Requirements Modeling: Class-Based

Prof. Alex Bardas

Class-Based Modeling

- A class-based model contains
  - **Objects**
    - What the system will manipulate
  - **Operations** (methods or services)
    - What to be applied to the objects to effect the manipulation
  - **Relationships** (some hierarchical) between objects
  - **Collaborations** between the classes that are defined

Identifying Classes

6 selection characteristics

1. Retained information

   The potential class will be useful during analysis ***only if information about it must be remembered*** so that the system can function.

2. Needed services

   The potential class ***must have a set of identifiable operations*** that can change the value of its attributes in some way.

Identifying Classes

6 selection characteristics

3. Multiple attributes

During requirement analysis, the focus should be on “major” information.

A class with a single attribute may, in fact, be useful during design, but is probably better represented as an attribute of another class during the analysis activity.

4. Common attributes

A set of attributes can be defined for the potential class and these attributes apply to all instances of the class.

Identifying Classes

6 selection characteristics

5. Common operations

A set of operations can be defined for the potential class and these operations apply to all instances of the class.

6. Essential requirements

External entities that appear in the problem space and ***produce or consume information essential to the operation*** of any solution for the system will almost always be defined as classes in the requirements model.

Attributes

- Attributes define a class
  - For the same class, attributes can be very *different* in different contexts
  - *What data items fully define this class in the problem context?*

The **Player** class for professional baseball players

- Playing statistics software
  - Name, position, batting average, fielding percentage, years played, and games played, …
- Pension fund software
  - Name, average salary, pension plan options chosen, mailing address, …

Operations

- Operations define the behavior of an object:
  - Manipulate data
    - e.g., adding, deleting, reformatting, selecting
  - Perform a computation
  - Inquire the state of an object
  - Monitor an object for the occurrence of a controlling event
    - e.g., communications between objects

Case Study: Safe Home

The SafeHome security function *enables* the homeowner to *configure* the security system when it's *installed, monitors* all sensors *connected* to the security system, and *interacts* with the homeowner through the Internet, a PC, or a control panel.

Potential Class	Type

Case Study: Safe Home

The SafeHome security function *enables* the homeowner to *configure* the security system when it is *installed, monitors* all sensors *connected* to the security system, and *interacts* with the homeowner through the Internet, a PC, or a control panel.

Potential Class	Type
homeowner	role
(security) system	thing
sensor	external entity
control panel	external entity

Case Study: Safe Home

During installation, the SafeHome PC is used to *program* and *configure* the system. Each sensor is assigned a number and type, a master password is programmed for *arming* and *disarming* the system, and telephone number(s) are *input* for *dialing* when a sensor event occurs.

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity

Case Study: Safe Home

During installation, the SafeHome PC is used to *program* and *configure* the system. Each sensor is assigned a number and type, a master password is programmed for *arming* and *disarming* the system, and telephone number(s) are *input* for *dialing* when a sensor event occurs.

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity
Installation	event
number, type	thing
master password	thing
telephone number	thing
sensor event	event

Case Study: Safe Home

When a sensor event is *recognized*, the software *invokes* an audible alarm attached to the system. After a delay time that is *specified* by the homeowner during system configuration activities, the software dials a telephone number of a monitoring service, *provides* information about the location, *reporting* the nature of the event that has been detected. The telephone number will be *redialed* every 20 seconds until telephone connection is *obtained*.

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity
Installation	event
number, type	thing
master password	thing
telephone number	thing
sensor event	event

Case Study: Safe Home

When a sensor event is *recognized*, the software *invokes* an audible alarm attached to the system. After a delay time that is *specified* by the homeowner during system configuration activities, the software dials a telephone number of a monitoring service, *provides* information about the location, *reporting* the nature of the event that has been detected. The telephone number will be *redialed* every 20 seconds until telephone connection is *obtained*.

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity
Installation	event
number, type	thing
master password	thing
telephone number	thing
sensor event	event
audible alarm	external entity
delay time	thing
monitoring service	external entity

Recap: Identifying Classes

6 selection characteristics

1. Retained information
2. Needed services
3. Multiple attributes
4. Common attributes
5. Common operations
6. Essential requirements

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity
Installation	event
number, type	thing
master password	thing
telephone number	thing
sensor event	event
audible alarm	external entity
delay time	thing
monitoring service	external entity

Class	Selection Characteristics

Potential Class	Type
homeowner	role
system	thing
sensor	external entity
control panel	external entity
Installation	event
number, type	thing
master password	thing
telephone number	thing
sensor event	event
audible alarm	external entity
delay time	thing
monitoring service	external entity

Class	Selection Characteristics
No	Does not retain info
Yes	All 6 apply
Yes	All 6 apply
Yes	All 6 apply
No	None applies
No	Attributes of sensor class
No	Does not have multiple attributes
No	Does not have multiple attributes
Yes	All 6 apply
Yes	All 6 apply
No	Attribute of system class
No	So far it does not need service

Analyzing Class Elements (1/2)

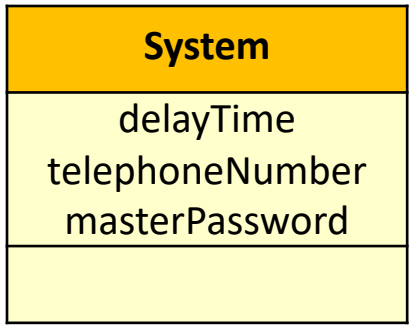
- Consider more fine-grained element types
  - **Roles** and **external entities** (actors)
    - Roles played by people who interact with the system
    - External entities that produce or consume information
  - **Organizational units** that are relevant to an application
    - e.g., team, group, division
  - **Structures**
    - Define a class of objects or related classes of objects
      e.g., sensors, computers, four-wheeled vehicles

Analyzing Class Elements (2/2)

- Consider more fine-grained element types
  - **Things**
    - Part of the information domain for the problem
    - e.g., reports, displays, letters, signals
  - **Occurrences**
    - Events occur within the context of system operation
  - **Places**
    - The context of the problem and the overall function

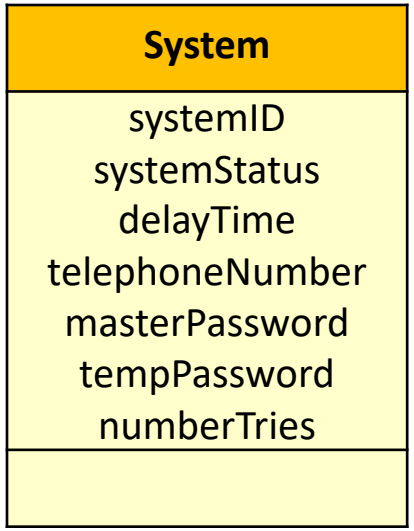
Case Study: Safe Home

- Let's look at the **system** class
  - Alarm response information
    - delayTime, telephoneNumber
  - Activation/deactivation
    - masterPassword
    - number of tries
    - temporary password
  - Identification
    - system ID, status



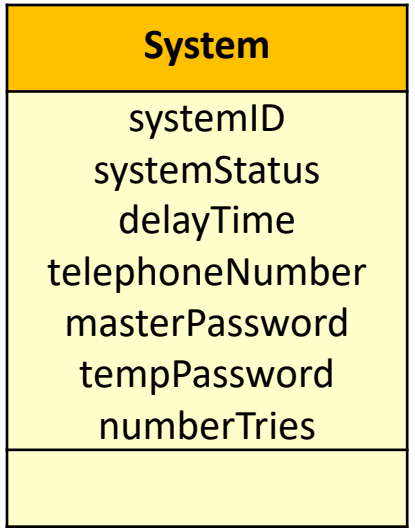
Case Study: Safe Home

- Let's look at the **system** class
  - Alarm response information
    - delayTime, telephoneNumber
  - Activation/deactivation
    - masterPassword
    - number of tries
    - temporary password
  - Identification
    - system ID, status



Case Study: Safe Home

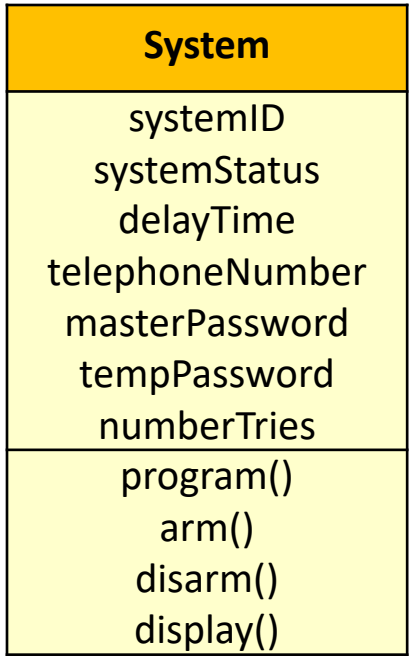
During installation, the SafeHome PC is used to *program* and *configure* the system. Each sensor is assigned a number and type, a master password is programmed for *arming* and *disarming* the system, and telephone number(s) are *input* for *dialing* when a sensor event occurs.



Case Study: Safe Home

During installation, the SafeHome PC is used to *program* and *configure* the system. Each sensor is assigned a number and type, a master password is programmed for *arming* and *disarming* the system, and telephone number(s) are *input* for *dialing* when a sensor event occurs.

- Display() typically should exist too.
- Divide operations into sub-operations if needed
  - e.g., program()

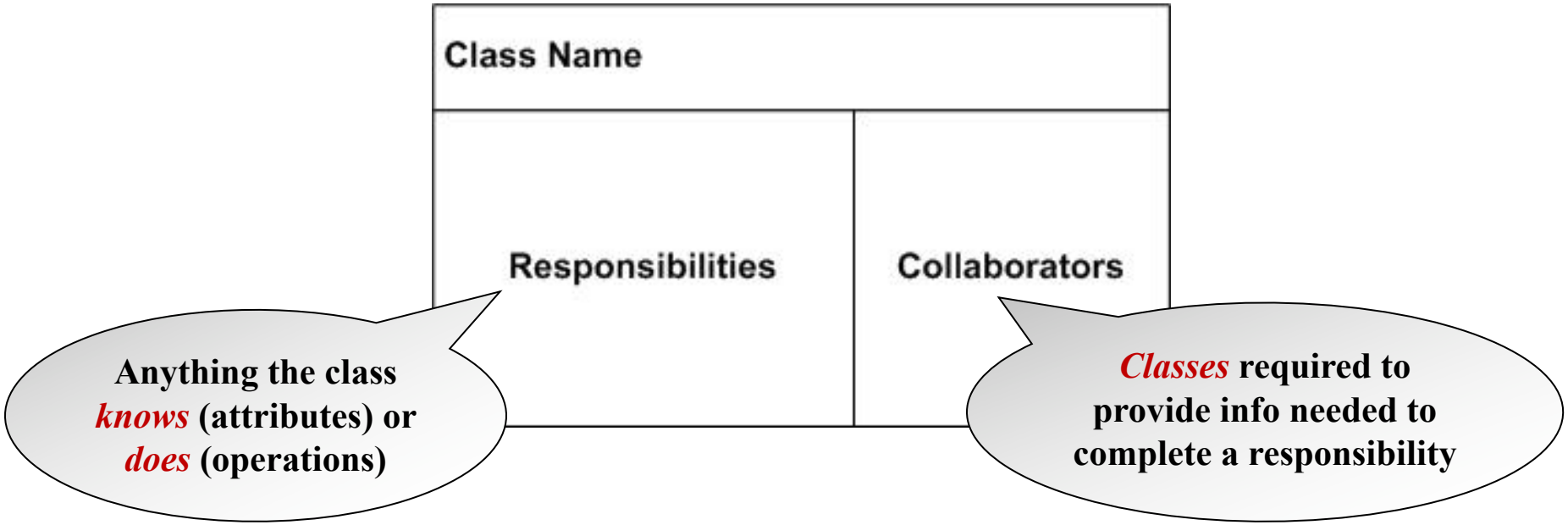


Class-Responsibility-Collaborator Modeling

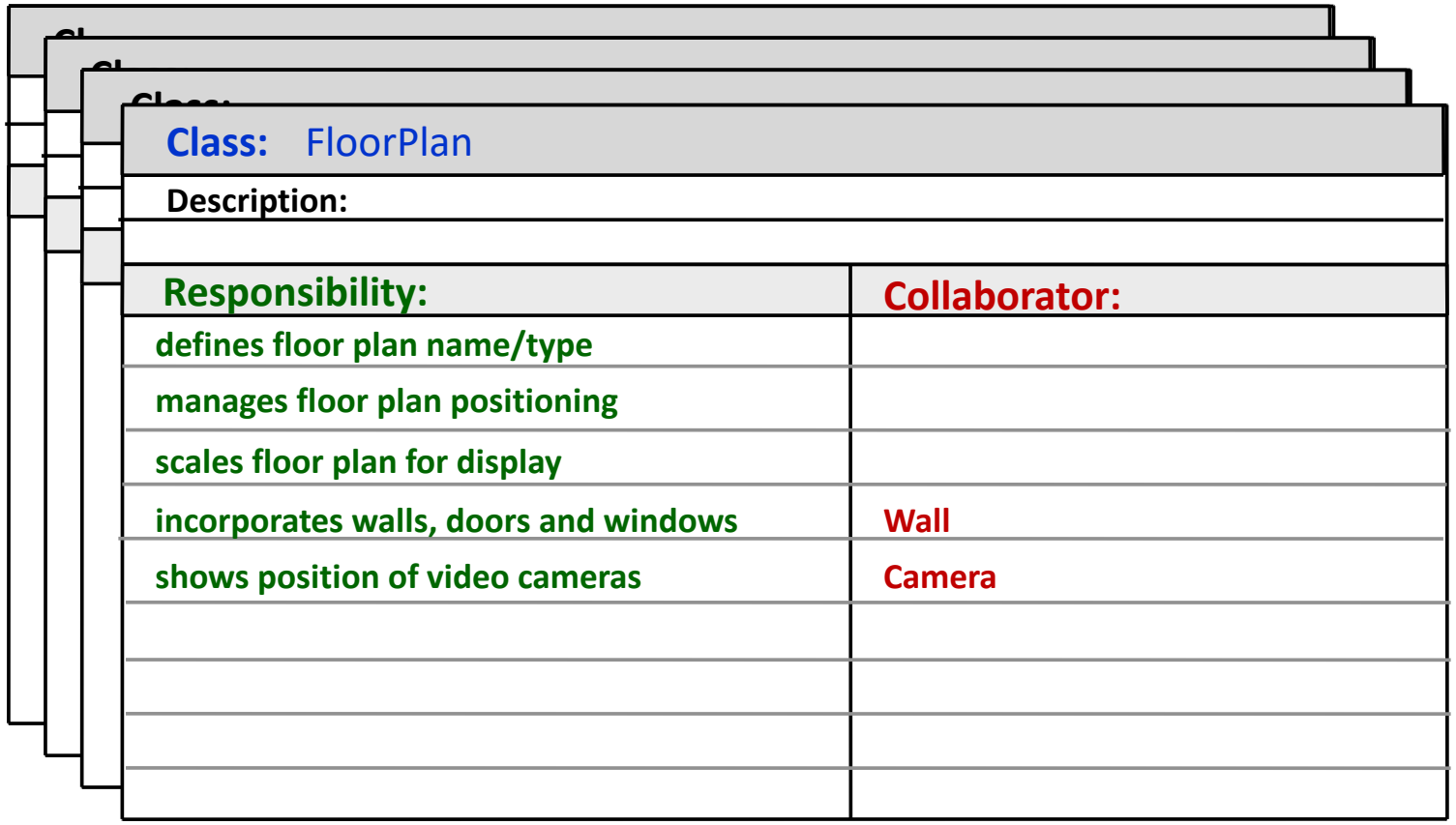
- CRC model:
  - Used to identify and organize classes
  - Originally introduced as a technique for teaching object-oriented concepts
  - Use a collection of (actual or virtual) index cards representing classes

CRC Modeling

- A CRC model - index cards represent classes



CRC Modeling



Classes

- Entity classes
  - Extracted directly from the statement of the problem
  - Represent things to be stored or persist throughout the development
- Boundary classes
  - Create/display interface
  - Mange how to represent entity objects to users
- Controller classes
  - Create/update entity objects
  - Initiate boundary objects
  - Control communications
  - Validate data exchanged

Responsibilities (1/3)

- System intelligence should be distributed across classes
  - Intelligence: what the system knows and what the system can do
  - How to distribute across classes?
  - Distributed more evenly to enhance maintainability: avoid extra long list
- Each responsibility should be stated as generally as possible
  - Responsibility reside high in the class hierarchy
  - Can be applied to subclasses

Responsibilities (2/3)

- Information and the behavior related to a responsibility should reside within the same class
  - Achieves encapsulation
- Information about one thing should be localized with a single class, not distributed across multiple classes
  - Avoid spreading across classes
  - Encapsulation is good in testing and maintenance

Responsibilities (3/3)

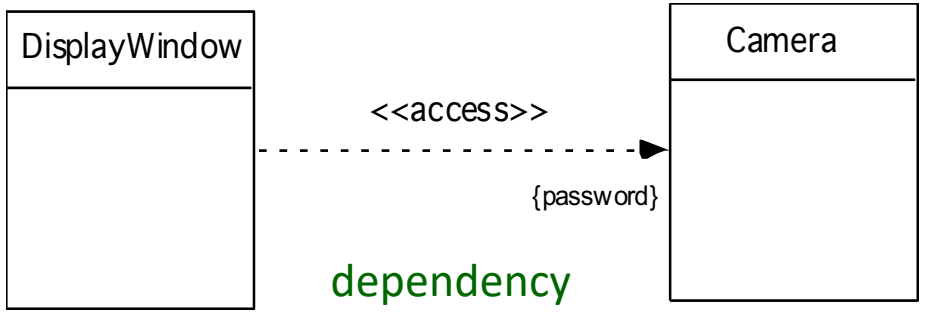
- Responsibilities should be shared among related classes, when appropriate
  - When some related objects need to exhibit the same behavior at the same time

  e.g., Play, PlayerHead, PlayerBody classes in video game: update() and display()

Collaborations

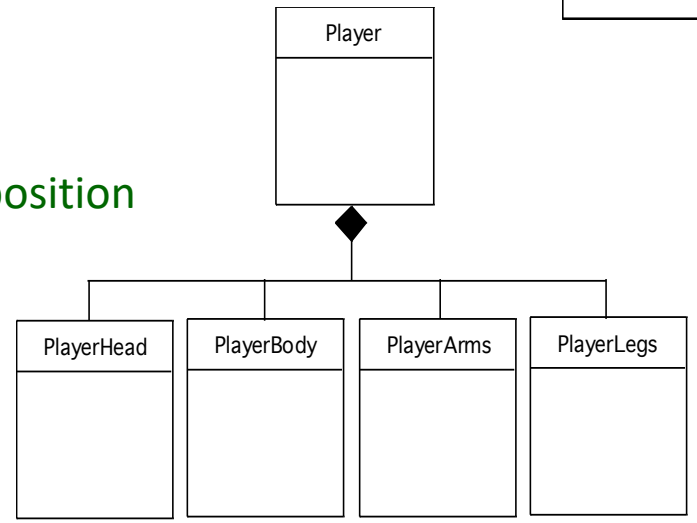
- A class may collaborate with other classes to fulfill responsibilities
  - If a class cannot fulfill every single responsibility itself, it must interact with another class
- Collaboration refers to identifying relationships between classes
  - is-part-of relationship
    - Aggregation
  - has-knowledge-of relationship: one class must acquire information from another class
    - Association
  - depends-upon relationship: dependency other than the above two

Relationships between Classes

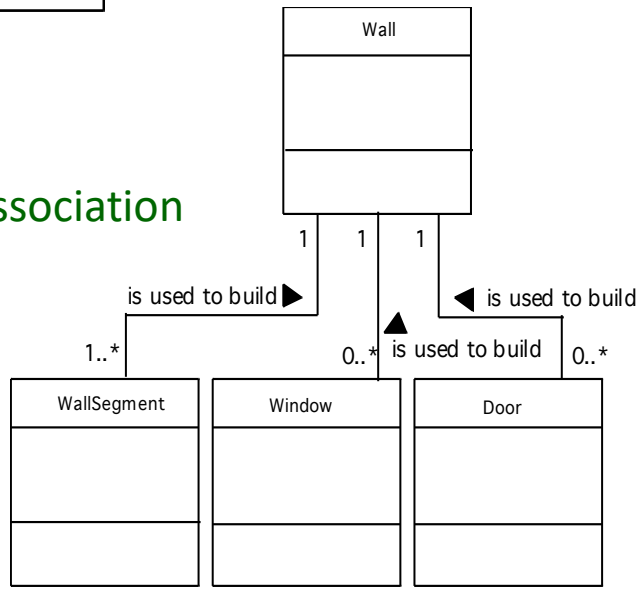


dependency

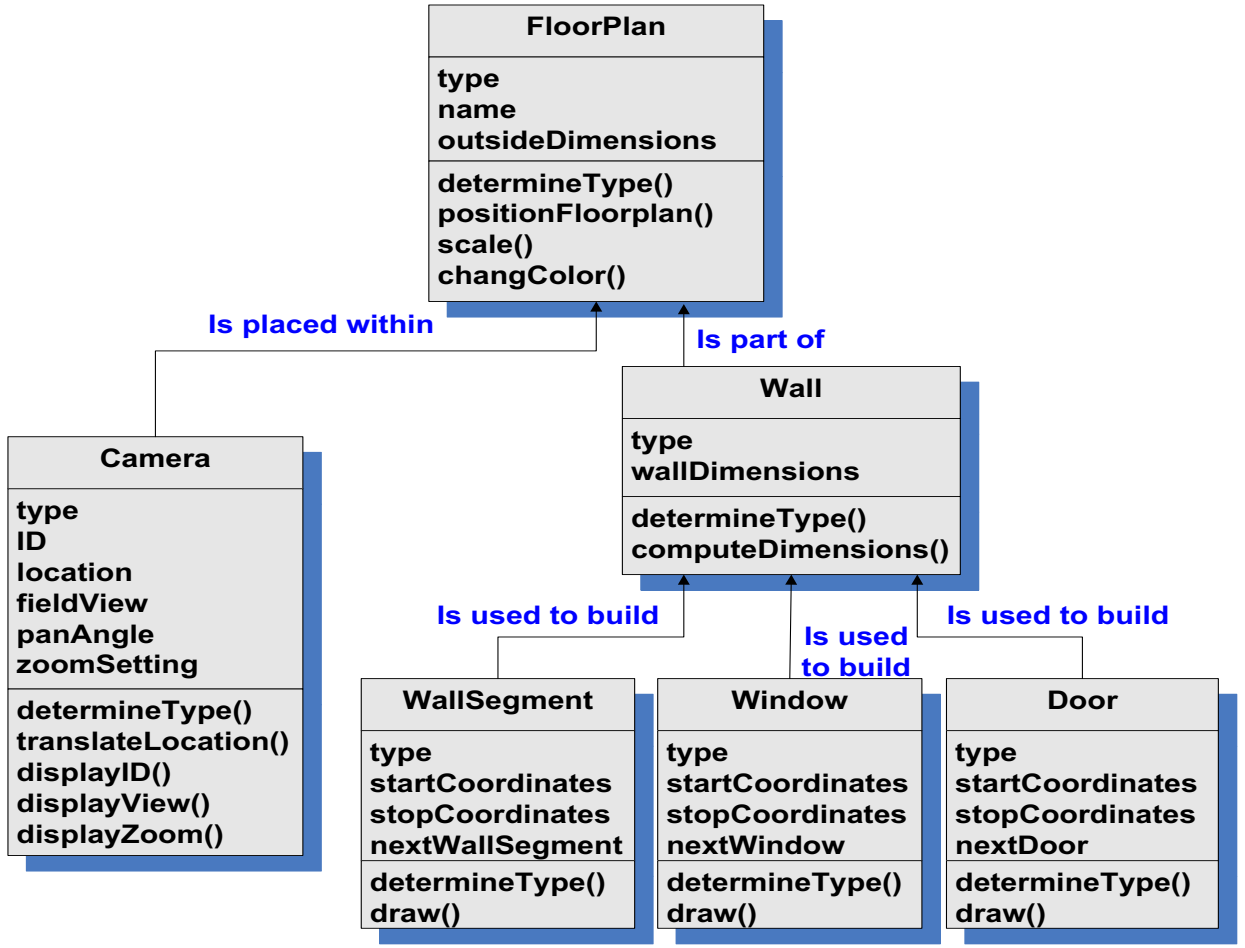
composition



association



Class Diagram



Validating a Class Diagram

- One of the most important, and often overlooked issues is how to validate a class diagram.

- Given a specification or a use-case, can you look at the class diagram and use features of it to manually “execute” the use case?

Reviewing a CRC Model

- Stakeholders review the CRC model once it is developed
  - All participants are given a subset of CRC index cards
    - No reviewer should have two cards that collaborate
  - Organize all use-case scenarios into categories
    - Review leader reads the use case
    - When it comes to an object, pass a token to the person holding the corresponding class index card
    - Check the responsibility on this index card, find the collaborator
    - Pass the token to the person with the collaborator index card
    - Describe the responsibilities on the card
    - The entire group checks the responsibilities
    - If cannot accommodate the use case, make modifications

UML Class Modeling

- An object-oriented modeling language developed in 1997
  - Models structure (static) and behavioral (dynamic) aspects of a system
  - Semi-formal: UML 2.0 added much more formality
  - Process-independent: can be used with a variety software development process models
  - Customizable and extensible

Abstraction Levels

- Three perspectives for class models
  - Analysis
    - Represents concepts in the domain
    - Drawn with no regard for implementation (language independent)
  - Specification
    - Focus on interfaces not on how implementation is broken into classes
  - Implementation
    - A blue-print for coding
    - Direct code implementation of each class in the diagram

Student Records Management System

{Joe, Sue, Mary, Frank, Tim, …}

Student

Analysis

Student
name major GPA standing interests
-- The set of students known to the registration system

Specification

:Student
name: String major: String GPA: real standing: Scode
add(Course) drop(Course)
-- Software representation of students; support registration in courses

Implementation

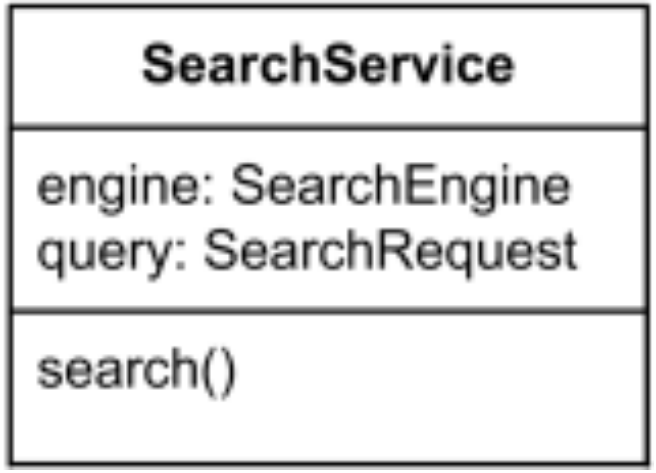
Student
-major: String -GPA: Real -standing: String
+add(Course) +drop(Course)
-- Handle a registration in courses

0..1
1

CourseList
-- Display a dynamic list courses

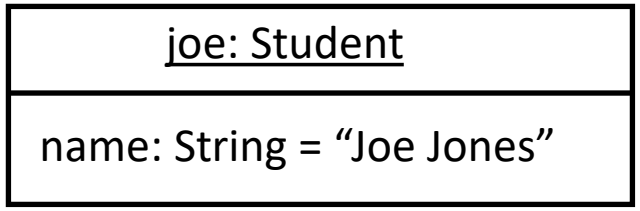
Classes in UML Diagrams

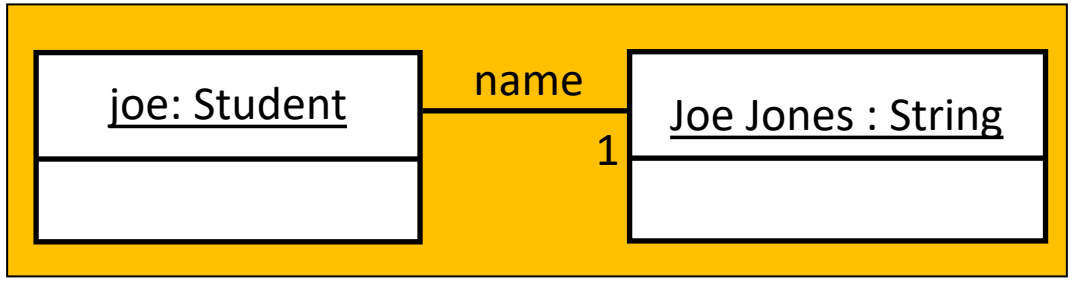
- An abstraction which describes a collection of objects sharing some commonalties
- Syntax
  - Name: noun, singular
    - centered, bold, first letter capitalized
  - Attribute
    - left justified, lower cases
  - Operations
  - Visibility
    + public
    - private
    # protected



Attributes

- An attribute can be defined for individual objects or a class of objects
  - Static: if defined for a class, every object in the class has that attribute (place holder)
- An attribute relates an object to some other object

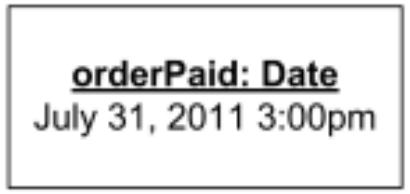


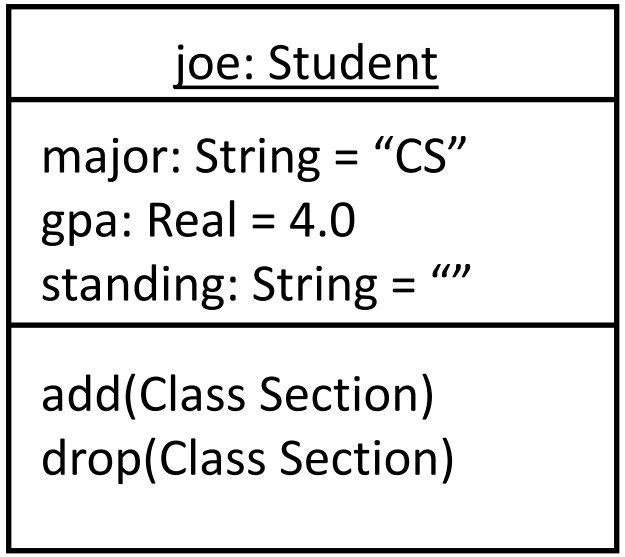


Objects

- Object is an instance of a class
  - Fundamental building blocks of object-oriented systems
  - Instance name and class path are separated by a ":"
  - Operation syntax:
    name (params) : return type
- An instance may have some value
  - Instance orderPaid of the Date class has

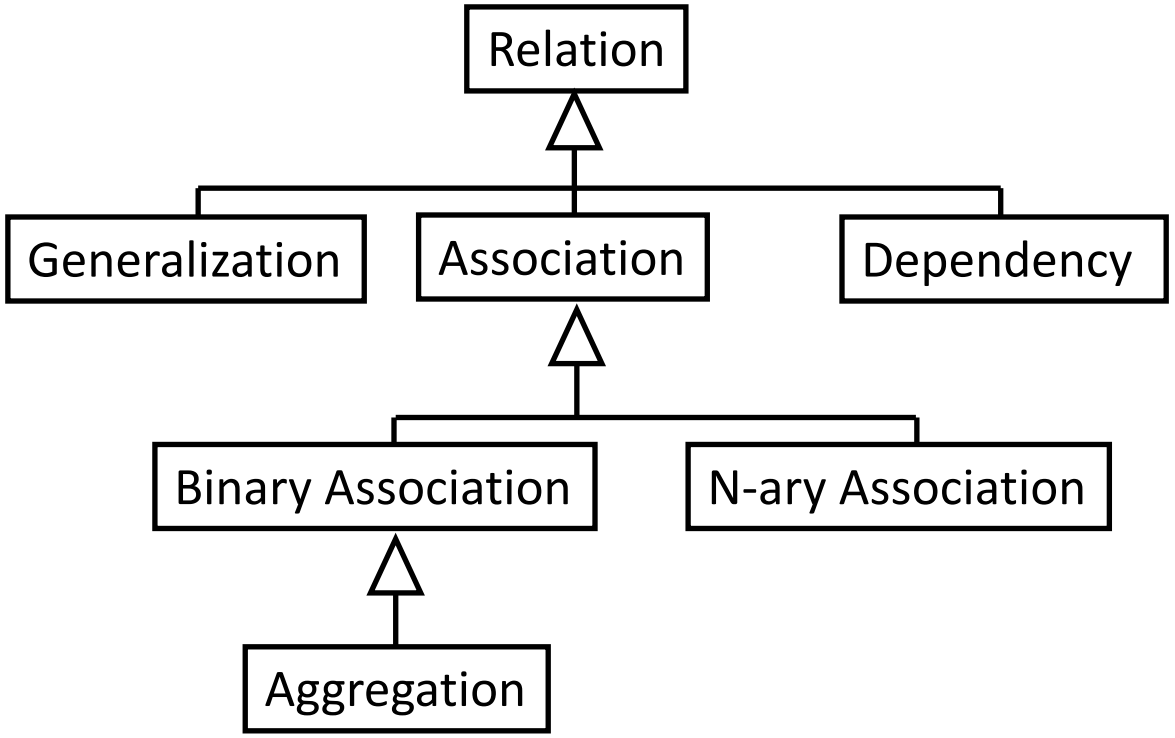
  the value July 31, 2011 3:00 pm





Type of Relationships in Class Diagrams

- Class diagrams show relationships between classes.



Associations

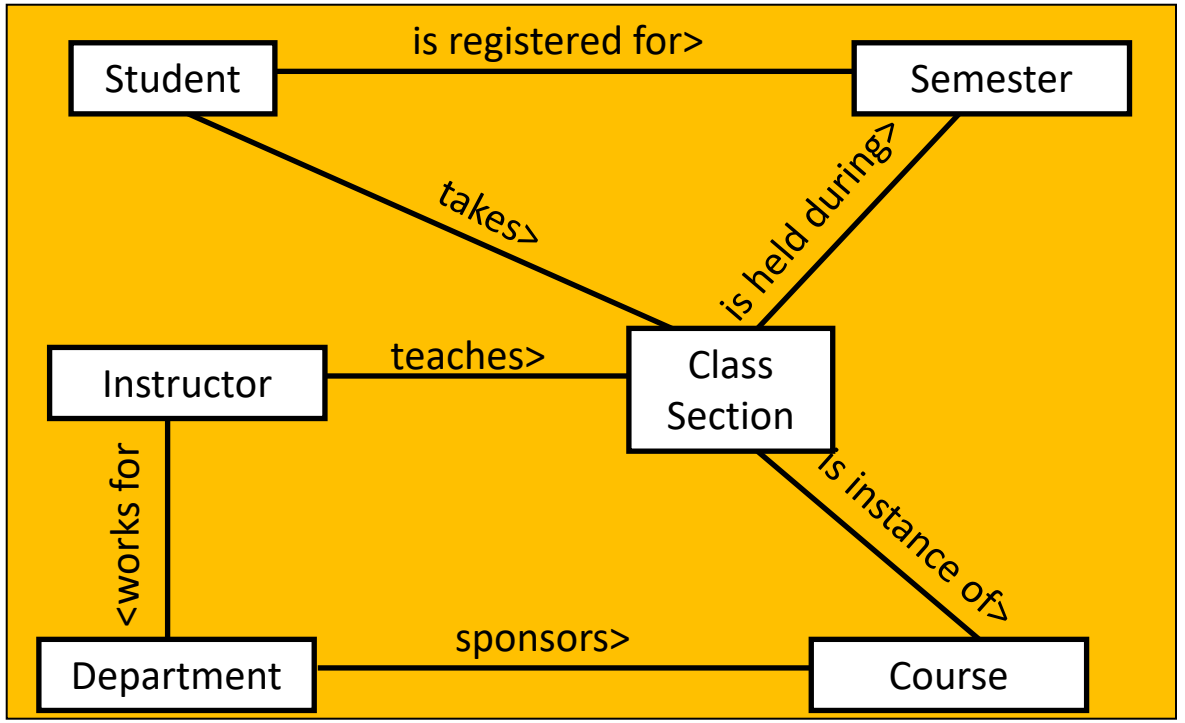
- An association is a *structural relationship* that specifies a connection between classes
- Classes A and B are associated if:
  - An object of class A sends a message to an object of B
  - An object of class A creates an instance of class B
  - An object of class A has an attribute of type B or collections of objects of type B
  - An object of class A receives a message with an argument that is an instance of B (maybe…)
    - Depends whether it “uses” that argument

Associations

- Associations
  - Links are instances of associations
  - Association names are typically verb phrases (in lower case)
  - The name should include an arrow indicating the direction in which the name should be read
  - Often interaction diagrams are useful for modeling objects

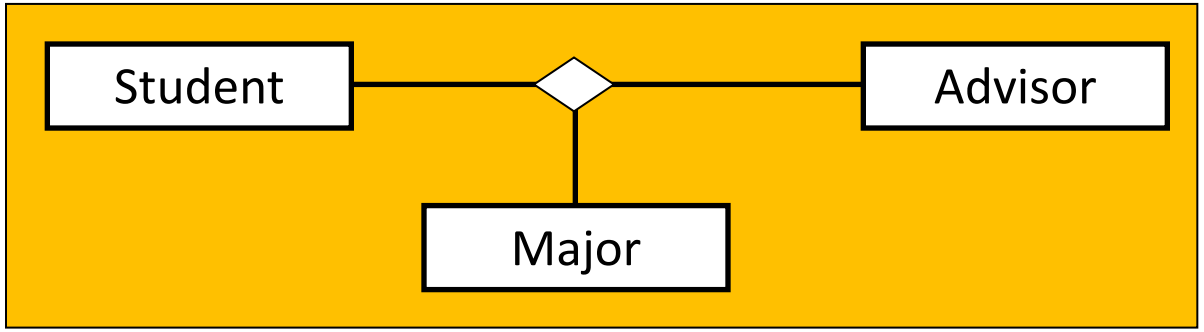
Associations

- A solid line connecting two classes



N-ary Associations

- Associations can connect more than one class

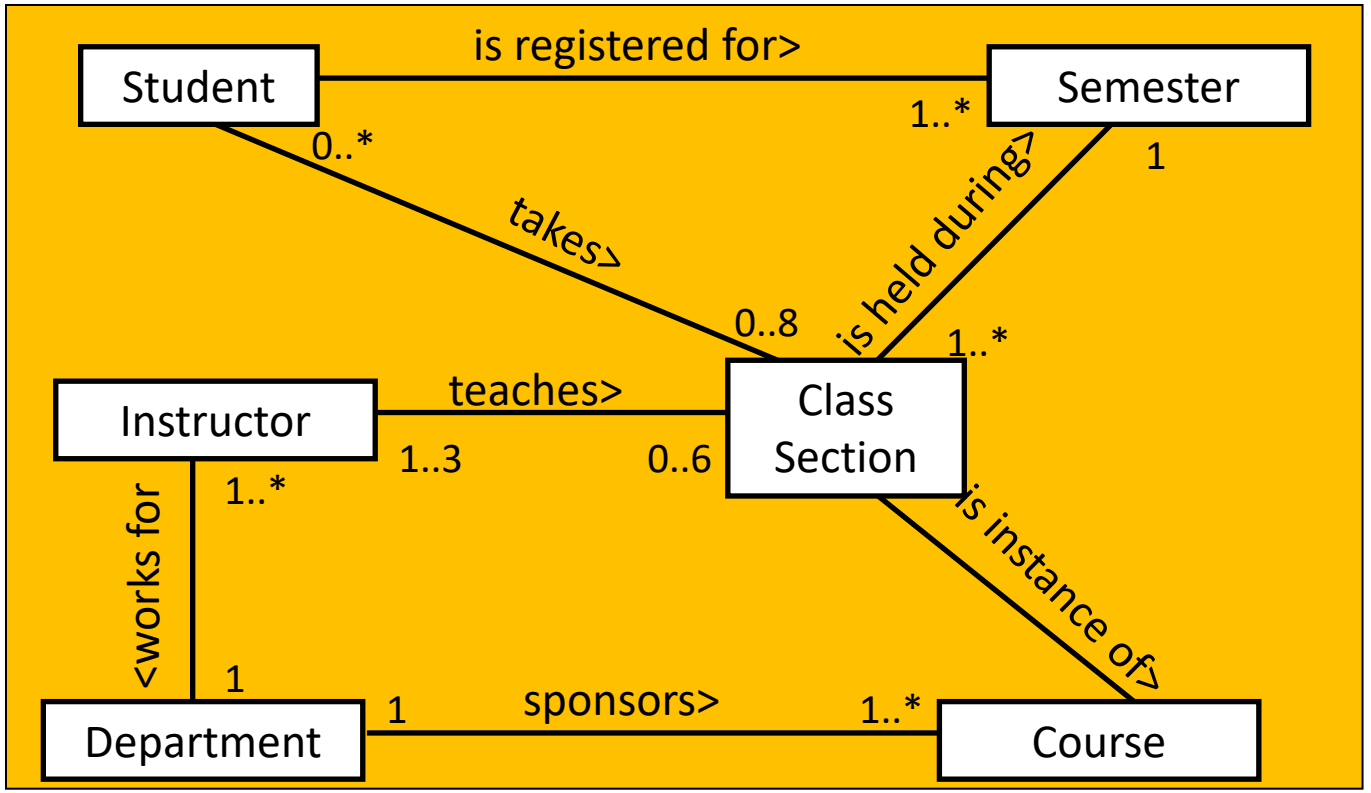


Multiplicity

- How many objects from two classes are linked?
  - An exact number: indicated by the number
  - A range: two dots between a pair of numbers
  - An arbitrary number: indicated by * symbol
  - (Rare) A comma-separated list of ranges

  - e.g., 1 1..2 0..* 1..* * (same as 0..*)
  - Implementing associations depends on multiplicity

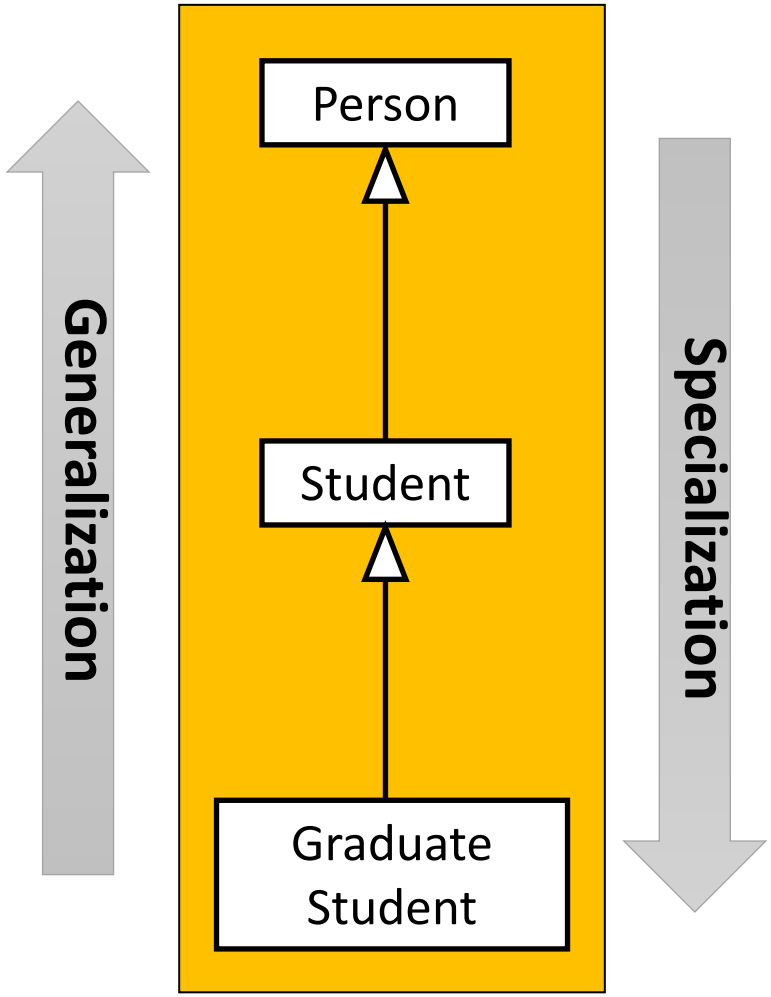
Multiplicity



Generalization

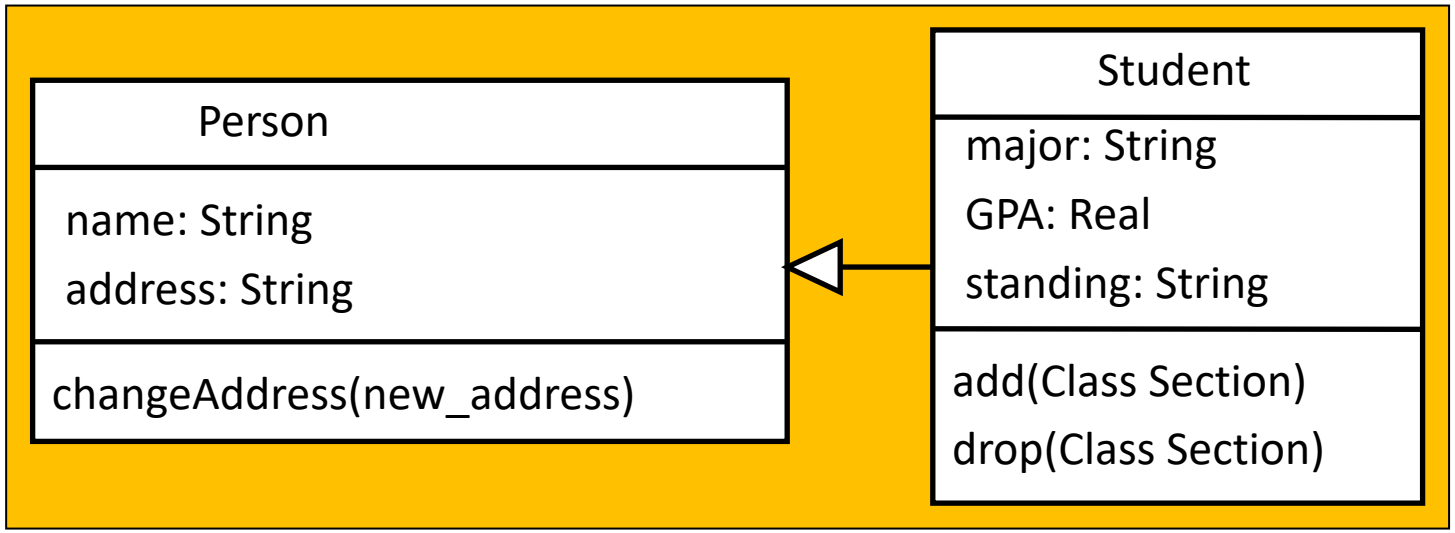
- Generalization is an association between classes
  - A subclass is connected to a superclass by an arrow with a solid line with a hollow arrowhead.

- From an analysis perspective, it represents generalization/specialization:
  - Specialization is a subset of the generalization



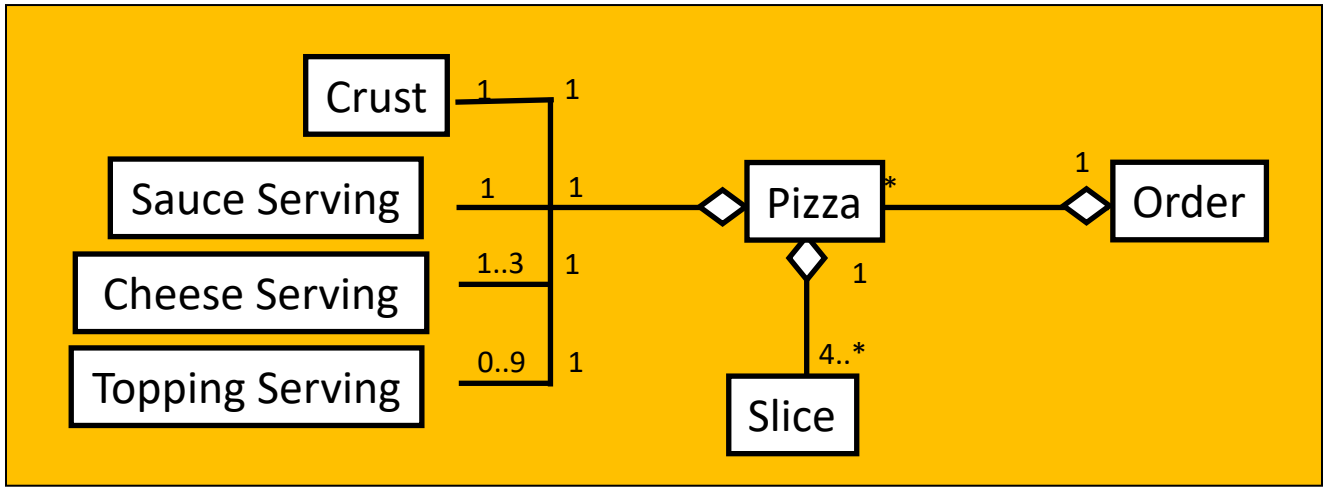
Generalization

- Generalization represents implementation inheritance
  - You model “inheritance” early, but not implement it at the conceptual level



Aggregation

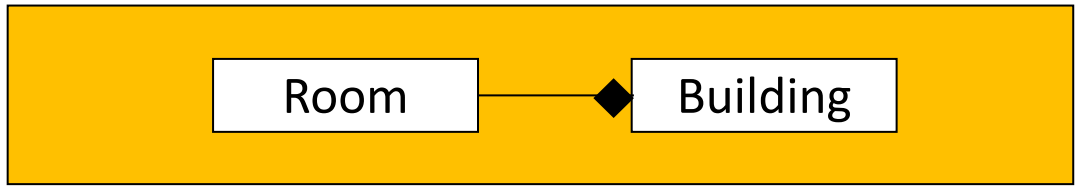
- Aggregation: is a special kind of association that means “part of”
- Aggregations should focus on a single type of composition (physical, organization, etc.)



Coming up: Composition (very similar to aggregation)

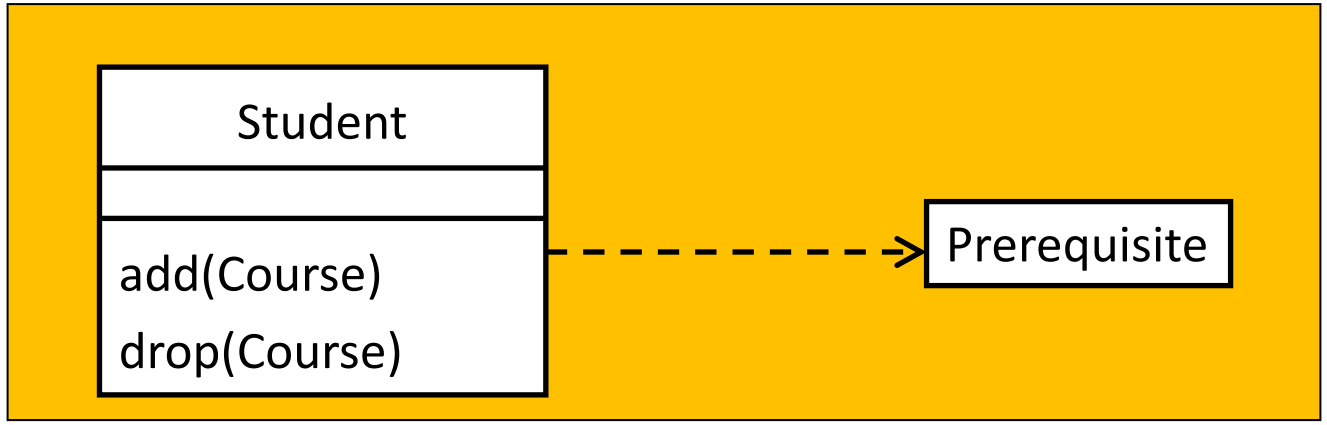
Composition

- Very similar to aggregation:
  - Think of composition as a stronger form of aggregation
  - **Composition means something is a part of the whole, but cannot survive on it's own**



Dependencies

- A using relationship
  - A change in the specification of one class may affect the other
  - But not necessarily the reverse



Properties/Stereotypes

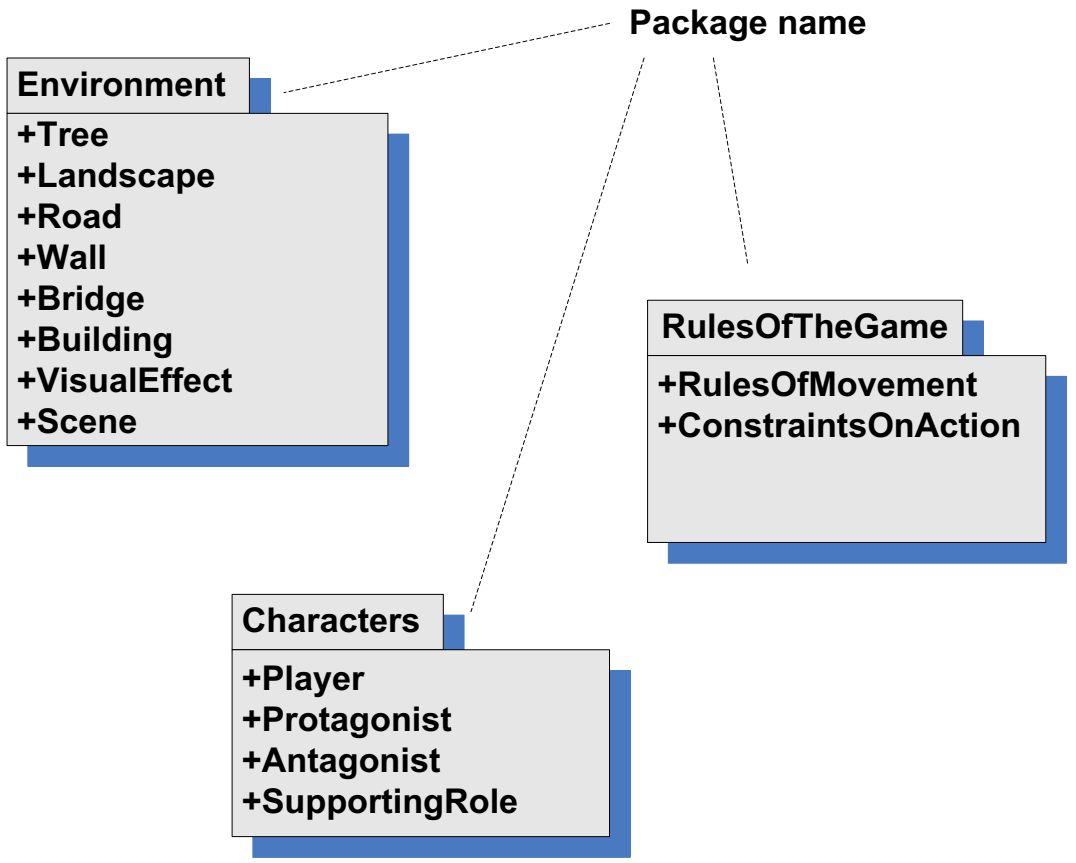
- Extends the “vocabulary” of UML
  - Syntax: <<property/stereotype>>
- UML predefines many:
  - Classes: <<interface>>, <<type>>, <<implementationClass>>, <<enumeration>>, <<thread>>
  - Constraints: <<precondition>>
  - Dependencies: <<friend>>, <<use>>
  - Comments: <<requirement>>, <<responsibility>>
  - Packages: <<system>>, <<subsystem>> (maybe classes, too)
  - Or, create your own if needed

Analysis Packages

+ public

– hidden

accessible only to a given package



Revisit Class Diagrams

- Class diagrams are like the paragraphs of a technical paper
  - Each diagram should focus on a specific topic
  - A diagram provides supporting details for the main concept that is trying to communicate
  - The level of the abstraction used in the diagrams should be consistent
- Together, all the diagrams for a system comprise a “model” of that system

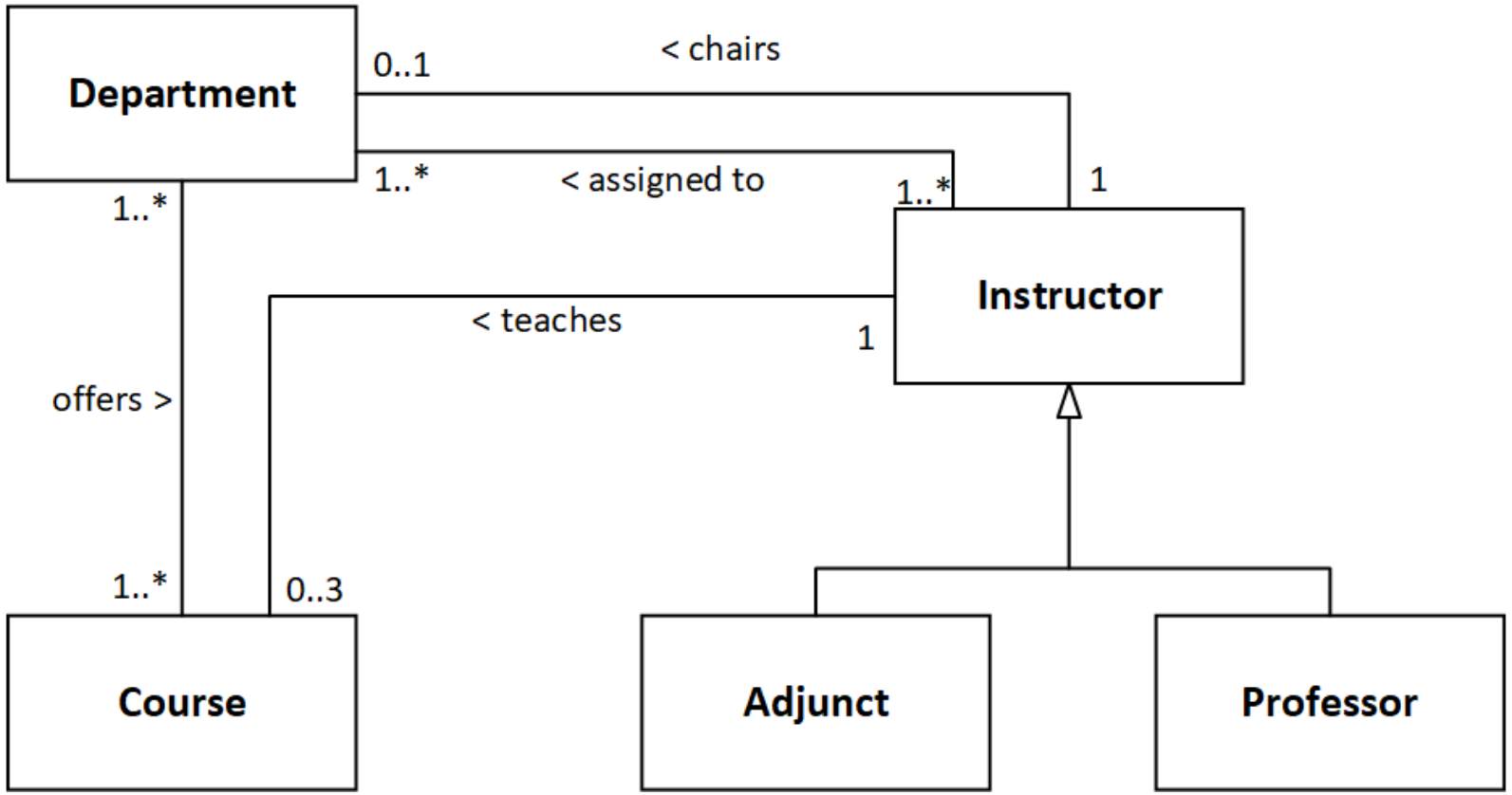
Class Diagrams

- Pitfalls of Class Diagrams
  - Using class diagrams alone can cause developers to focus too much on structure and ignore behavior
  - Using the wrong (or a mixed) perspective can lead to misunderstanding
  - Using the wrong level of abstraction can be confusing to the target audience
  - Using mixed levels of abstraction can reduce the usefulness of diagram

Example

- University Courses
  - Some instructors are professors, while others have job title adjunct
  - Departments offer many courses, but a course may be offered by more than 1 department
  - Courses are taught by instructors, who may teach up to three courses
  - Instructors are assigned to one (or more) departments
  - One instructor also serves a department chair

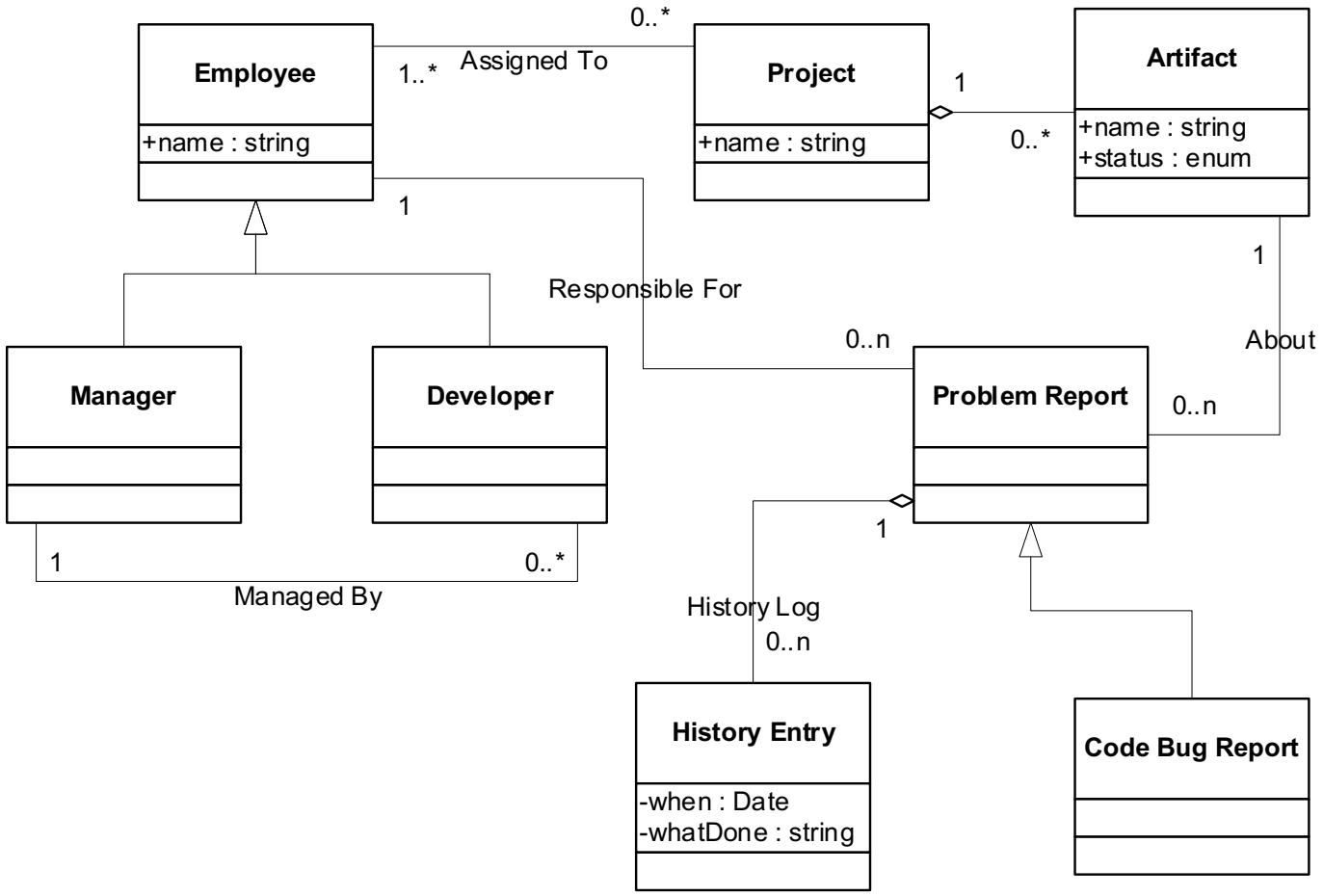
Class Diagram



Another Example

- Problem Reporting Tool: a CASE tool for storing and tracking problem reports
  - Employees are assigned to a project
  - A manager may add new artifacts and assign problem reports to developers
  - Each report contains a problem description and a status
  - Each problem can be assigned to someone
  - Problem reports are made in one of the “artifacts” of a project

Class Diagram



References

- Prof. Fengjun Li's EECS 448 Fall 2015 slides

- This slide set has been extracted and updated from the slides designed to accompany *Software Engineering: A Practitioner's Approach, 8/e* (McGraw-Hill 2014) by Roger Pressman