Design Engineering

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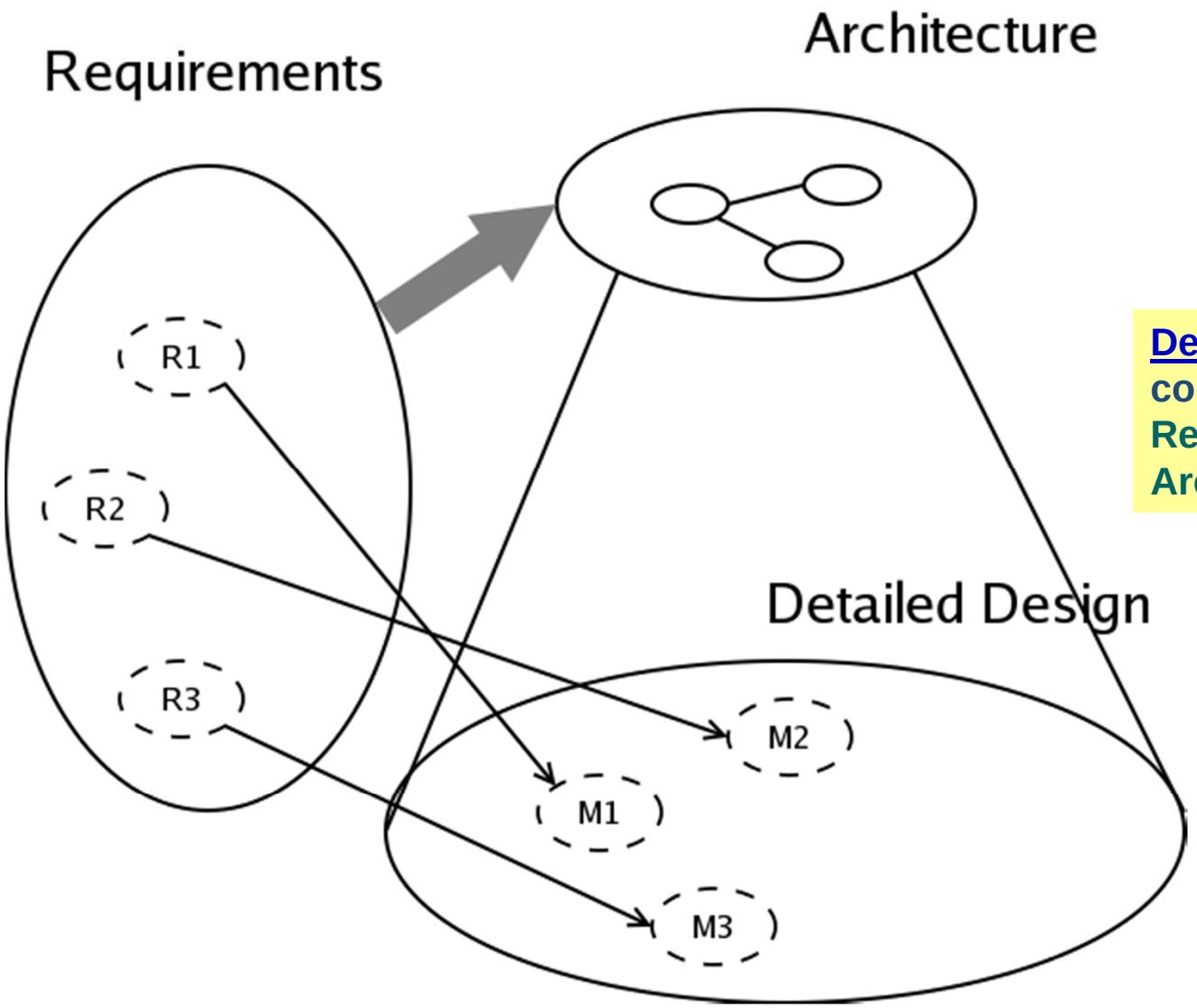
Design

- Starts mostly from/with requirements (evolving mostly from functionalities and other non-functional characteristics)
- How is the software solution going to be structured?
  - What are the main *components* --- (*functional comp*)
    - *Often* directly *from Requirements' Functionalities (use Cases)*
  - How are these *components related ?*
    - possibly re-organize the components (composition/decomposition)
- Two main levels of design:
  - Architectural (high-level)
  - Detailed design



Detailed Design come from Requirements & Architecture

Relationship between Architecture and Design

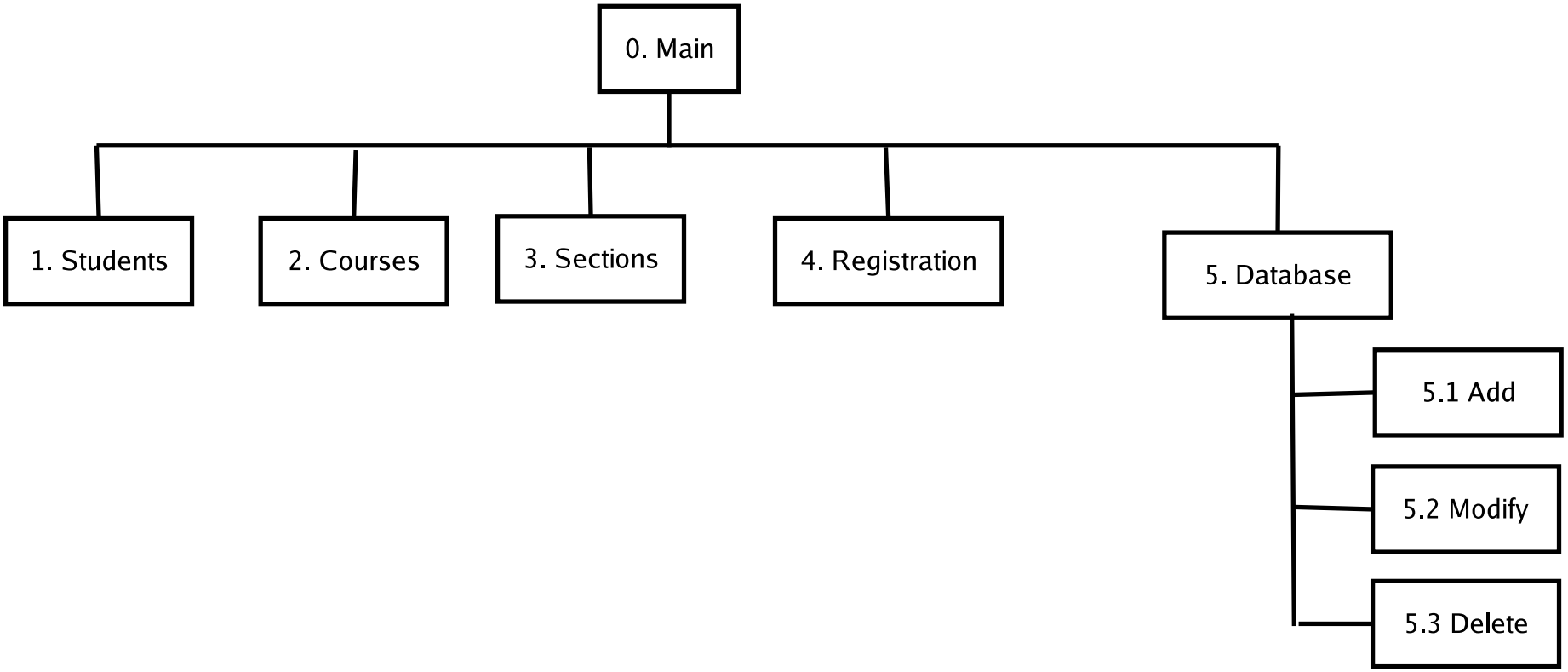
Detailed Design

- **Further Refine Architecture and match with Requirements**
- **How detailed ?**
- **Maybe of different levels of detail for different views**

Functional Decomposition Technique

- Dates back to "structured programming" [now (non-OO)Web apps with PHP tool]
- Start with: main (task/requirements) -> module
- Refine into sub-modules
- There are alternative decompositions

"Alternative" Decomposition/Composition



OO Design

- First step: Review & Refine use cases

- Decide
  - Which classes to create
  - How the classes are related

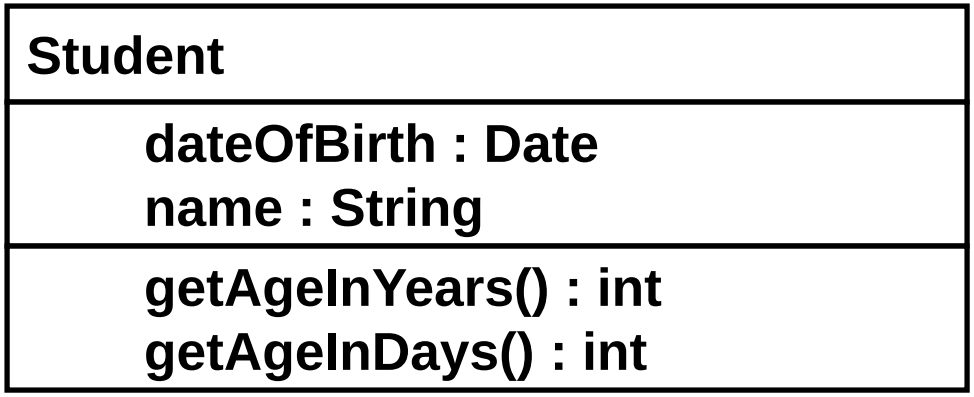
- Use UML as the Design Language

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

Class Design

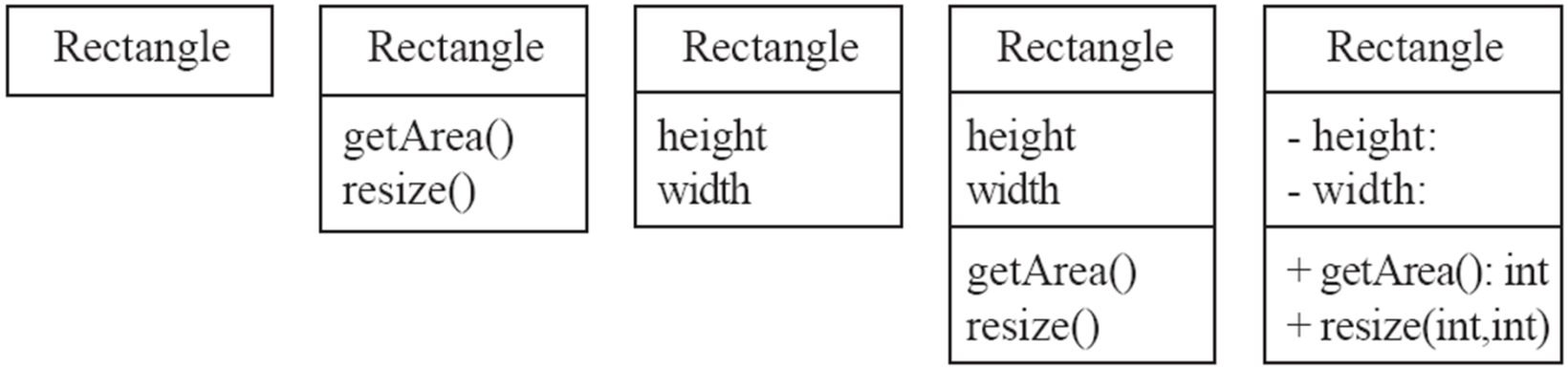
- **Classes** represent real-world entities or system concepts
- Organized into **classes**: objects in a class have similar characteristics
- **Classes** have properties (attributes or data)
- **Classes** also have methods (performs functions)



Classes

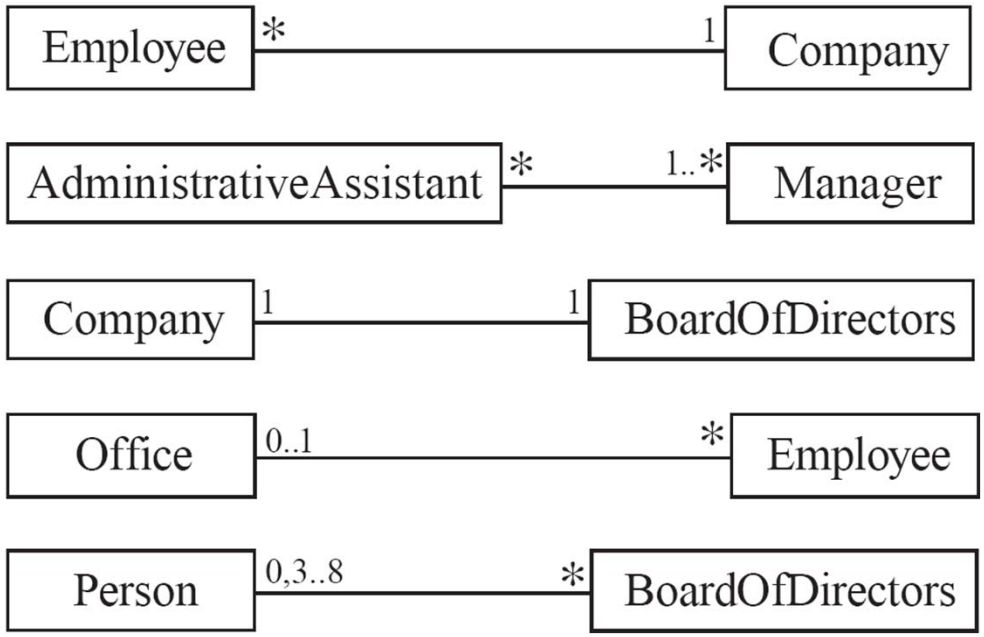
- A class is simply represented as a box with the name of the class inside
  - The diagram may also show the attributes and operations
  - The complete signature of an operation is:

    operationName(parameterName: parameterType …): returnType



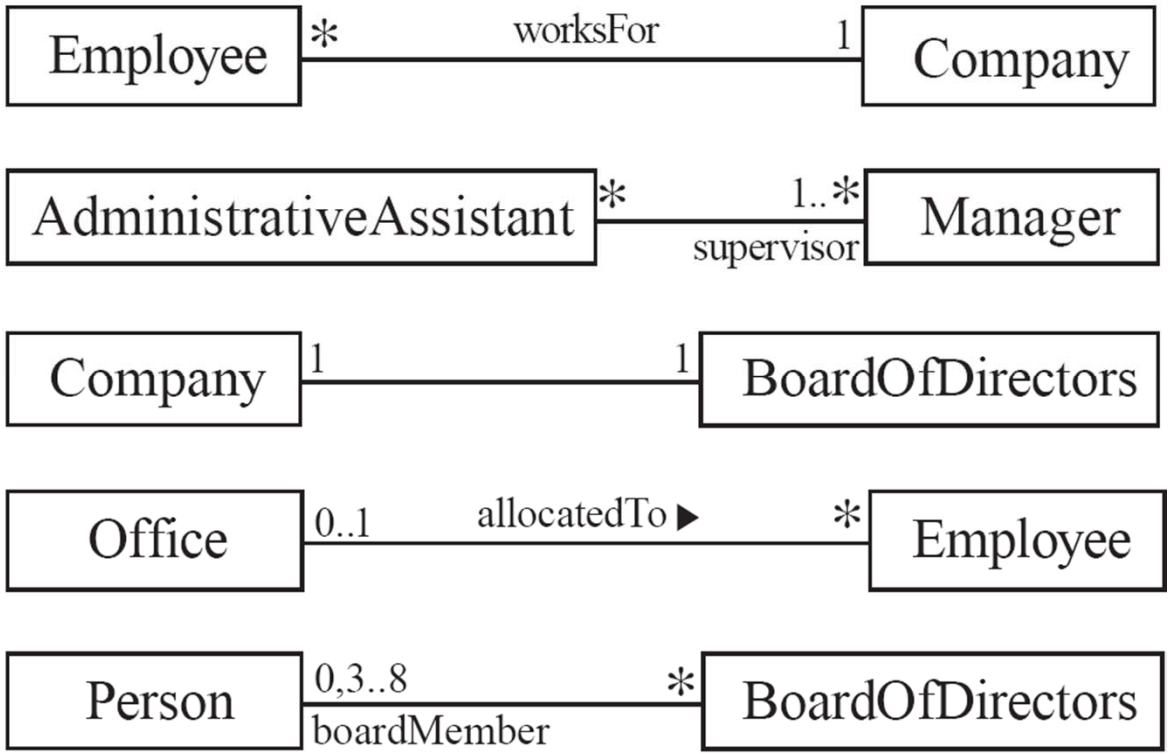
Associations and Multiplicity

- 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



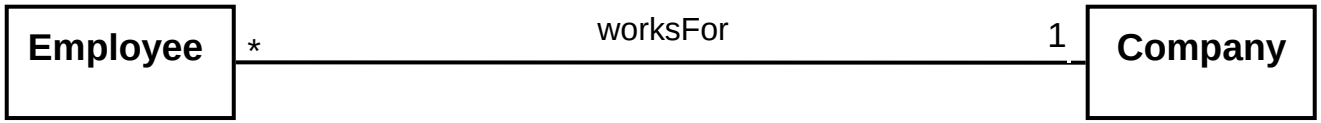
Labelling associations

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



Analyzing and validating associations

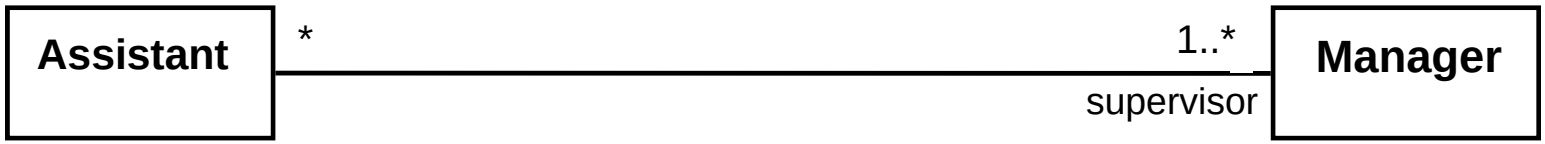
- **Many-to-one**
  - A company has many employees,
  - An employee can only work for one company.
    - This company will not store data about the moonlighting activities of employees!
  - A company can have zero employees
    - E.g. a 'shell' company
  - It is not possible to be an employee unless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



Analyzing and validating associations

– **Many-to-many**

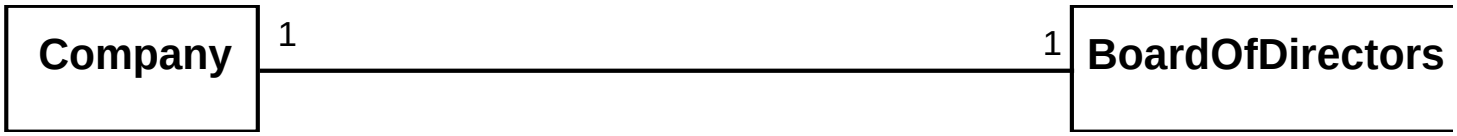
- An assistant can work for many managers
- A manager can have many assistants
- Assistants can work in pools
- Managers can have a group of assistants
- Some managers might have zero assistants.
- Is it possible for an assistant to have, perhaps temporarily, zero managers?



Analyzing and validating associations

– **One-to-one**

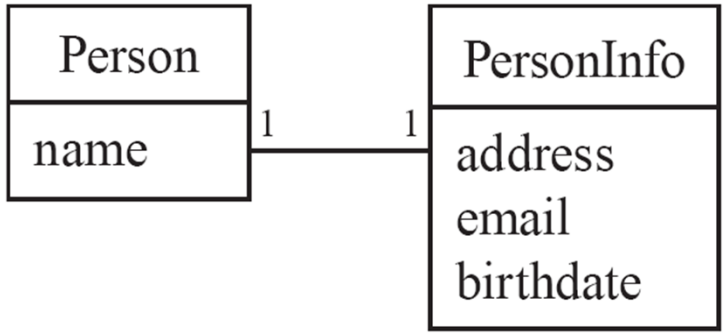
- For each company, there is exactly one board of directors
- A board is the board of only one company
- A company must always have a board
- A board must always be of some company



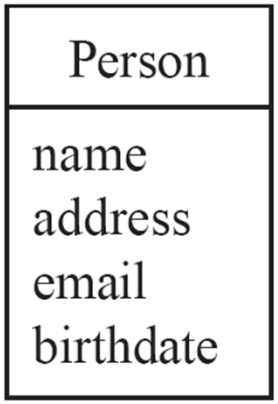
Analyzing and validating associations

- Avoid unnecessary one-to-one associations

Avoid this

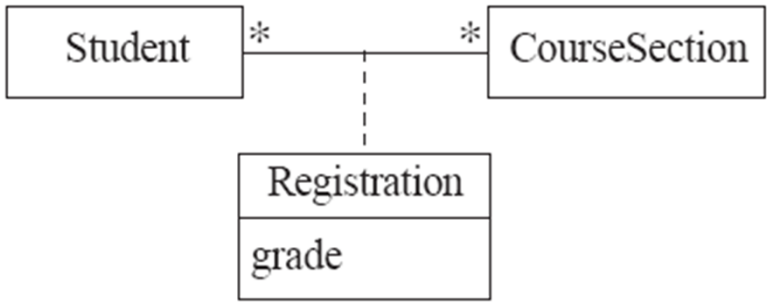


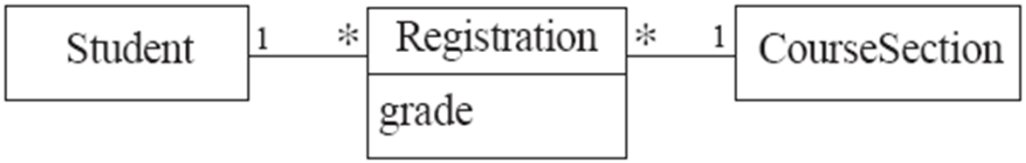
do this



Association classes

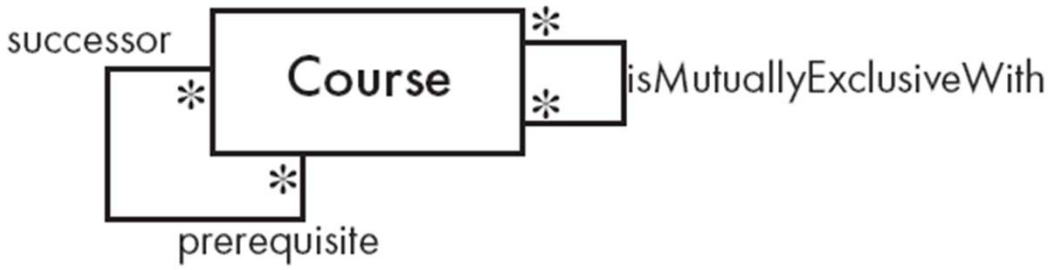
- Sometimes, an attribute that concerns two associated classes cannot be placed in either of the classes
- The following are equivalent





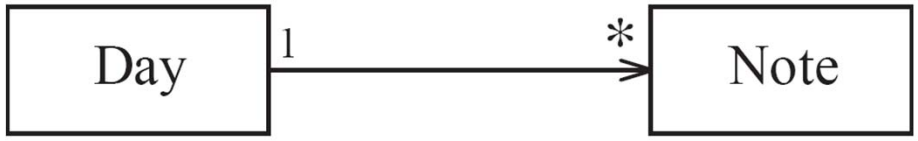
Reflexive associations

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



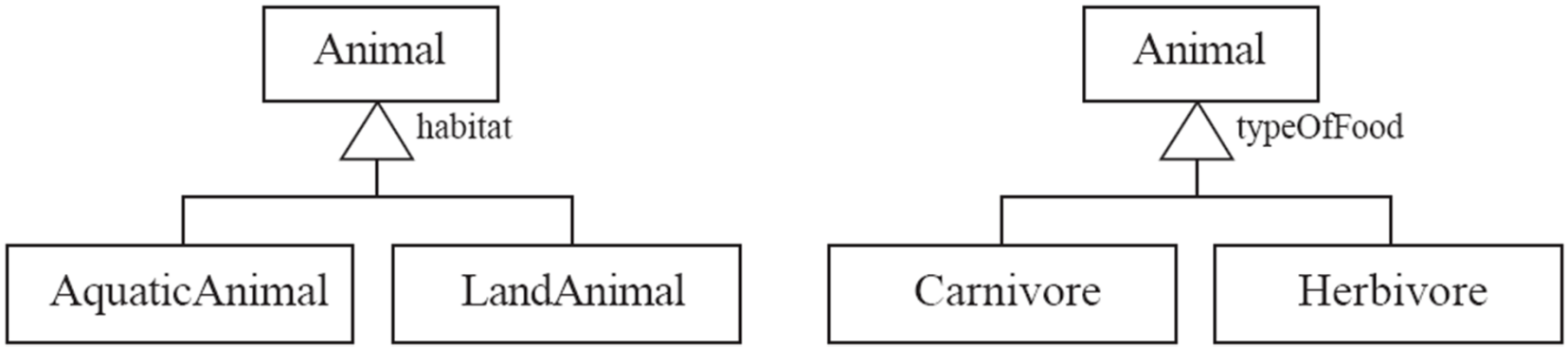
Directionality in associations

- Associations are by default *bi-directional*
- It is possible to limit the direction of an association by adding an arrow at one end



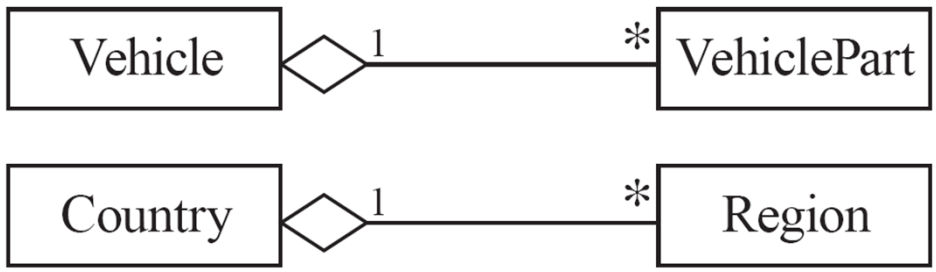
Generalization

- Specializing a superclass into two or more subclasses
  - A *generalization set* is a labeled group of generalizations with a common superclass
  - The label (sometimes called the *discriminator*) describes the criteria used in the specialization



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`



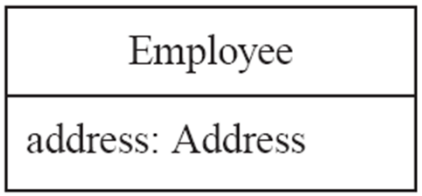
When to use an aggregation

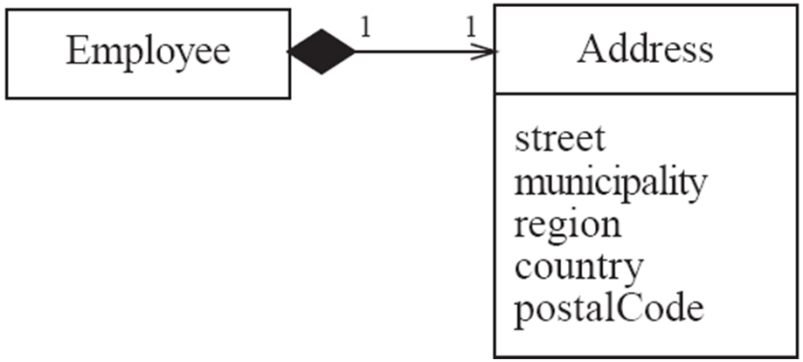
- As a general rule, you can mark an association as an aggregation if the following are true:
  - You can state that
    - the parts 'are part of' the aggregate
    - or the aggregate 'is composed of' the parts
  - When something owns or controls the aggregate, then they also own or control the parts

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





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

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

A simple technique for discovering 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

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.

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

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

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.

Identifying operations

- Operations are needed to realize the responsibilities of each class
  - There may be several operations per responsibility
  - The main operations that implement a responsibility are normally declared **public**
  - Other methods that collaborate to perform the responsibility must be as private as possible

Implementing Class Diagrams in Java

- Attributes are implemented as instance variables
- Generalizations are implemented using extends
- Interfaces are implemented using implements
- Associations are normally implemented using instance variables
  - Divide each two-way association into two one-way associations
    —so each associated class has an instance variable.
  - For a one-way association where the multiplicity at the other end is ‘one’ or ‘optional’
    —declare a variable of that class (a reference)
  - For a one-way association where the multiplicity at the other end is ‘many’:
    —use a collection class implementing List, such as Vector

Difficulties and Risks when creating class diagrams

- Modeling is particularly difficult skill
  - *Even excellent programmers have difficulty thinking at the appropriate level of abstraction*
  - *Education traditionally focus more on design and programming than modeling*
- Resolution:
  - *Ensure that tem members have adequate training*
  - *Have experienced modeler as part of the team*
  - *Review all models thoroughly*