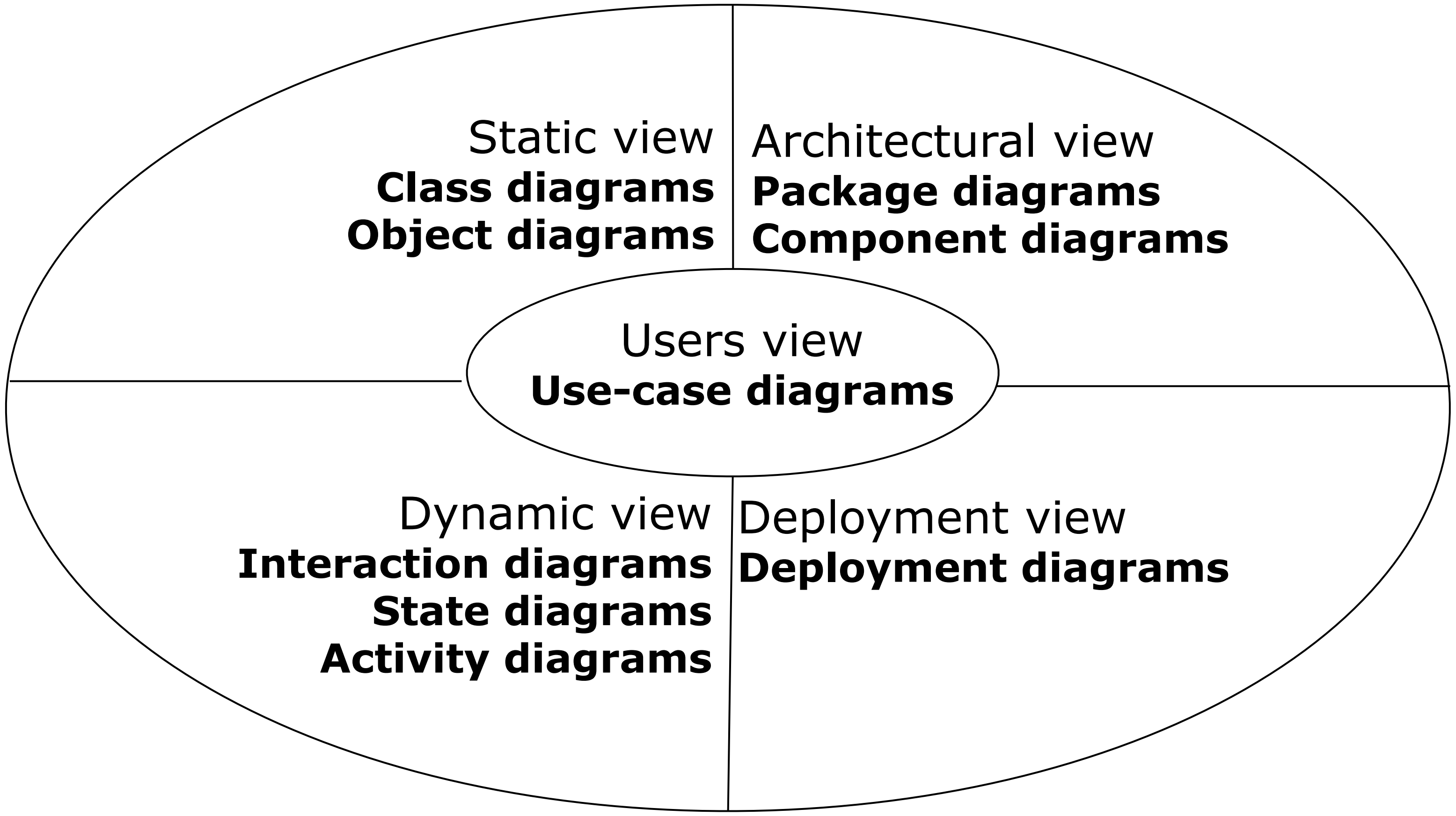
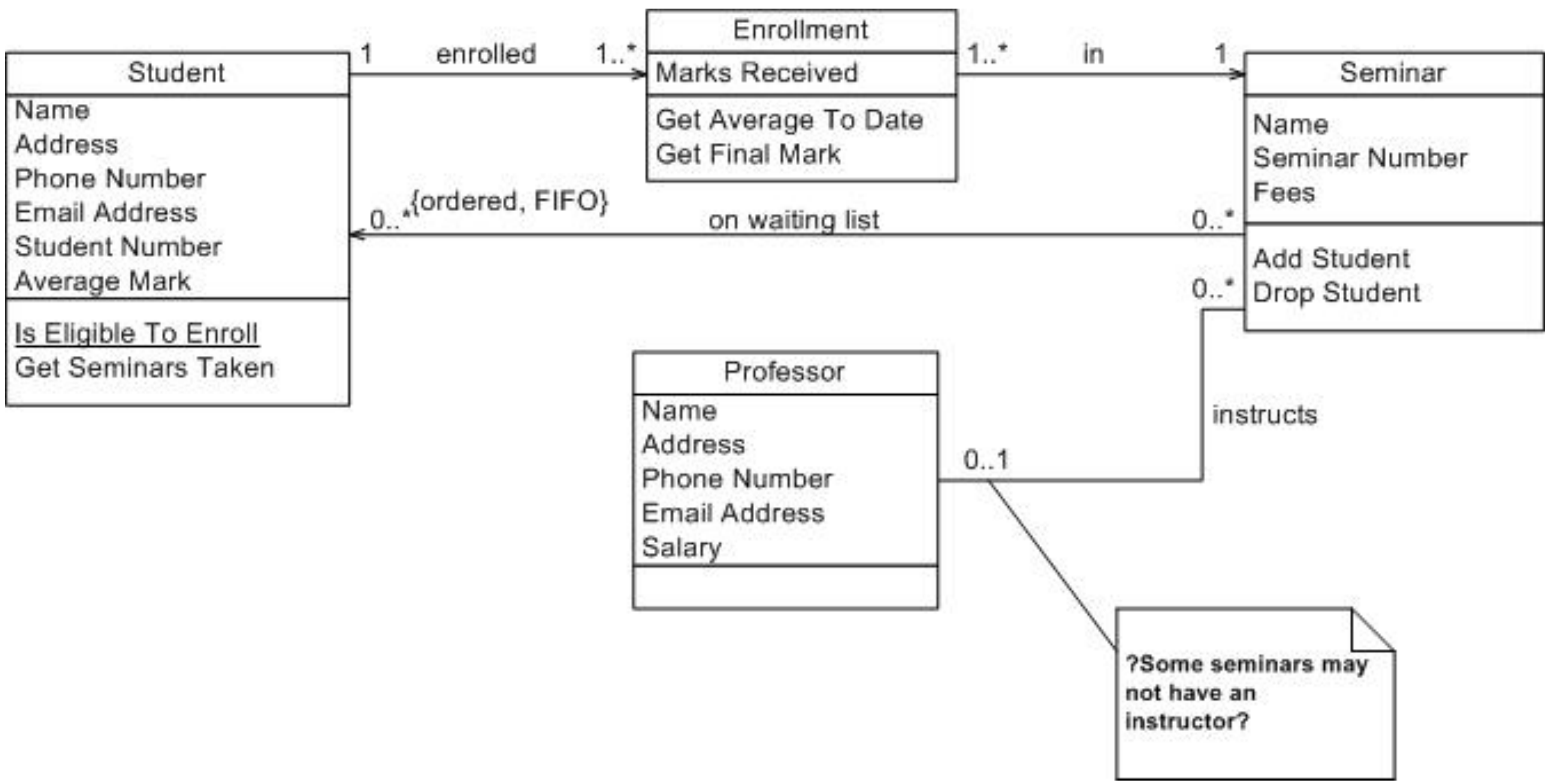
Modelling static structure

- Class diagrams
- Object diagrams



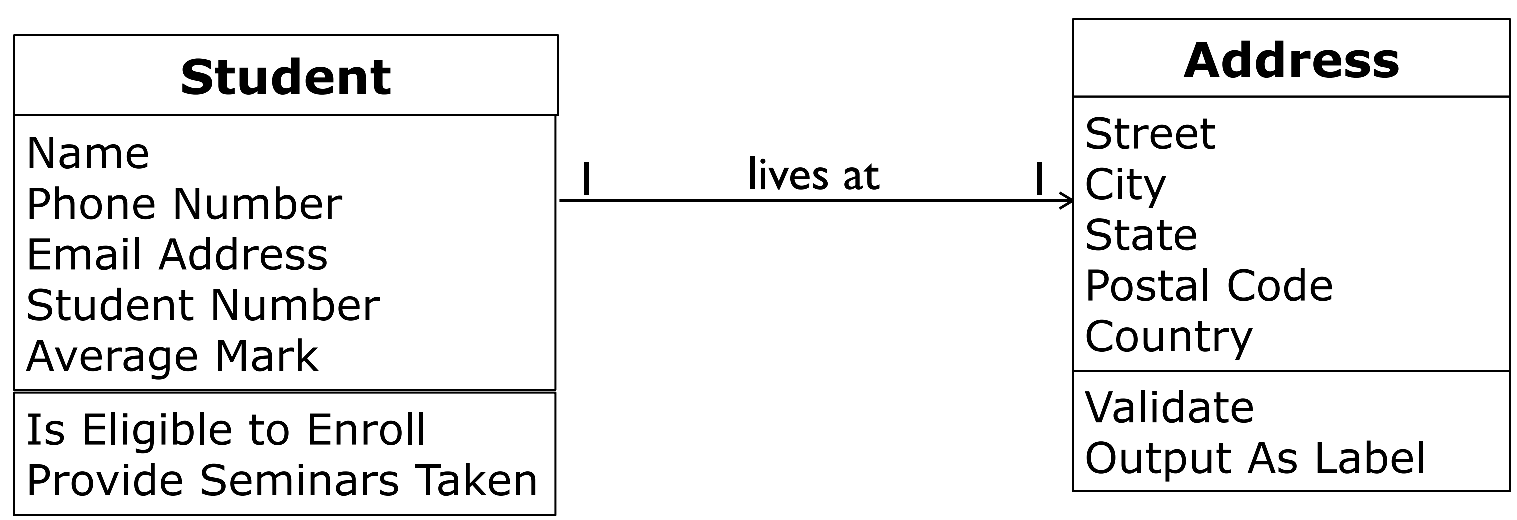
Class diagrams

- Class diagrams
  - consist of a set of classes, interfaces and their relationships
  - represent the **static view** of the system
  - can produce / build the **skeleton** of the system
- Modelling class diagrams is the **essential step** in object-oriented design



Analysis Class Diagram

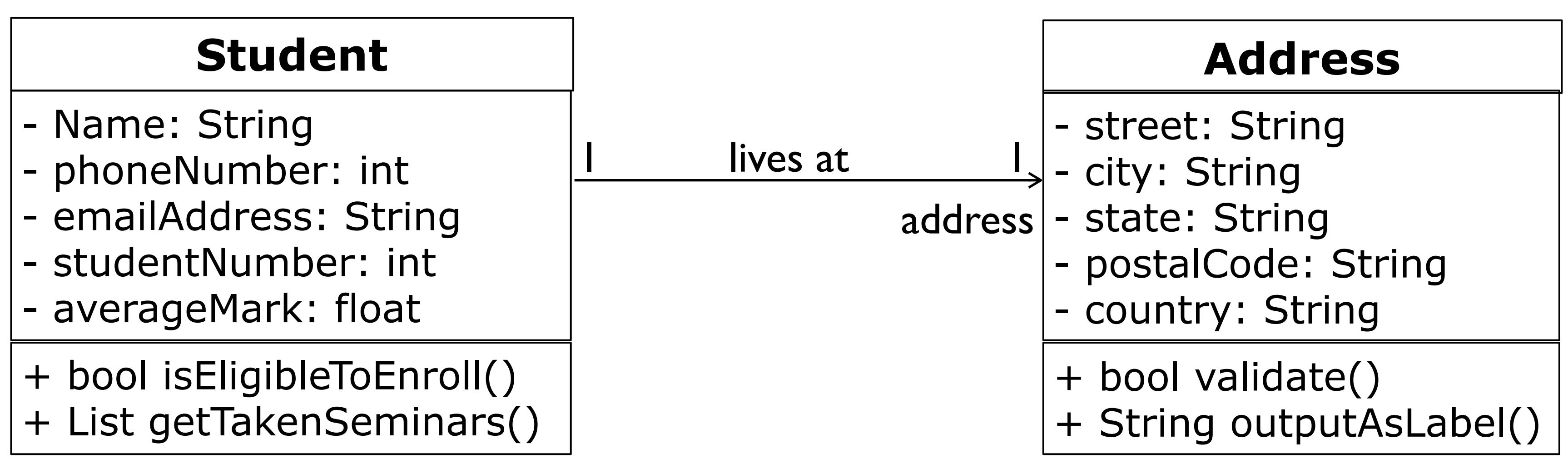
- Conceptual/analysis class diagram (domain model)
  - is constructed in the analysis phase
  - captures the concepts recognised by user/customer/stakeholder
  - doesn’t contain information of how the software system should be implemented



Analysis class diagram

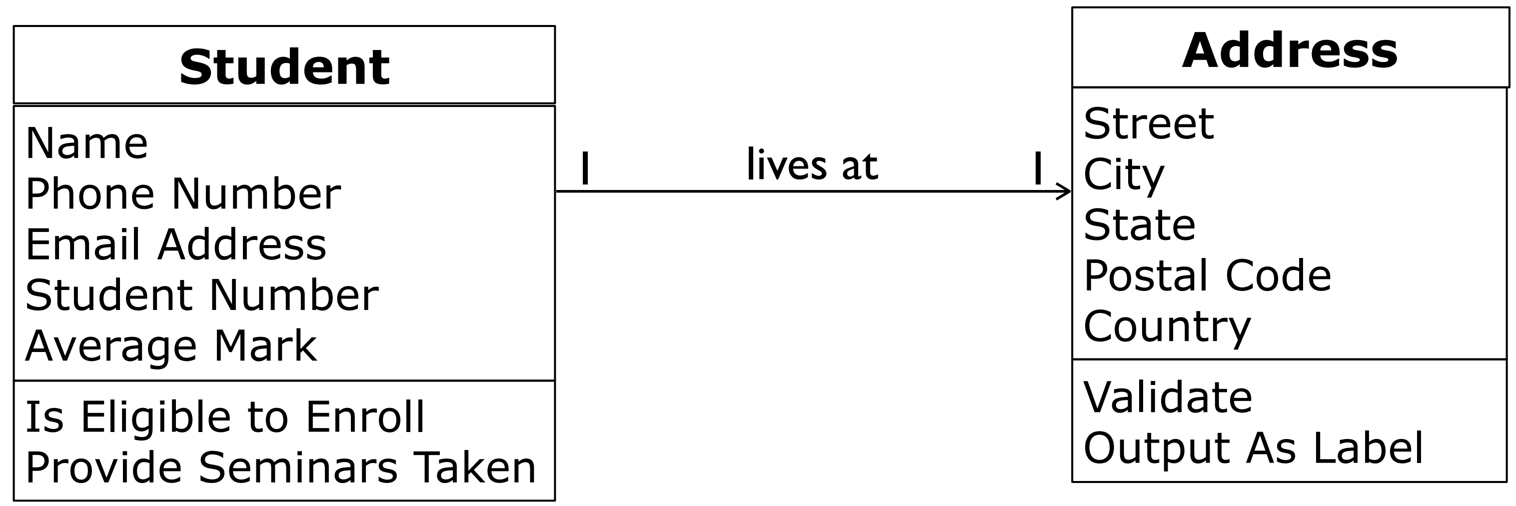
Design Class Diagram

- Design class diagram
  - is construct in the design phase
  - a detail version of the analysis class diagram
    - an analysis class may correspond to several design classes
  - contains information about how the software system should be implemented
    - attributes’ and methods’ visibility
    - attributes’ and methods’ name conform to the target programming language

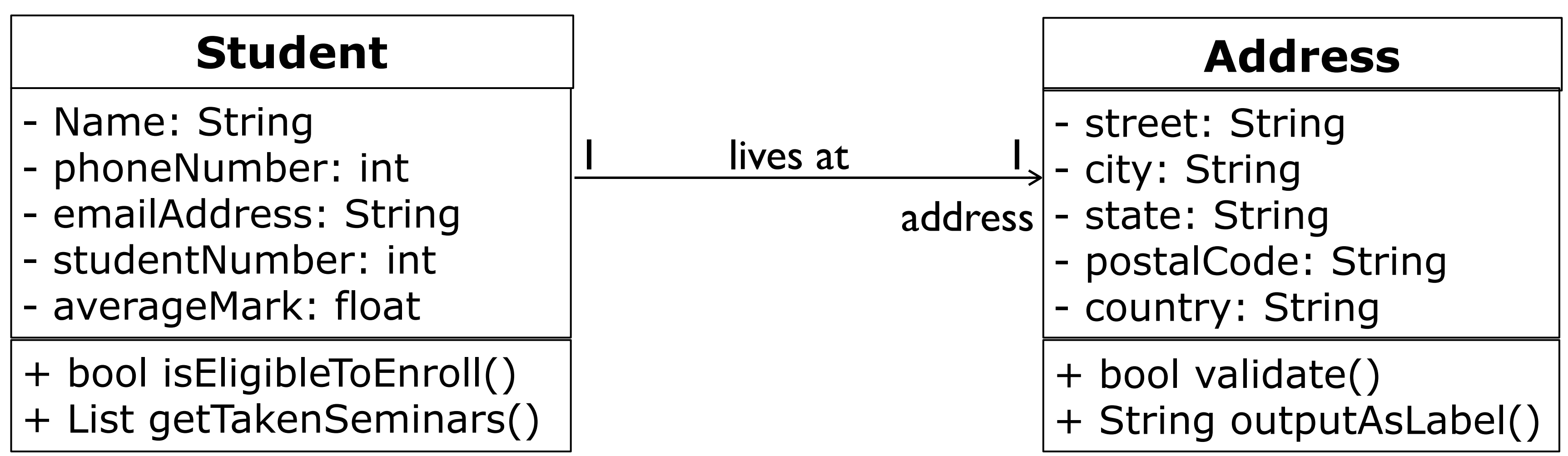


Design class diagram (for Java implementation)

Analysis Class Diagram v.s. Design Class Diagram



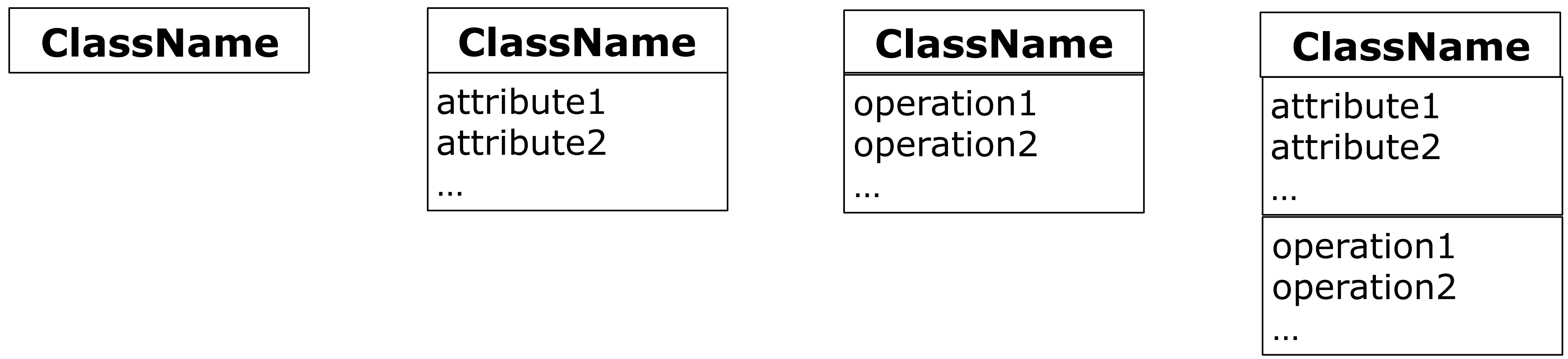
Analysis class diagram

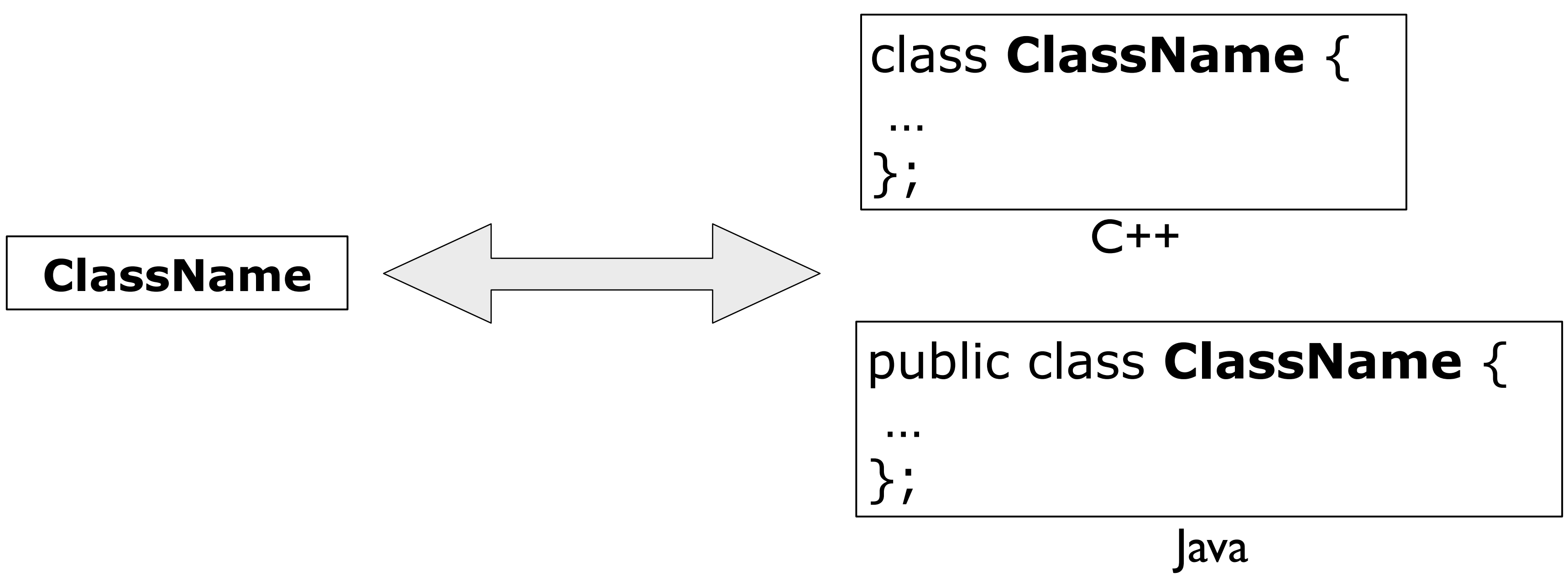


Design class diagram (for Java implementation)

Class

- UML class
  - represents the class or interface concept of object-oriented programming language
  - consists of a set of attributes and operation
  - can be graphically represented in several forms





Attributes

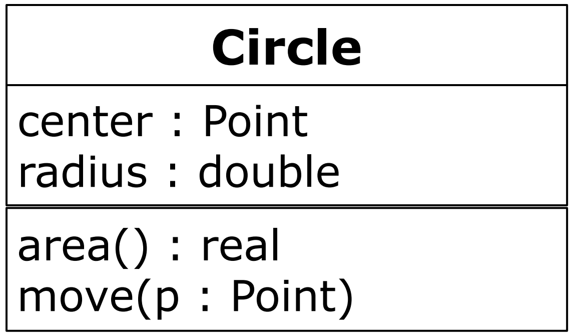
- Attributes represent the necessary data of class instances
- Attributes can have
  - a type
    - simple type
      - number : integer
      - length : double
      - text : string
    - complex type
      - center : point
      - date : Data
  - A value by default
    - number : integer = 10
  - A list of possible value
    - color : Color = red {red, blue, purple, yellow}

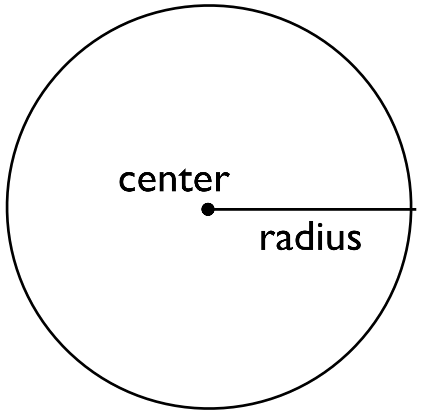
Person
name : string firstName : string dateOfBirth : Date nbChildren : integer = 0 married : Boolean = false profession : string = « not defined »

Operations / Methods

- Operations represent the **behaviours** of instance of the class
- The behaviour of a class includes
  - The **getters** and **setters** that manipulate the data of class instances
  - A certain number of tasks associated with the **responsibility** of the class

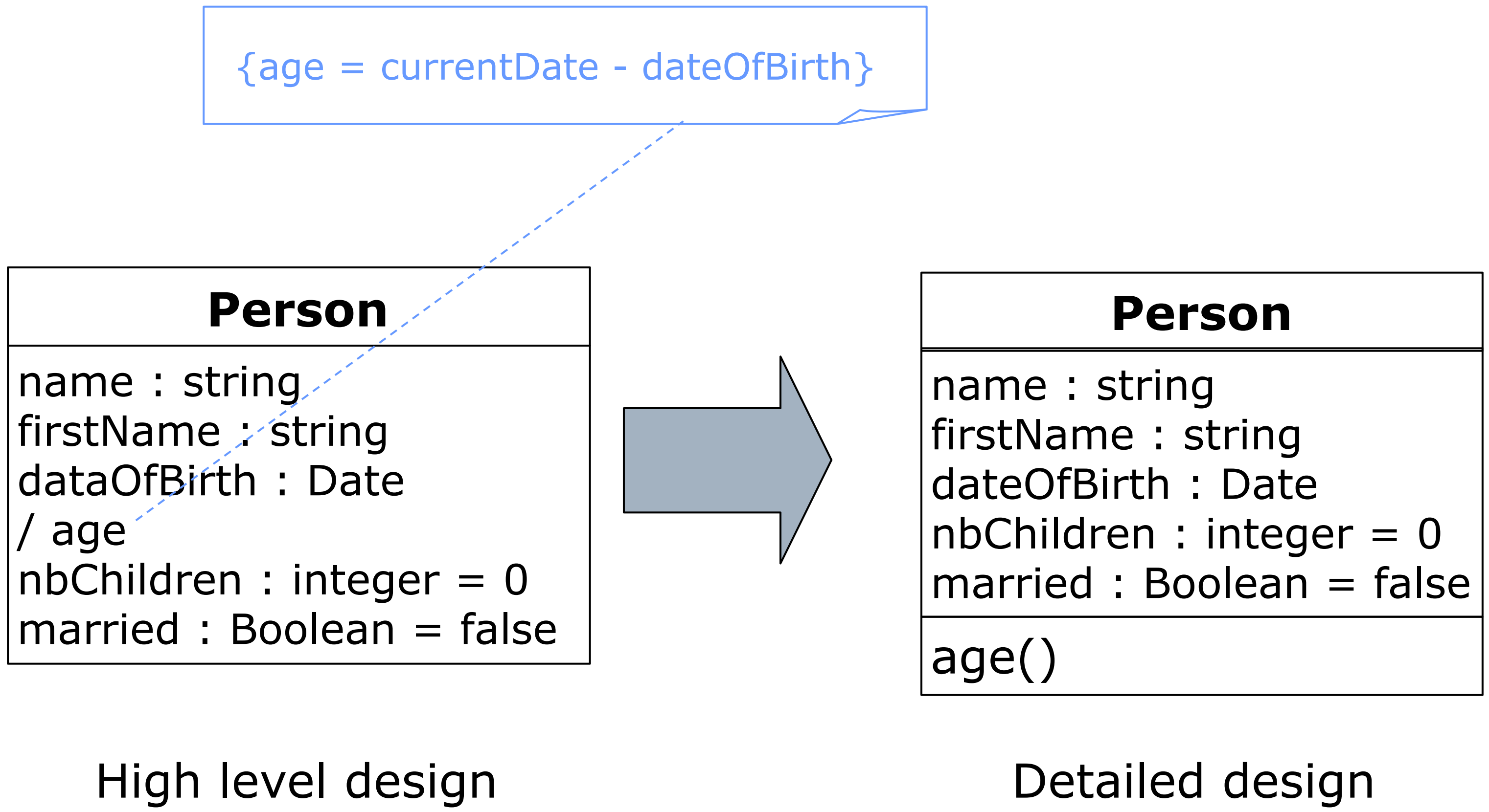
- Operations can have
  - a name
    - area, calculate, …
  - a returned type
    - area() : double
  - arguments with type
    - move(p : Point)





Derived attributes

- Attributes can be deducted from other attributes
  - age of a person can be derived from date of birth



Visibility

- Attributes and operations have the visibility
  - Public
    - visible outside the class
    - notation “ + ”
  - Protected
    - visible only to objects of the same class and objects of sub-classes
    - notation “ # “
  - Private
    - visible only to objects of the class
    - notation “ - “

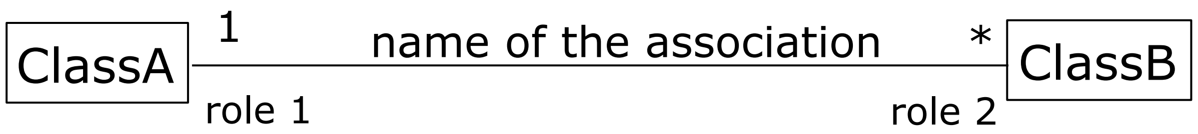
Shape
− origin : Point
+ setOrigin(p : Point) + getOrigin() : Point) + move(p : Point) + resize(s : real) + display() # pointInShape(p : Point) : Boolean

Relationship types

- Relationships between classes
  - Association
    - Semantic relation between classes
  - Inheritance
    - A class can inherit one or more classes
  - Aggregation
    - An association shows a class is a part of another class
  - Composition
    - A strong form of aggregation
  - Dependency
    - shows the dependency between classes

Association

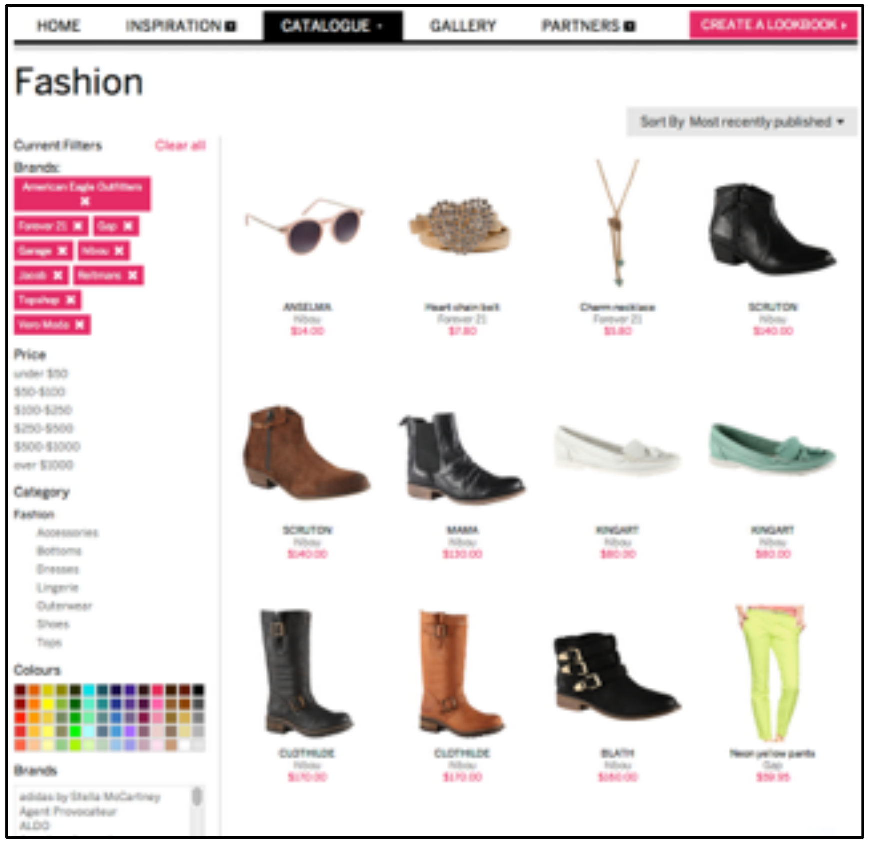
- An association
  - is used to show how two classes are linked together
  - expresses a bidirectional semantic connection between classes
  - is an abstraction of the links between instances of classes
  - Notation



  - Each end of an association is called a **role**
    - A role shows the purpose of the association
    - A role can have
      - an name
      - an expression of **multiplicity**

Association

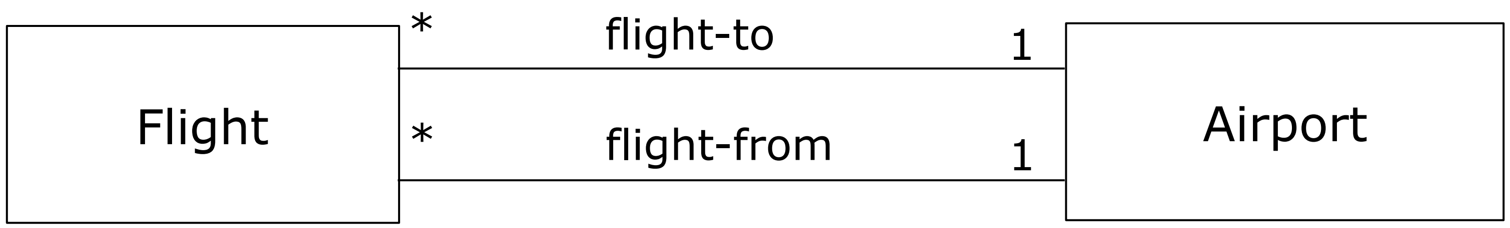
- Multiplicity
  - defines how many instances of a class A are associated with an instance of class B



  - Different expressions of multiplicity
    - 1 : one and only one
    - 0..1 : zero or only one
    - m..n : from m to n (integer, n >= m >= 0)
    - n : exactly n (integer, n >= 0)
    - * : zero or many
    - 1..* : from one to many

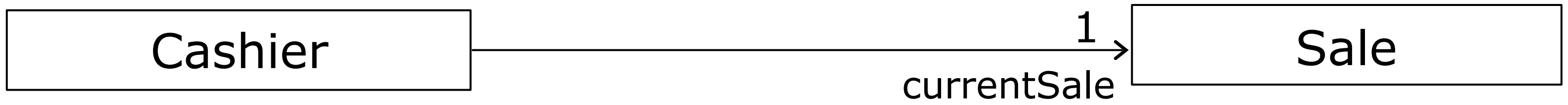
Association

- Multiple associations
  - Two classes can have several associations between them



Association

- Directional association and attributes
  - By default, the associations are bi-directional
  - However, associations can be directional
    - Example



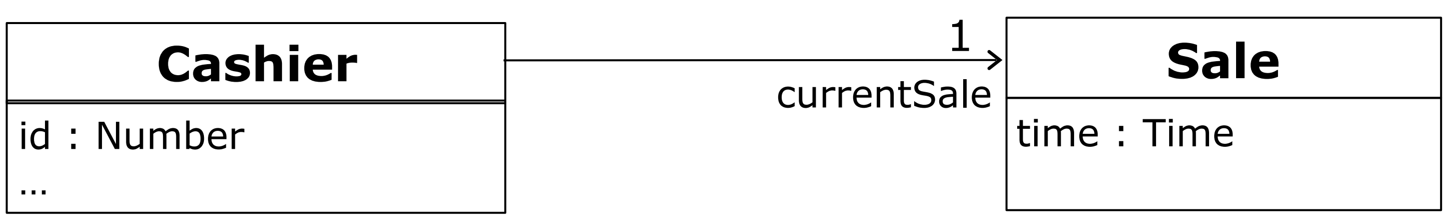
- The navigability pointing from *Cashier* to *Sale* shows that an attribute with *Sale* type
- This attribute is called *currentSale*

- Another form of representation: use of attributes

Association

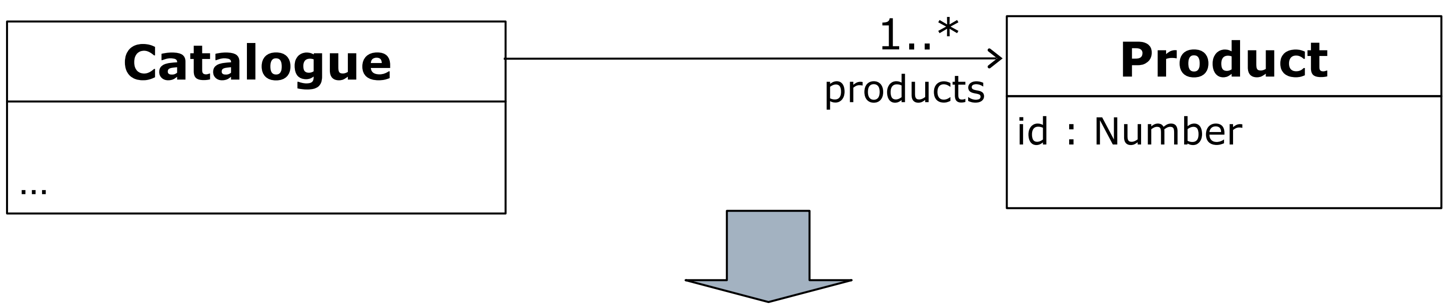
- Directional association and attributes
  - When do we use the directional association or attribute?
    - We use the attribute for “primitive” data types, such as Boolean, Time, Real, Integer, …
    - We use the directional association for other classes
      - To better see the connections between classes
    - It is just to better represent, these two ways are semantically equivalent

    - Example

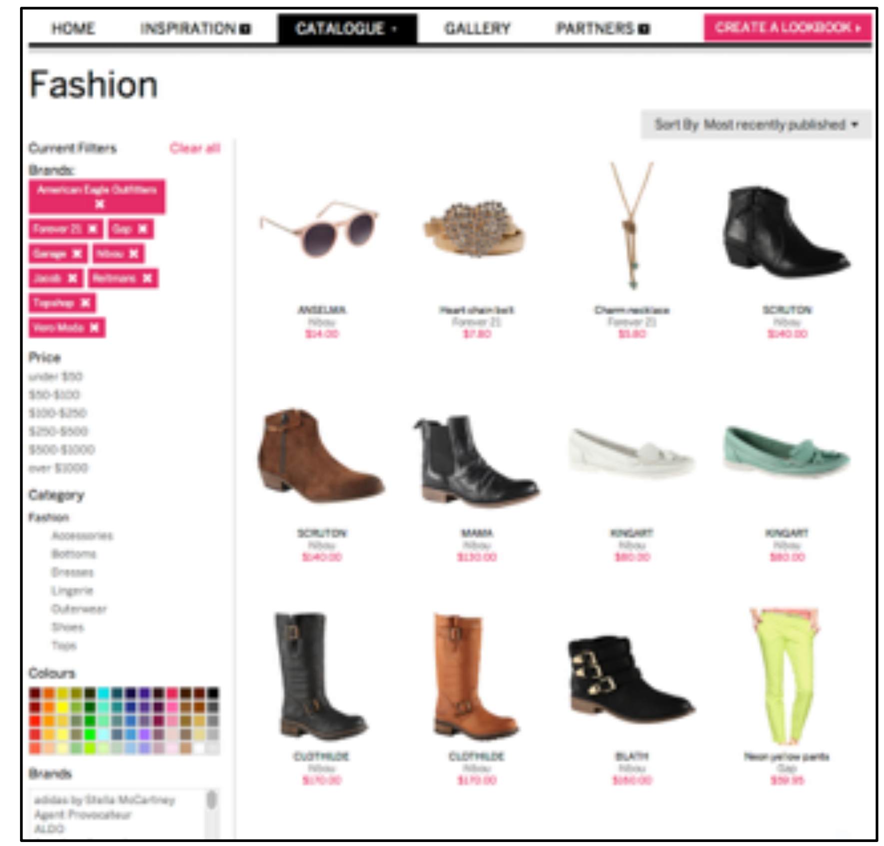


Association

- Directional association and attributes
  - Another example

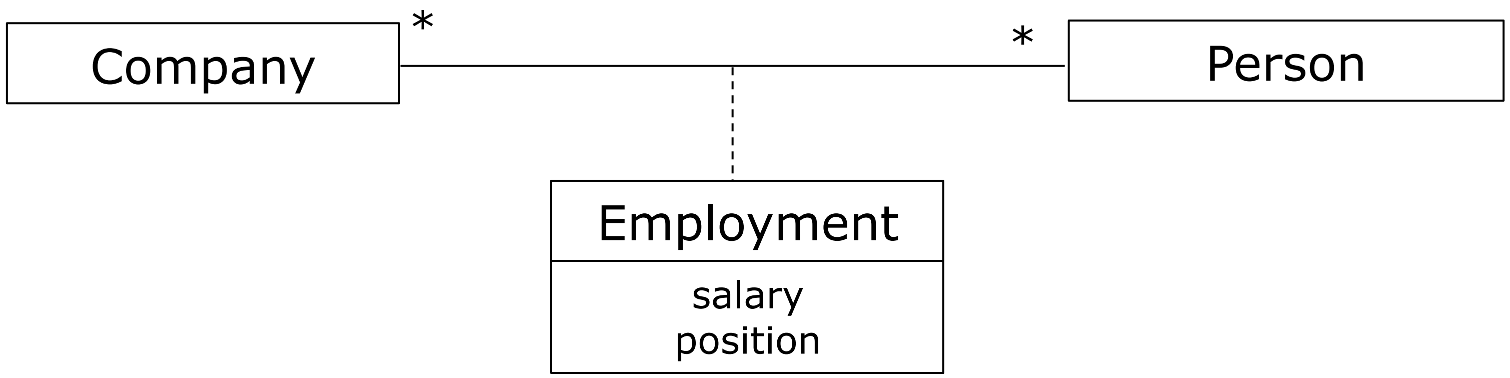


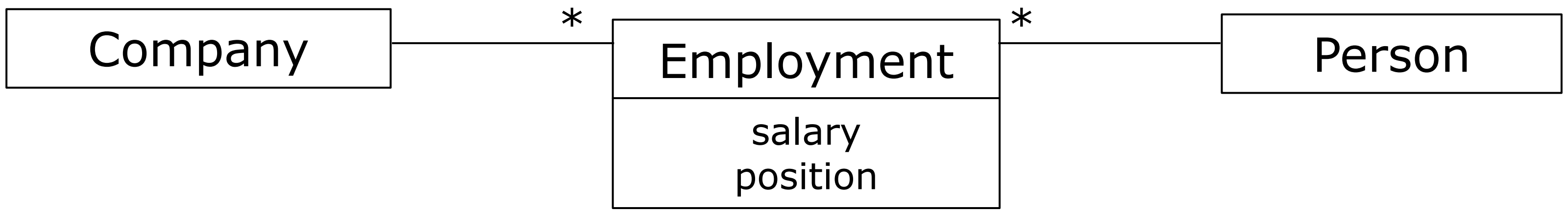

```
public class Catalogue {
        private List<Product> products =
                        new ArrayList<Product>();
// …
}
```



Association

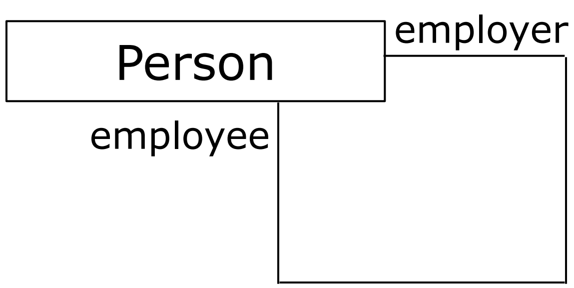
- Association classes
  - An association class allows an association to be considered as a class
    - When an attribute cannot be attached to any of the two classes of an association
  - Example





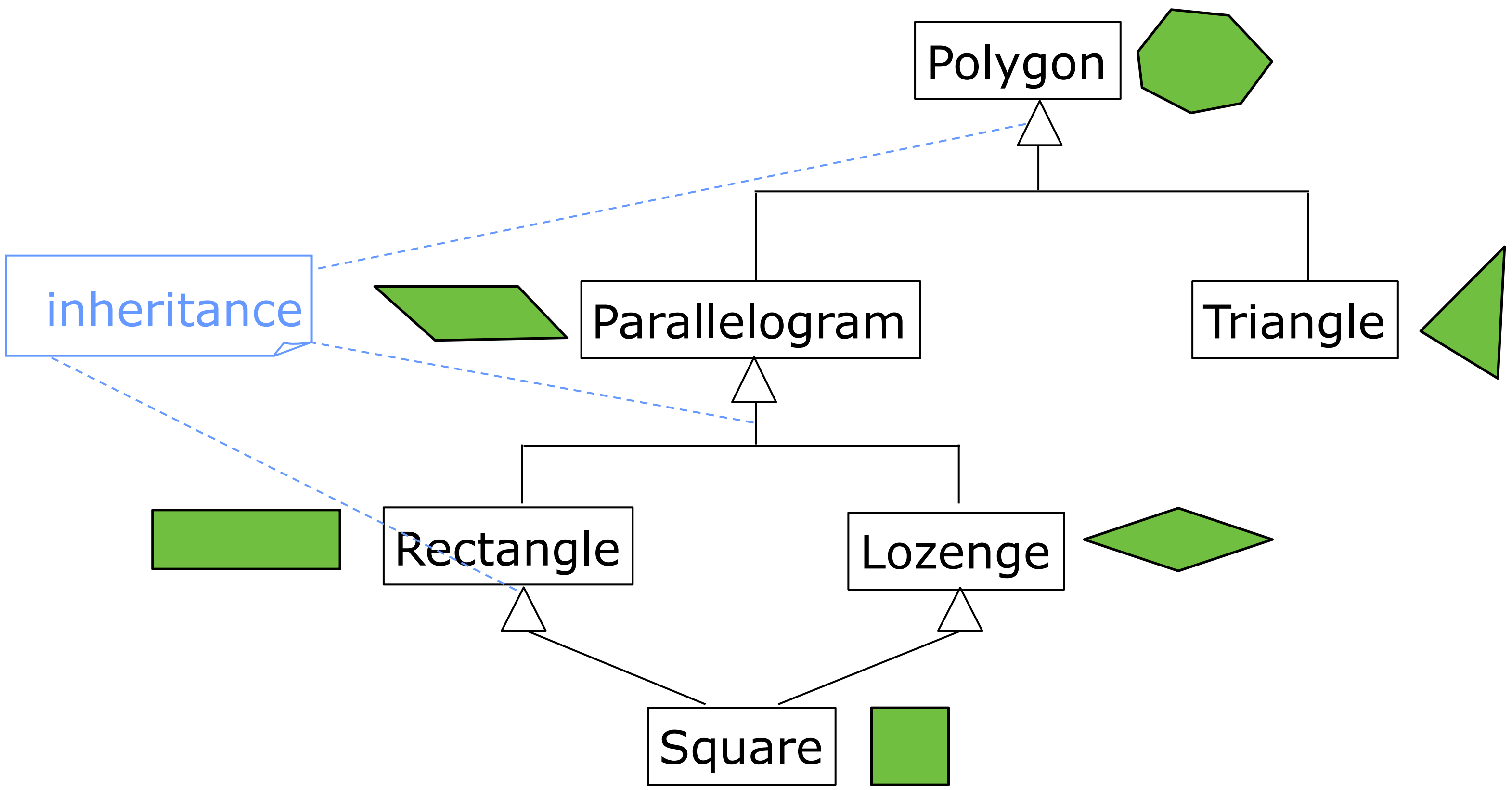
Association

- A class can be associated to itself
  - example



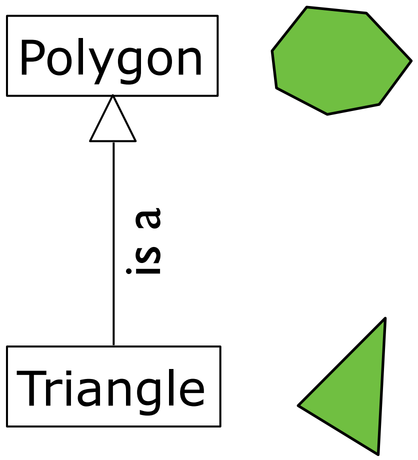
Inheritance

- A class can have several sub-classes



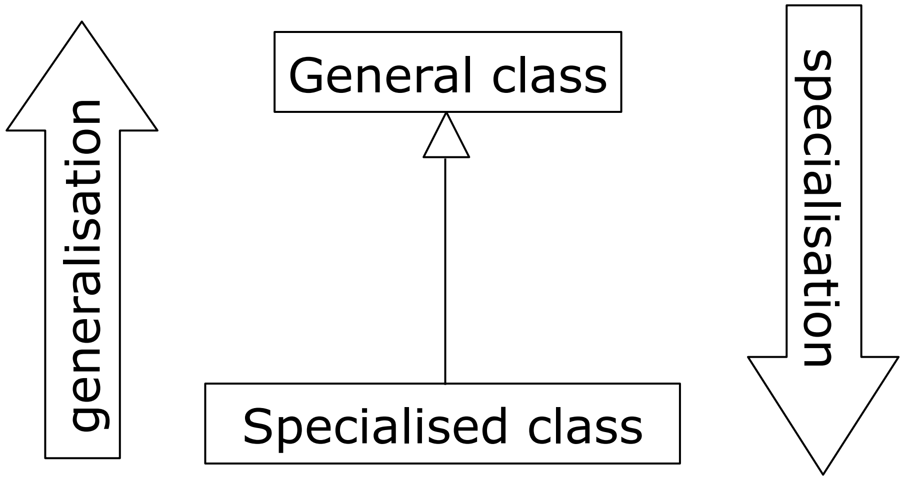
Inheritance

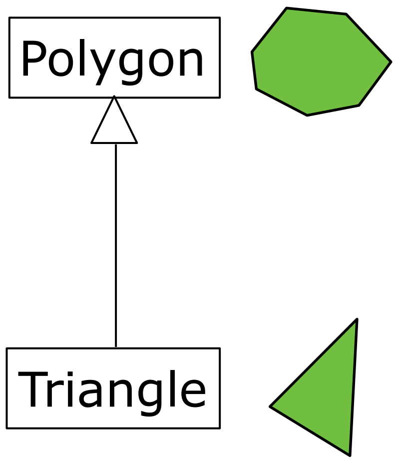
- Substitution principle
  - All subclass objects can play the role of an object of its parent-class
  - An object of a subclass can override an object of its superclass
- Informally
  - A subclass is a kind of superclass
- Example
  - A triangle is a polygon



Inheritance

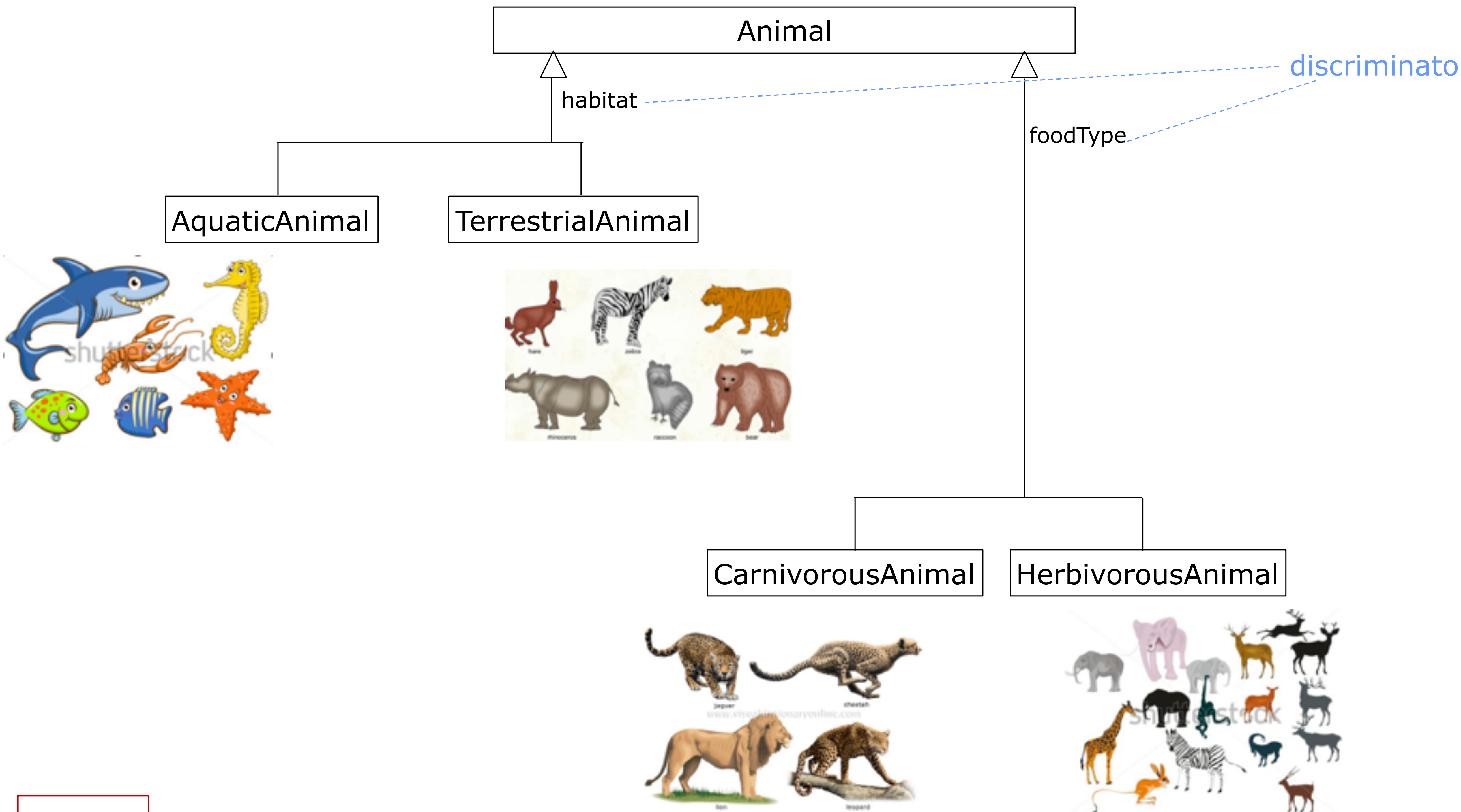
- The subclasses are also called **specialised classes**
- Parent-classes are also called **general classes**
- The inheritance is also called the **specialisation** or **generalisation**





Inheritance

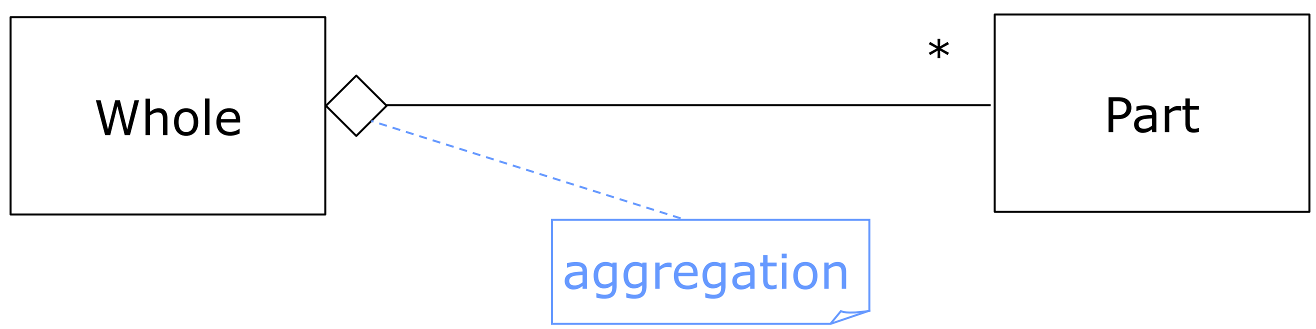
- The (optional) **discriminator** is a label describing the criterion that the specialisation bases on



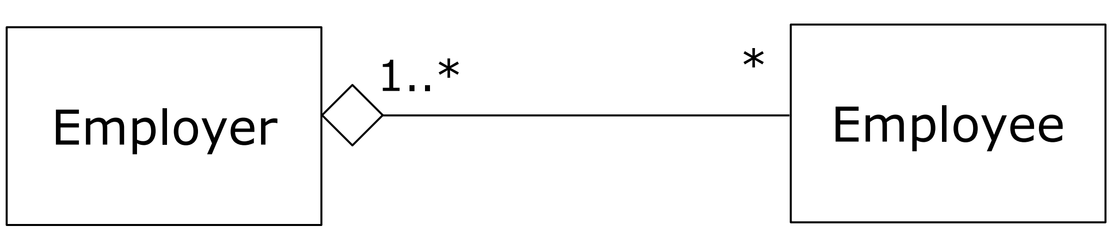
Aggregation

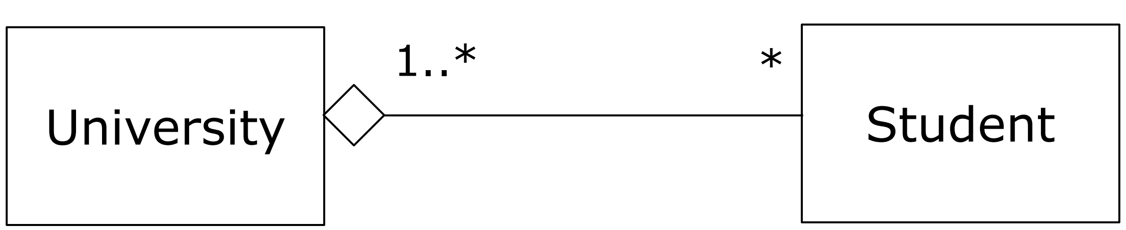
- An aggregation is a form of association that expresses a stronger (than normal association) coupling between class
- An aggregation is used between two classes
  - master and slave: “belongs to”
  - whole and part: “is a part of”

- Notation
  - The symbol denoting the place of aggregation of the aggregate side



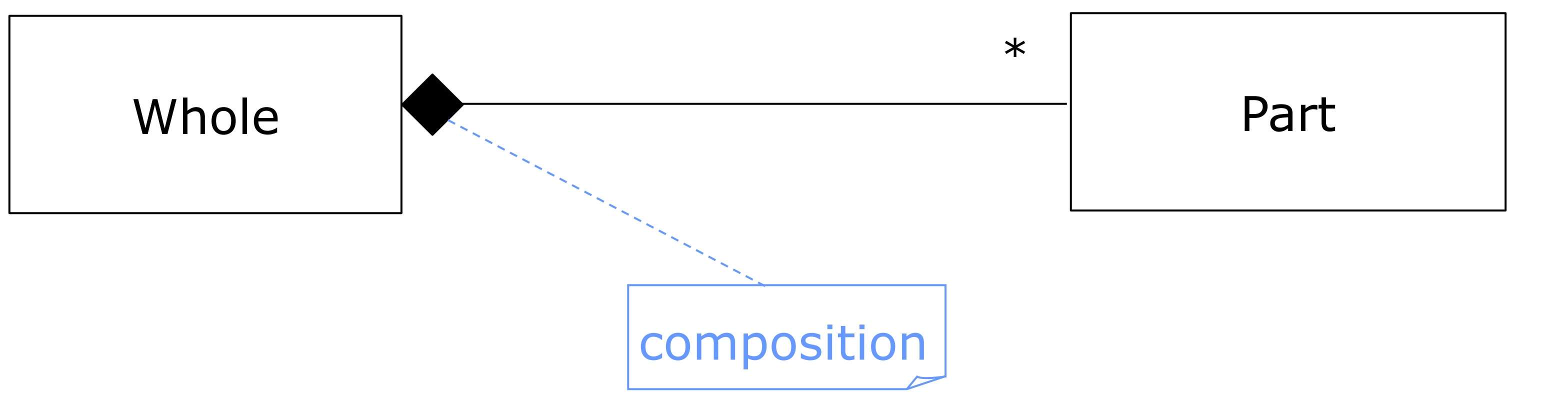
- Examples



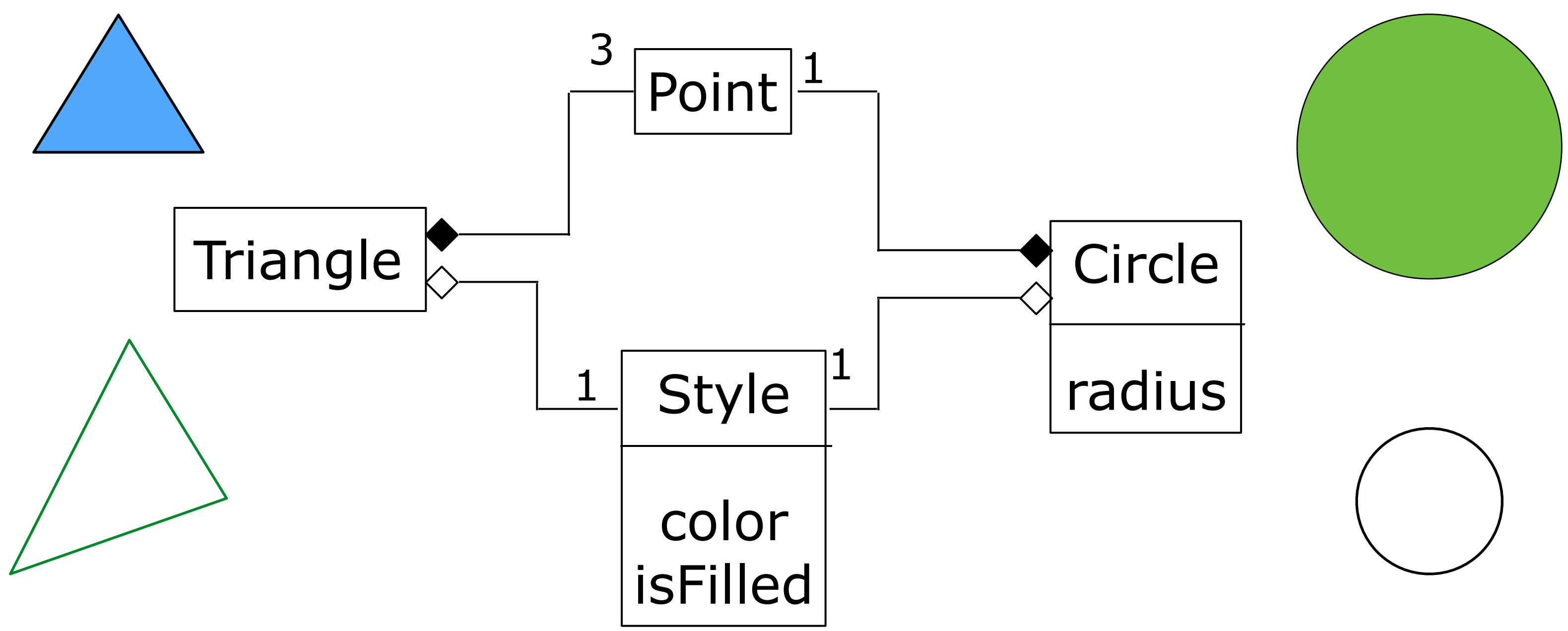


Composition

- A composition is a strong form of aggregation
- A composition is also a "whole-part" relationship but the aggregate is stronger
  - If the whole is destroyed then parts will be also destroyed



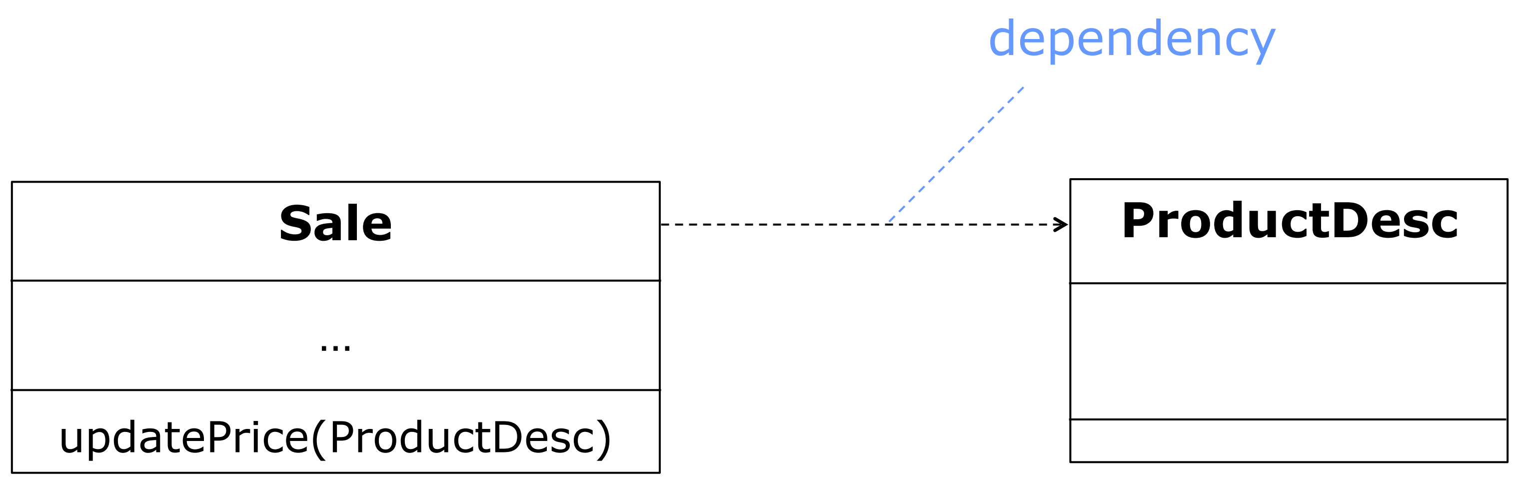
- Example



Dependency

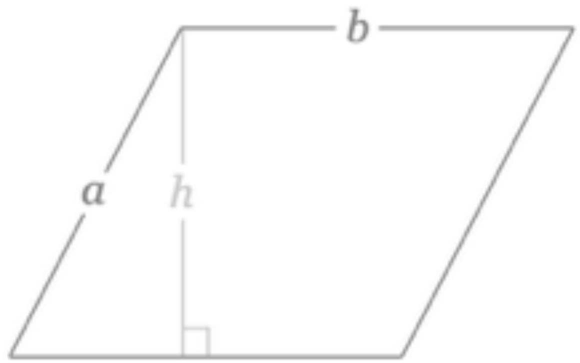
- A class may depend on another class
- The dependency between classes can be implemented in different ways
  - Having an attribute with the type of another class
  - Sending a message using an attribute, a local variable, a global variable of another class or static methods
  - Receiving a parameter having type of another class

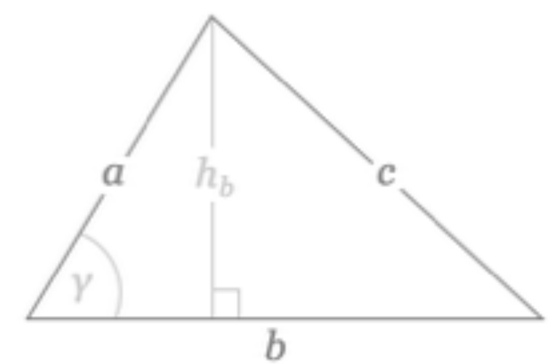
- Example



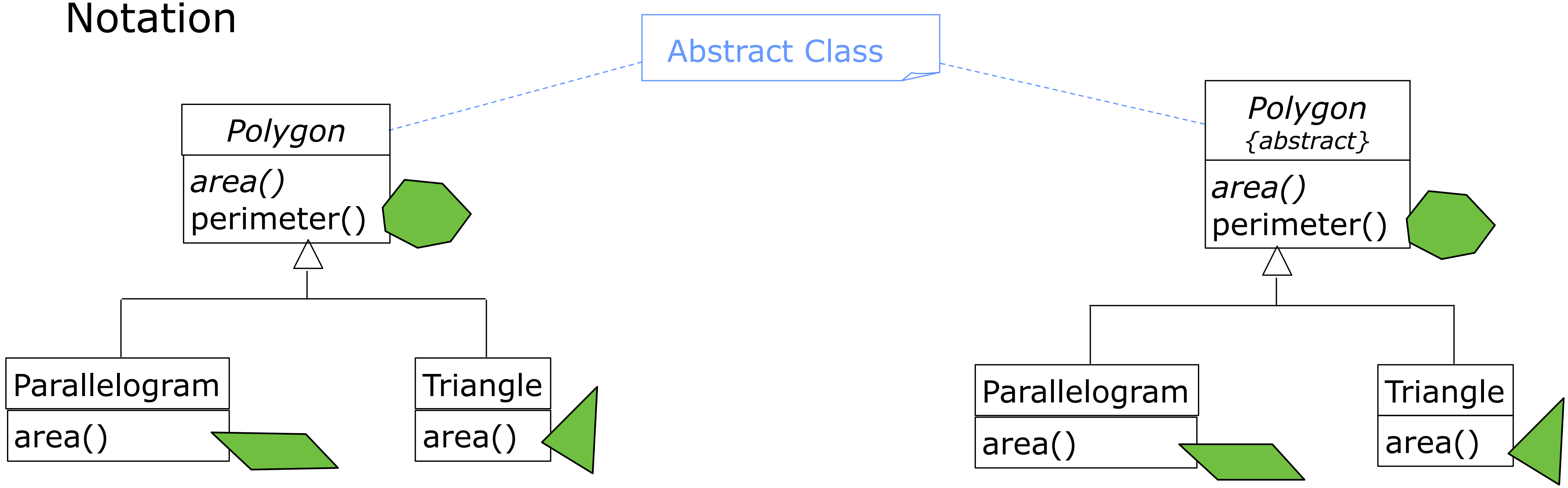
Abstract class

- An abstract class is a class that has no instances
  - inheritance: *area()*, perimeter()
  - polymorphism: *area()*
    - Parallelogram = b * h   Triangle = (h * b) / 2



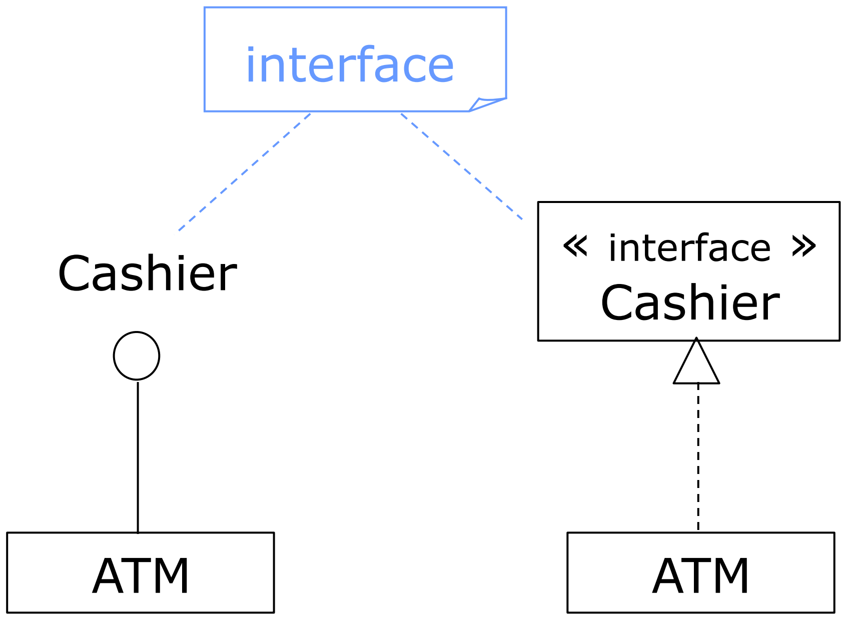


- Notation



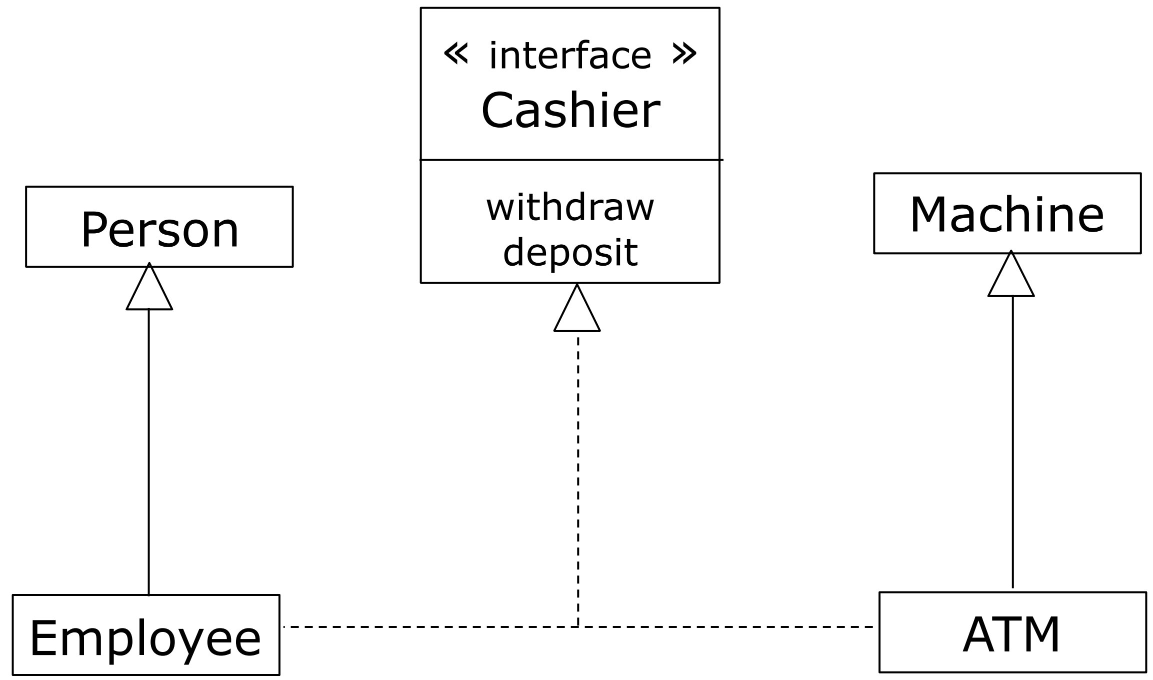
Interface

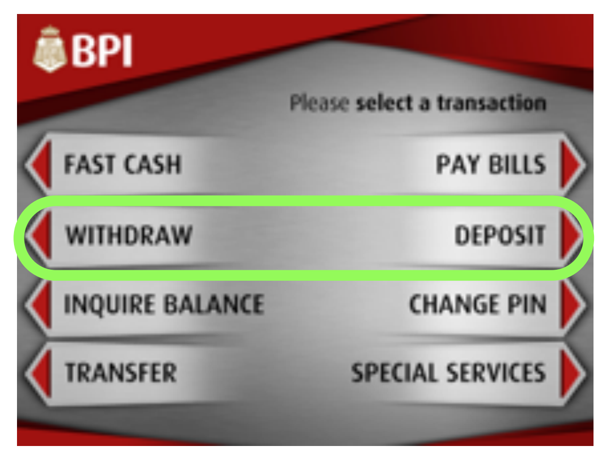
- An interface
  - describes a portion of the visible behaviour of a set of objects
  - is very similar to an abstract class that contains only abstract operations
  - **specifies only the operations without implementation**
- Two notations

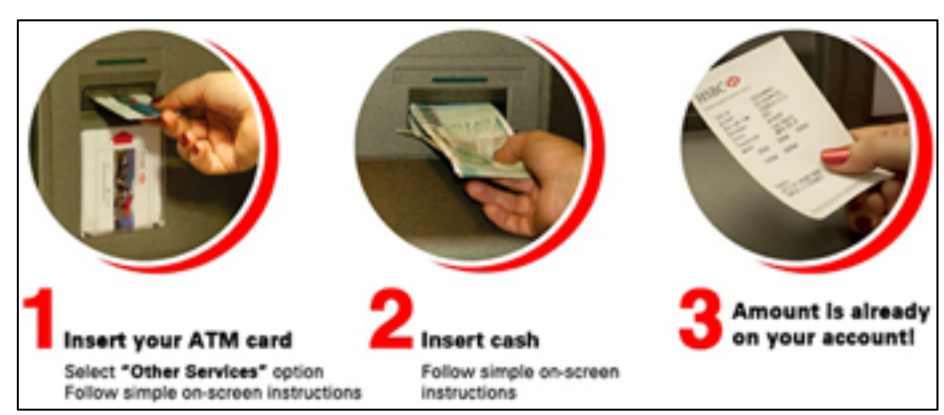


Interface

- Example

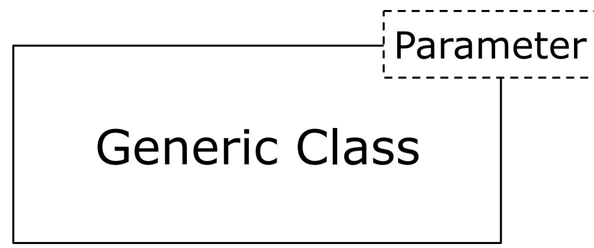






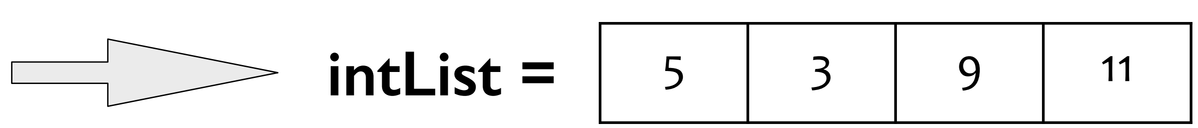
Generic class

- A generic class (or parameterised) allows to consider the types of data as parameters
- Generic classes are often used for the types of collection classes: vector, table, stack, …
- Notation



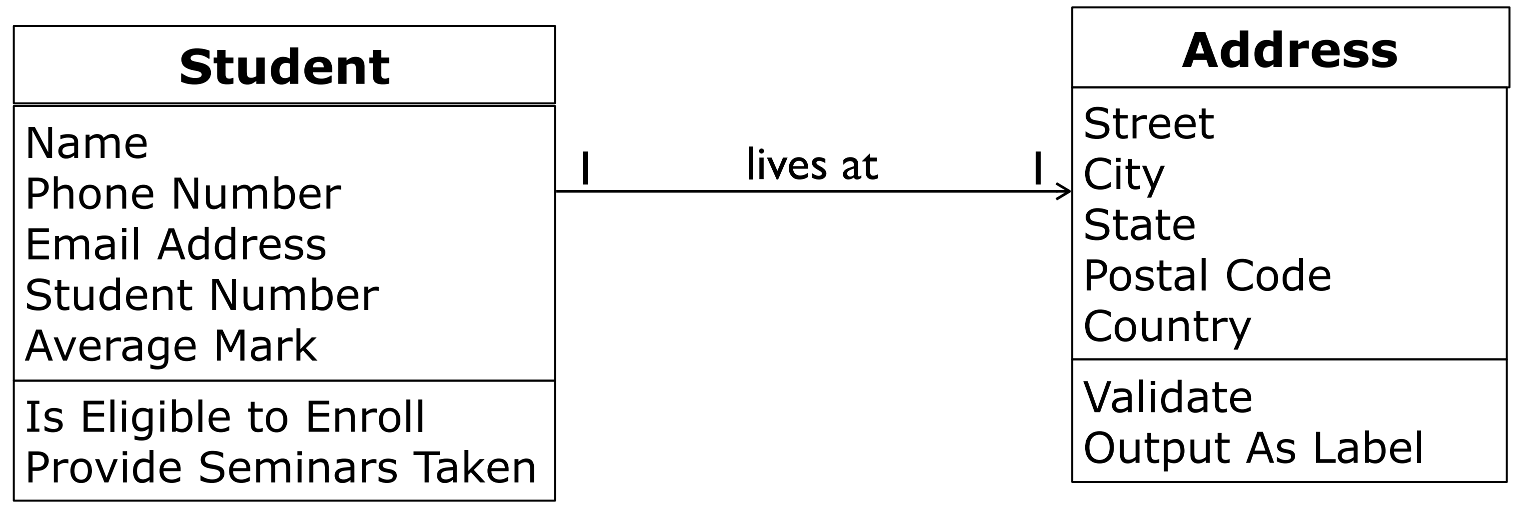
- Example

- “template” in C++
- Generic type in Java
  - List<Integer> **intList** = new ArrayList<Integer>();

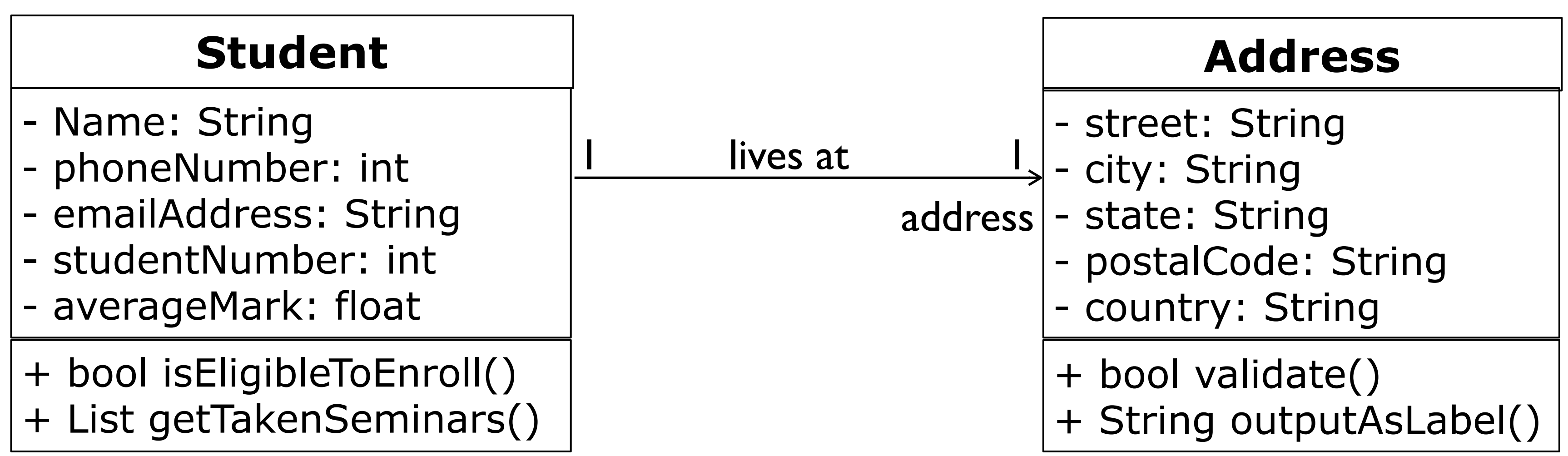


Building class diagrams

- Class diagrams are progressively built at different phases of software development process



Analysis class diagram



Design class diagram (for Java implementation)

Building class diagrams

- Identifying classes
  - The question "How to find classes?"
  - The concepts in the studied domain can be also classes
    - These concepts are called **conceptual classes**
    - So, we **firstly** identify the conceptual classes, and **then other** classes are added during the development

- The principles for finding conceptual classes
  - Use of a **list of categories**
  - Identification of **nouns**

Building class diagrams

- Identifying classes
  - Use of a list of categories

Categories of conceptual classes	Examples
transaction (of business)	Reservation, Payment
product ou service relating to the	Product, Flight
where transactions are recorded?	Cash desk, Cash
actors of use-cases	Cashier, Customer
location (of service, of transaction)	Station, Store
important events	purchase
physical objects	Car
description of things	Description of products
catalog	Product catalog
containing things	Store
other collaboration systems	Bank, database
organisations	University
policy, principle	Tax
…	

Building class diagrams

- Identifying classes
  - Identification of **nouns**
    - Review written documents such as specification or description of use-cases
    - Extract names and consider them as conceptual class candidates
    - Remove the nouns which
      - are redundant
      - are vague or too general
      - aren’t conceptual classes by experience and knowledge in the context of the application

Building class diagrams

- Identifying classes
  - Identification of **nouns** from use-case spec
    - Example

Actions of actor	Actions of system
• The **customer** comes to the **cash desk** with the **products** to buy	
• The **cashier** encodes **the identifier** of each **product** If a **product** has more than one **item,** the **cashier** inputs the number of **items**	• The **cash desk** displays the description and price of the product This number is displayed
• After having encoded all of the **products,** the **cashier** signals the end of the **purchase**	• The **cash desk** calculates and displays the total amount that the customer has to pay
• The **cashier** announces the total amount to the customer	
• The **customer** pays	• The **cash desk** displays the balance
• The **cashier** input the amount of **money** paid by the customer	

Building class diagrams

- Identifying classes
  - Identification of **nouns**
    - Example (continue)

Actions of actor	Actions of system
• The cashier receives the cash payment	• The **cash desk** prints the receipt
• The **cashier** gives **change** to the customer and the receipt	• The **cash desk** saves the **purchase**
• The **customer** leaves the **cash desk** with the bought **products**	

Building class diagram

- Candidate classes from nouns identified from use-case description
  - customer, cash desk, product, item, cashier, purchase, change

Building class diagrams

- Identifying the relationships and attributes
  - Starting with central classes of the system
  - Determining the attributes of each class and associations with other classes
  - Avoiding adding too many attributes or associations to a class
    - To better manage a class

Building class diagrams

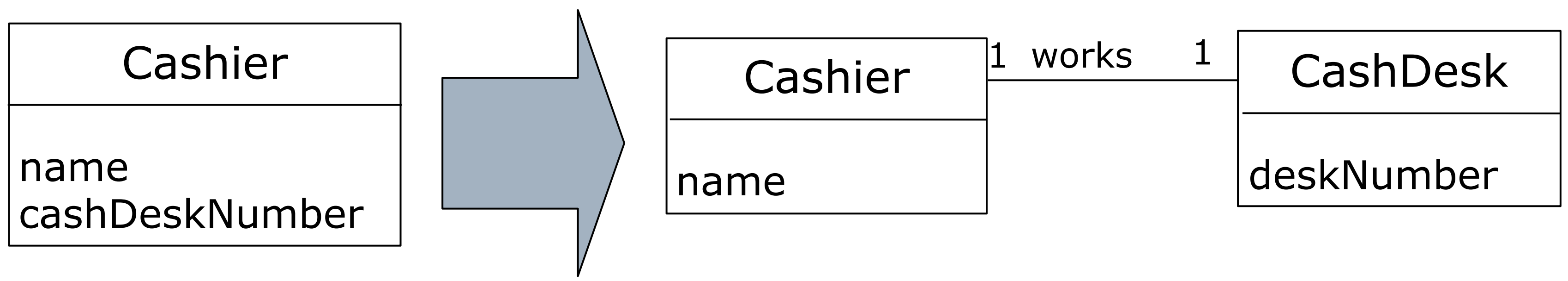
- Identify the relationships
  - A association should exist between class A and class B, if
    - A is a service or product of B
    - A is a part of B
    - A is a description for B
    - A is a member of B
    - A is connected to B
    - A possesses B
    - A controls B
    - …
  - Specify the multiplicity at each end of the association
  - Label associations

Building class diagrams

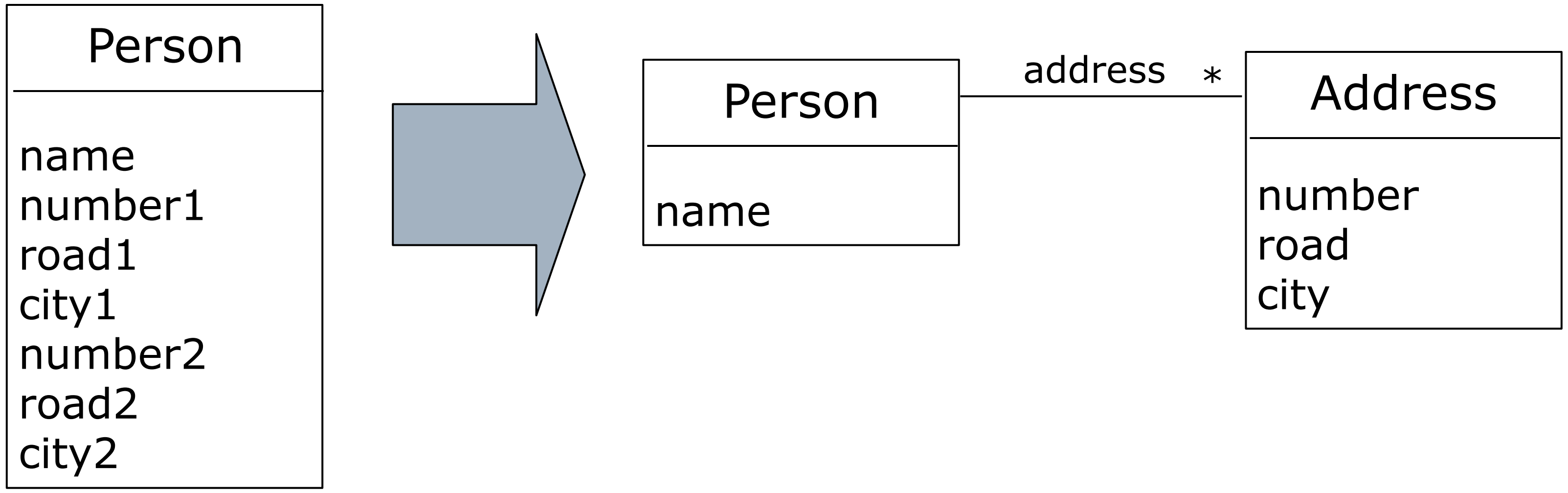
- Identifying attributes
  - For each class, determine the information needed to store according to the requirement specification or use-case
    - Example: Cashier needs an identifier, a name, …
  - Principle to determine attributes
    - An attribute represents only data related to the class that owns the attribute
    - If a subset of the attributes form a coherent group, it is possible that a new class is introduced
  - Determine only the names of attributes at this stage (i.e., analysis phase)

Building class diagrams

- Identifying attributes
  - Example
    - An attribute represents only data related to the class that owns the attribute

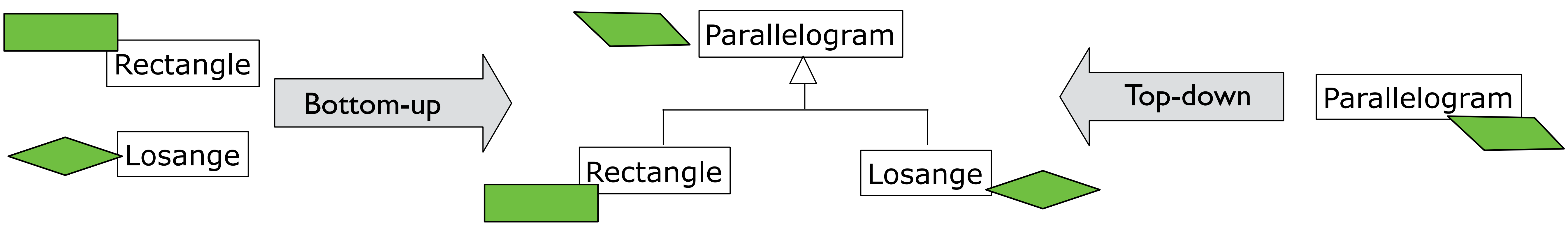


  - If a subset of the attributes form a coherent group, it is possible that a new class is introduced



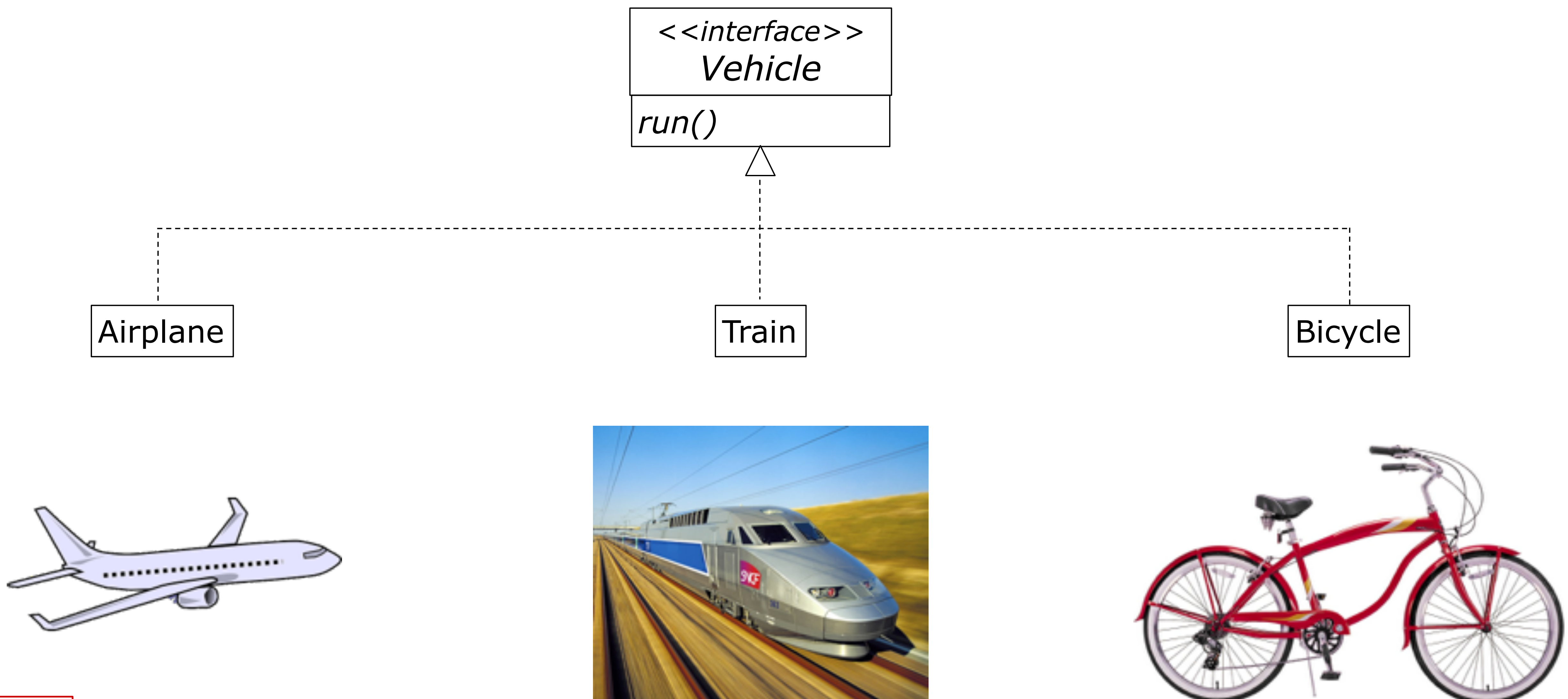
Building class diagrams

- Identifying inheritances
  - Two approaches
    - Bottom-up
      - Generalisation: group similar classes to create super-classes
    - Top-down
      - Specialisation: build sub-classes from existing general classes



Building class diagrams

- Identifying interfaces
  - Create interfaces rather than super-class, if
    - It is necessary to realise different implementations of the same class
    - Two classes to generate share the operations that are not similar
    - The class to generalise already has its own super-class



Building class diagram

- Determining the responsibilities of classes
  - A responsibility is one or several tasks that the system has to perform
  - Each functional requirements must be attributed to one of the classes
    - All the responsibilities of a class must be attributed to one of the classes
    - If a class has too many responsibilities, it must be divided into several classes
    - If a class has no responsibility, it should be probably be useless
    - If responsibility can not be assigned to any class, a new class can be introduced

  - The responsibilities can be determined by analysing the actions/verbs in the use-case specification.

Building class diagrams

- Developing design class diagrams
  - Basing on analysis class diagrams (domain models)
  - Detailing analysis class diagrams
    - Introducing new classes, if necessary
      - For example, an association of class becomes a new class
    - Detailing attributes
    - Adding and detail relationships
    - Determining operations

Building class diagrams

- Detailing attributes
  - Determining the types of attributes
    - Using primitive types: boolean, int, real, …
    - Defining new type for an attribute (new class), if
      - It consists of several sections
      - It has other attributes
      - It is associated with other operations
  - Determining initial values if necessary
  - Determining the visibility of attributes

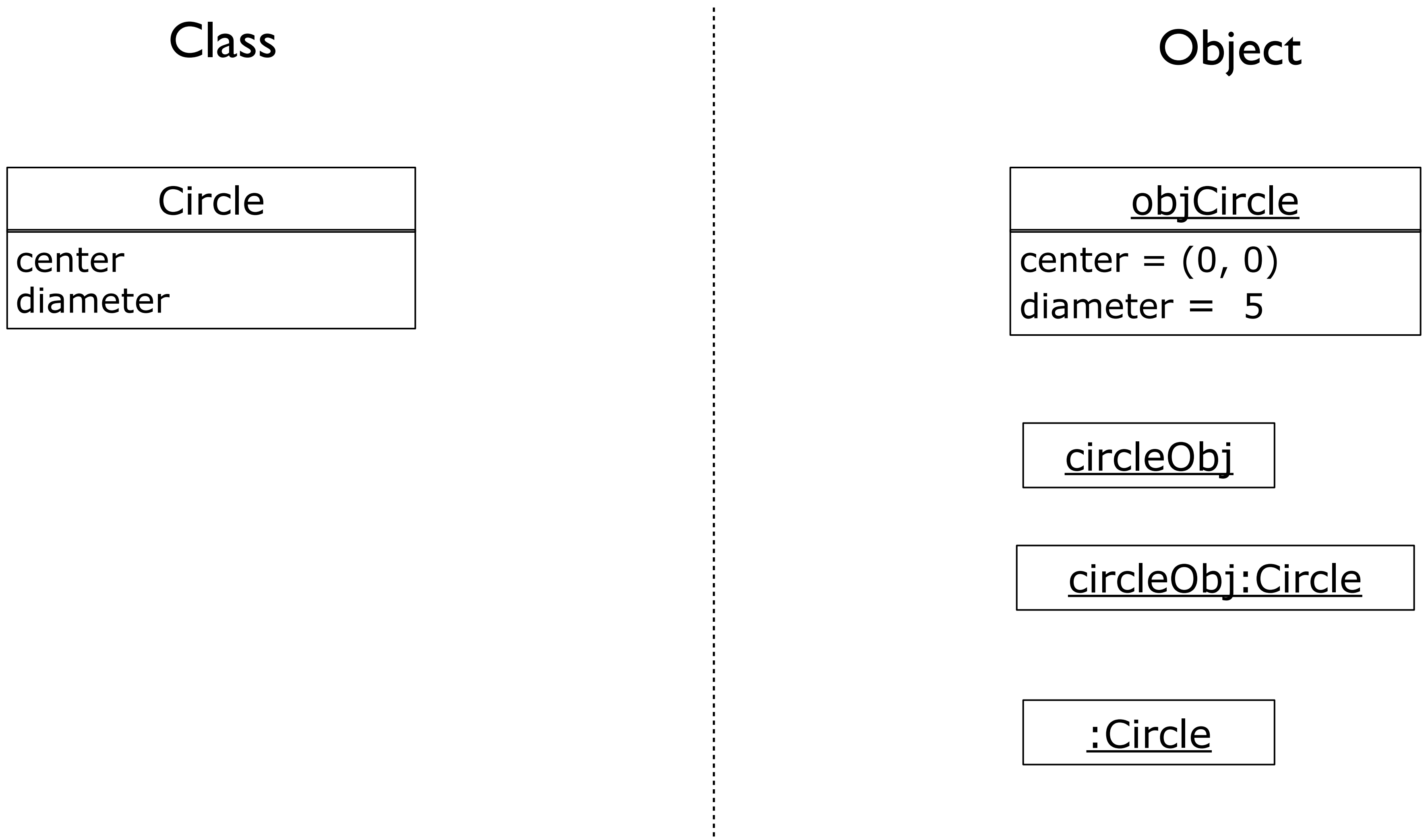
- Detailing relationships
  - Introducing relationships according to newly added classes
  - Specifying if an association is an aggregate or composition
  - Naming the relationship
  - Giving the direction

Building class diagrams

- Determining the operations of each class
  - getters and setters
  - Operations are used to achieve the identified responsibilities
  - A responsibility can be carried out by several operations
  - Determining the visibility of operations
    - Essential operations carrying out responsibilities are declared “public”
    - Operations serving only in the class are declared “private” or “protected” if the class should be inherited

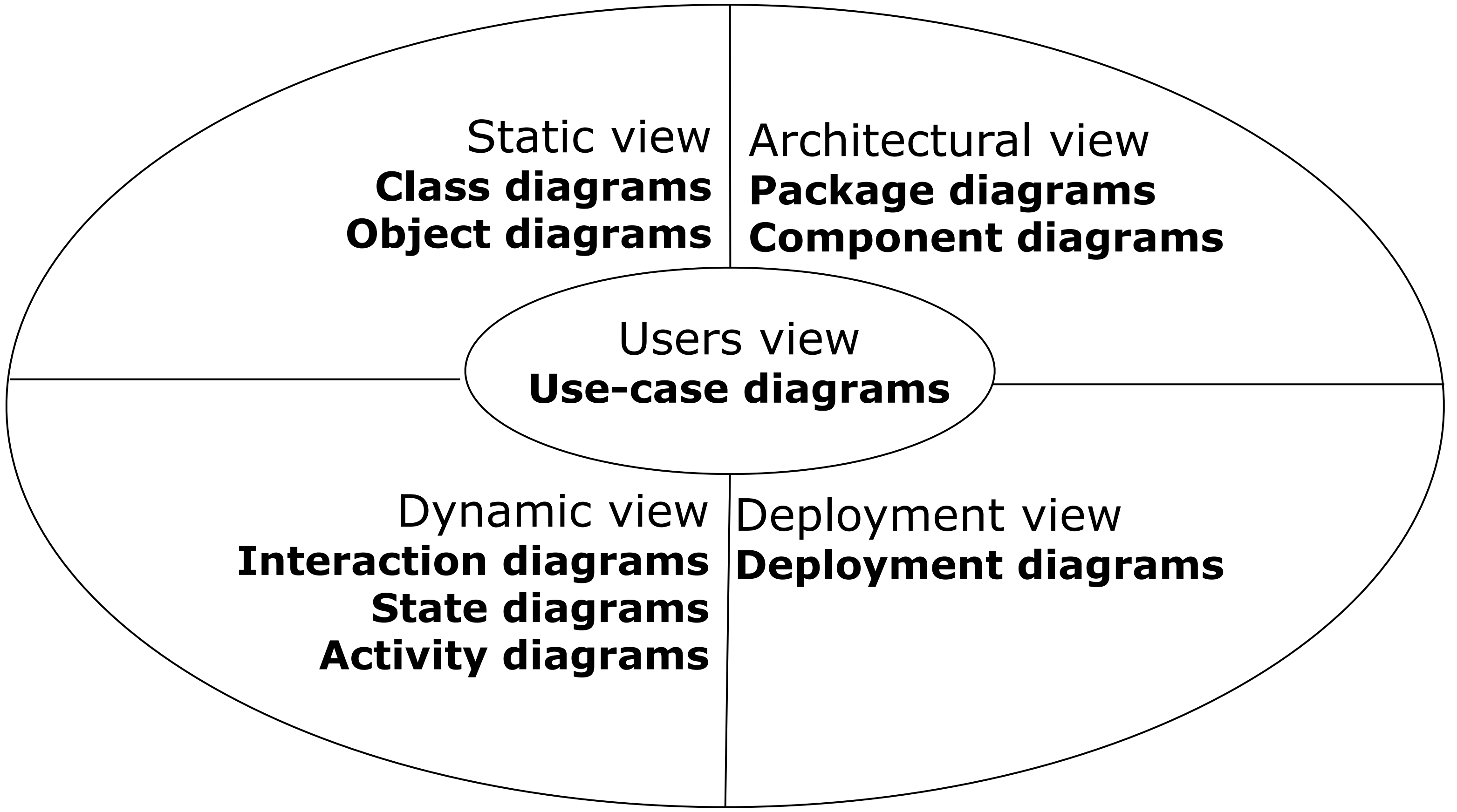
Object diagrams

- Objects
  - Objects are instances of classes
  - Notation
    - Values of attributes can be indicated
    - Name of object is underlined



Object diagrams

- Objects
  - Three types of diagrams with objects
    - Static view
      - Object diagrams
    - Dynamic view
      - Sequence diagrams
      - Collaboration diagrams



Object diagrams

- Object diagrams
  - represent a set of objects and links between them
  - are static views of instances of the elements appearing in class diagrams
- An object diagrams is an instance of a class diagram