



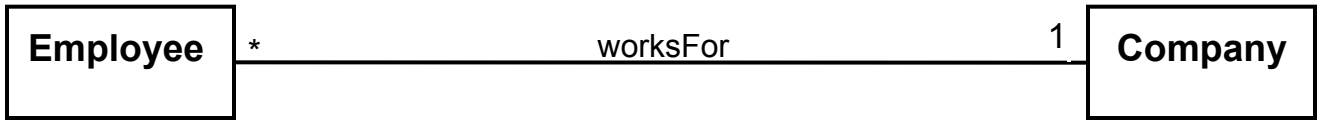
Labelling associations

- Each association can be labelled, to make explicit the nature of the association



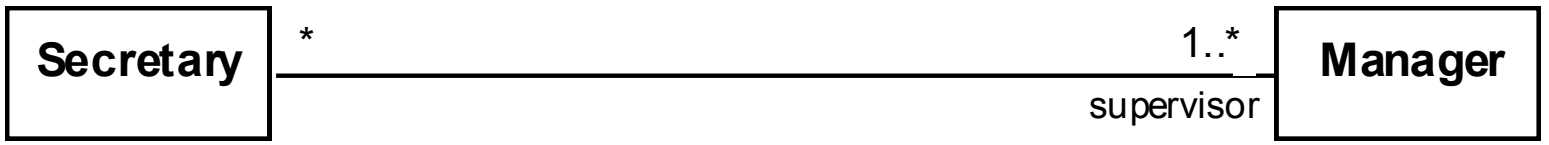
Analyzing and validating associations

- **Many-to-one**
  - —A company has many employees,
  - —An employee can only work for one company.
    - This company will not store data about the moonlighting activities of employees!
  - —A company can have zero employees
    - E.g. a ‘shell’ company
  - —It is not possible to be an employee unless you work for a company



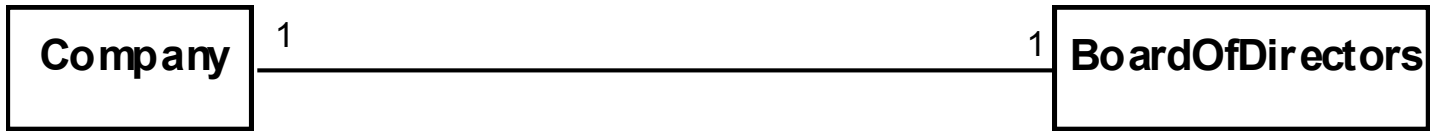
Analyzing and validating associations

- **Many-to-many**
  - —A secretary can work for many managers
  - —A manager can have many secretaries
  - —Secretaries can work in pools
  - —Managers can have a group of secretaries
  - —Some managers might have zero secretaries.
  - —Is it possible for a secretary to have, perhaps temporarily, zero managers?



Analyzing and validating associations

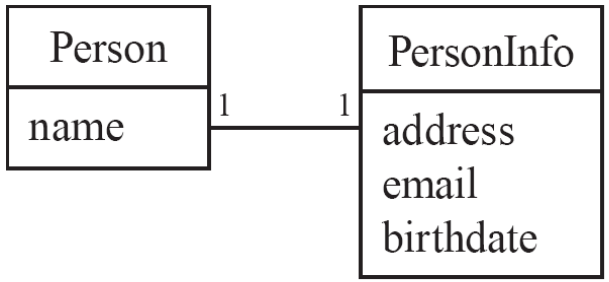
- **One-to-one**
  - —For each company, there is exactly one board of directors
  - —A board is the board of only one company
  - —A company must always have a board
  - —A board must always be of some company



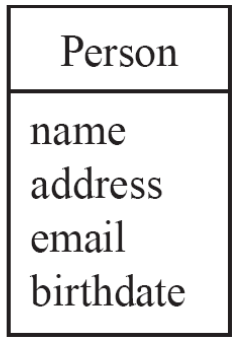
Analyzing and validating associations

Avoid unnecessary one-to-one associations

Avoid this

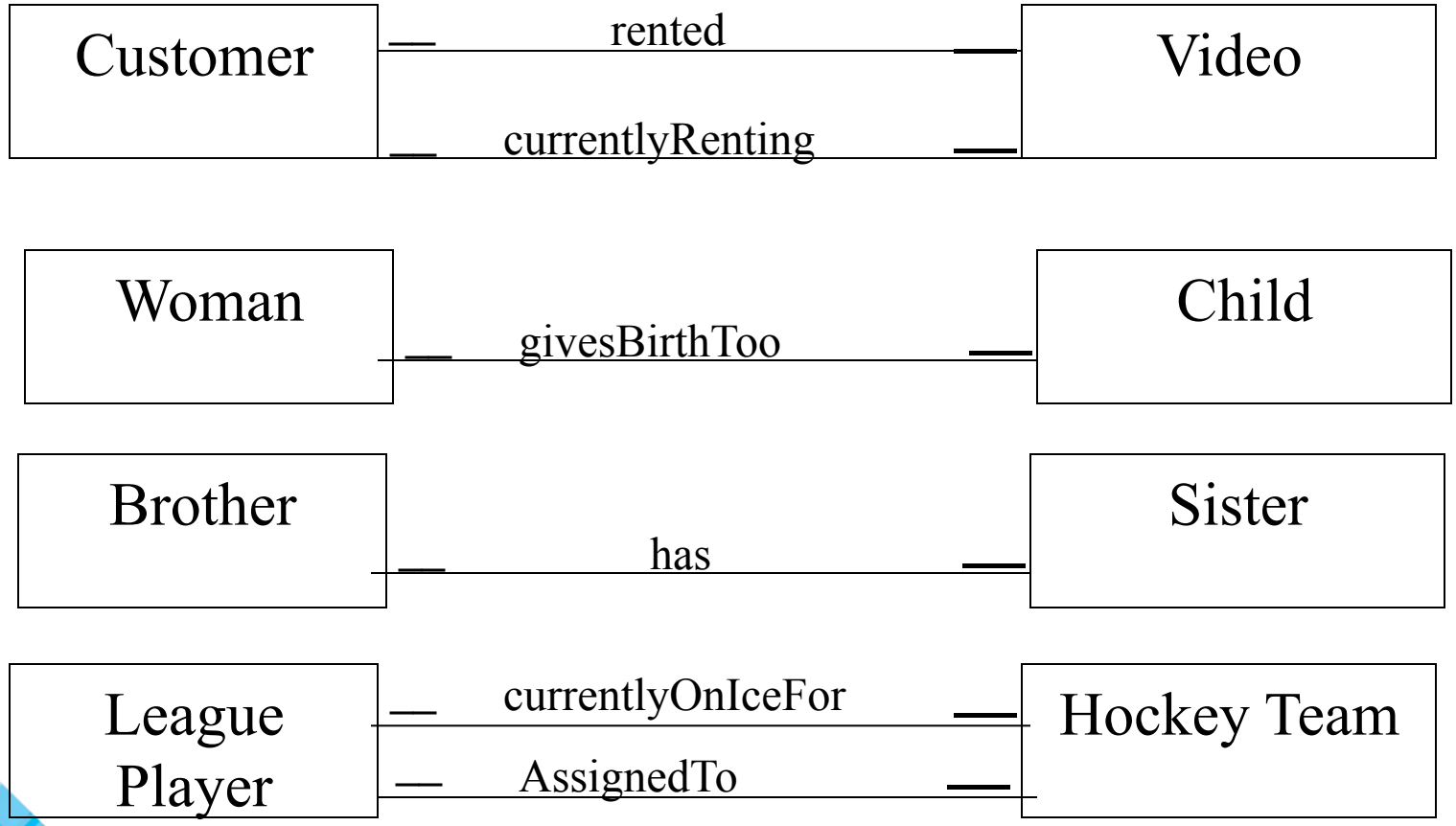


do this



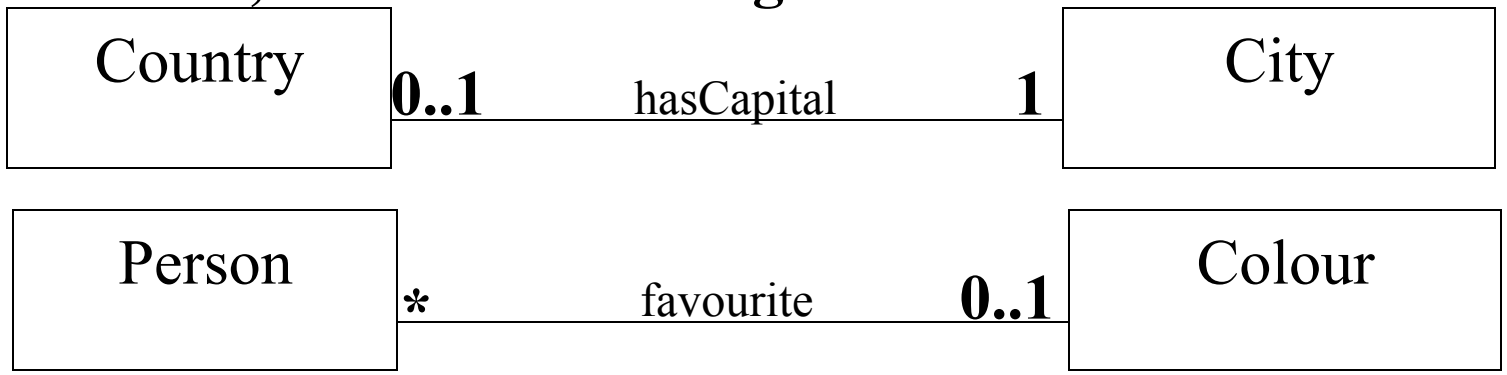
Question

Label the multiplicities for the following examples:



Question

In words, what do these diagrams mean?



A Country has *one and only one city as its capital*

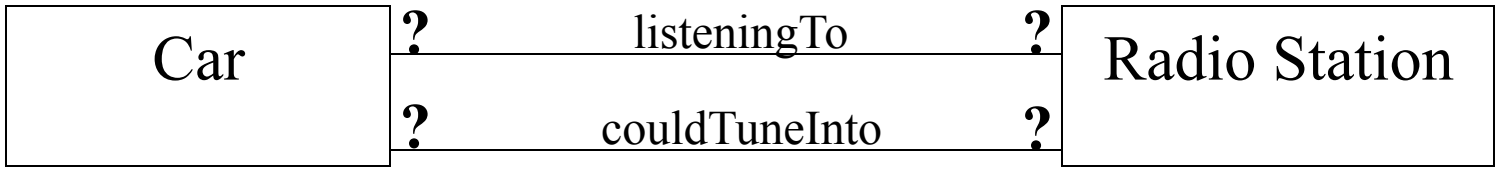
A City _____

A Colour _____

A Person _____

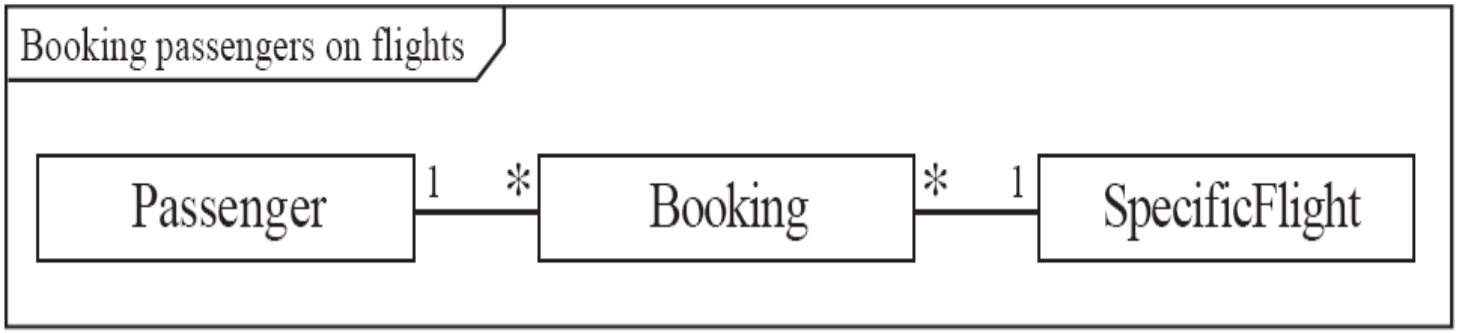
Another Question:

Correctly label this diagrams multiplicity:



A more complex example

- A booking is always for exactly one passenger
  - —no booking with zero passengers
  - —a booking could *never* involve more than one passenger.
- A Passenger can have any number of Bookings
  - —a passenger could have no bookings at all
  - —a passenger could have more than one booking

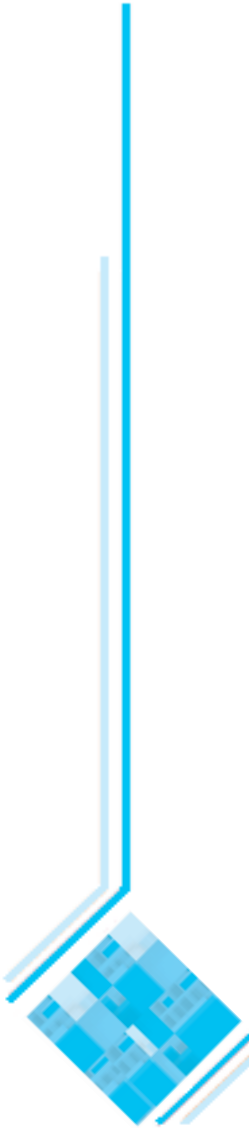


Question

Create two or three classes linked by associations to represent the following situations:

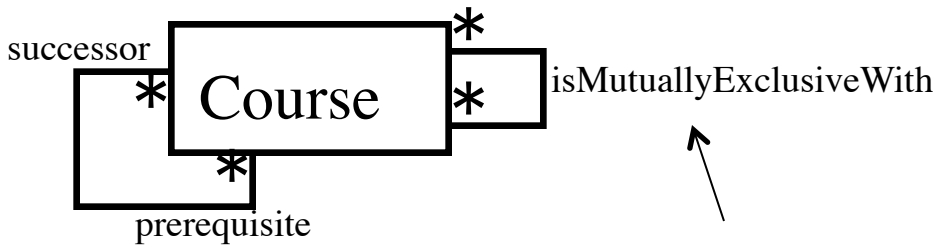
- ***A landlord renting apartments to tenant***
- ***An author writing books distributed by publishers***
- Label the multiplicities (justify why you picked them)
- Give each class you choose at least 1 attribute

Your Answer



Reflexive associations

- It is possible for an association to connect a class to itself

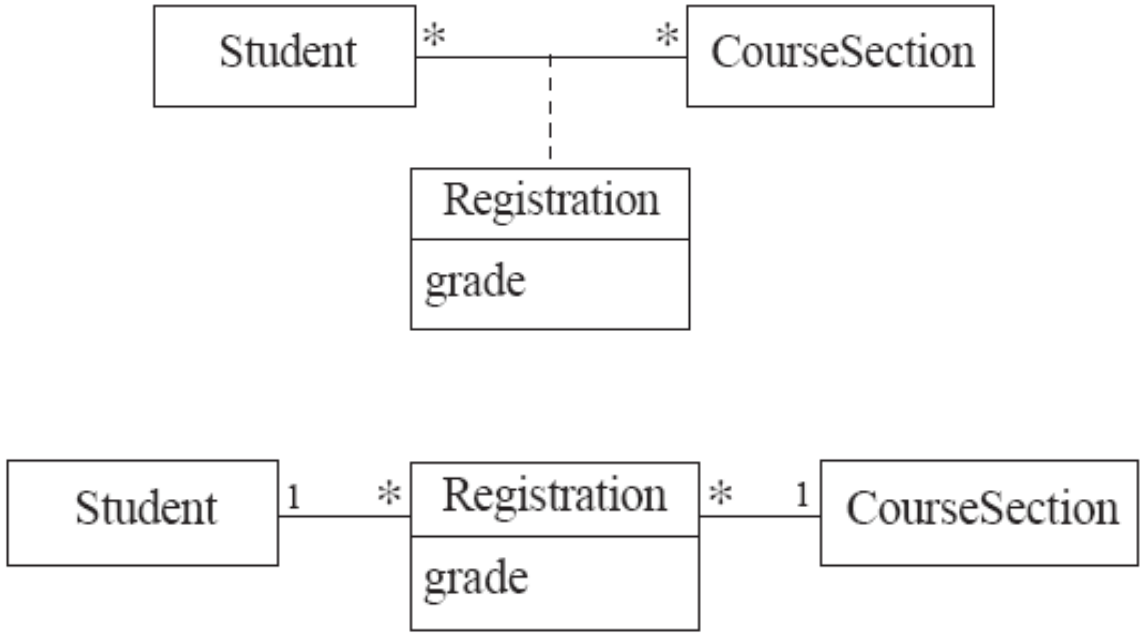


At Western, you must have CS2210 and CS2211 to take CS2212

At Western, you can't take Calc 1301b and Calc1501b

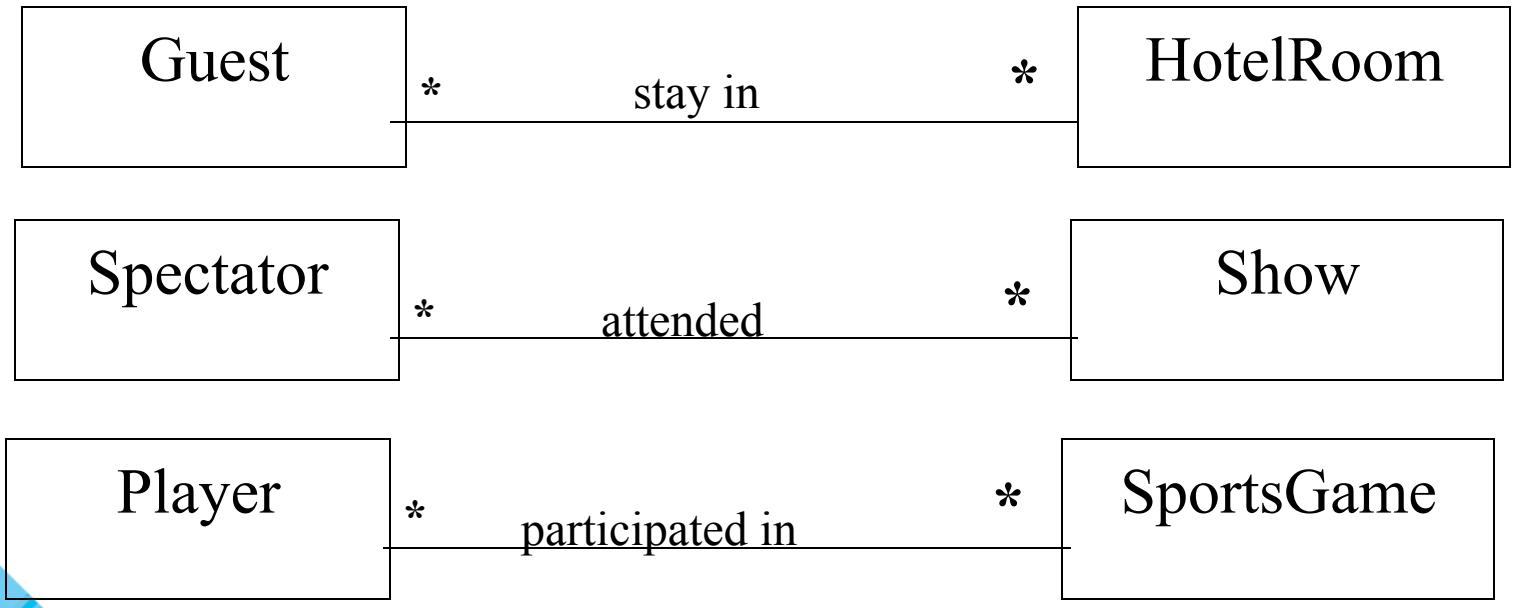
Association classes

- Sometimes, an attribute that concerns two associated classes cannot be placed in either of the classes
- The following are equivalent



Question

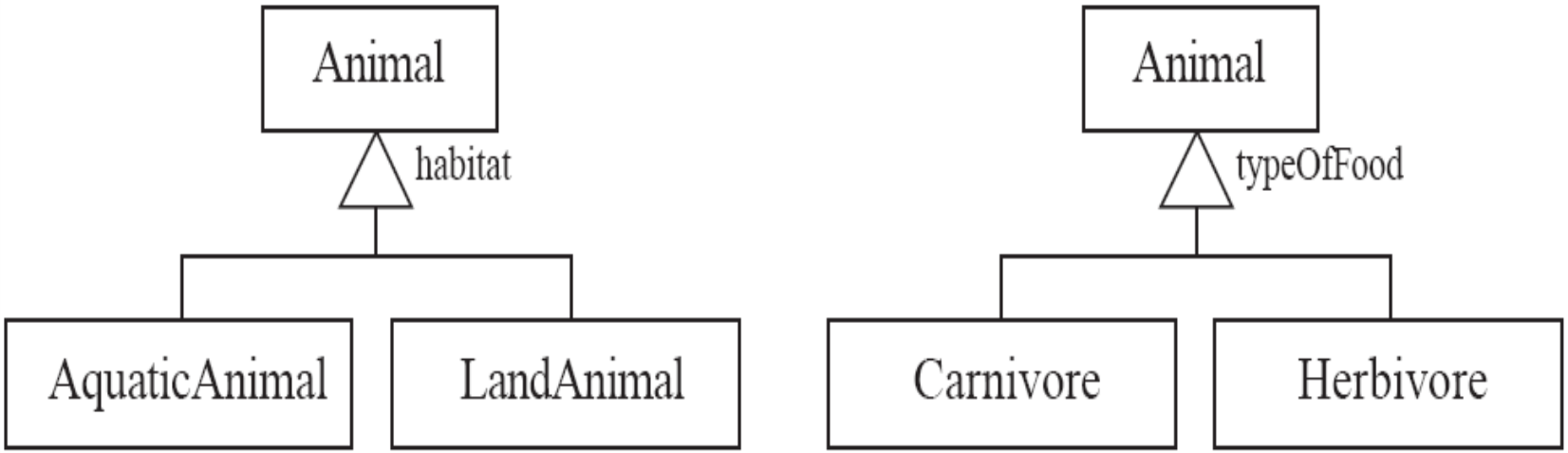
Add association classes to the following many to many associations and come up with at least one attribute for the new association class:



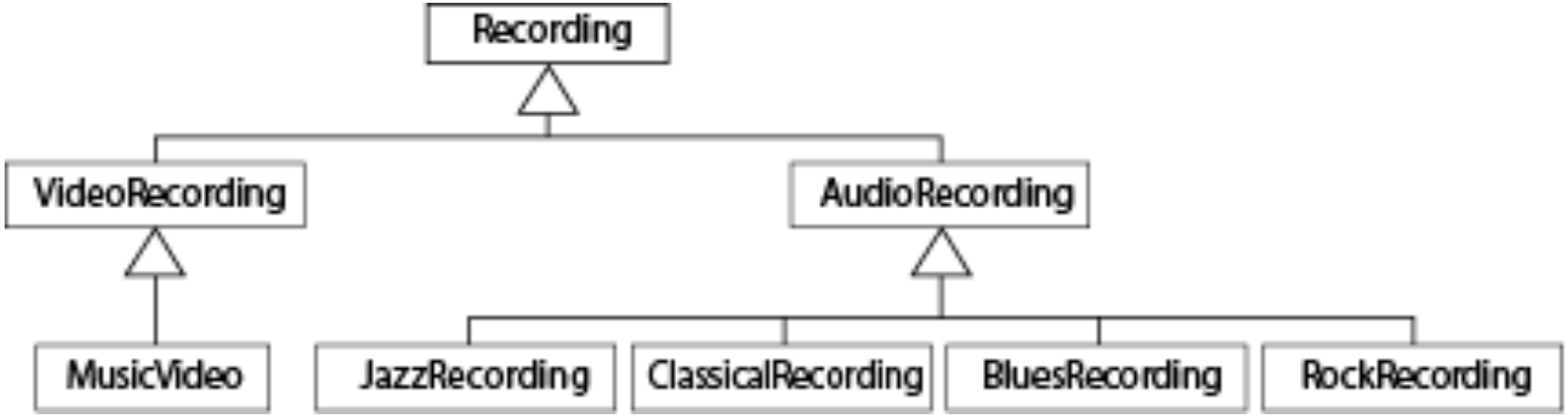
5.4 Generalization

Specializing a superclass into two or more subclasses

- The *discriminator* is a label that describes the criteria used in the specialization

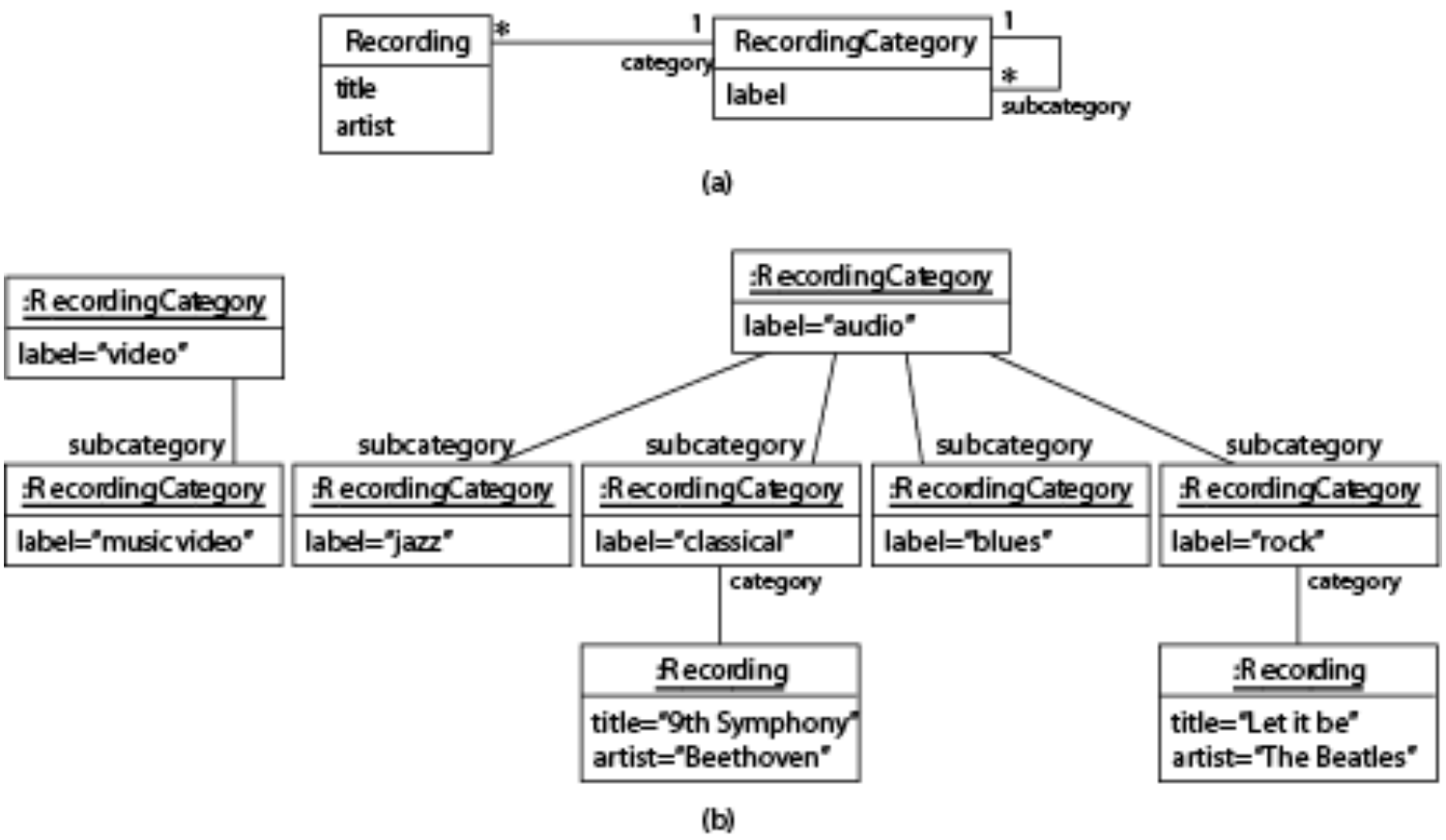


Avoiding unnecessary generalizations



Inappropriate hierarchy of classes, which should be instances
Ask yourself: Does this class require any operations that will be done differently than the other classes? If answer is no, don't make it a class!

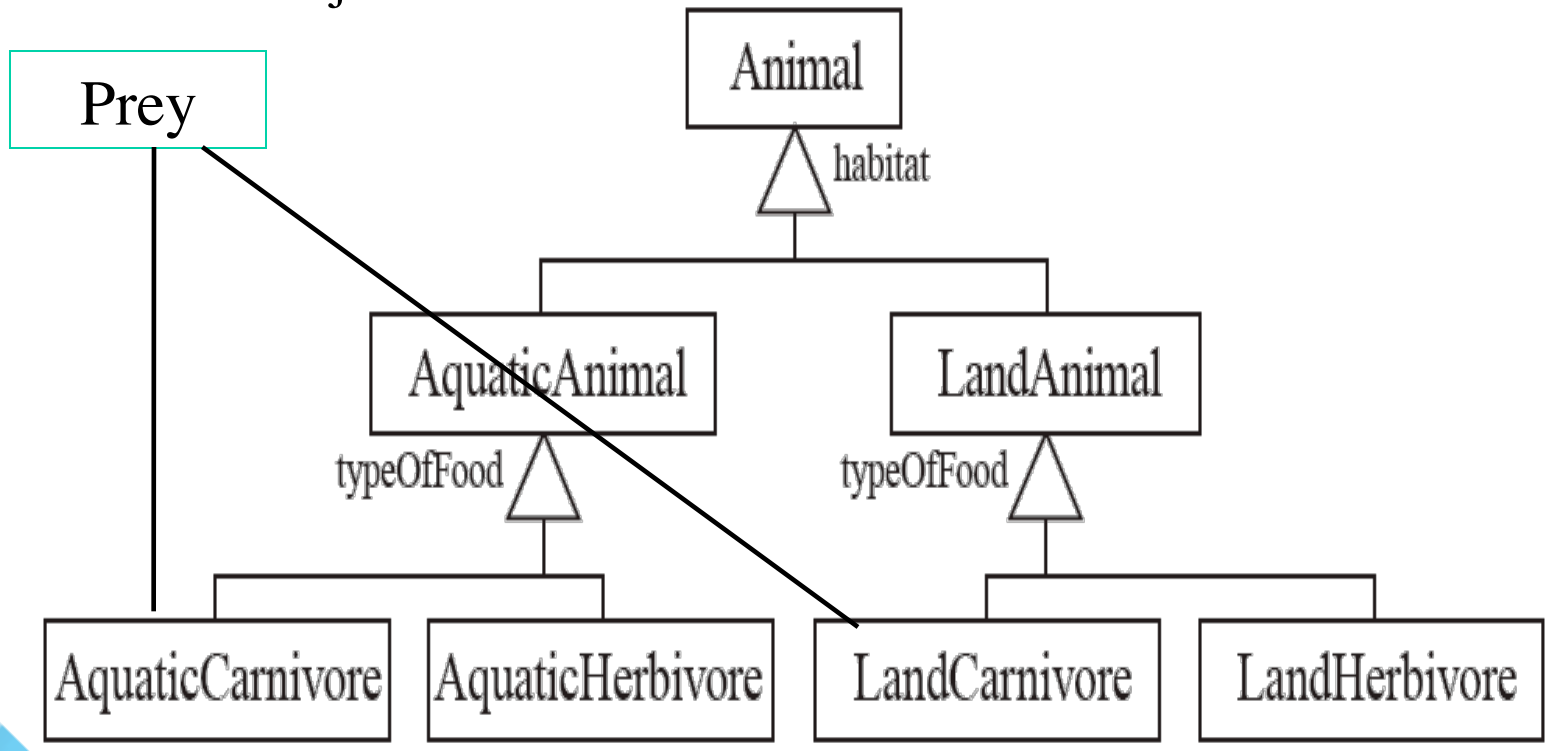
Avoiding unnecessary generalizations (cont)



Improved class diagram, with its corresponding instance diagram

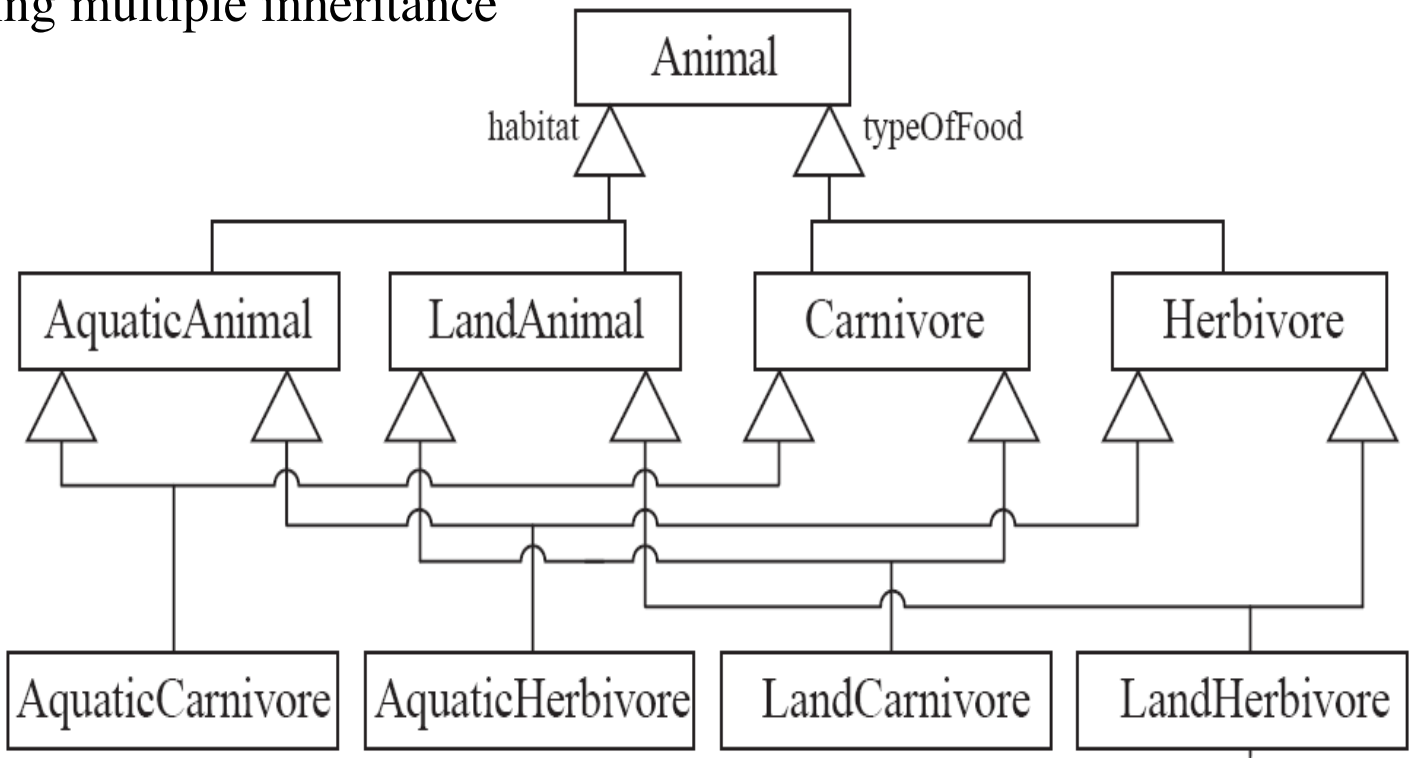
Handling multiple discriminators

- Creating higher-level generalization
- Say we had a Prey class, we would need TWO associations instead of just one.



Handling multiple discriminators

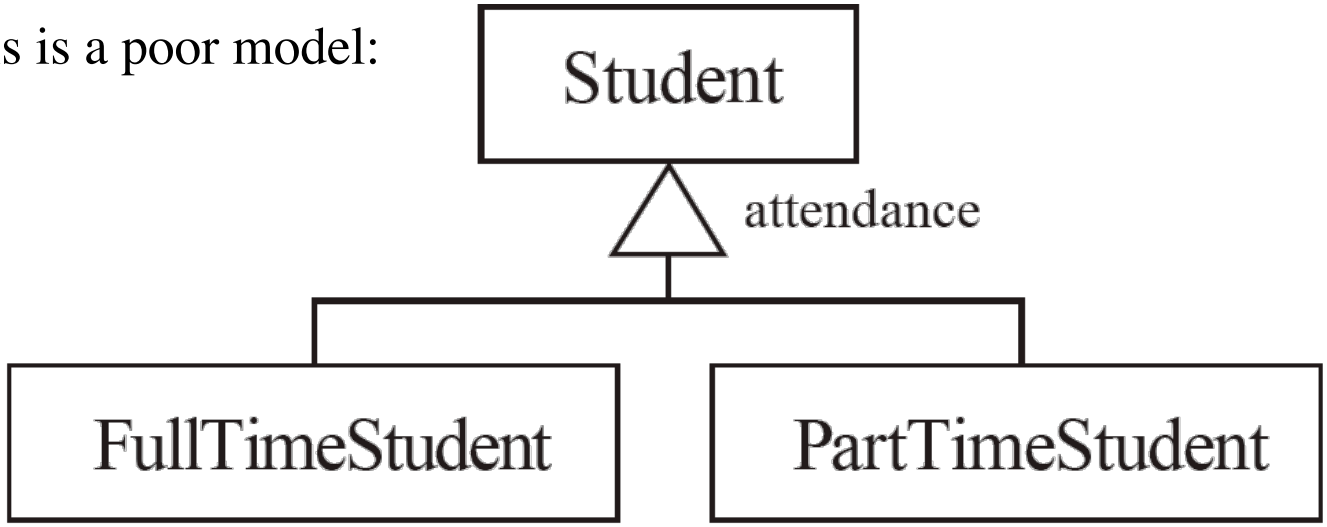
- Using multiple inheritance



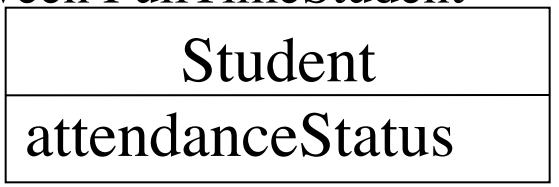
- Using the Player-Role pattern (in Chapter 6)

Avoiding having instances change class

- An instance should never need to change class
- This is a poor model:

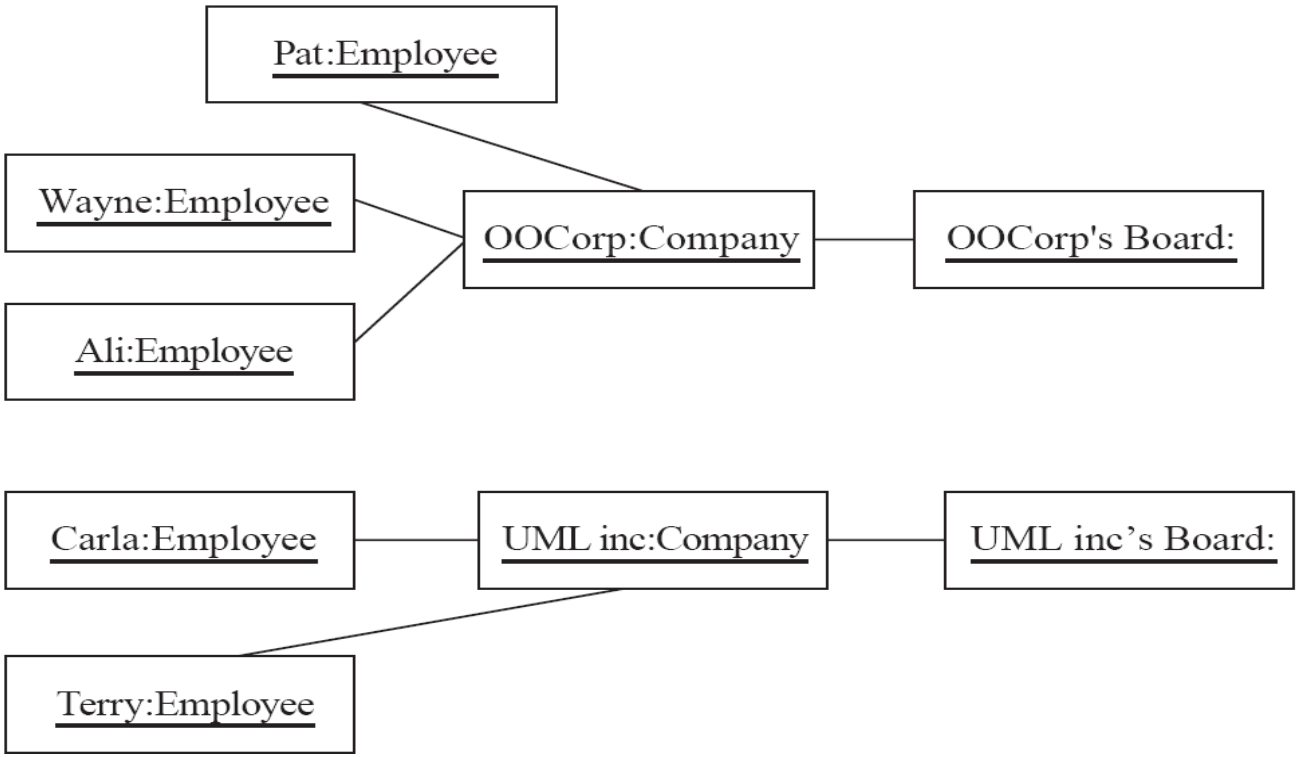


- A bit better solution, but then we lose the polymorphism advantage for any operations that differ between FullTimeStudent and PartTimeStudent:



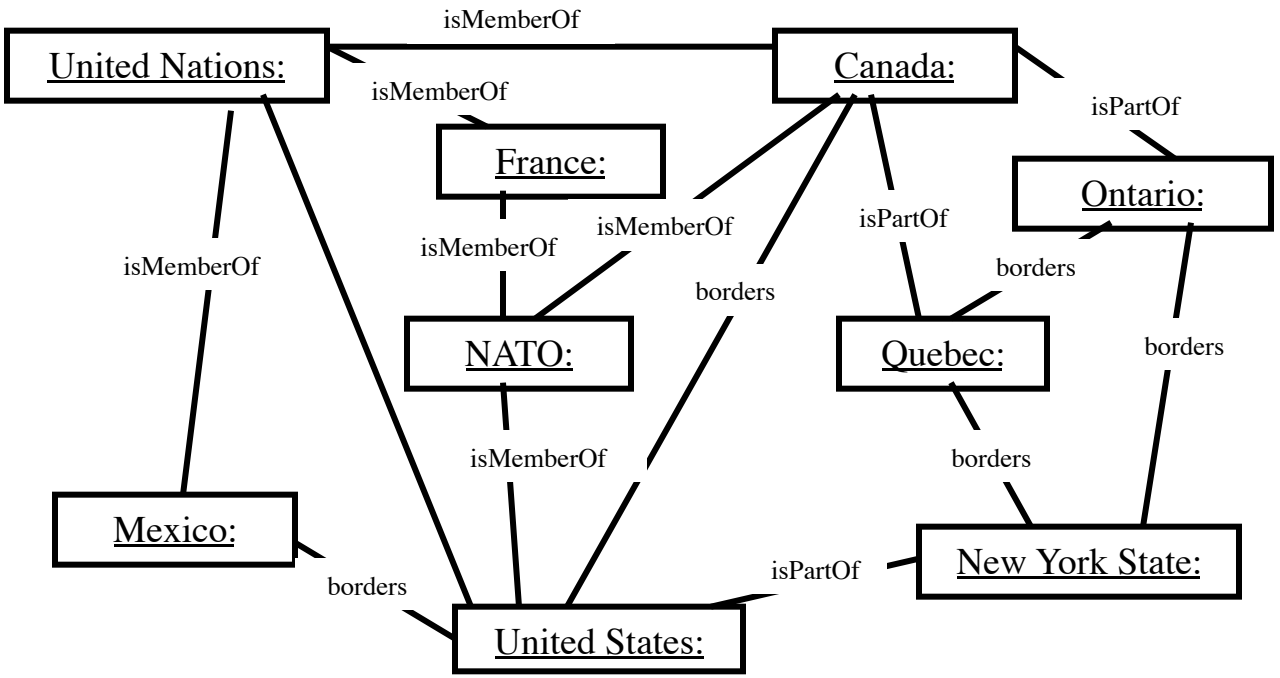
5.5 Object Diagrams

- A *link* is an instance of an association
  - —In the same way that we say an object is an instance of a class

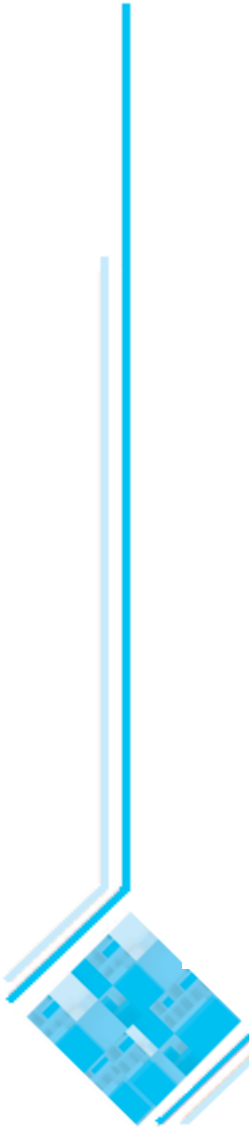


Question:

Draw a class diagram that could generate the object diagram shown below:



Your answer:

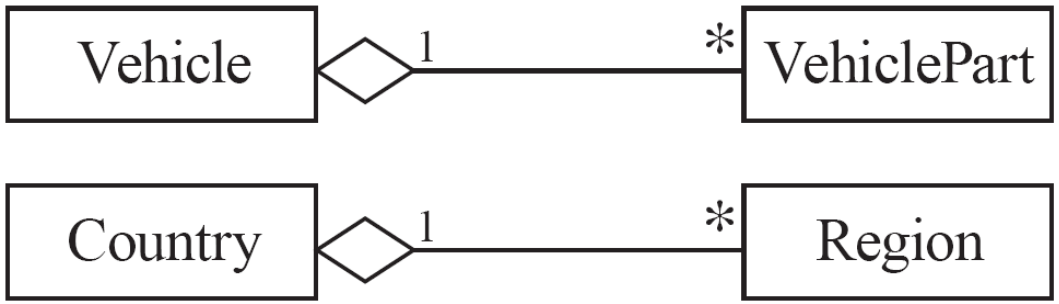


Associations versus generalizations in object diagrams

- Associations describe the relationships that will exist between *instances* at run time.
  - —When you show an instance diagram generated from a class diagram, there will be an instance of *both* classes joined by an association
- Generalizations describe relationships between *classes* in class diagrams.
  - —They do not appear in instance diagrams at all.
  - —An instance of any class should also be considered to be an instance of each of that class's superclasses

5.6 More Advanced Features: Aggregation

- Aggregations are special associations that represent 'part-whole' relationships.
  - —The 'whole' side is often called the *assembly* or the *aggregate*
  - —This symbol is a shorthand notation association named `isPartOf`

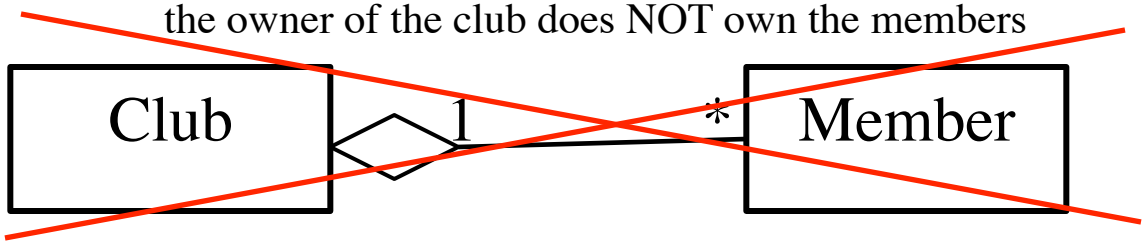


When to use an aggregation

As a general rule, you can mark an association as an aggregation if the following are true:

- You can state that
  - —the parts ‘are part of’ the aggregate
  - —or the aggregate ‘is composed of’ the parts
- When something owns or controls the aggregate, then they also own or control the parts

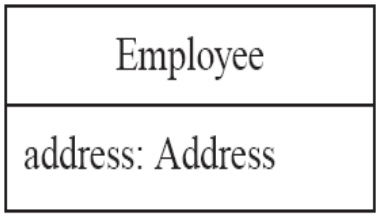
NOTE: Might be able to say a person is part of a club BUT the owner of the club does NOT own the members

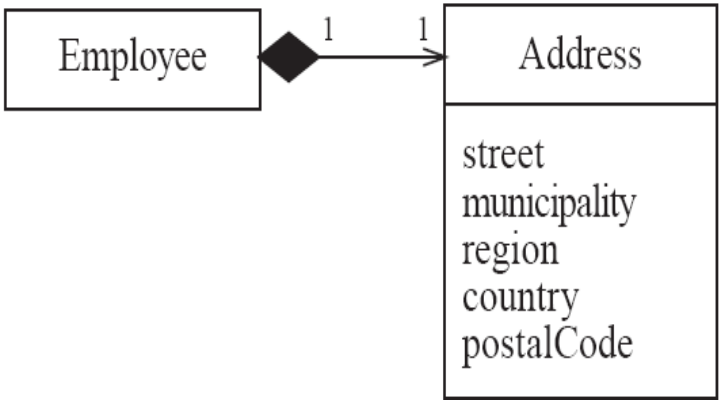


Composition

- A *composition* is a strong kind of aggregation
  - —if the aggregate is destroyed, then the parts are destroyed as well

- Two alternatives for addresses





Propagation

- A mechanism where an operation in an aggregate is implemented by having the aggregate perform that operation on its parts
- At the same time, properties of the parts are often propagated back to the aggregate
- Propagation is to aggregation as inheritance is to generalization.
  - —The major difference is:
    - inheritance is an implicit mechanism
    - propagation has to be programmed when required
  - —Eg. Deleting a polygon means deleting the line segments

- Marking a part-whole association as an aggregation using the diamond symbol is optional. Leaving it as an ordinary association is not an error, whereas marking a non-aggregation with a diamond is an error, therefore, **when in doubt, leave it out!**

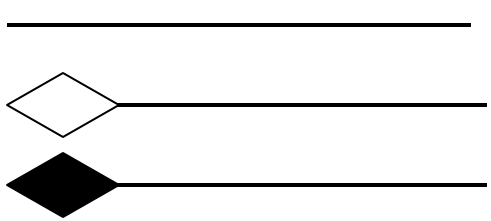
Question

For each of the following associations, indicate whether it should be

an *ordinary association*

a *standard aggregation*

a *composition*



a) A person and his/her brain

b) A school and its teachers

c) A book and its chapters

Composition in Code

```
public class Car {

  private VehiclePart engine;

  public Car() {
    this.engine = new Engine();
  }

}
```

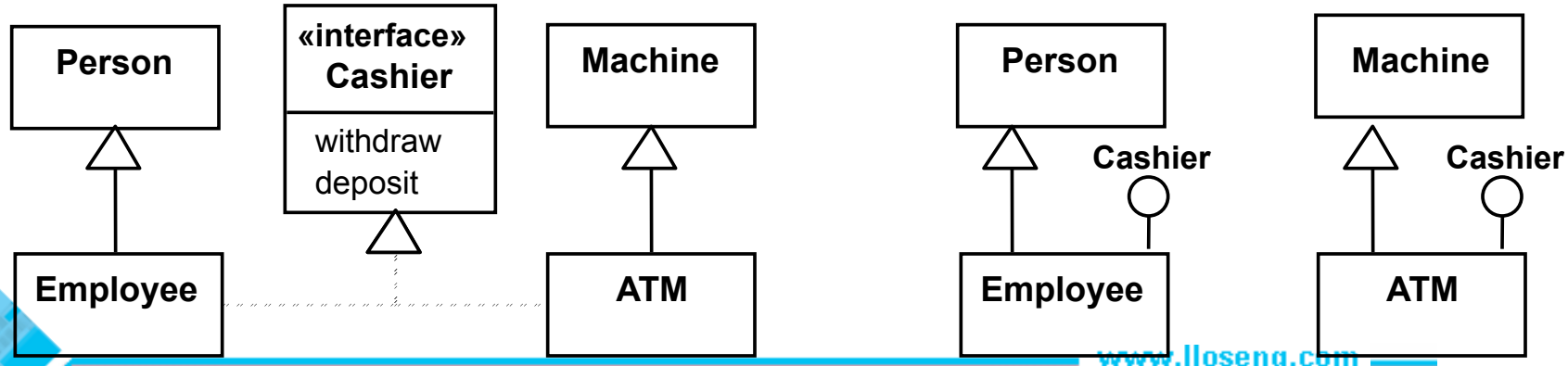
Aggregation in Code

```
public class Car {

  private VehiclePart engine;

  public Car(VehiclePart engine) {
    this.engine = engine;
  }

}
```

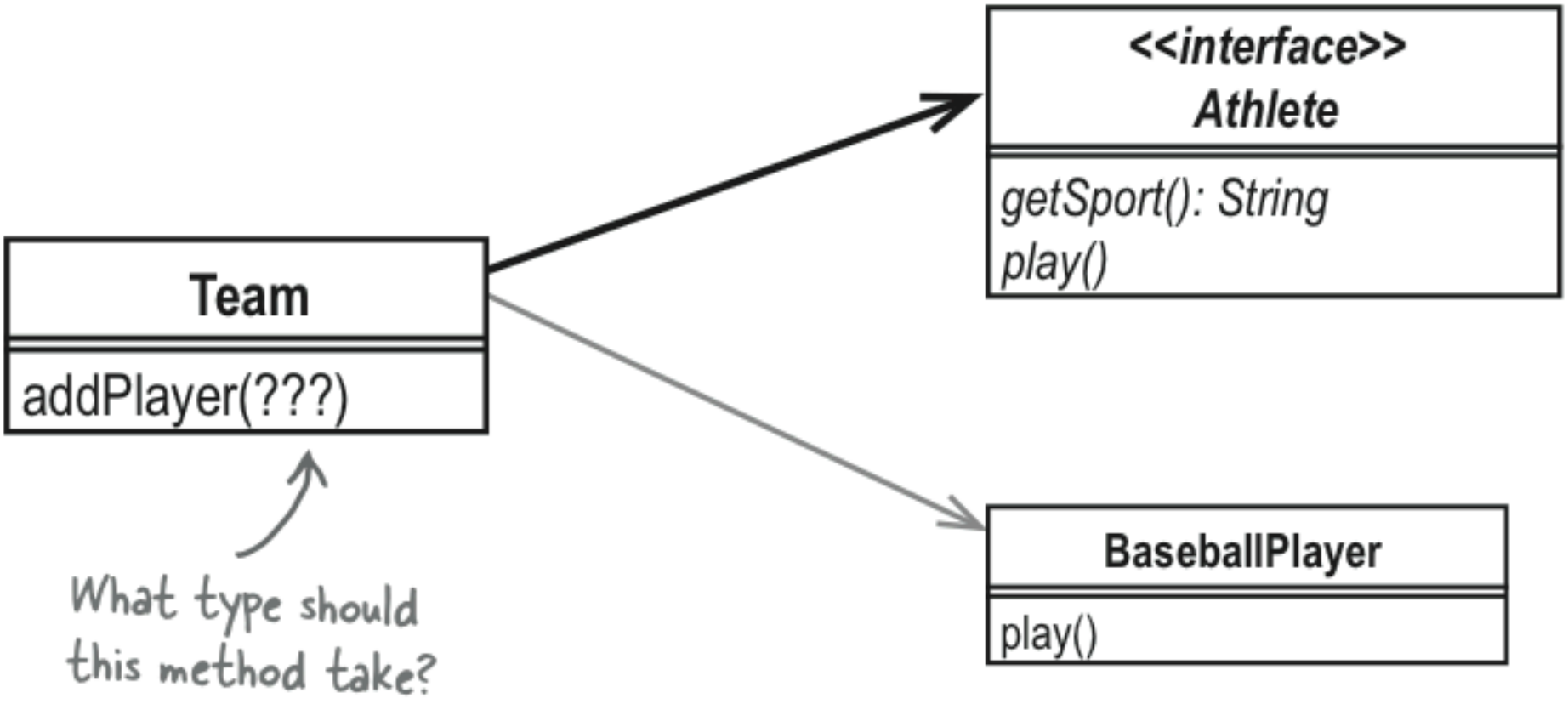
Interfaces

An interface describes a *portion of the visible behaviour* of a set of objects.

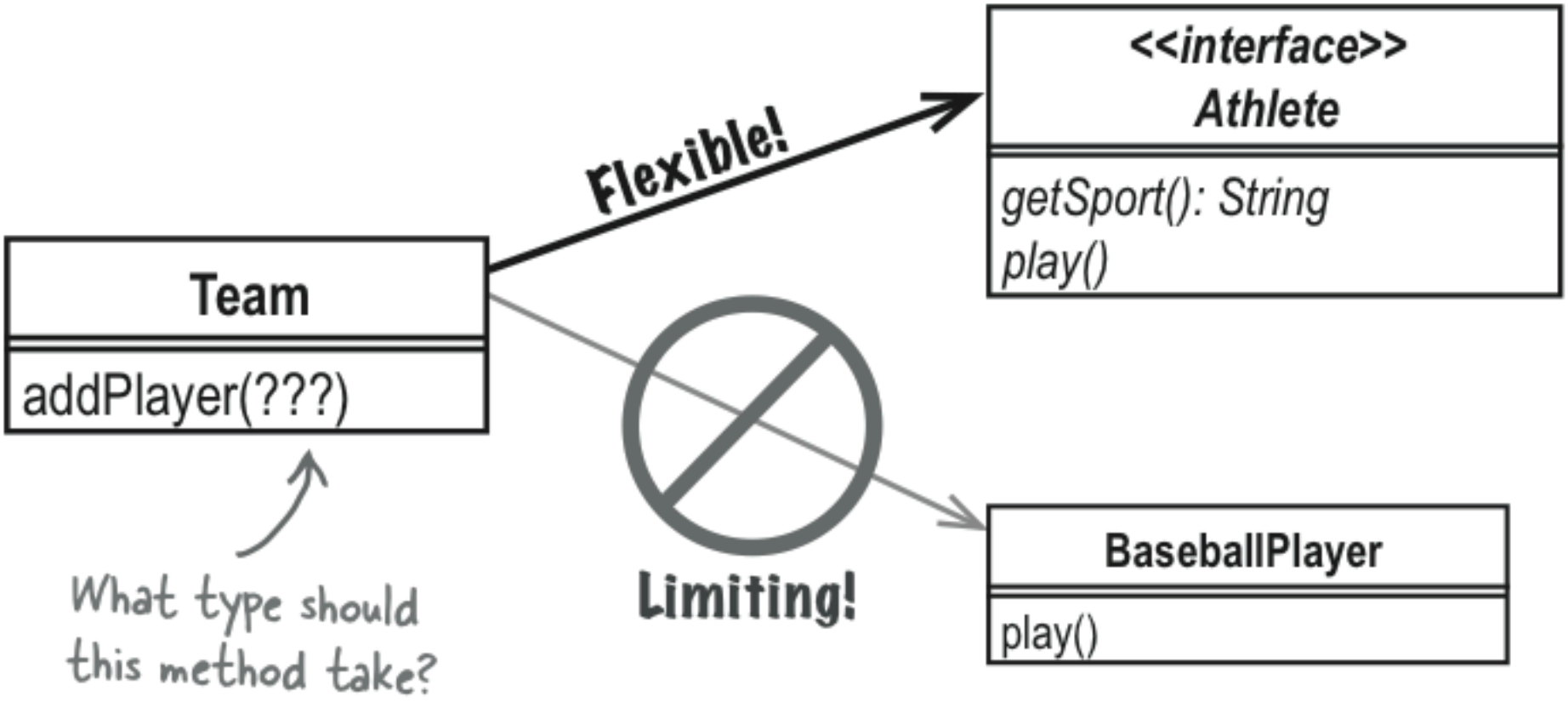
- An *interface* is similar to a class, except it lacks instance variables and implemented methods
- Although Employee and ATM share common operations they have different superclasses. This means they cannot be put in the same inheritance hierarchy; therefore the interface called Cashier is used
- A key advantage of using interfaces is that they can reduce what is called *coupling* between classes.
- Inheritance indicates an ***is-a*** relationship, interfaces indicate a ***can-be-seen-as*** relationship



Interfaces



Interfaces



5.9 The Process of Developing Class Diagrams

You can create UML models at different stages and with different purposes and levels of details

- **Exploratory domain model**:
  - —Developed in domain analysis to learn about the domain
- **System domain model**:
  - —Models aspects of the domain represented by the system
- **System model**:
  - —Includes also classes used to build the user interface and system architecture

System domain model vs System model

- The *system domain model* omits many classes that are needed to build a complete system
  - —Can contain less than half the classes of the system.
  - —Should be developed to be used independently of particular sets of
    - user interface classes
    - architectural classes
- The complete *system model* includes
  - —The system domain model
  - —User interface classes
  - —Architectural classes such as the database, files, servers, clients
  - —Utility classes

Suggested sequence of activities

- Identify a first set of candidate **classes**
- Add **associations** and **attributes**
- Find **generalizations**
- List the main **responsibilities** of each class
- Decide on specific **operations**
- **Iterate** over the entire process until the model is satisfactory
  - —Add or delete classes, associations, attributes, generalizations, responsibilities or operations
  - —Identify interfaces
  - —Apply design patterns (Chapter 6)

Don't be too disorganized. Don't be too rigid either.

Identifying classes

- When developing a domain model you tend to *discover* classes
- When you work on the user interface or the system architecture, you tend to *invent* classes
  - —Needed to solve a particular design problem
  - —(Inventing may also occur when creating a domain model)
- Reuse should always be a concern
  - —Frameworks
  - —System extensions
  - —Similar systems

A simple technique for discovering domain classes

- Look at a source material such as a description of requirements
- Extract the *nouns* and *noun phrases*
- Eliminate nouns that:
  - —are redundant
  - —represent instances
  - —are vague or highly general
  - —not needed in the application. For example in a domain model, you would eliminate classes that represent command or menus in the UI. As a rule of thumb, a class is only needed in a domain model if you have to store or manipulate instances of it in order to implement a requirement
- Pay attention to classes in a domain model that represent *types of users* or other actors

Identifying associations and attributes

- Start with classes you think are most **central** and important
- Decide on the clear and obvious data it must contain and its relationships to other classes.
- Work outwards towards the classes that are less important.
- Avoid adding many associations and attributes to a class
  - —A system is simpler if it manipulates less information

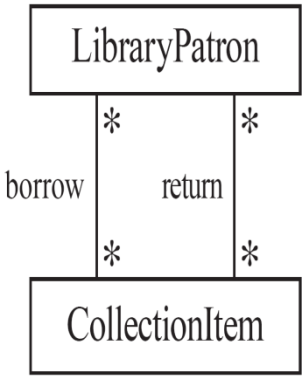
Tips about identifying and specifying valid associations

- An association should exist if a class
  - *possesses*
  - *controls*
  - *is connected to*
  - *is related to*
  - *is a part of*
  - *has as parts*
  - *is a member of*, or
  - *has as members*

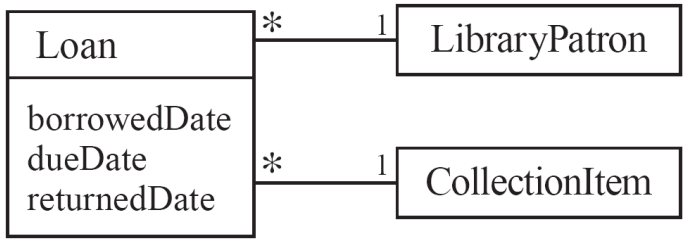
  some other class in your model
- Specify the multiplicity at both ends
- Label it clearly.

Actions versus associations

- A common mistake is to represent *actions* as if they were associations



Bad, due to the use of associations that are actions



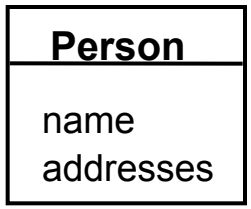
Better: The **`borrow`** operation creates a **Loan** object and the return operation set the **returnedDate** attribute

Identifying attributes

- Look for information that must be maintained about each class
- Several nouns rejected as classes, may now become attributes
- An attribute should generally contain a simple value
  - —e.g. string, number

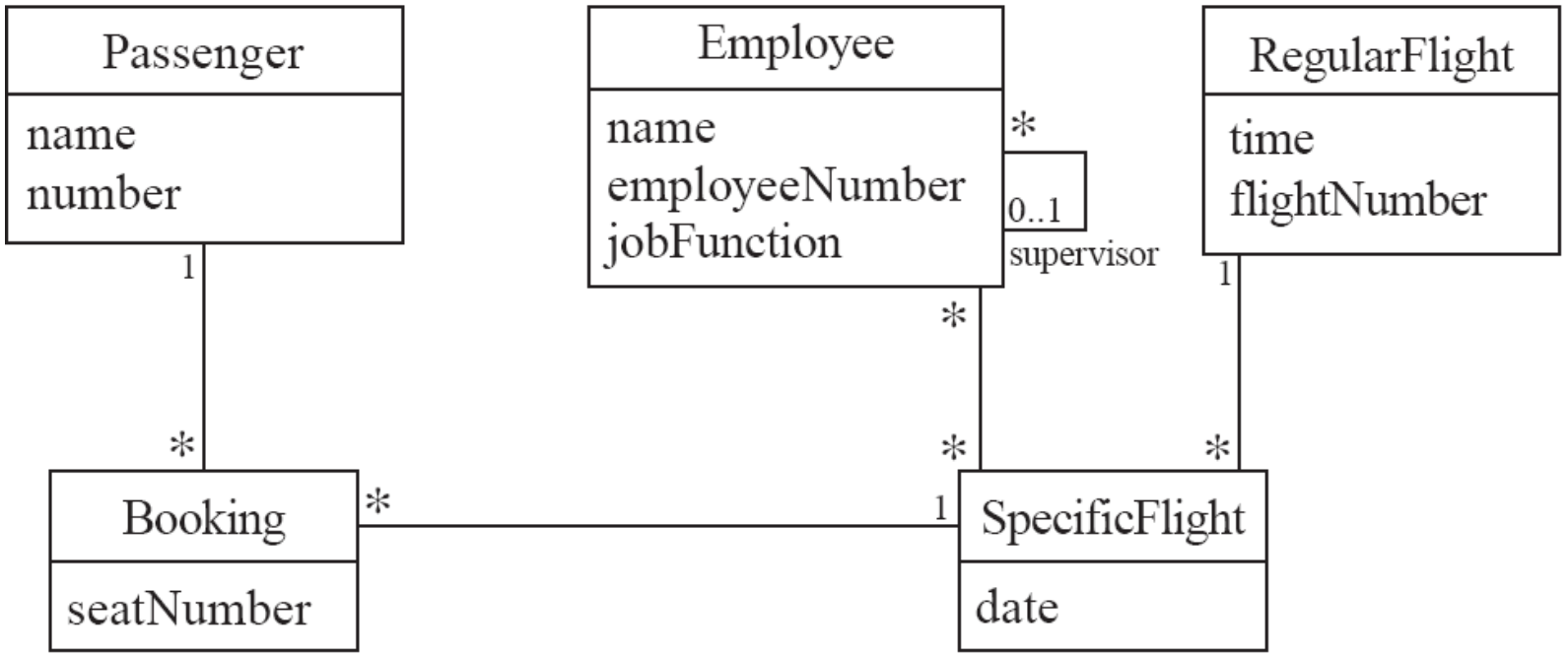
Tips about identifying and specifying valid attributes

- It is not good to have many duplicate attributes
- If a subset of a class' attributes form a coherent group, then create a distinct class containing these attributes



Bad due to a plural attribute

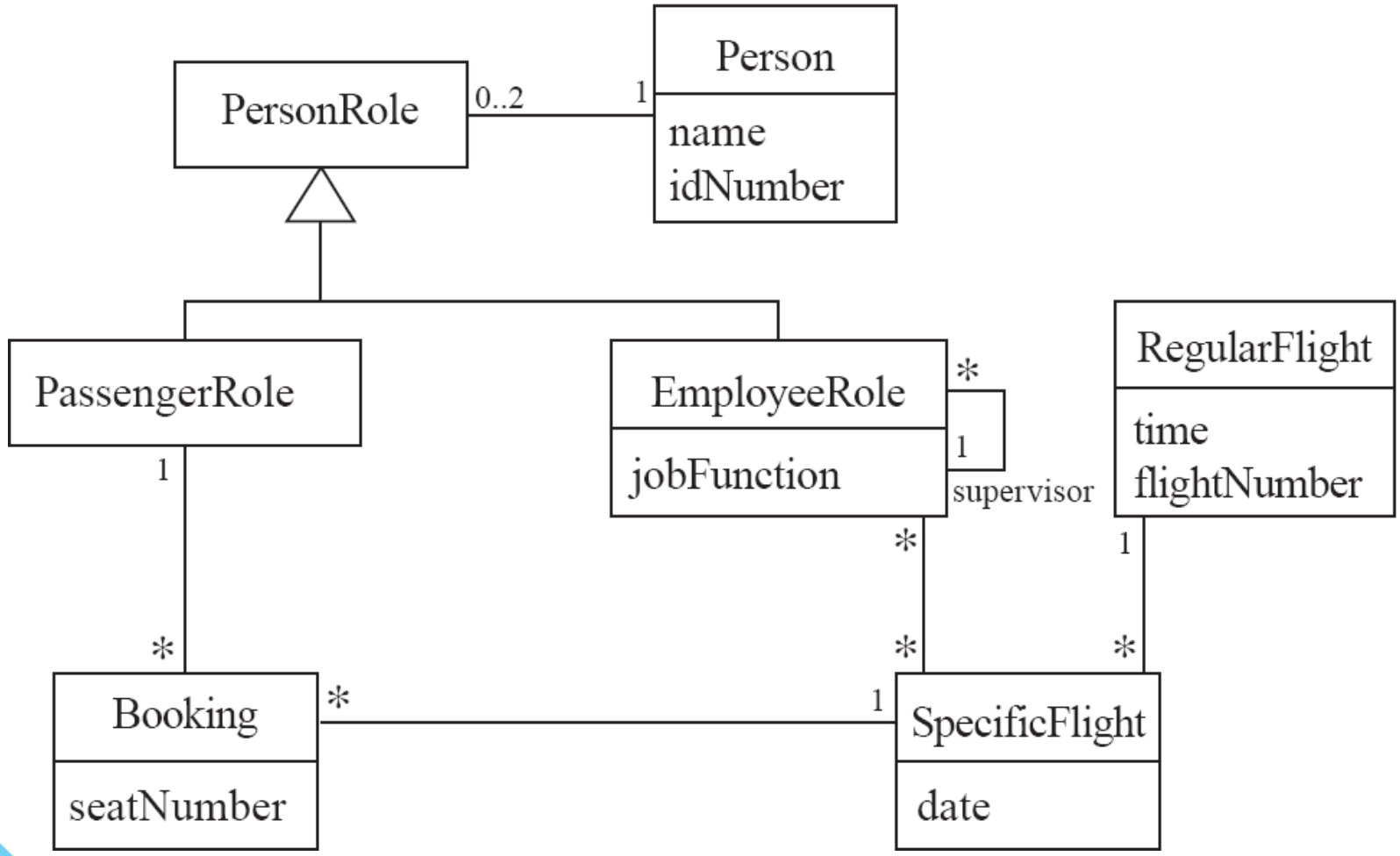
An example (attributes and associations)



Identifying generalizations and interfaces

- There are two ways to identify generalizations:
  - —bottom-up
    - Group together similar classes creating a new superclass
  - —top-down
    - Look for more general classes first, specialize them if needed
- Create an *interface*, instead of a superclass if
  - —The classes are very dissimilar except for having a few operations in common
  - —One or more of the classes already have their own superclasses
  - —Different implementations of the same class might be available

An example (generalization)



Allocating responsibilities to classes

A *responsibility* is something that the system is required to do.

- Each functional requirement must be attributed to one of the classes
  - —All the responsibilities of a given class should be *clearly related*.
  - —If a class has too many responsibilities, consider *splitting* it into distinct classes
  - —If a class has no responsibilities attached to it, then it is probably *useless*
  - —When a responsibility cannot be attributed to any of the existing classes, then a *new class* should be created

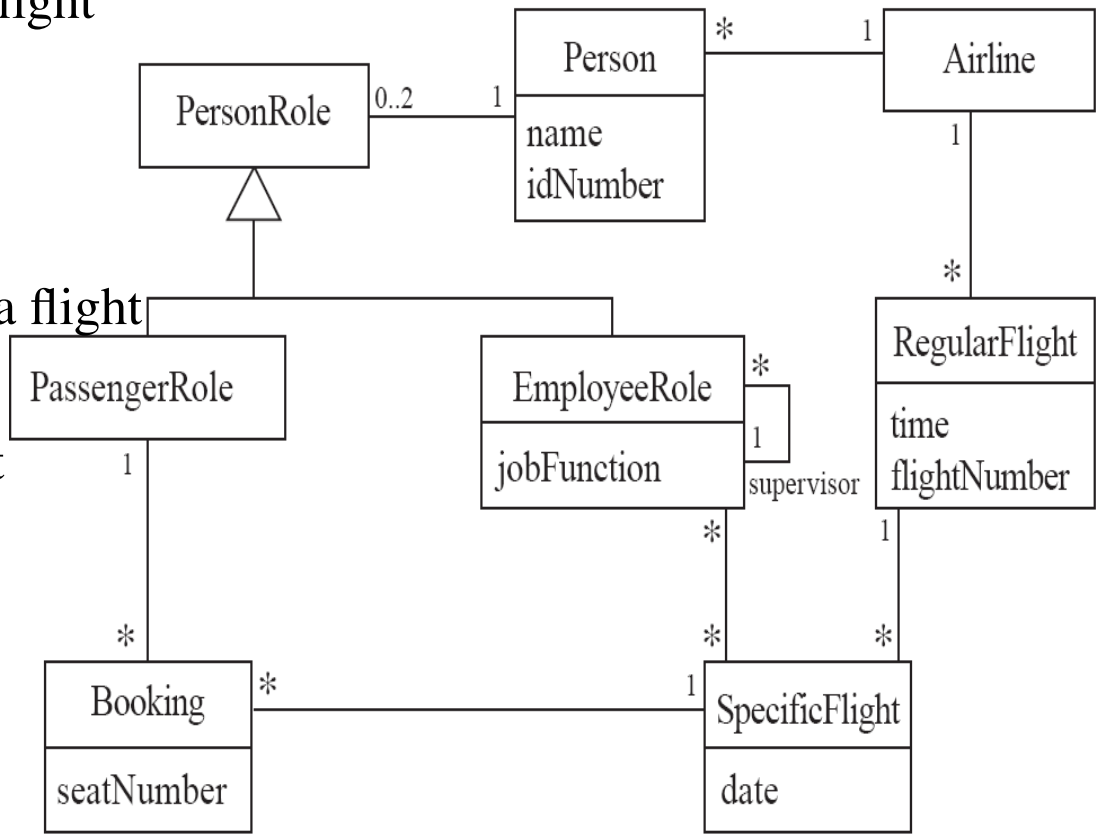
- To determine responsibilities
  - —Analyze your user stories
  - —Look for verbs and nouns describing *actions* in the system description

Categories of responsibilities

- Setting and getting the values of attributes
- Creating and initializing new instances
- Loading to and saving from persistent storage
- Destroying instances
- Adding and deleting links of associations
- Copying, converting, transforming, transmitting or outputting
- Computing numerical results
- Navigating and searching
- Other specialized work

An example (responsibilities)

- Creating a new regular flight
- Searching for a flight
- Modifying attributes of a flight
- Creating a specific flight
- Booking a passenger
- Canceling a booking



Prototyping a class diagram on paper

- As you identify classes, you write their names on small cards
- As you identify attributes and responsibilities, you list them on the cards
  - If you cannot fit all the responsibilities on one card:
    - this suggests you should split the class into two related classes.
- Move the cards around on a whiteboard to arrange them into a class diagram.
- Draw lines among the cards to represent associations and generalizations.