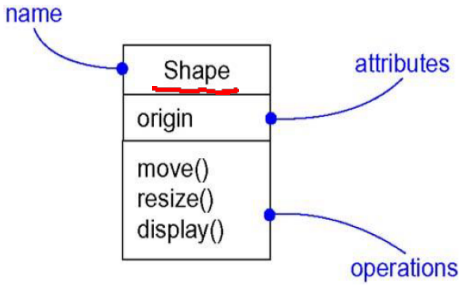
CLASS DIAGRAM

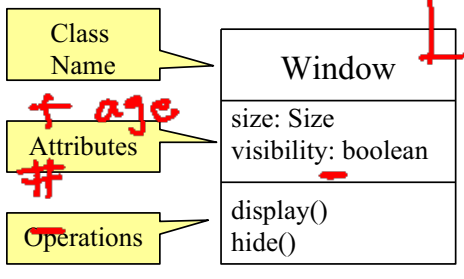
Introduction

- Most important building block
- Description of a set of objects that share the same attributes, operations, relationships and semantics
- Used to capture the vocabulary of the system
  - Include abstractions of the problem domain
  - Classes that make up the implementation
- Form a part of a balanced distribution of responsibilities across the system



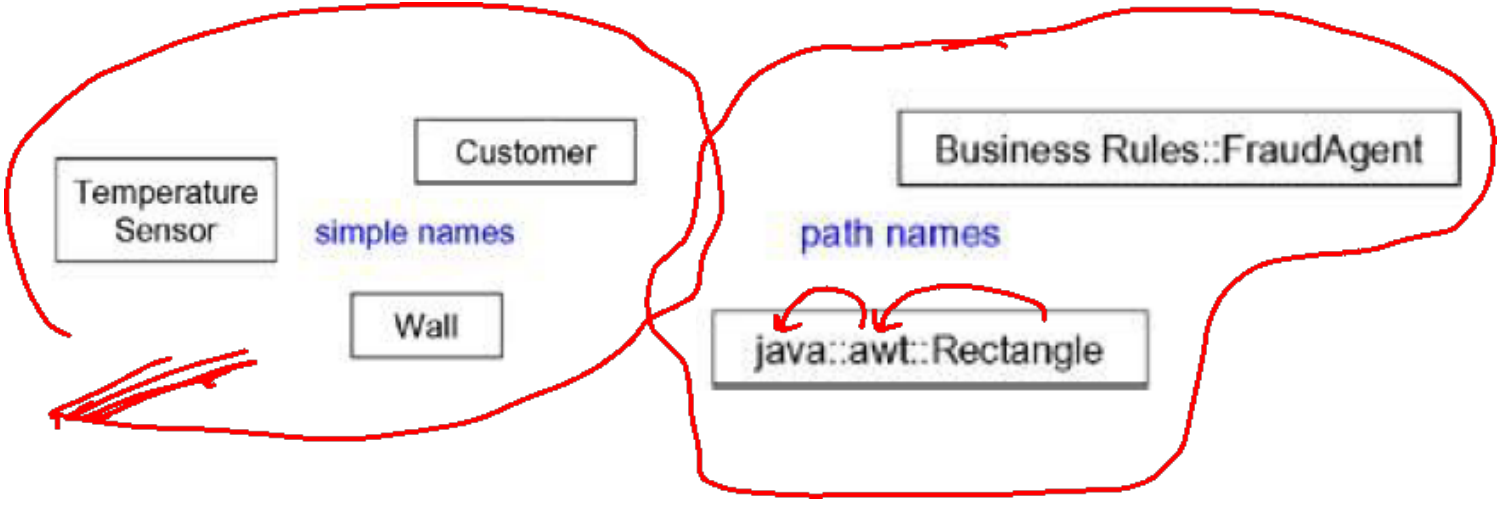
Class

- Describes a set of objects having similar:
  - Attributes (status)
  - Operations (behavior)
  - Relationships with other classes
- Attributes and operations may
  - have their visibility marked:
  - "+" for *public*
  - "#" for *protected*
  - "–" for *private*
  - "~" for *package*



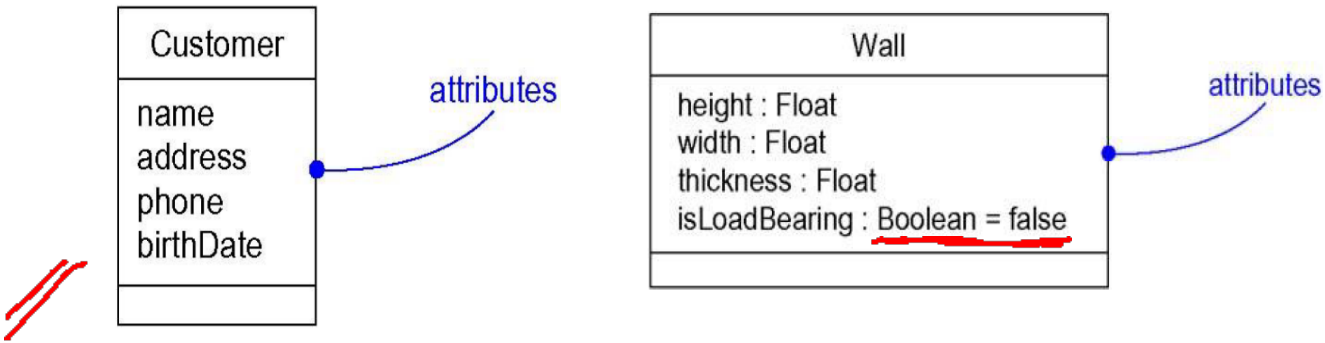
Class Names

- Name must be unique within its enclosing package
- Simple name and Path name
- Class names are noun phrases from the vocabulary of the system



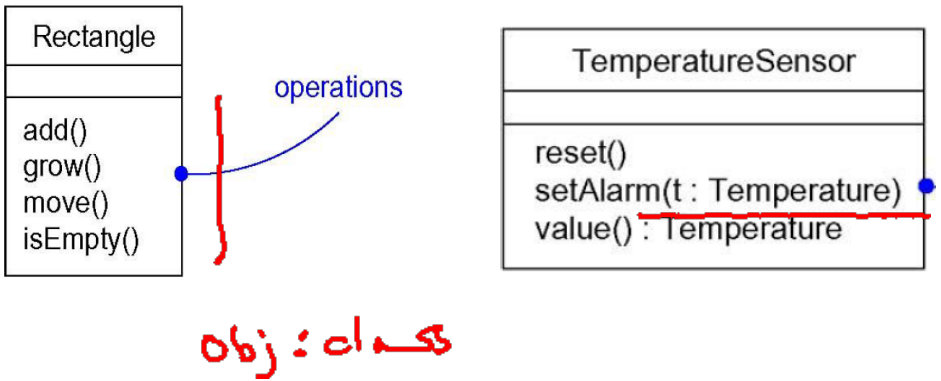
Attributes

- Named property of a class
  - Describes a range of values that instances of the property hold
  - Shared by all objects of that class
- An abstraction of the kind of data or state of an object
  - At a given moment, an object will have specific values for each of its attributes
- Noun phrase that represents some property



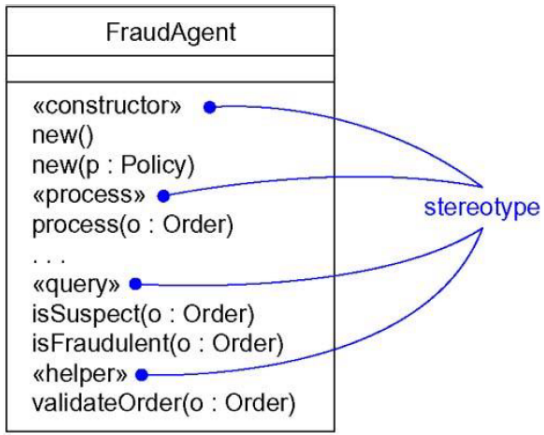
Operations

- A service that can be requested from any object of the class to affect behavior
- Invoking an operation changes the object's data or state
- Verb phrase representing some behavior of the class



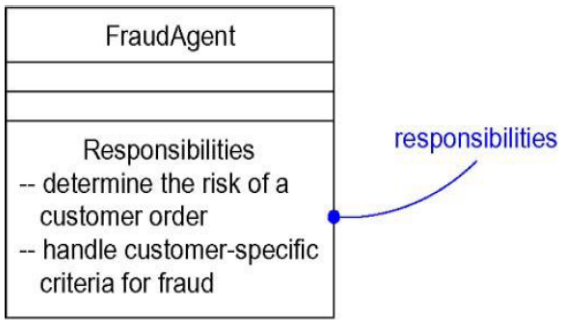
Organizing Attributes and Operations

- Don’t have to show every attribute and operation at once
- End each list with ellipsis (…)
- Can also prefix each group with a descriptive category using stereotypes



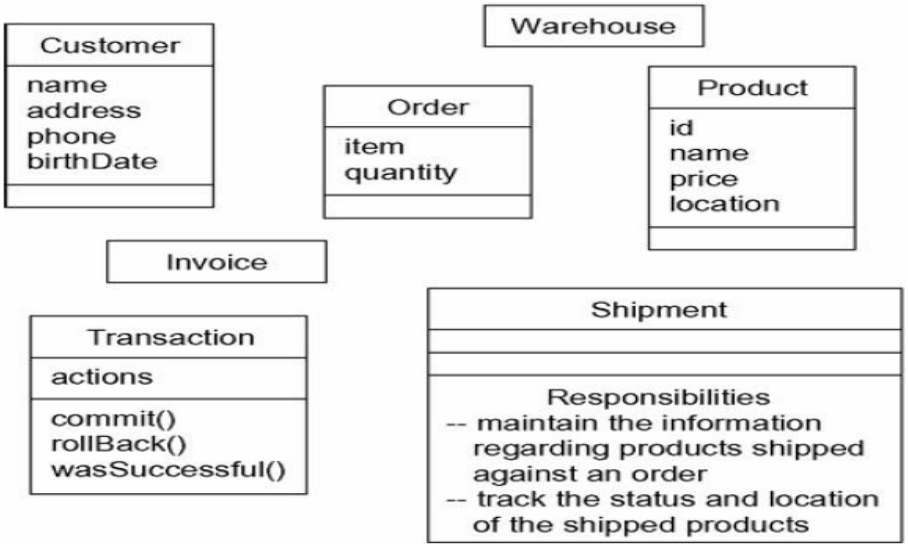
Responsibilities

- Is a contract or an obligation of a class
  - All objects of the class have the same kind of state and behavior
- Attributes and operations are the features that carry out the class's responsibility
  - `TemperatureSensor` class responsible for measuring temperature and raising an alarm
- Techniques used - CRC cards and use case based-analysis



Modeling the Vocabulary of a System

- Identify the things that describe the problem
- For each abstraction, identify a set of responsibilities
- Provide the attributes and operations needed to carry out those responsibilities



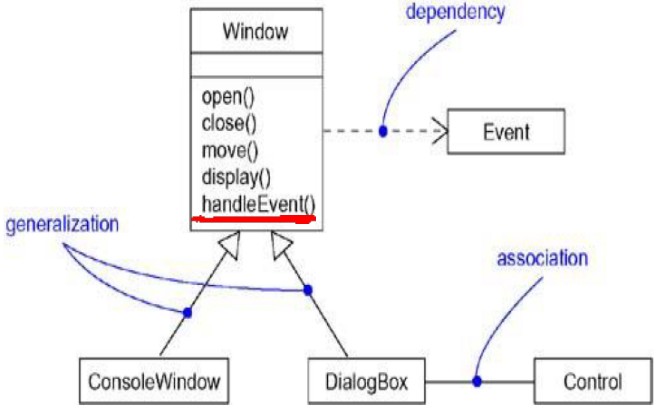
CLASS RELATIONSHIPS

Introduction

- Classes collaborate with other classes in a number of ways
- Three kinds of relationships in OO modeling
  - Dependencies
  - Generalizations
  - Associations
- Provide a way for combining your abstractions
- Building relationships is not like creating a balanced set of responsibilities

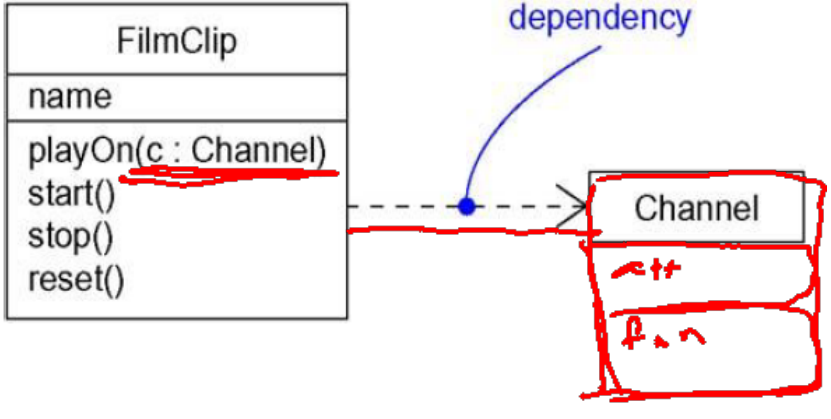
Introduction

- Relationship is a connection among things
- UML graphical notation
  - Permits to visualize relationships apart from any specific programming language
  - Emphasize the most important parts of a relationship
    - Name
    - Things it connects
    - Properties



Dependency

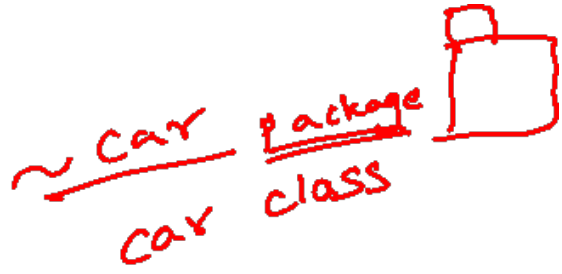
- *Using* relationship
  - States that a change in specification of one thing may affect another thing that uses it
- Used in the context of classes
  - Uses operations or variables/arguments typed by the other class
  - Shown as an argument in the signature of an operation
  - If used class changes, the operation of the other class may be affected

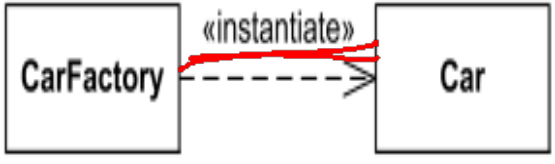


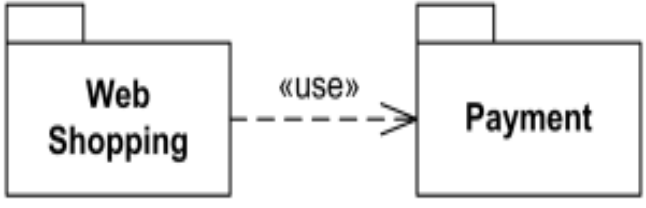
Dependency

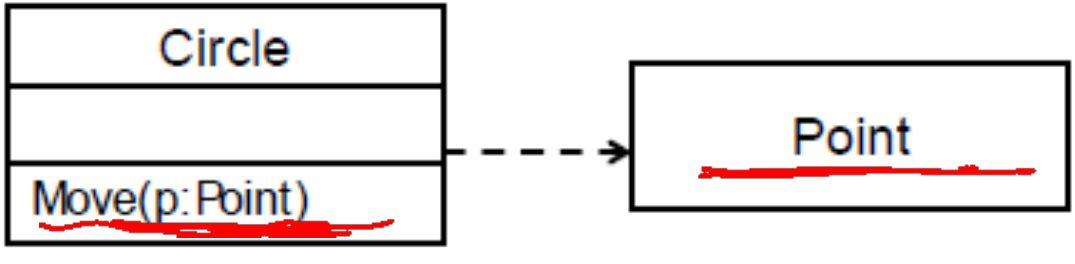
- Dependency is a weaker form of relationship which indicates that one class depends on another because it uses it at some point in time.
- One class depends on another if the independent class is a parameter variable or local variable of a method of the dependent class.
- This is different from an association, where an attribute of the dependent class is an instance of the independent class.

Dependency


~ car
package
car
class

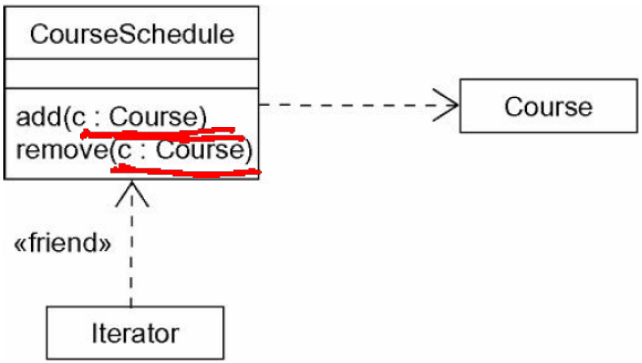

CarFactory
«instantiate»
Car


Web
Shopping
«use»
Payment


Circle
Move(p:Point)
Point

Modeling Simple Dependencies

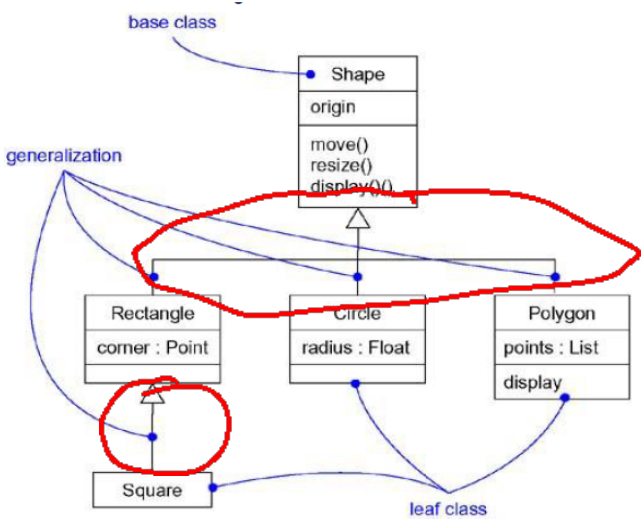
- To model the using dependency
  - Create a dependency pointing from the class with the operation to the class used as a parameter in the operation



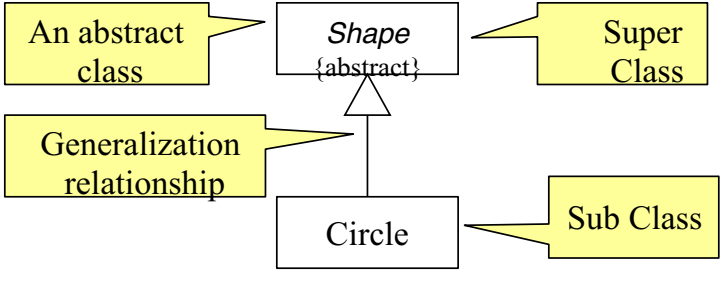
Generalization

- Relationship between a general thing (superclass) and a more specific kind of that thing (subclass)
- "Is-a-kind-of" relationship
- Child is substitutable for the parent
- Polymorphism
  - Operation of child has the same signature as an operation in the parent but overrides it

Generalization



{abstract} is a tagged value that indicates that the class is abstract.
The name of an abstract class should be italicized

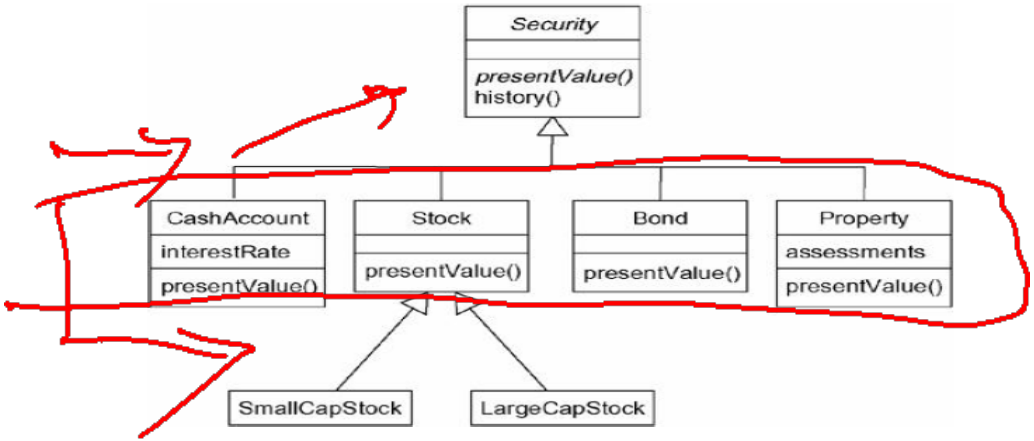


Generalization

- A sub-class inherits from its super-class
  - Attributes
  - Operations
  - Relationships
- A sub-class may
  - Add attributes and operations
  - Add relationships
  - Refine (override) inherited operations
- A generalization relationship **may not** be used to model interface implementation.

Modeling Single Inheritance

- Find classes that are structurally or behaviorally similar while modeling the vocabulary
- To model inheritance
  - Look for common responsibilities
  - Elevate these to a more general class
  - Specify that the more specific class inherits from the more general class

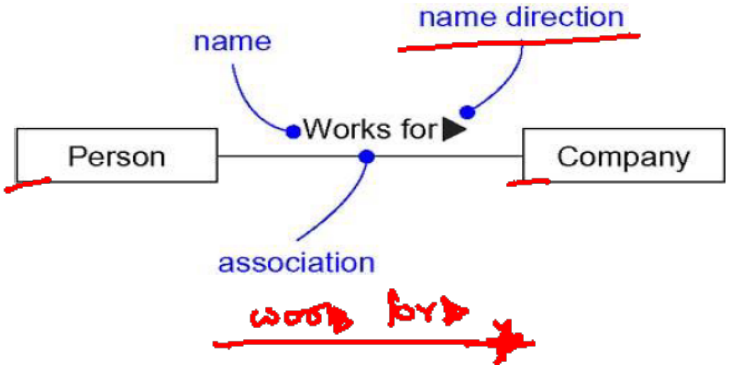


Association

- Structural relationship
  - Specifies that objects of one thing are connected to objects of another
- Can navigate from objects of one class to the other
- Self Association
  - Connects a class to itself
- Binary Association
  - Connects exactly two classes

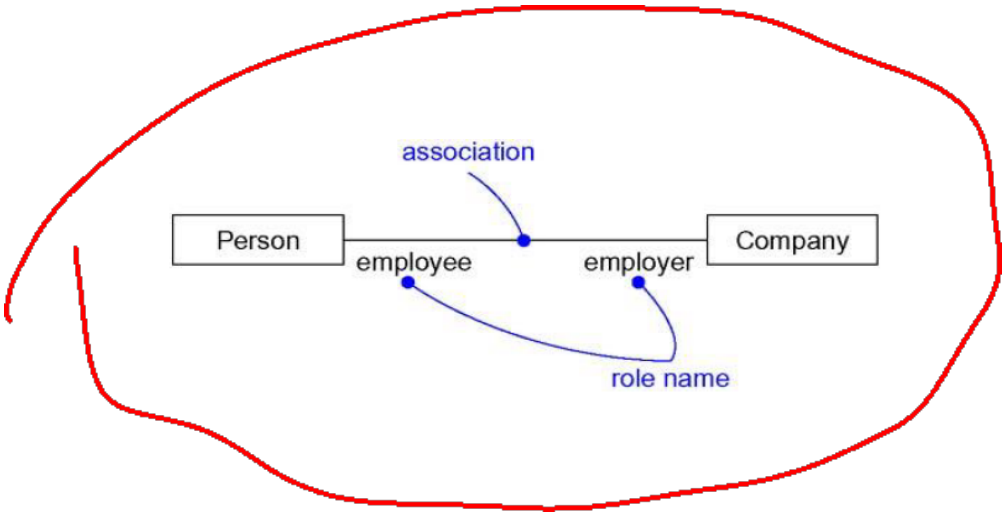
Association : Adornments

- Name
  - Use a name to describe the nature of the relationship
  - Can give a direction to the name



Association : Adornments

- Role
  - The face that the class at the far end of the association presents to the class at the near end
  - Explicitly name the role a class plays (*End name* or *Role name*)
  - Same class can play the same or different roles in other associations



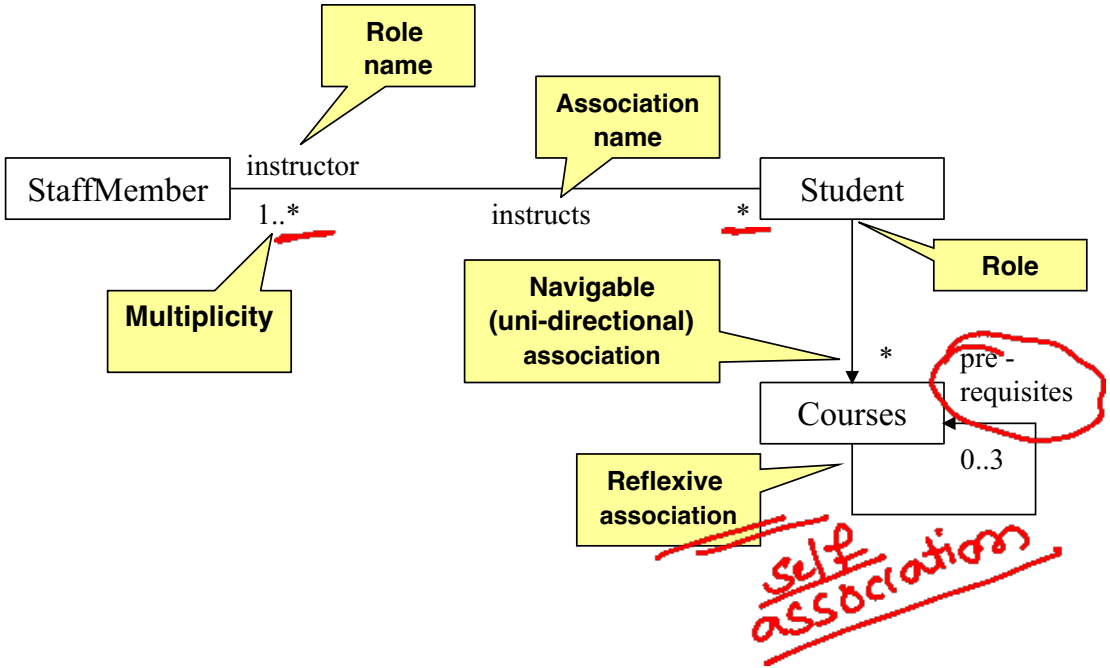
Association : Adornments

- Multiplicity
  - States how many objects may be connected across an instance of an association
  - An expression that evaluates to a range of values or an explicit value
  - Multiplicity at one end of an association means
    - For each object of the class at the opposite end, there must be that many objects at the near end
  - Show a multiplicity of
    - Exactly one (1)
    - Zero or one (0 . . 1)
    - Many (0 . . *)
    - One or more (1 . . *)
    - State an exact number (ex: 3)

Multiplicity

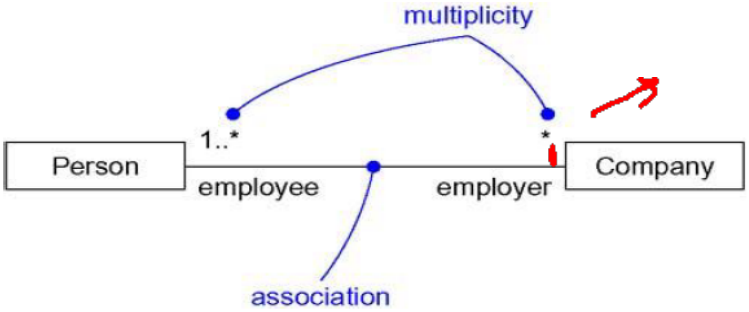
- 1:1
- 1:N
- N:1
- N:M
- Meta character – “*” and “+”:

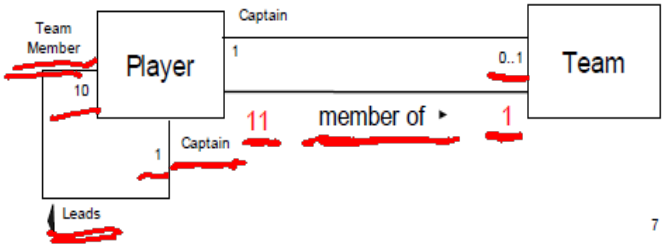
Associations (cont.)

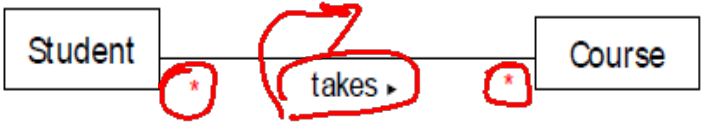


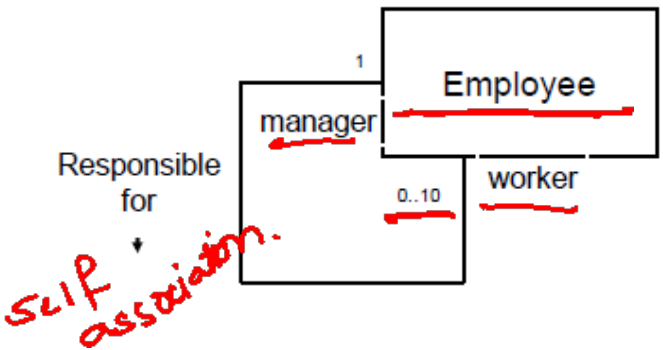
Association : Adornments

- Multiplicity
  - Specify complex multiplicities by using a list, 0..1, 3..4, 6..* (any number of objects other than 2 or 5)



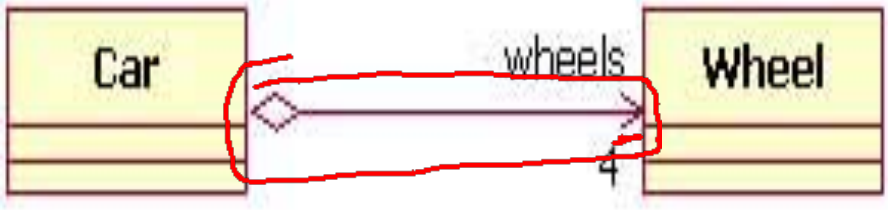






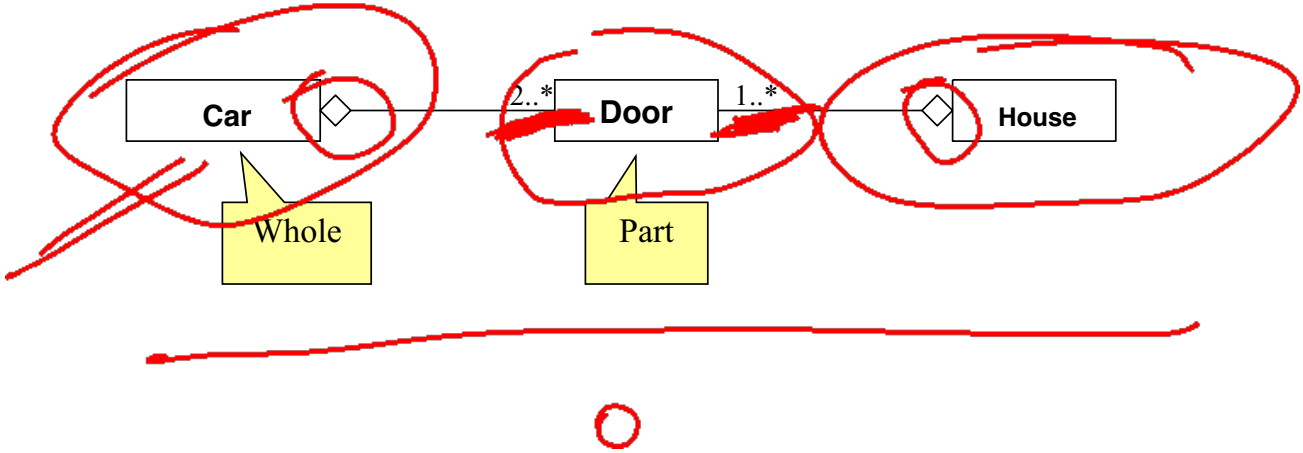
Association : Adornments

- Aggregation
  - Model a whole/part relationship
  - Represents a “has-a” relationship



Aggregation

- A special form of association that models a whole-part relationship between an aggregate (the whole) and its parts.
  - Models a “is a part-part of” relationship.



Aggregation (cont.)

- Aggregation tests:
  - Is the phrase "part of" used to describe the relationship?
    - A door is "part of" a car.
  - Are some operations on the whole automatically applied to its parts?
    - Move the car, move the door.
  - Are some attribute values propagated from the whole to all or some of its parts?
    - The car is blue, therefore the door is blue.
  - Is there an intrinsic asymmetry to the relationship where one class is subordinate to the other?
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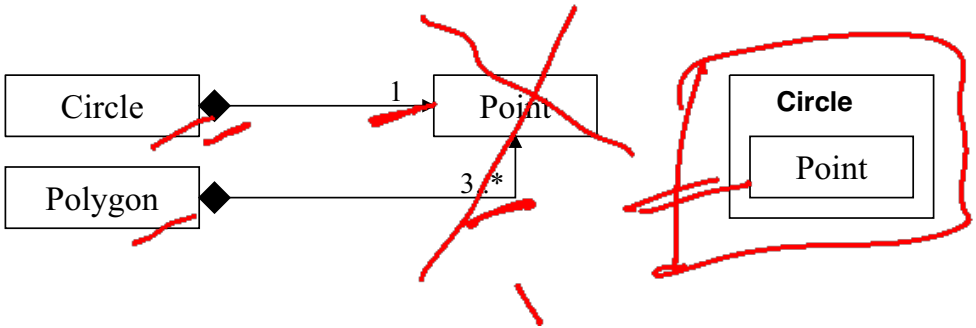
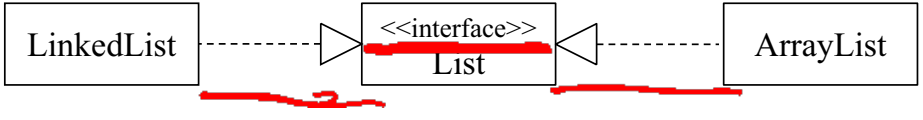
Composition

- A strong form of aggregation
  - The whole is the sole owner of its part.
    - The part object may belong to only one whole
  - Multiplicity on the whole side must be zero or one.
  - The life time of the part is dependent upon the whole.
    - The composite must manage the creation and destruction of its parts.



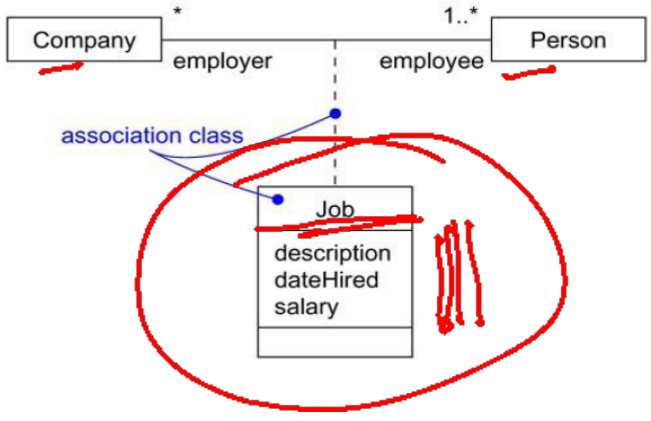
Realization

- A realization relationship indicates that one class implements a behavior specified by another class (an interface or protocol).
- An interface can be realized by many classes.
- A class may realize many interfaces.

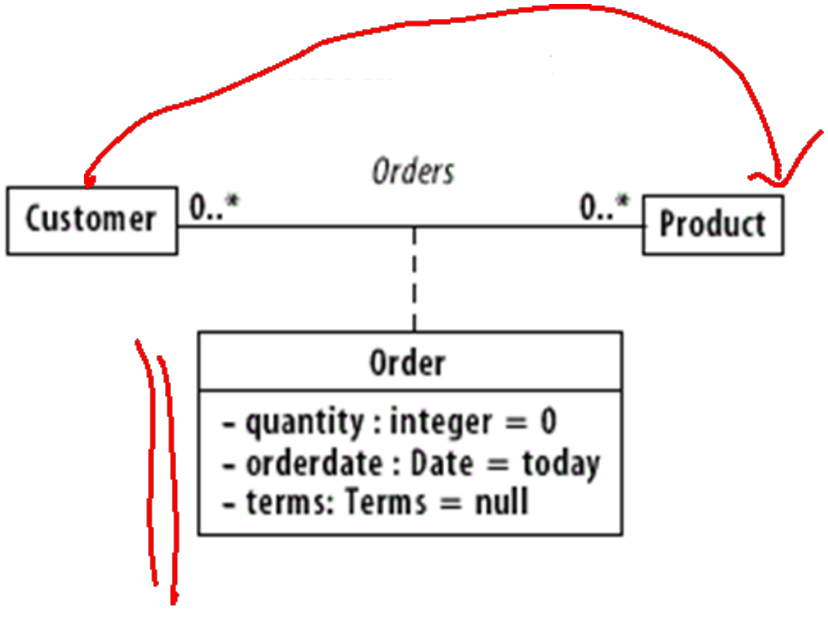


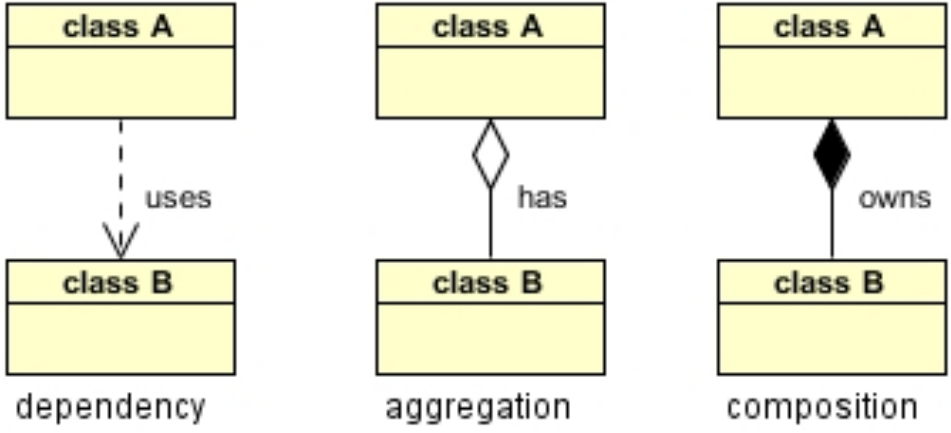
Association

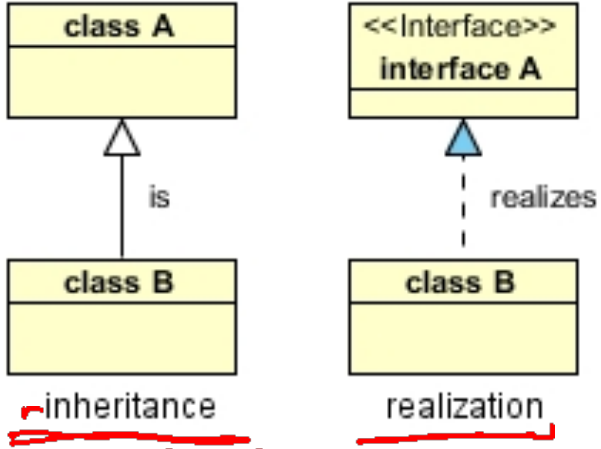
- **Association Classes**
  - Association itself may have properties
  - Ex: In the relationship between a Company and a Person, there is Job that represent the properties of that relationship
    - Represents exactly one pairing of Person and Company
  - Modeling element that has both association and class properties
  - Can't attach an association class to more than one association



Association Class



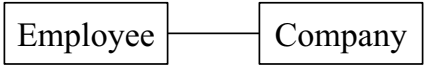

class A
uses
class B
dependency
class A
has
class B
aggregation
class A
owns
class B
composition


class A
is
class B
inheritance
<<Interface>>
interface A
realizes
class B
realization
Generd iR

Associations

- An association between two classes indicates that objects at one end of an association “recognize” objects at the other end and may send messages to them.

- Example: “An Employee works for a Company”



Associations (cont.)

- To clarify its meaning, an association may be named.
  - The name is represented as a label placed midway along the association line.
  - Usually a verb or a verb phrase.
- A **role** is an end of an association where it connects to a class.
  - May be named to indicate the role played by the class attached to the end of the association path.
    - Usually a noun or noun phrase
    - Mandatory for reflexive associations

Associations (cont.)

- Multiplicity
  - the number of objects that participate in the association.
  - Indicates whether or not an association is mandatory.

Multiplicity Indicators

Exactly one	1
Zero or more (unlimited)	* (0..*)
One or more	1..*
Zero or one (optional association)	0..1
Specified range	2..4
Multiple, disjoint ranges	2, 4..6, 8

Aggregation

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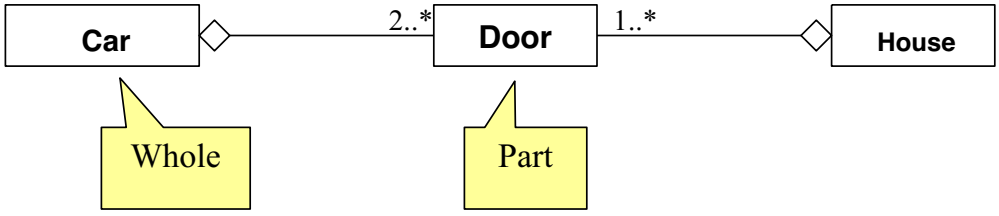
  - Models a “is a part-part of” relationship.



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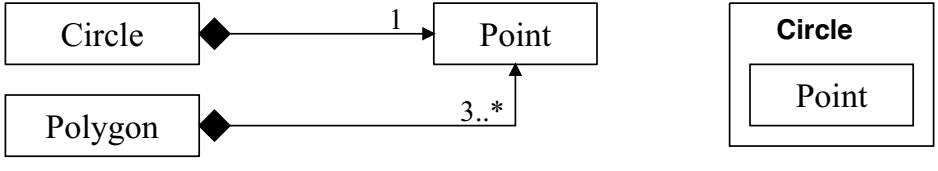
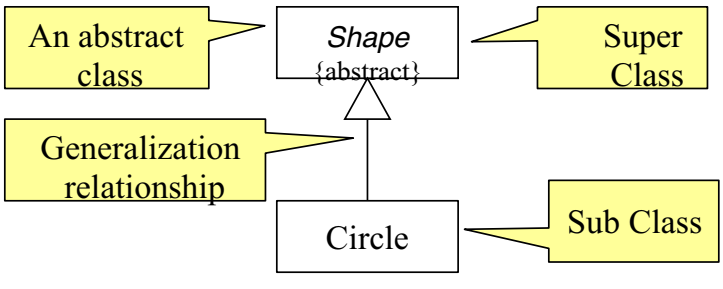


Generalization

- Indicates that objects of the specialized class (subclass) are substitutable for objects of the generalized class (super-class).
  - "is kind of" relationship.

{abstract} is a tagged value that indicates that the class is abstract.
The name of an abstract class should be italicized



Guidelines for Identifying Association

Class A and B are associated if

- An object of class A sends a message to an object of class B
- An object of class A creates an object of class B
- An object of class A has an attribute whose values are objects of class B
- An object of class A receives a message with an object of class B as an argument

Guidelines for Identifying a Super-sub Relationship

- Top-down
  - Look for noun phrases composed of adjectives in a class name.
- Bottom up
  - Look for classes with similar attributes or methods

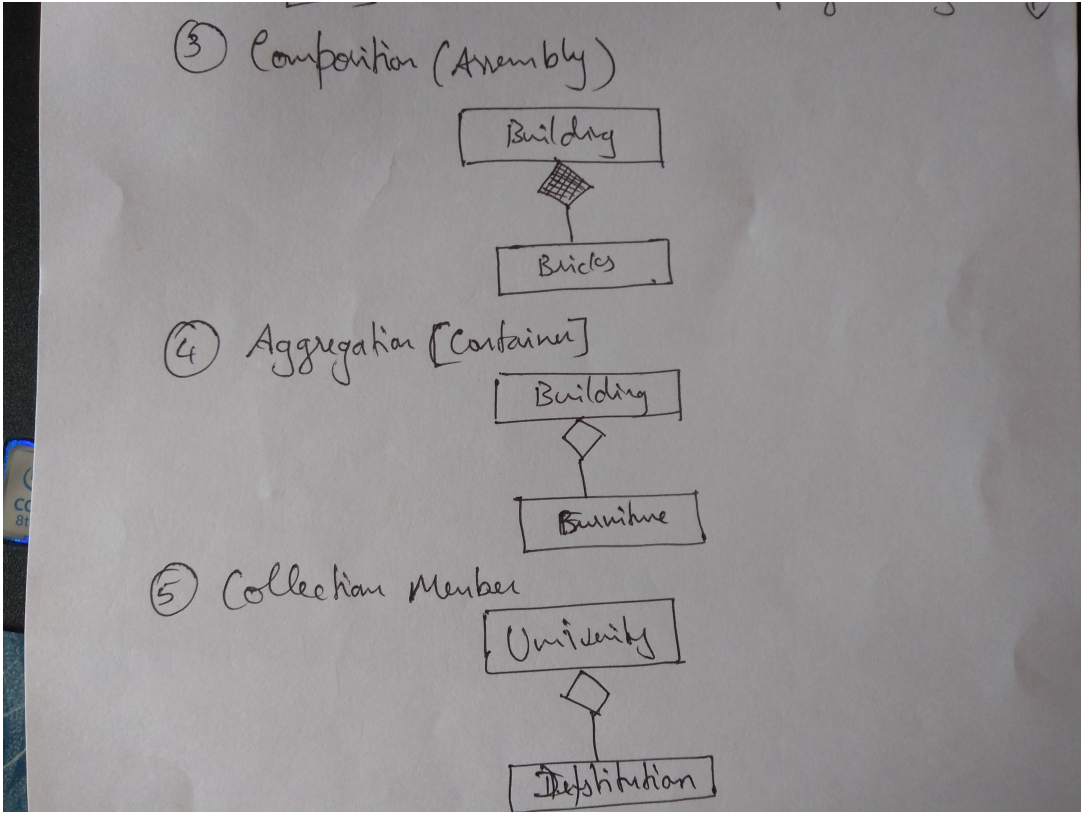
Identifying the Composition & Aggregation/a-part-of Relationship

- **Composition** - a physical whole is constructed from physical parts (Assembly)
  - Eg1: Building constructed by bricks, stones
  - Eg2: ATM with Card Reader, Console, Printer, Key Pad

- **Aggregation** - a physical whole encompasses but is not constructed from physical parts (Container)
  - Eg1: Building with Furniture, Appliances
  - Eg2: Car with AC and Radio

- **Collection-member** – a ~~conceptual whole~~ encompasses parts that may be ~~physical or conceptual~~
  - Eg: Employer, employees

Examples on Relationships



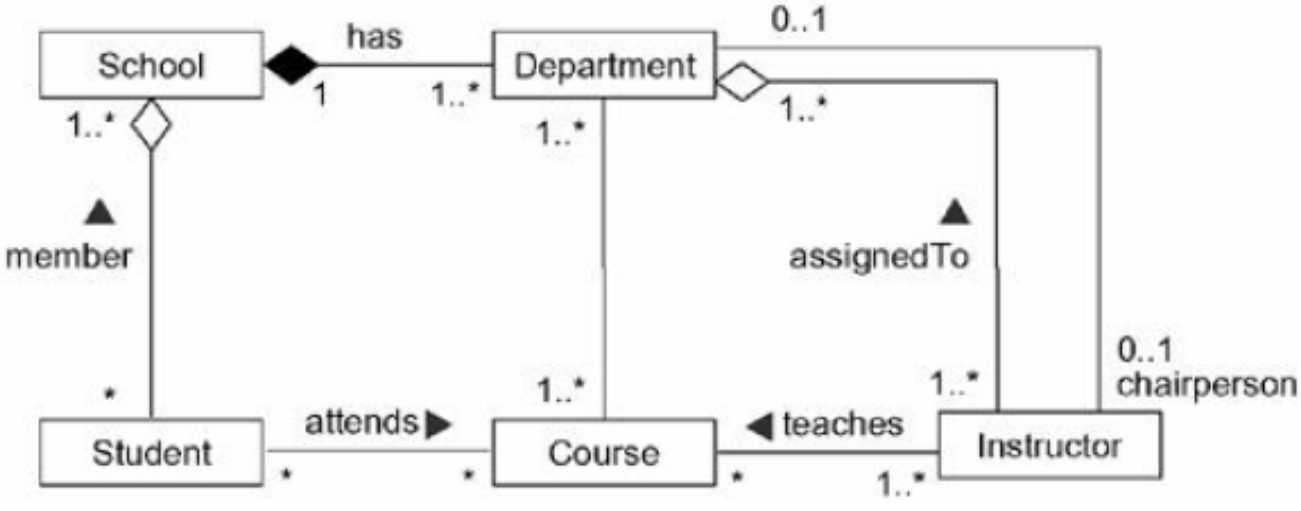
Modeling Structural Relationships

- Given an association between two classes
  - Both rely on each other in some way
  - Can navigate in either direction
  - Specifies a structural path across which objects can interact
- To model structural relationships
  - Navigation from object of one class to object of other – data-driven
  - Specify multiplicity and role names (helps to explain the model)
  - Mark as an aggregation if one class is structurally a whole compared with classes at the other end that look like parts

Modeling Structural Relationships

- Identify the association relationships among classes drawn from an information system for a school
  - School has one or more departments
  - Department offers one or more Courses
  - A particular Course will be offered by only one Department
  - Department has Instructors and Instructors can work for one or more Departments
  - Student can attend any number of Courses in a School
  - Every Course may have any number of Students
  - Instructors can teach zero or more Courses
  - Same Course can be taught by different Instructors
  - Students can be enrolled in more than one School
  - For every Department, there is exactly one Instructor who is the chairperson

Modeling Structural Relationships



Object Relationship in Code

- **Association**

```
public class A {
        public void doSomething(B b) { }
        }
```

- **Aggregation**

```
public class A {
        private B  b1;
        public void setB(B b) { b1 = b; } }
```

- **Composition**

```
public class A {
        private B b1;
        public A() {
                b1 = new B();
                } }
```

Object Relationship in Code

- **Generalization**

```
public class A {
        ...
        } // class A
public class B extends A {
        ....
        } // class B
```

- **Realization**

```
public interface A {
        ...
        } // interface A
public class B implements A {
        ...
        } // class B
```

Aggregation vs Composition

1. **Dependency:** Aggregation implies a relationship where the child **can exist independently** of the parent.

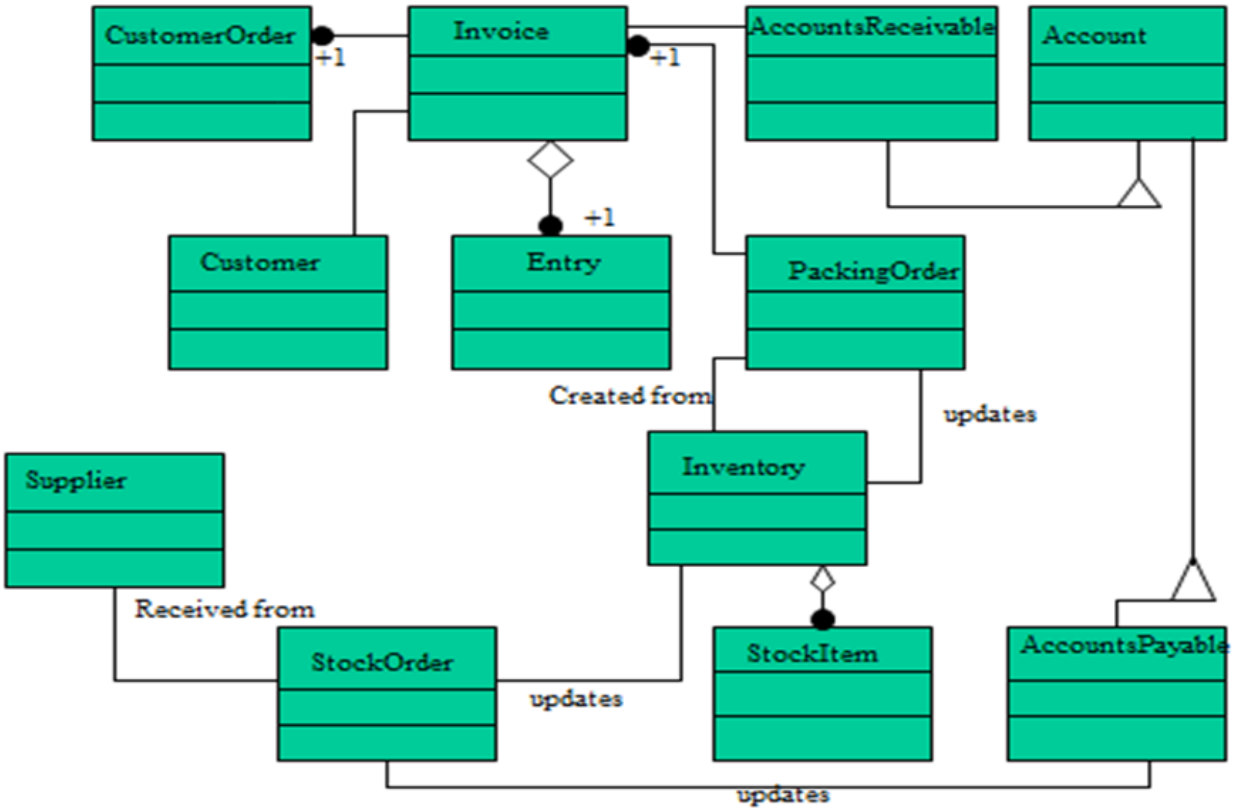
For example, Bank and Employee, delete the Bank and the Employee still exist. whereas Composition implies a relationship where the child **cannot exist independent** of the parent.

Example: Human and heart, heart don't exist separate to a Human

2.Type of Relationship: Aggregation relation is **"has-a",** and composition is **"part-of"** relation.

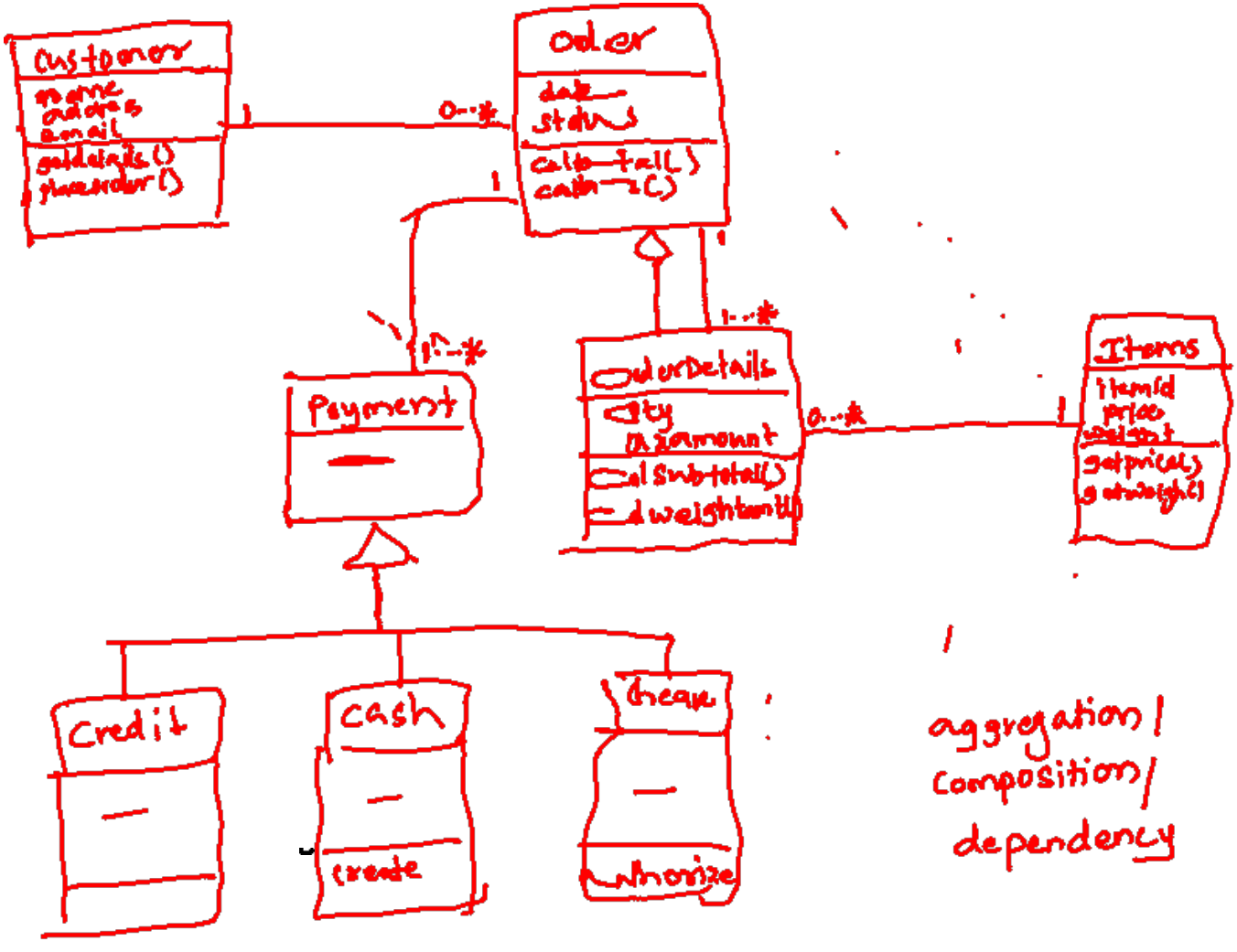
3. Type of association: Composition is a **strong** Association whereas Aggregation is a **weak** Association.

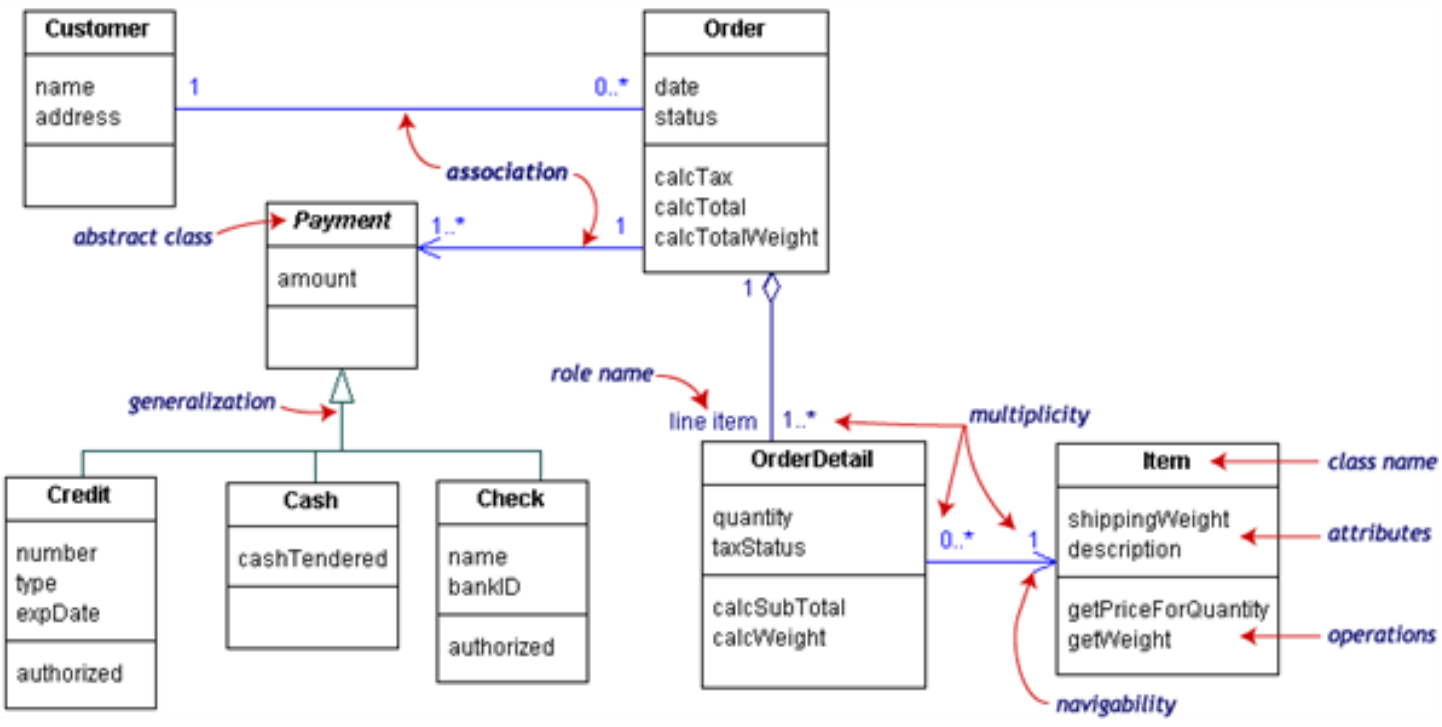
- An Invoice is composed of one or more Entries
- An Invoice is created for exactly one Customer
- An Invoice is created from one or more CustomerOrders
- An Invoice is used to update the AccountsReceivable account
- An Inventory is composed of zero or more StockItems
- A PackingOrder is initiated from one or more Invoices
- A PackingOrder is created from Inventory items
- A PackingOrder is used to update the Inventory
- A StockOrder is received from a Supplier
- A StockOrder is used to update the Inventory
- A StockOrder is used to update the AccountsPayable account


CustomerOrder
+1
Invoice
+1
AccountsReceivable
Account
+1
Customer
Entry
PackingOrder
Created from
updates
Supplier
Inventory
Received from
StockOrder
updates
StockItem
AccountsPayable
updates

Models a customer order from a retail catalog.

A customer order from a retail catalog. The central class is the **Order**. Associated with it are the **Customer** making the purchase and the **Payment**. A **Payment** is one of three kinds: **Cash**, **Check**, or **Credit**. The order contains **OrderDetails** (line items), each with its associated **Item**.


Customer
name
address
email
getdetails()
placeorder()
Order
date
status
calcTotal()
calcTax()
1
0..*
1
1..*
1..*
Payment
OrderDetails
qty
amount
calSubtotal()
calWeightedAll()
0..*
1
Items
itemId
price
weight
getprice()
getweight()
Credit
cash
create
cheque
authorize
aggregation/
composition/
dependency

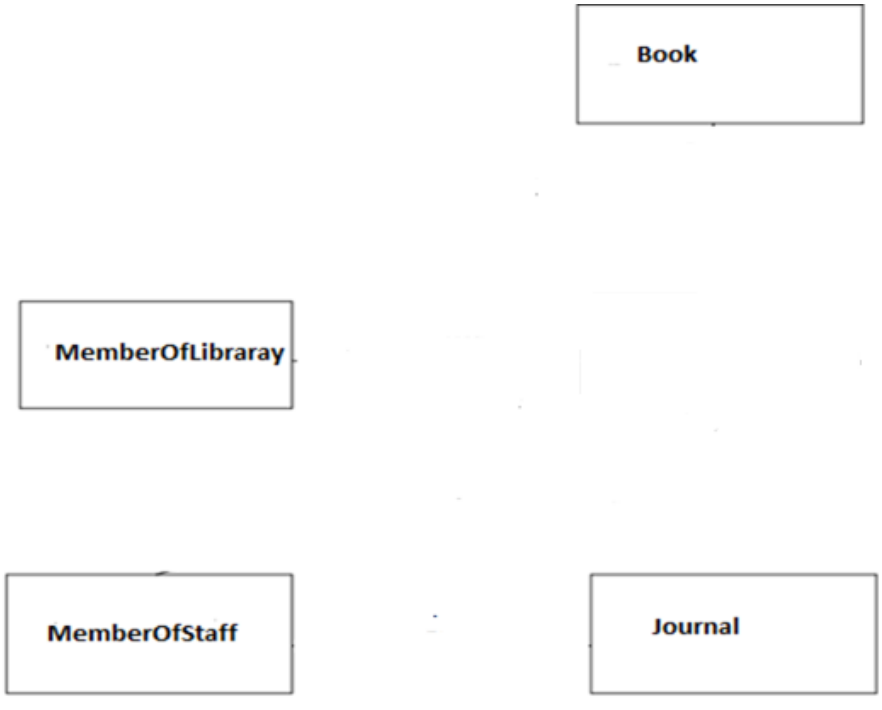

Customer
name
address
1
0..*
Order
date
status
association
calcTax
calcTotal
calcTotalWeight
abstract class
Payment
amount
1..*
1
1
role name
line item
1..*
multiplicity
generalization
Credit
number
type
expDate
authorized
Cash
cashTendered
Check
name
bankID
authorized
OrderDetail
quantity
taxStatus
calcSubTotal
calcWeight
0..*
1
Item
shippingWeight
description
getPriceForQuantity
getWeight
class name
attributes
operations
navigability

Identifying a list of candidate classes: Example

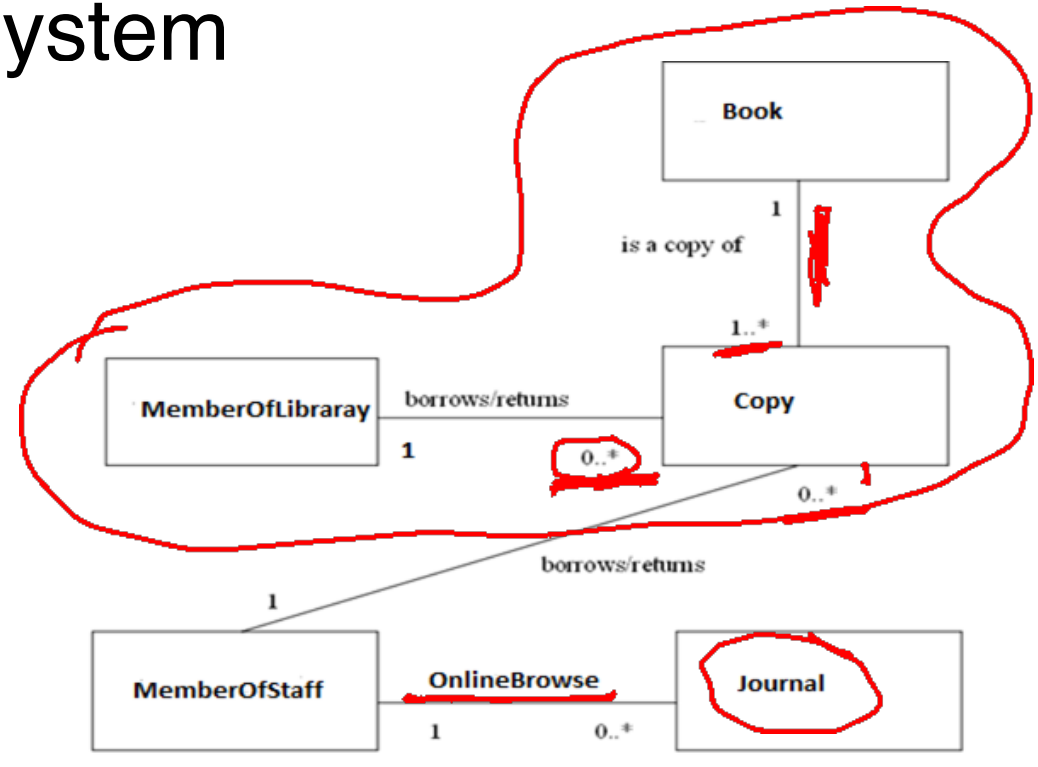
The library contains books and journals. It may have several copies of a given book. Some of the books are for short term loans only. All other books may be borrowed by any library members for 3 weeks. Member of the library can normally borrow up to 6 items at a time, but members of staff may borrow up to 12 items at one time. Only members of staff may borrow journals.

The system must keep track of when books and journals are borrowed and returned by the user, enforcing the rules described above.

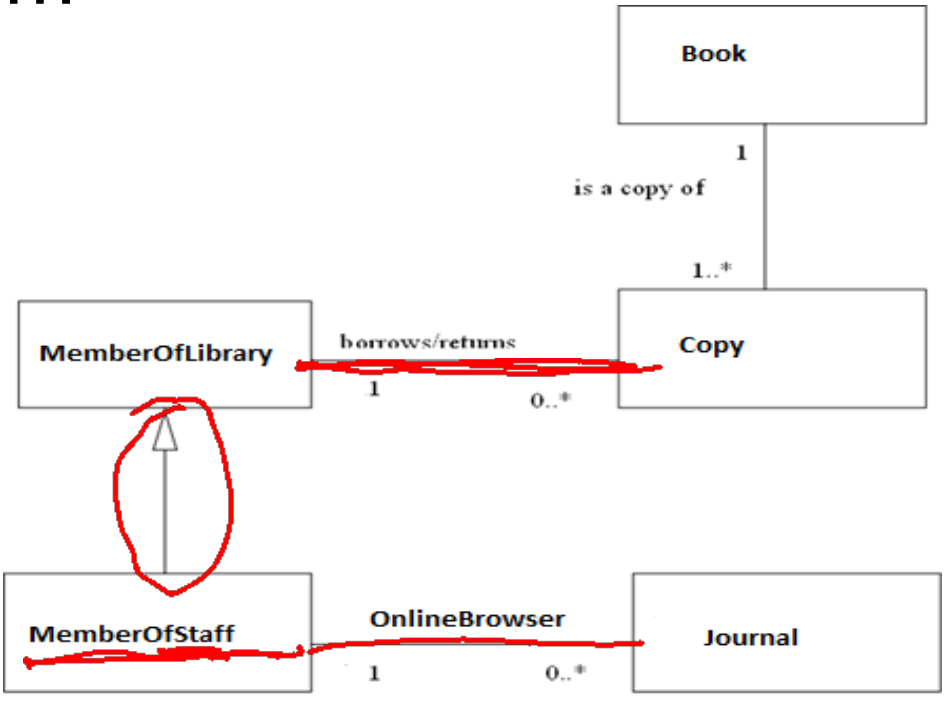
Identified Classes for Library System



Initial Class model for Library System

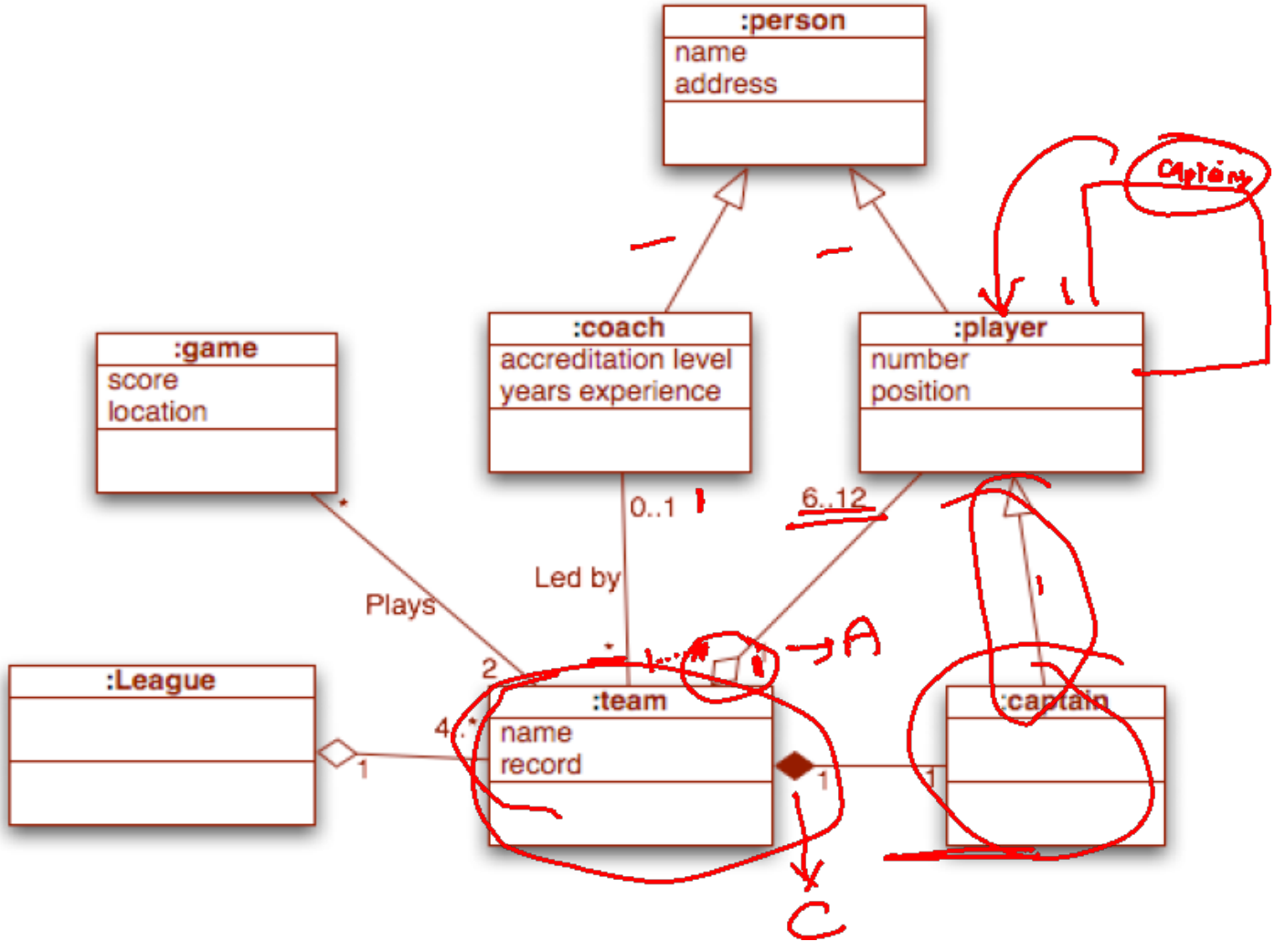


Revised class model for Library System



Class Diagram Example

A hockey league is made up of at least four hockey teams. Each hockey team is composed of six to twelve players, and one player captains the team. A team has a name and a record. Players have a number and a position. Hockey teams play games against each other. Each game has a score and a location. Teams are sometimes lead by a coach. A coach has a level of accreditation and a number of years of experience, and can coach multiple teams. Coaches and players are people, and people have names and addresses.


:person
name
address
:coach
accreditation level
years experience
:player
number
position
Captain
:game
score
location
0..1
6..12
Led by
Plays
2
:League
4
:team
name
record
:captain
1
A
C

Design concepts

Functional Independence

- Cohesion – is an indication of the relative functional strength of a module
- Coupling – is an indication of the relative interdependence among modules