Subject:

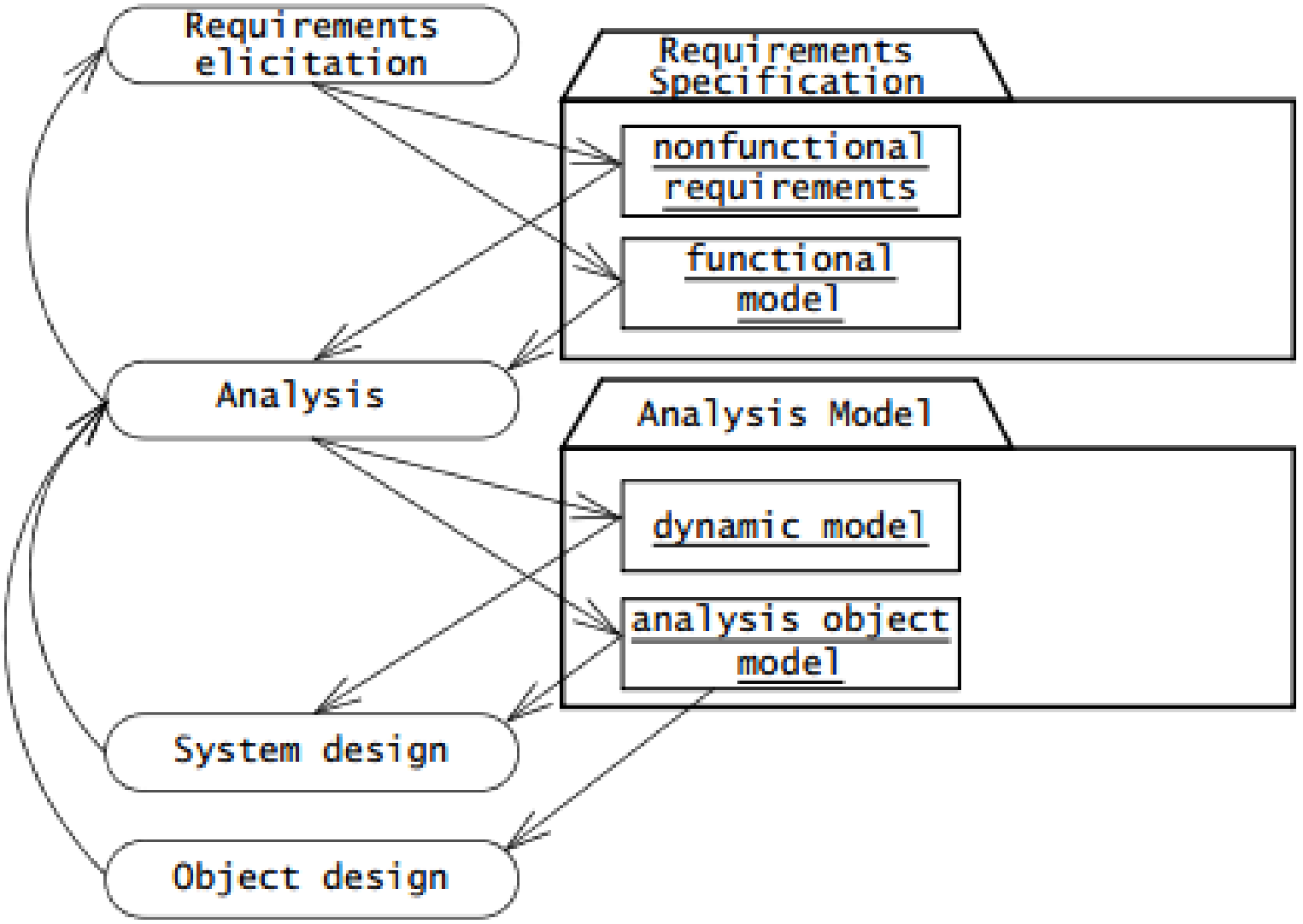
Object-oriented analysis and design

Chapter 3: Object-oriented Analysis

Lê Văn Vinh, PhD
Department of Software Engineering
Faculty of Information Technology
HCMC University of Technology and Education

Contents

I.Overview of Analysis



I.Overview of Analysis

- **Analysis focuses on**
  - producing a model of the system, called the analysis model
- **Analysis model**
  - Functional model (usecases, scenarios)
  - Analysis Object model (class/object diagrams)
  - Dynamic model (state diagrams, sequence diagrams, communication diagrams)

Contents

II. Analysis activities

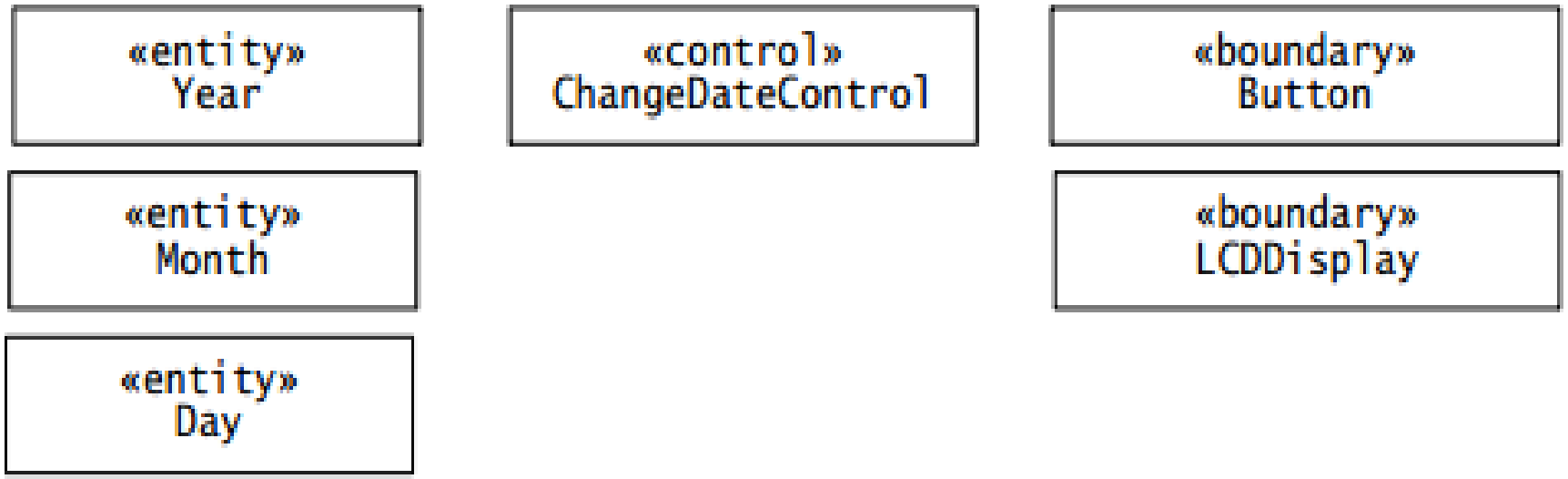
1. **Identifying Objects**
2. Mapping Usecase to Objects (with Sequence diagrams)
3. Identifying Class relationship
4. Identifying Attributes
5. Modeling State-dependent Behavior of Objects

Analysis Object models

- **Analysis object models**
  - Focus on idivididual concepts that are manipulated by the system.
  - UML class diagram:
    - Classes
    - Attributes
    - Operations
  - Common stereotypes:
    - Entity classes
    - Boudary classes
    - Control classes

Analysis Object models

- **Examples**



Entity Class

- An entity class models information and associated behavior that is generally long-lived (persistent)
  - It can reflect a real-life phenomenon
  - It may also be needed for the internal tasks of the system
  - The values of its attributes are often provided by an actor
  - The behavior is surroundings-independent
- Entity classes in the “Thêm đơn đặt hàng” use case
  - Mặt hàng
  - Đơn hàng

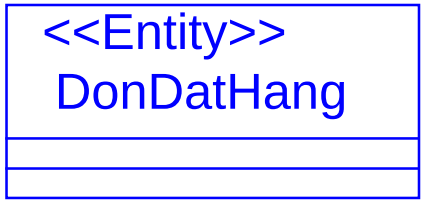
How to identify Entiy classes:

- Terms that developers or users need to clarify in order to understand the use
- Real-world entities that the system needs to track (e.g., FieldOfficer, Dispatcher, Resource)
- Real-world activities that the system needs to track (e.g., EmergencyOperationsPlan
- Find common noun

Examples

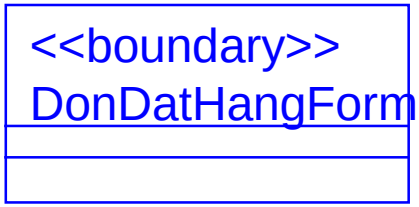
Name	**Đăng nhập**
Brief description	Thêm thông tin một đơn hàng mới
Actor(s)	Kế toán
Pre-conditions	Người dùng đã đăng nhập vào hệ thống
Post-conditions	
Flow of events	
Basic flow	Use case bắt đầu khi người dùng chọn chức năng thêm đơn hàng. 6. Hệ thống hiển thị cửa sổ cho người dùng nhập thông tin chung đơn hàng (Mã đơn hàng, ngày đặt hàng, nhà cung cấp, nhà nhập khẩu) và thông tin chi tiết của từng đơn hàng (Mã hàng, số lượng, giá nhập, thời điểm nhận hàng, khách hàng, Loại C/O, thành tiền) 7. Người dùng nhập các thông tin chung và thông tin chi tiết của đơn hàng bên trên. 8. Hệ thống kiểm tra giá nhập có hợp lệ không (>0), thời điểm nhận hàng (phải lớn hơn thời điểm đặt hàng) 9. Hệ thống lưu thông tin xuống cơ sở dữ liệu và thông báo đã nhập thành công.
Alternative flow (Nhập sai thông tin)	Nếu người dùng nhập thông tin không thỏa ràng buộc: Yêu cầu nhập lại Người dùng nhập lại thông tin và nhấn lưu thông tin
Alternative flow (Thoát)	Nếu người dùng nhấn vào nút thoát Hệ thống đóng màn hình thêm đơn hàng và trở về trang chủ.
Extension point	Không có

Examples



Boundary Class

- A boundary class models communication between the system's surroundings and its inner workings
- Typical boundary classes
  - Windows (user interface)
  - Communication protocol (system interface)
  - Printer interface
  - Sensors
- In the "Thêm đơn đặt hàng" scenario:

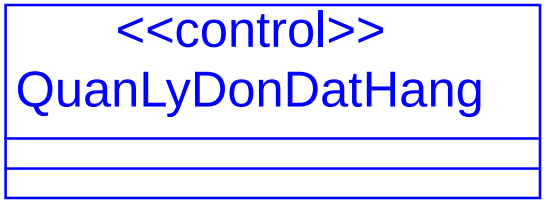


Boundary Class

- How to identify Boundary classes:
  - Identify user interface controls that the user needs to initiate the use case
  - Identify forms the users needs to enter data into the system
  - Identify notices and messages the system uses to respond to the user
  - *Always* use the end user's terms for describing interfaces; do not use terms from the solution or implementation domains.

Control Class

- Control objects are responsible for coordinating boundary and entity objects
- It is responsible for collecting information from the boundary objects and dispatching it to entity objects
- A control class models control behavior specific to one or more use cases
- A control class
  - Creates, initializes and deletes controlled objects
  - Controls the sequencing or coordination of execution of controlled objects
  - Controls concurrency issues for controlled classes
- In the “Thêm đơn đặt hàng” scenario



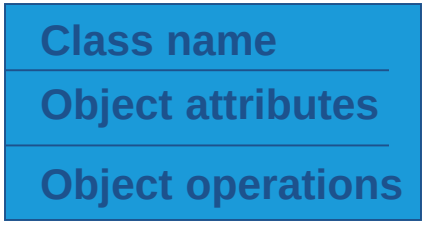
II. Analysis activities

1. Identifying Objects
2. **Mapping Usecase to Objects (with Sequence diagrams)**
3. Identifying Class relationship
4. Identifying Attributes
5. Modeling State-dependent Behavior of Objects

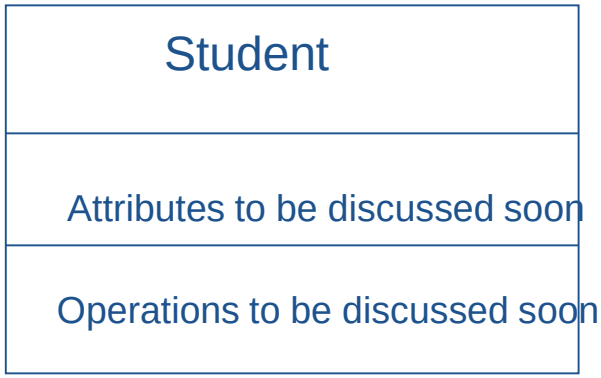
II.2.Mapping Usecase to Objects

- Sequence diagrams

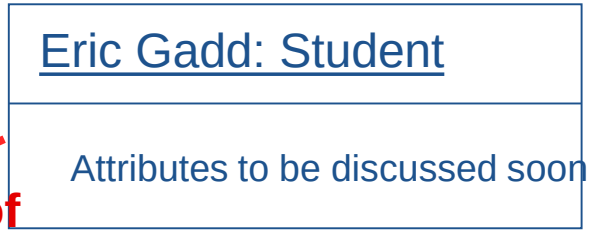
Class vs Object



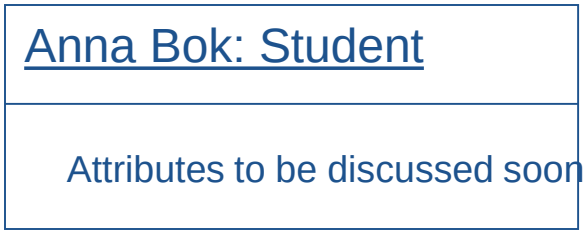
UML notation



Class



Instance object 1

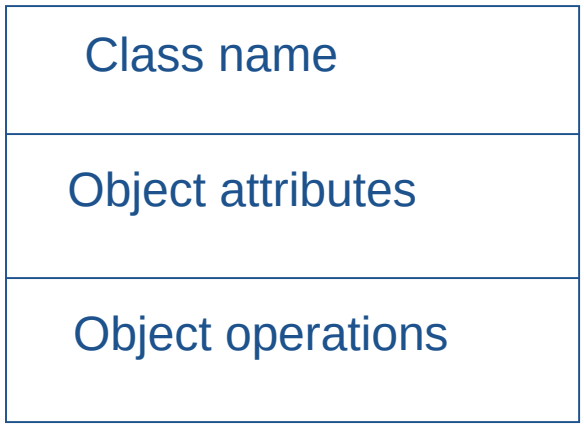


Instance object 2

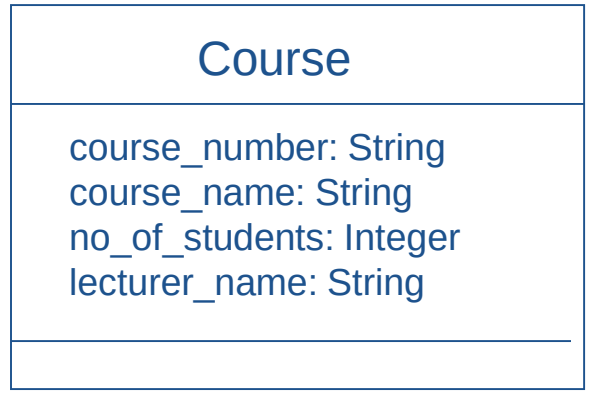
A class is the descriptor for a set of objects with the same attributes and operations.

Objects store data values for a certain instance of a student.

Class vs Object

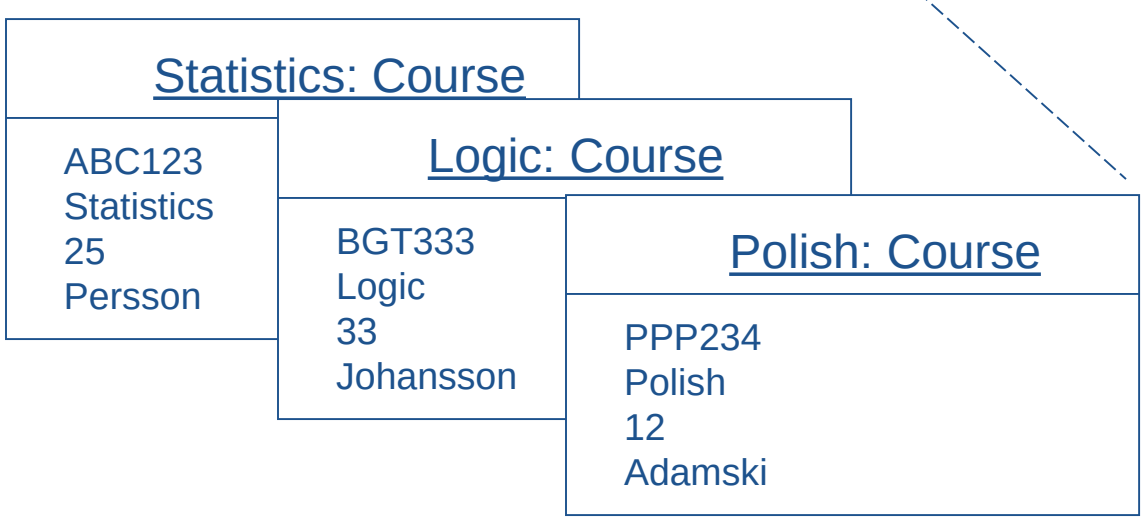


UML class notation



Attribute

to interpret the values

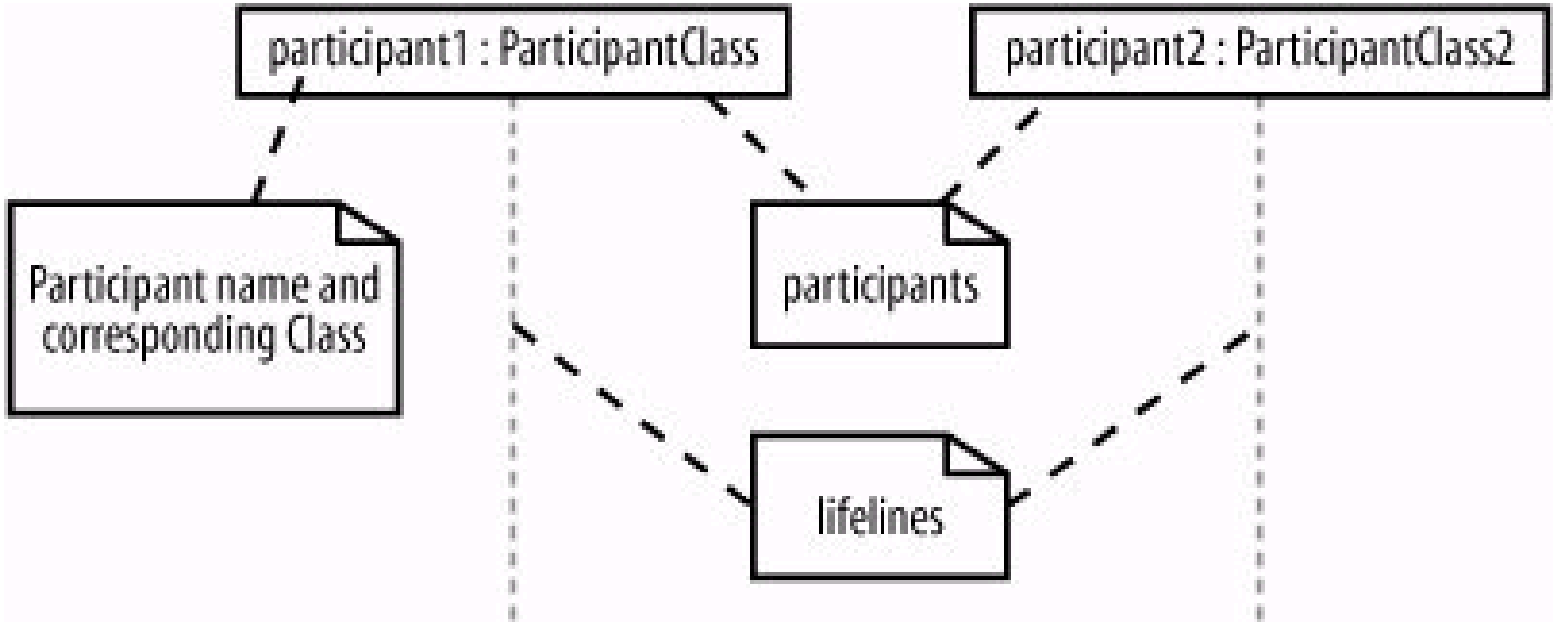


What is a Sequence Diagram?

- A sequence diagram shows object interactions arranged in time sequence
- The diagram shows
  - The objects participating in the interaction
  - The sequence of messages exchanged
- A sequence diagram contains:
  - Objects with their “lifelines”
  - Messages exchanged between objects in ordered sequence
  - Focus of control (optional)

Participants

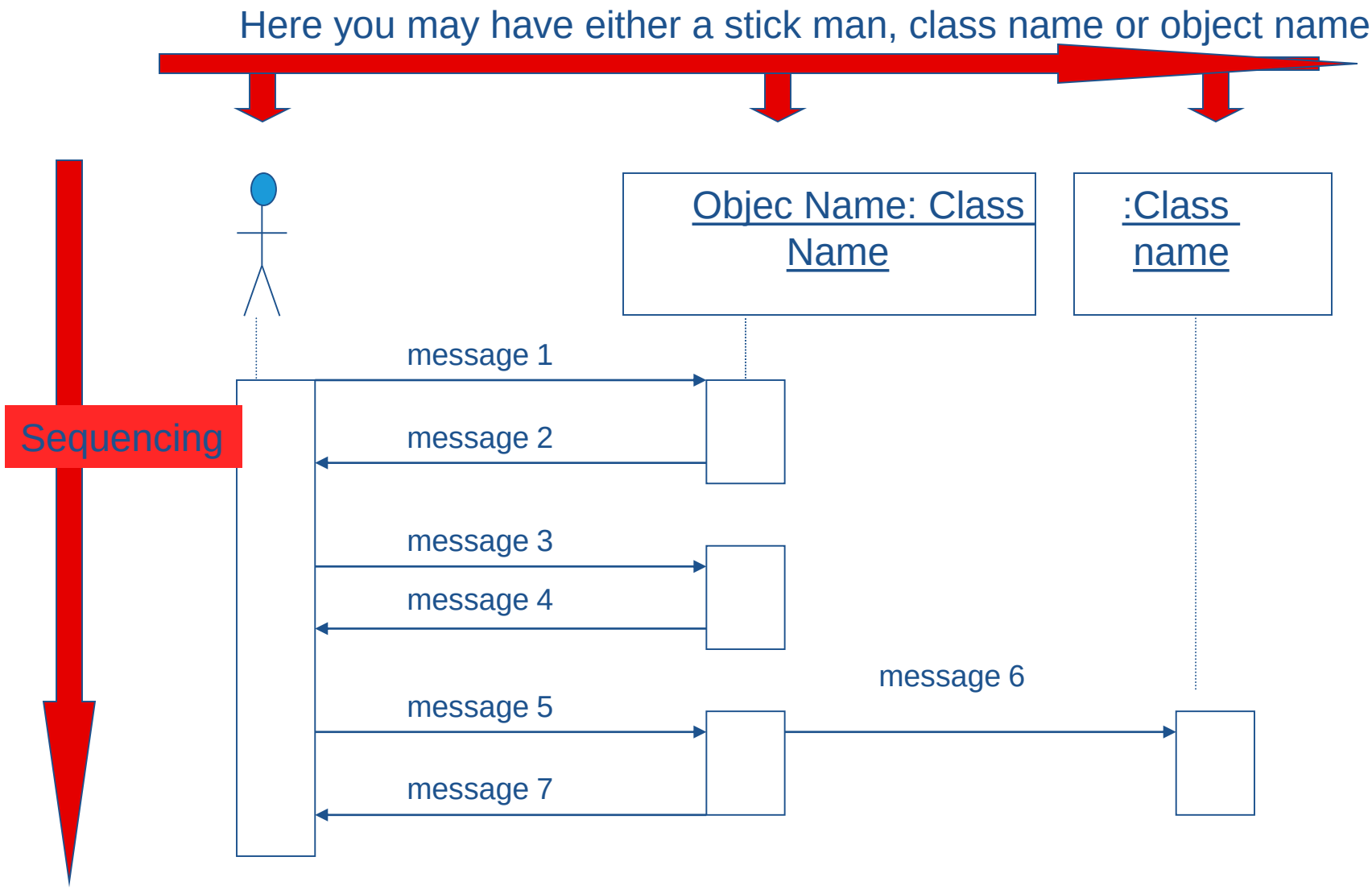
- **Participants in sequence diagrams are objects**



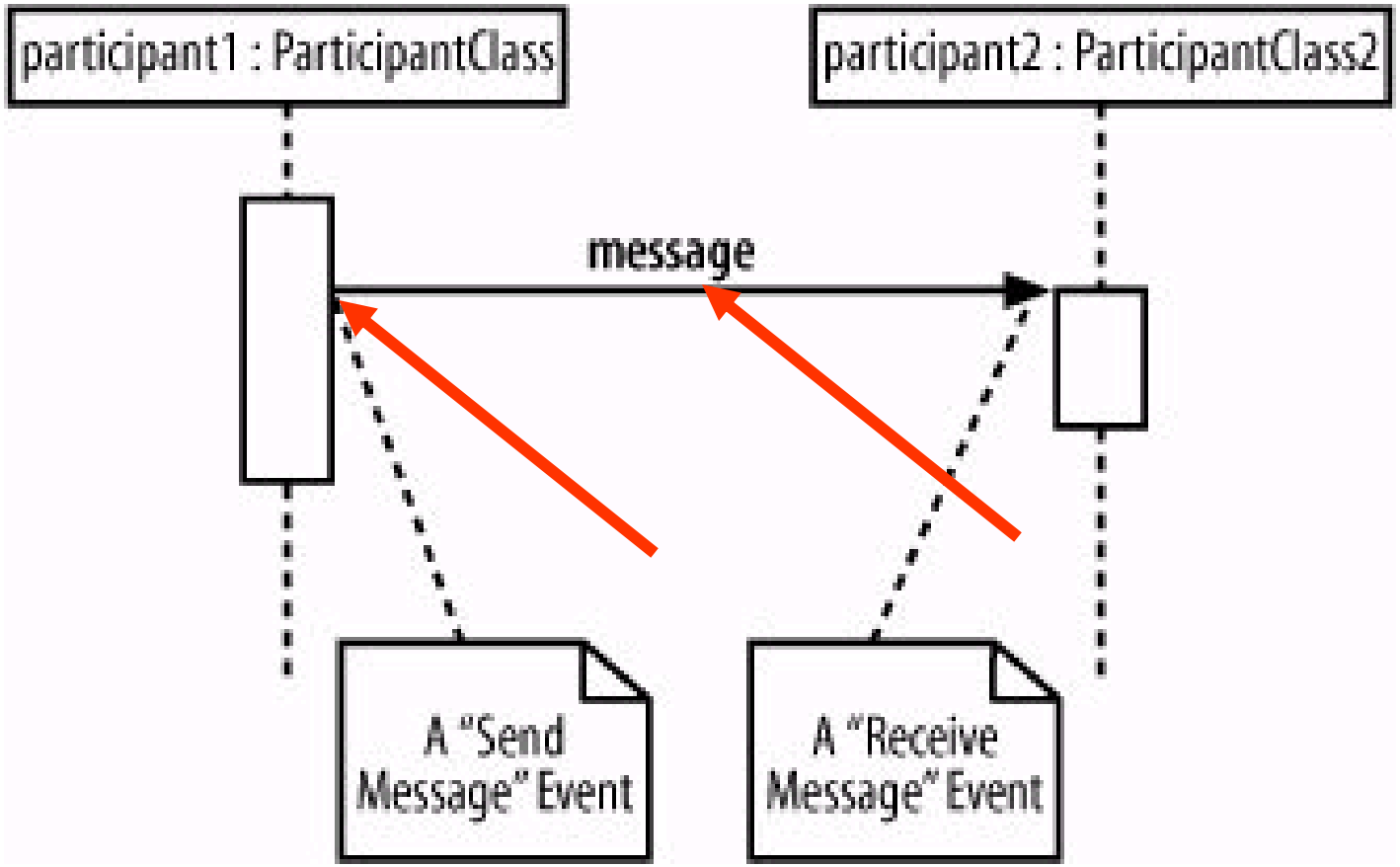
Naming Objects in Sequence Diagrams

admin	Object name, not assigned to a specific class
:BlogEntry	Object without a name, class name only
admin:Administrator	Object name with class
b [10]:BlogEntry	Array of 10 objects
:CMS ref cmsInteraction	Reference to another sequence diagram

Naming Objects in Sequence Diagrams

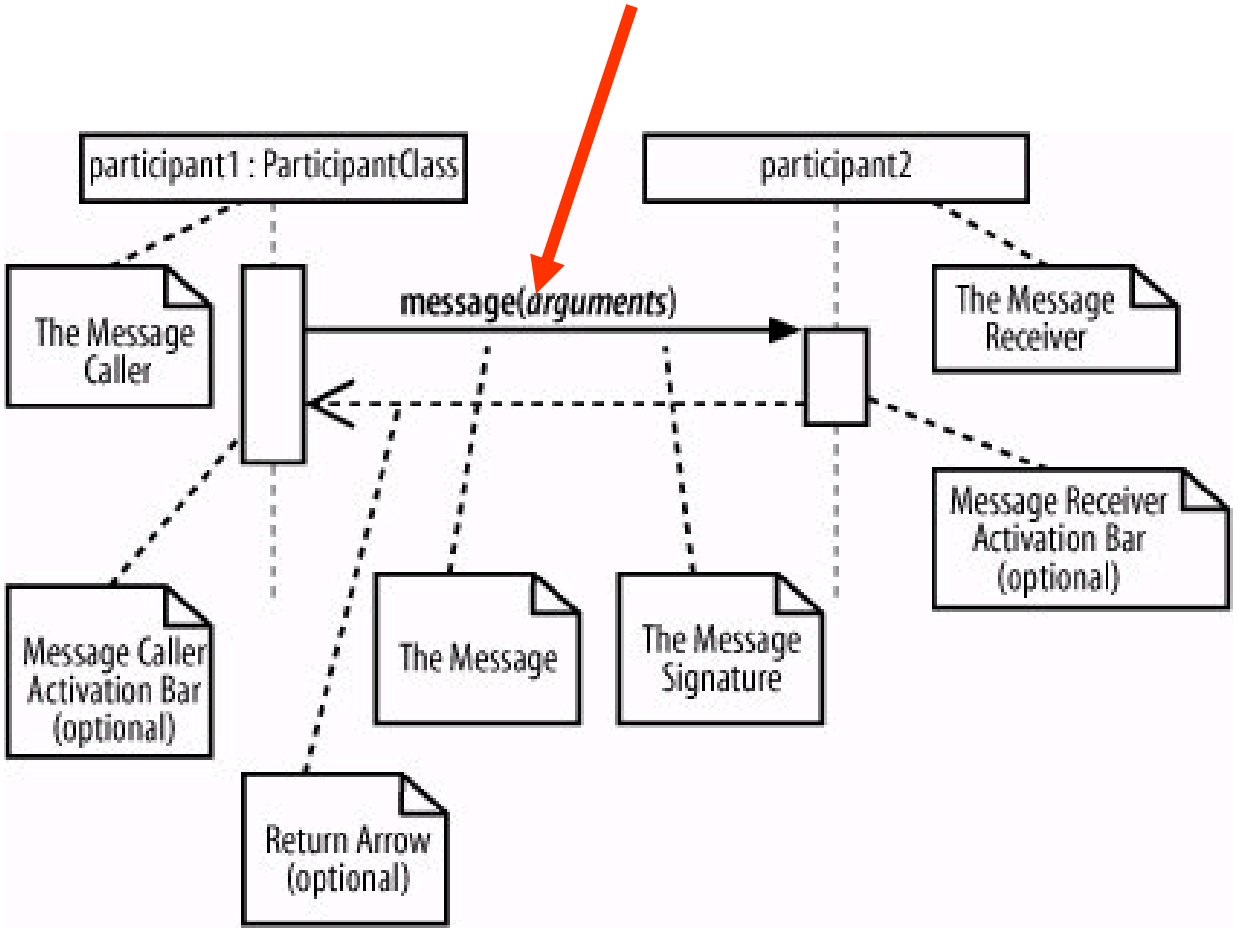


Events and Messages



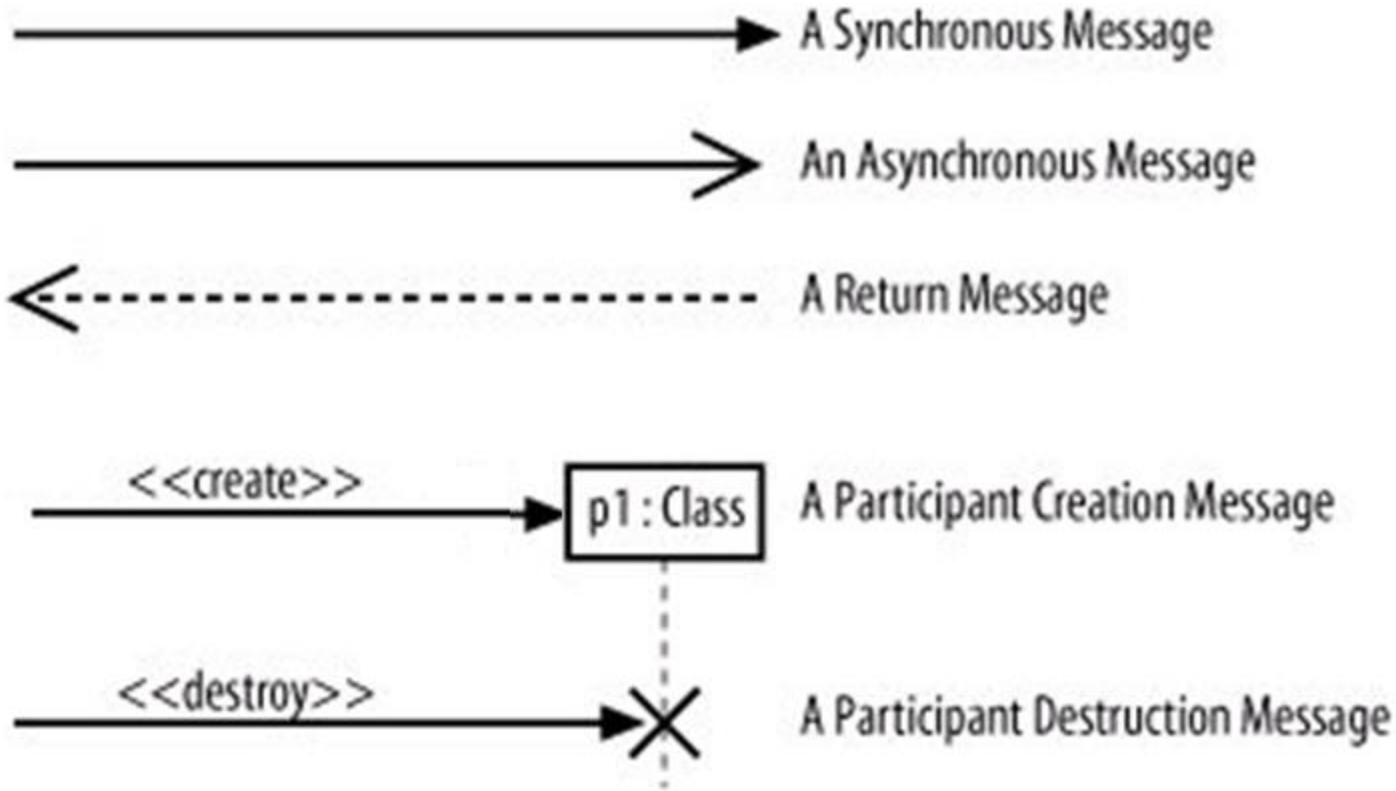
Events and Messages (2)

- **attribute=message_name(arguments):return_type**



Message arrows

- **There are 5 types of message arrows:**



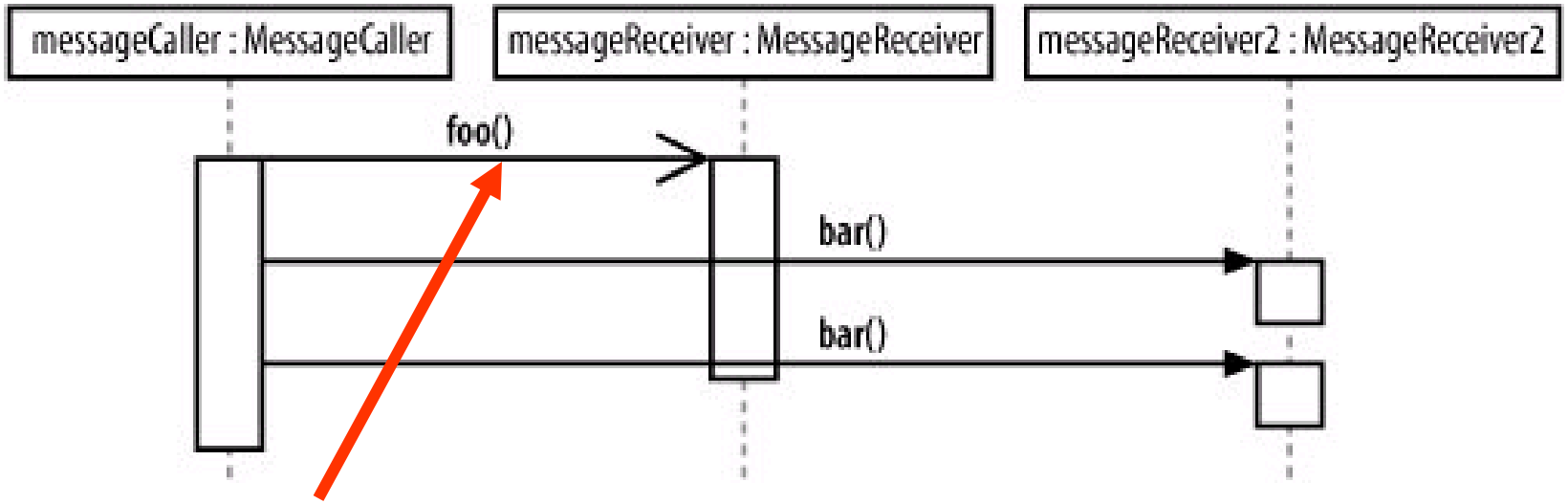
Message arrows

- **Synchronous message and asynchronous message:**

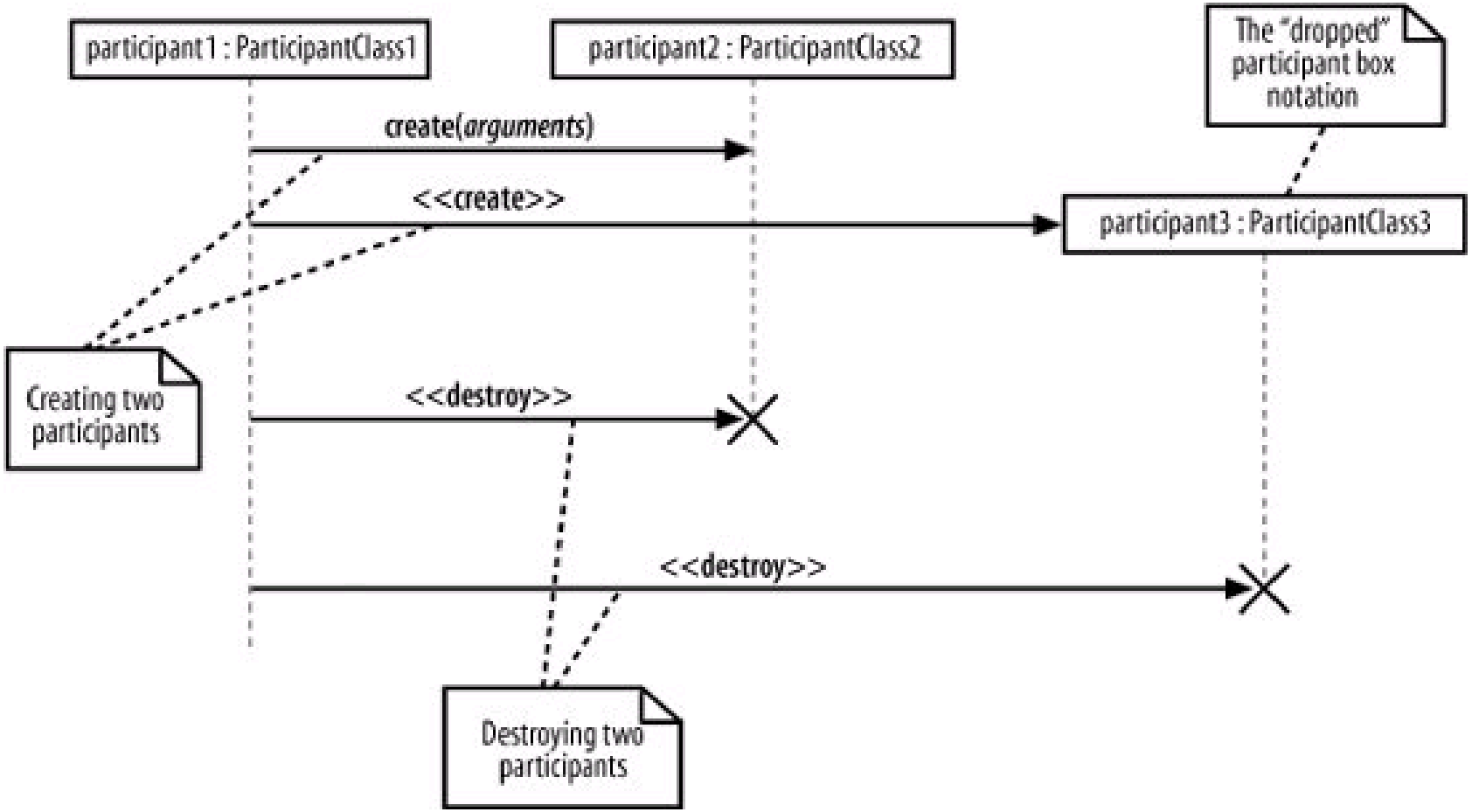
  If a caller sends a **synchronous message**, it must wait until the message is done, such as invoking a subroutine.
  If a caller sends an **asynchronous message**, it can continue processing and doesn't have to wait for a response

Message arrows - Async

- **Example:**

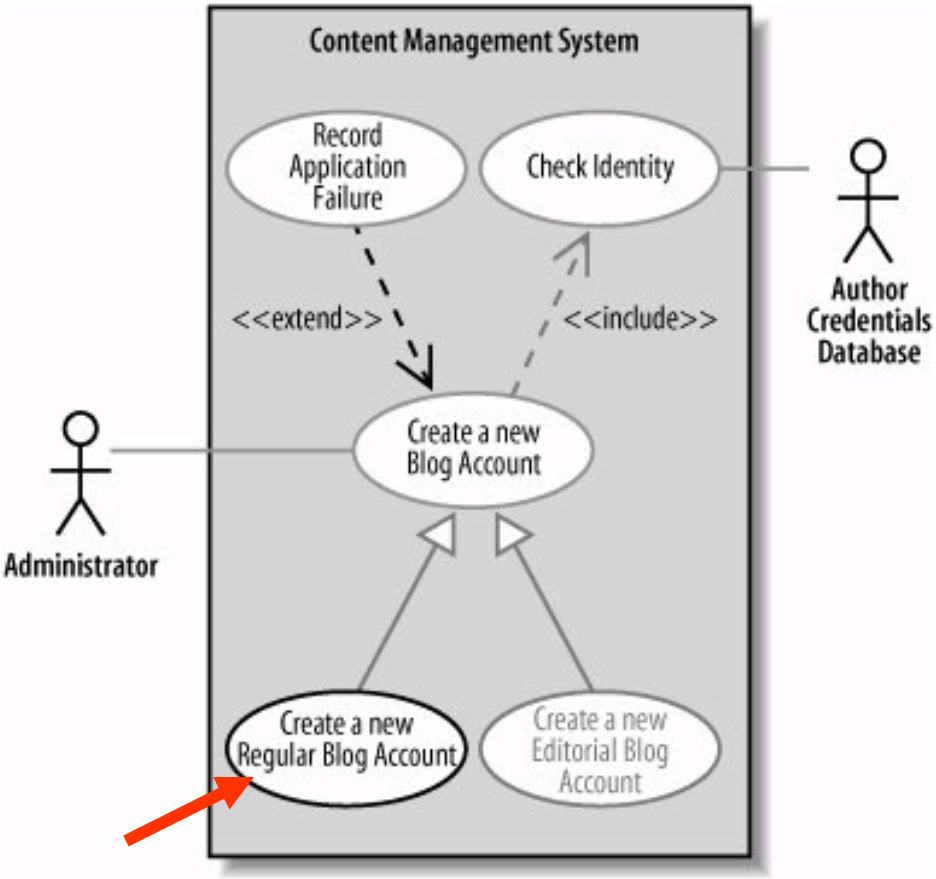


<<create>> and <<destroy>>



Realization of use case

- Each use case may have 1 or more sequence diagram
- Sequence diagram describe the flows of events

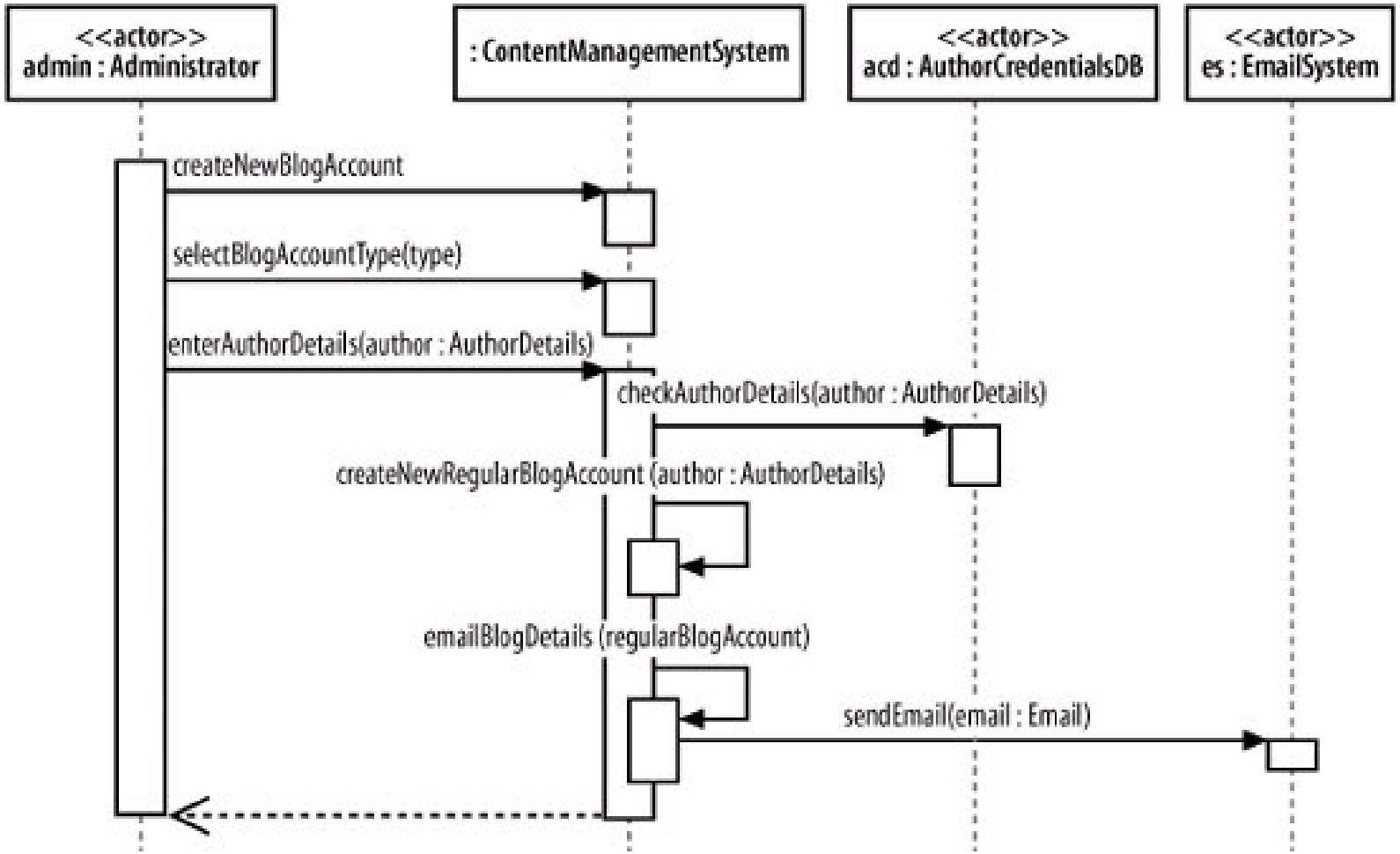


Realization of use case (2)

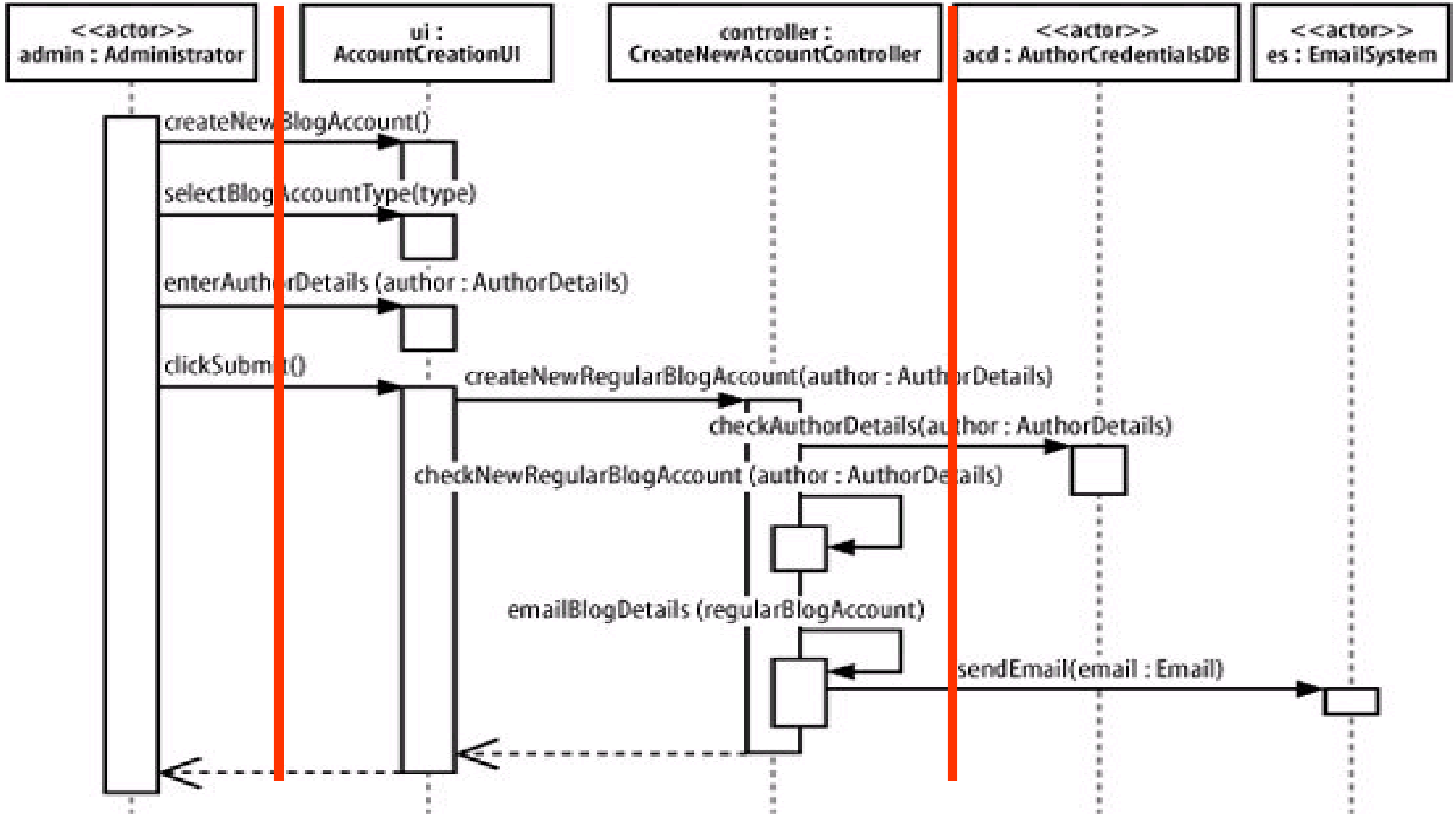
Create new Regular account use case

Main Flow	Step	Action
	1	The Administrator asks the system to create a new blog account.
	2	The Administrator selects the regular blog account type.
	3	The Administrator enters the author's details.
	4	The author's details are checked using the Author Credentials Database.
	5	The new regular blog account is created.
	6	A summary of the new blog account's details are emailed to the author.

Top level sequence diagram

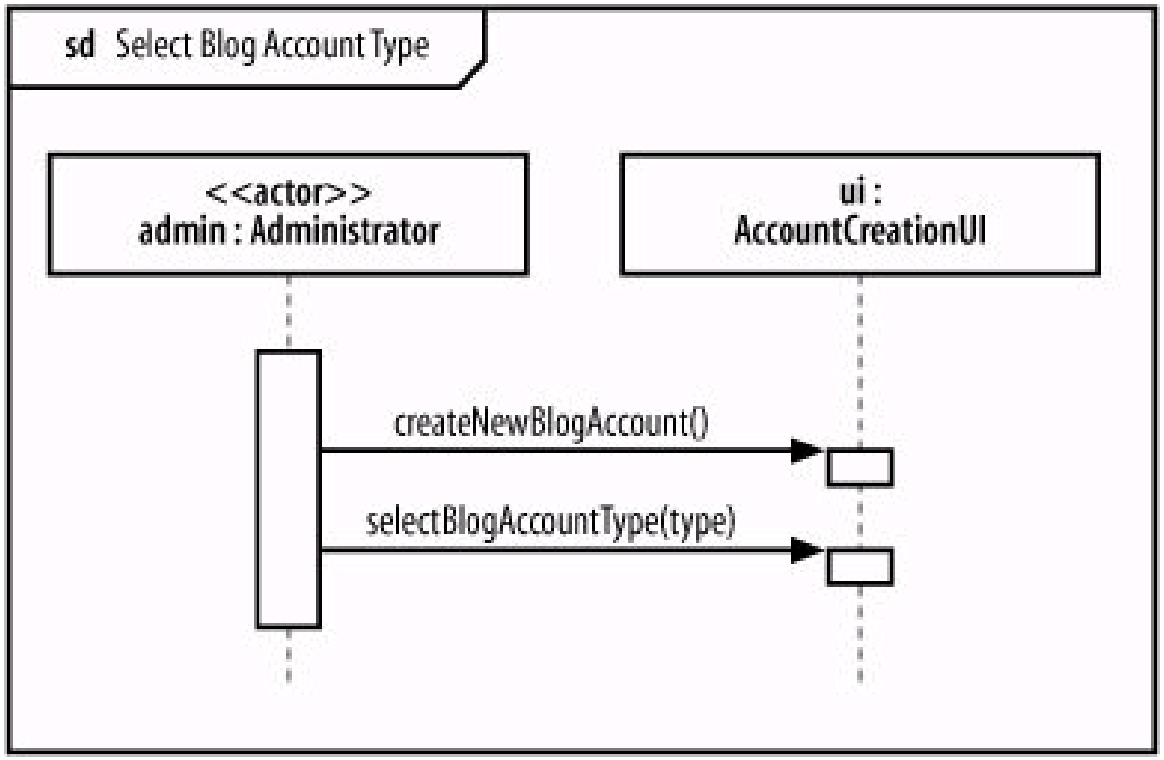


More details

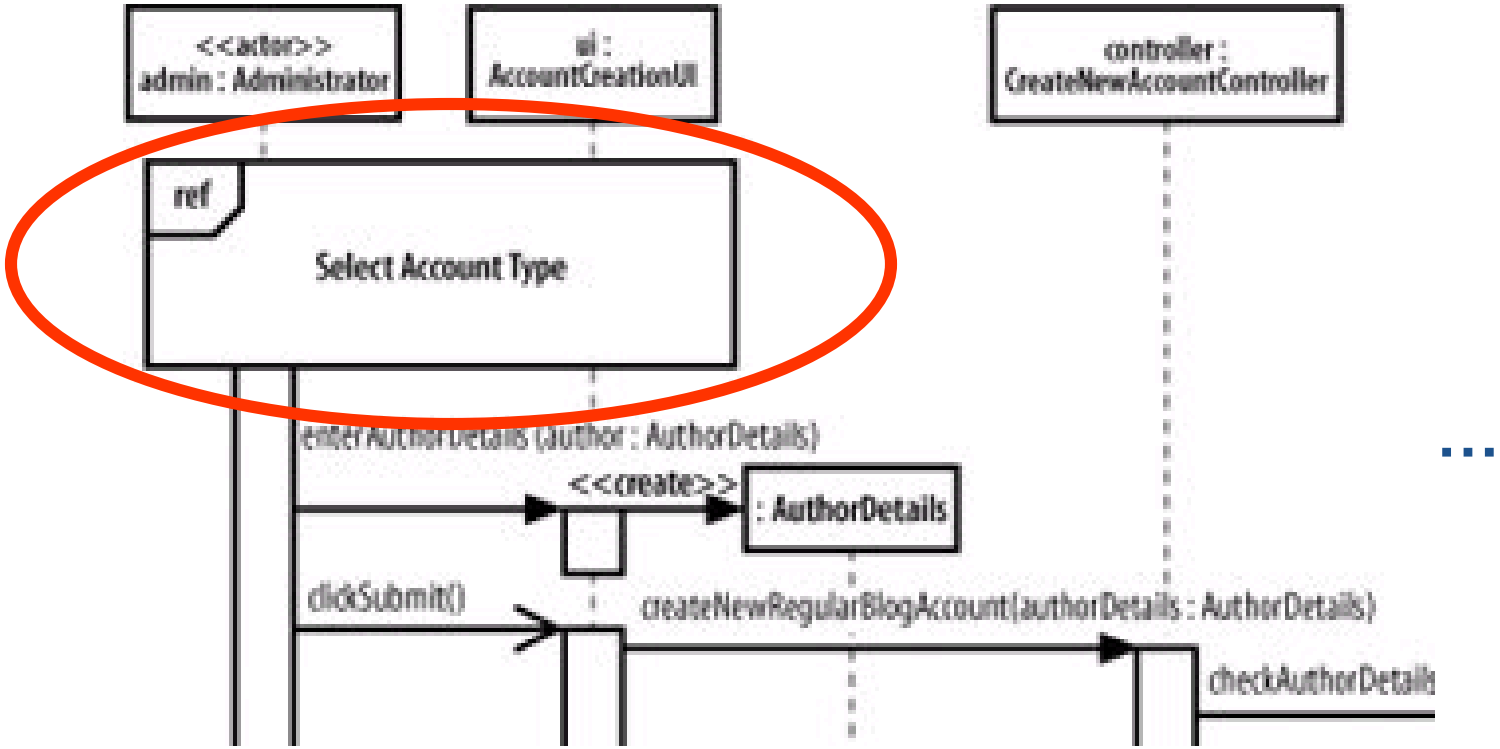


Fragments in sequence diagram

- **A sequence diagram may be broken into fragments**



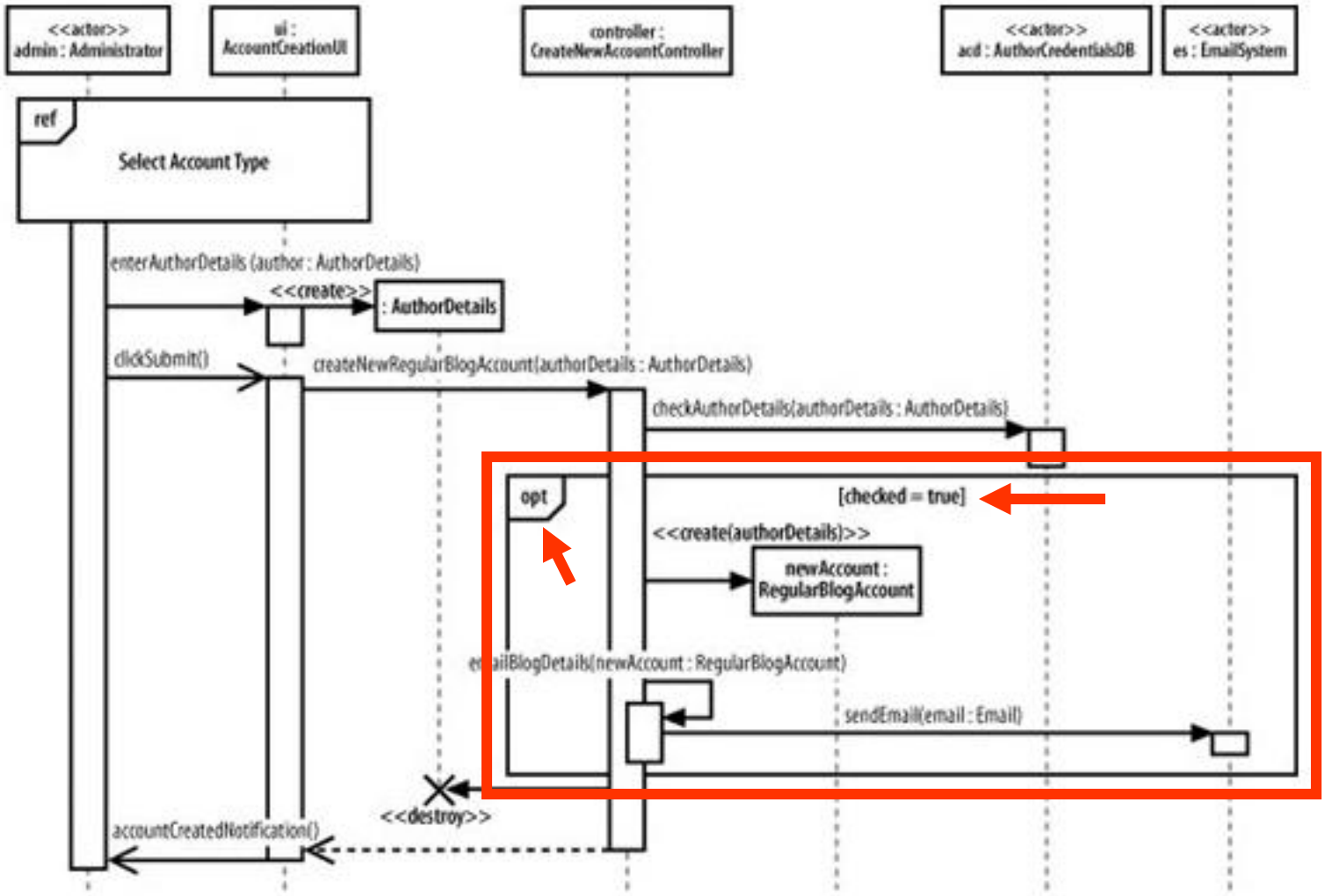
Using fragments



...

...

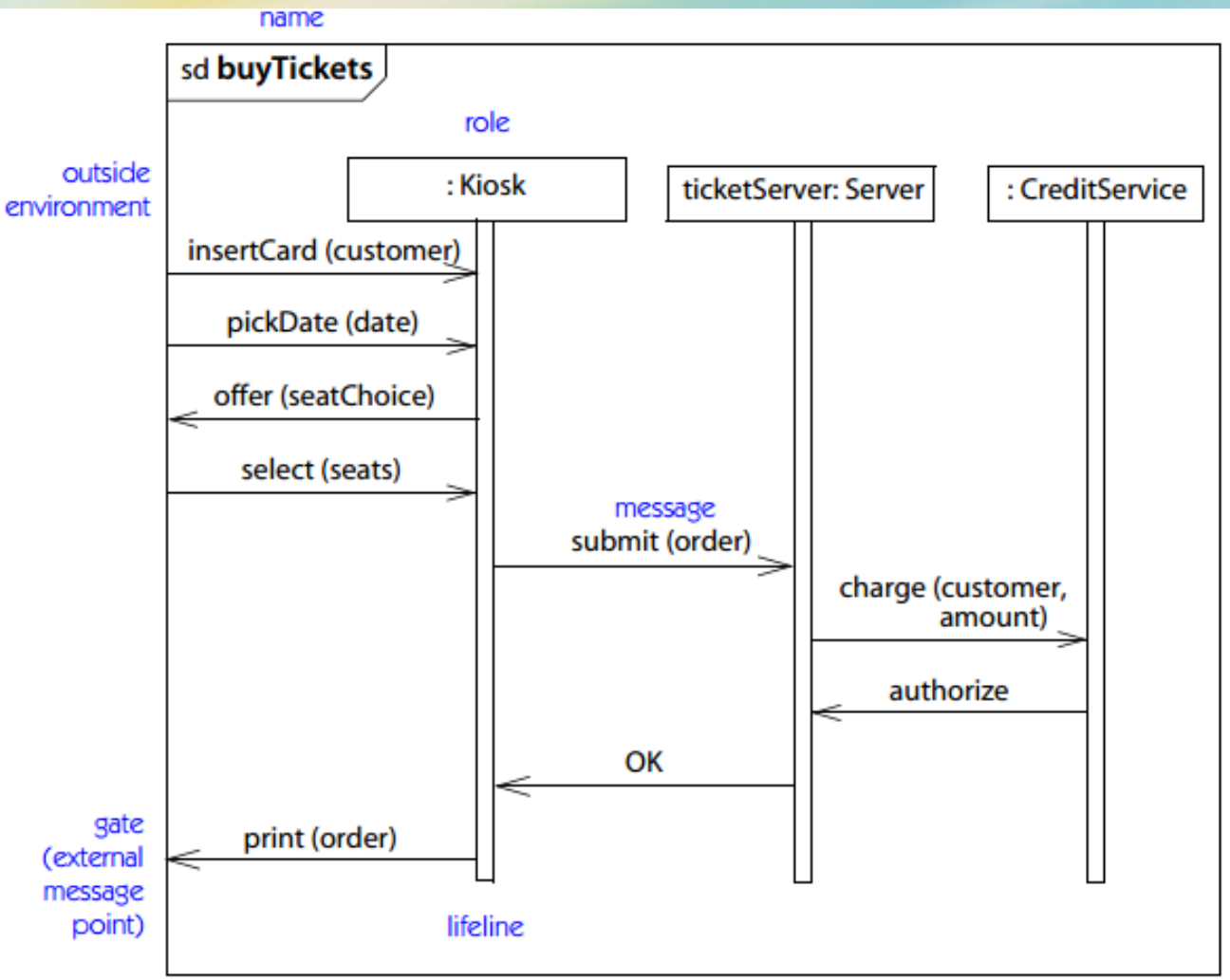
Using fragments (2)

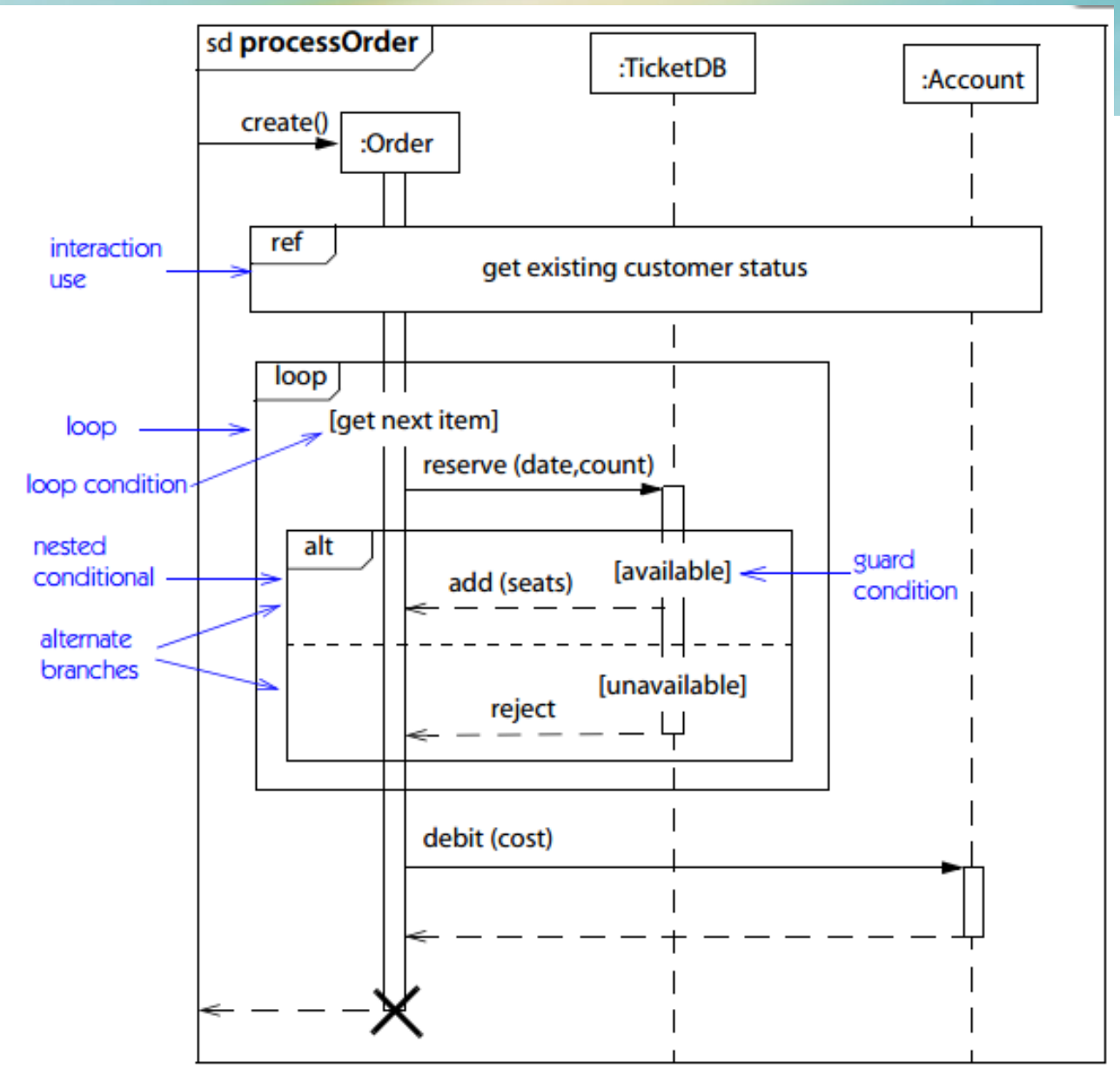


Some fragment types

- ref: an interaction defined elsewhere
- loop: repeat the interactions in the fragment many times
- alt [guard conditions]: execute the corresponding set of interactions, base on which guard condition is true
- opt [check]: optional fragment, executed only if the check value is true
- par: the interactions can be executed in parallel

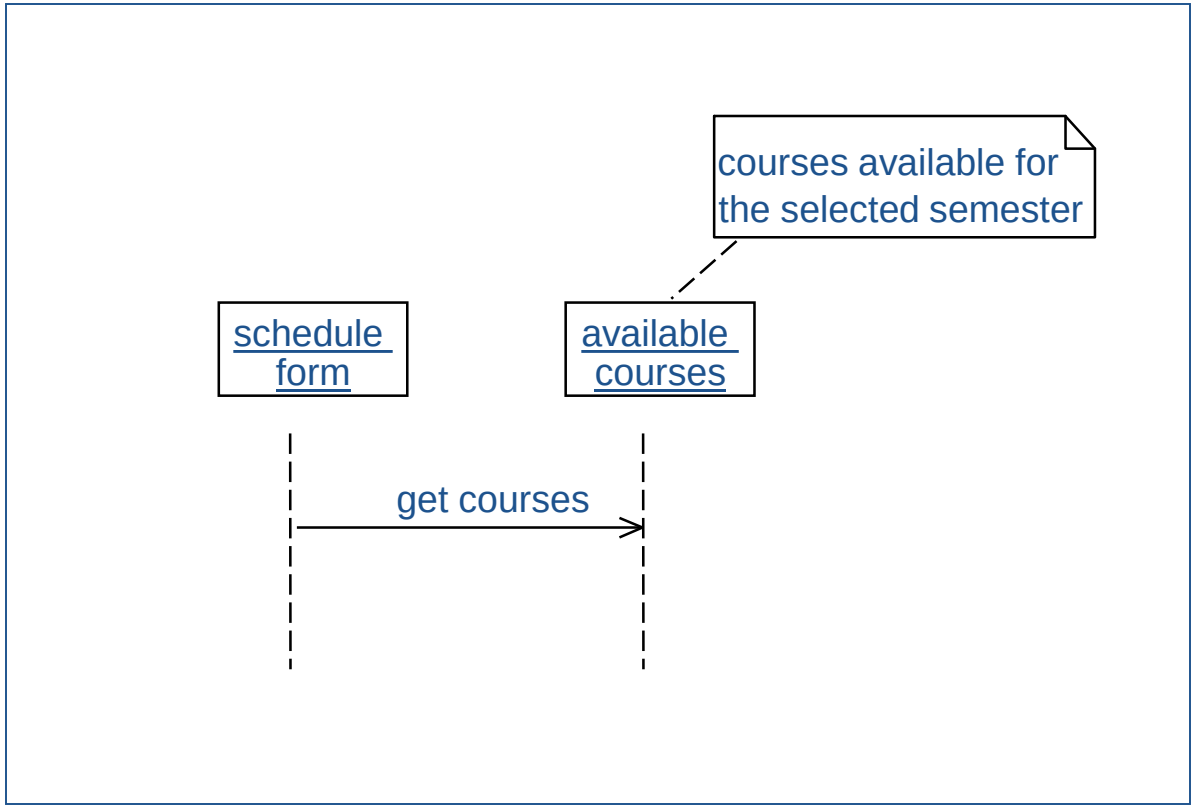
Examples


name
sd buyTickets
role
outside environment
: Kiosk
ticketServer: Server
: CreditService
insertCard (customer)
pickDate (date)
offer (seatChoice)
select (seats)
message
submit (order)
charge (customer, amount)
authorize
OK
gate (external message point)
print (order)
lifeline


sd processOrder
:TicketDB
:Account
create()
:Order
interaction use
ref
get existing customer status
loop
loop
[get next item]
loop condition
reserve (date,count)
nested conditional
alt
add (seats)
[available]
guard condition
alternate branches
[unavailable]
reject
debit (cost)

Notes

- Notes may be added to add more information to the diagram



II. Analysis activities

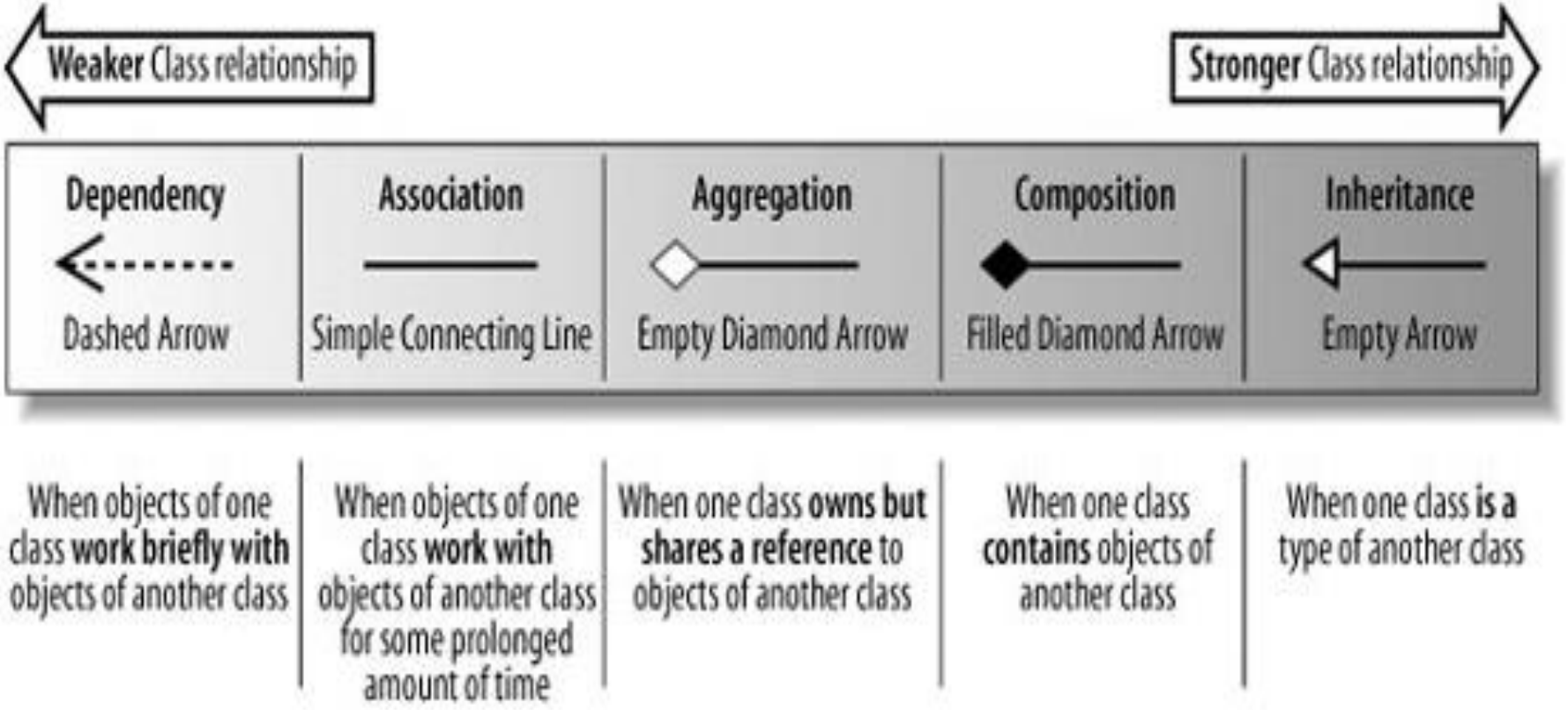
1. Identifying Objects
2. Mapping Usecase to Objects (with Sequence diagrams)
3. **Identifying Class relationship**
4. Identifying Attributes
5. Modeling State-dependent Behavior of Objects

Relationships

- **Types of relationship**
  - Association (Kết hợp)
  - Aggregation (Thu nạp)
  - Composition (Hợp thành)
  - Dependency (Phụ thuộc)
  - Generalization/Inheritance (Kế thừa)
  - Realization (Hiện thực hóa)

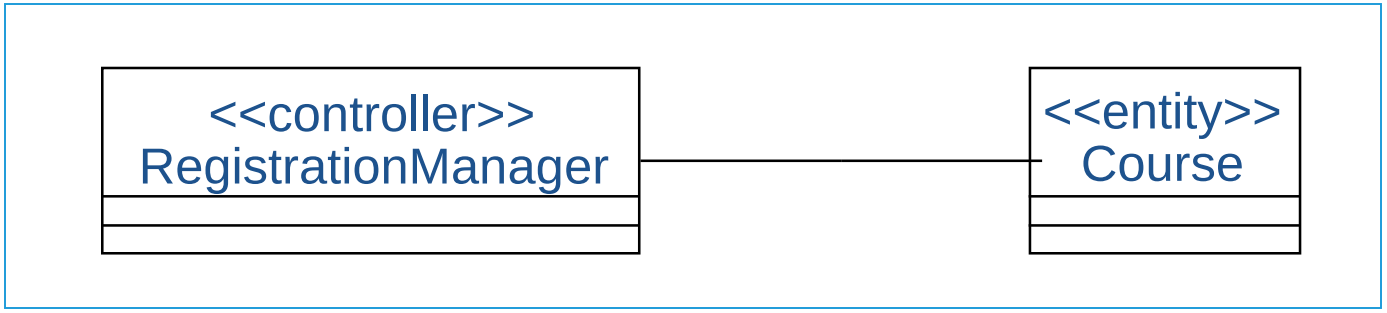
Class relationships

- **Dependency (“uses”)**
- **Association (“uses”)**
- **Aggregation (“has”)**
- **Composition (“has”)**
- **Inheritance (“is”)**


Weaker Class relationship
Stronger Class relationship
Dependency
Dashed Arrow
Association
Simple Connecting Line
Aggregation
Empty Diamond Arrow
Composition
Filled Diamond Arrow
Inheritance
Empty Arrow
When objects of one class work briefly with objects of another class
When objects of one class work with objects of another class for some prolonged amount of time
When one class owns but shares a reference to objects of another class
When one class contains objects of another class
When one class is a type of another class

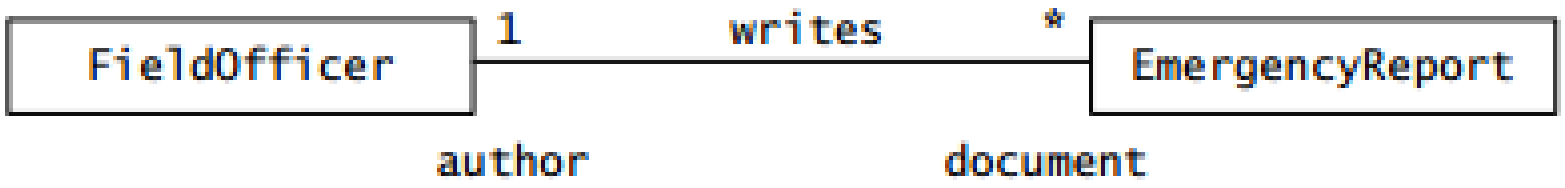
Associations

- An association is a bi-directional semantic connection between classes
  - This implies that there is a link between objects in the associated classes
- Associations are represented on class diagrams by a line connecting the associated classes
- Data may flow in either direction or both directions across a link



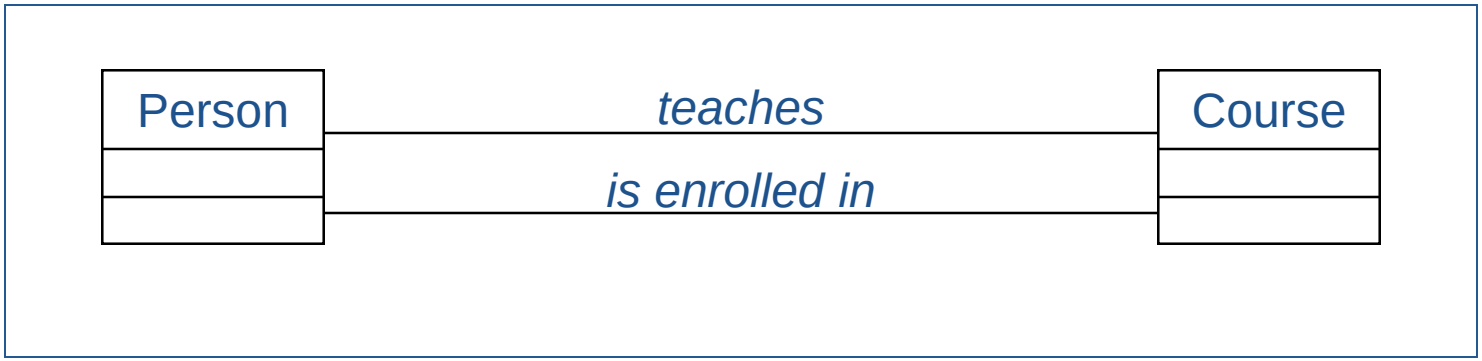
Associations

- To clarify its meaning, an association may be named
- A role denotes the purpose or capacity wherein one class associates with another



Multiple Associations

- More than one association may exist between two classes
- If there is more than one association between two classes then they MUST be named

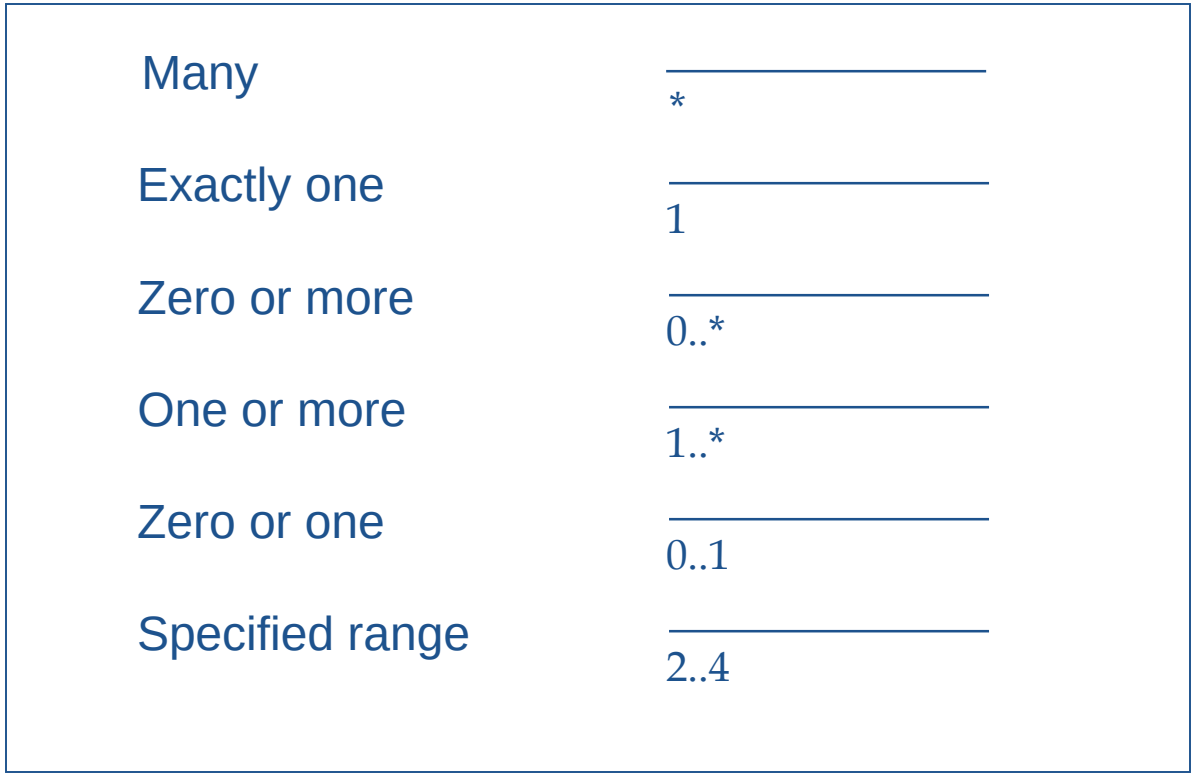


Multiplicity for Associations

- Multiplicity is the number of instances of one class related to ONE instance of the other class
- For each association, there are two multiplicity decisions to make: one for each end of the association
- For example, in the connection between Person playing the role of the teacher and Course
  - For each instance of Person, many (i.e., zero or more) Courses may be taught
  - For each instance of Course, exactly one Person is the teacher

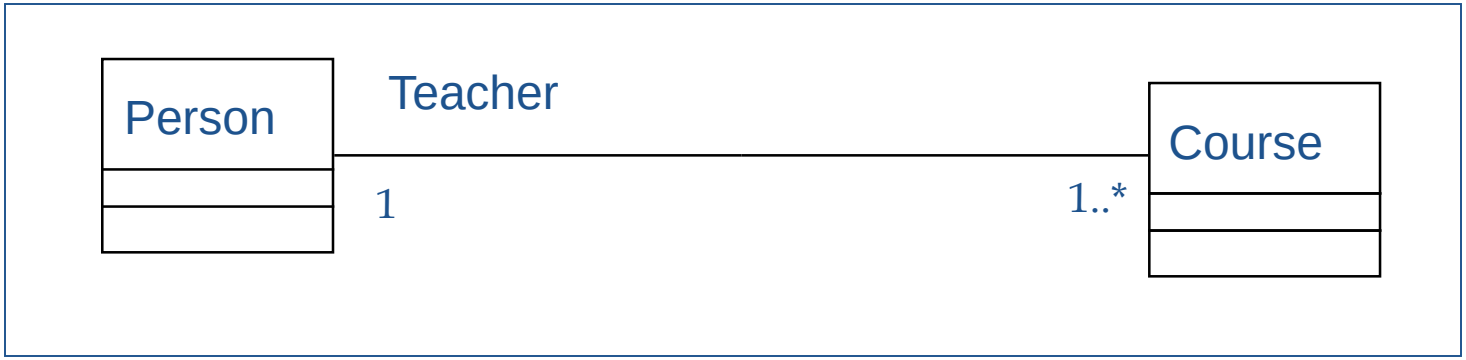
Multiplicity Indicators

- Each end of an association contains a multiplicity indicator
  - Indicates the number of objects participating in the relationship



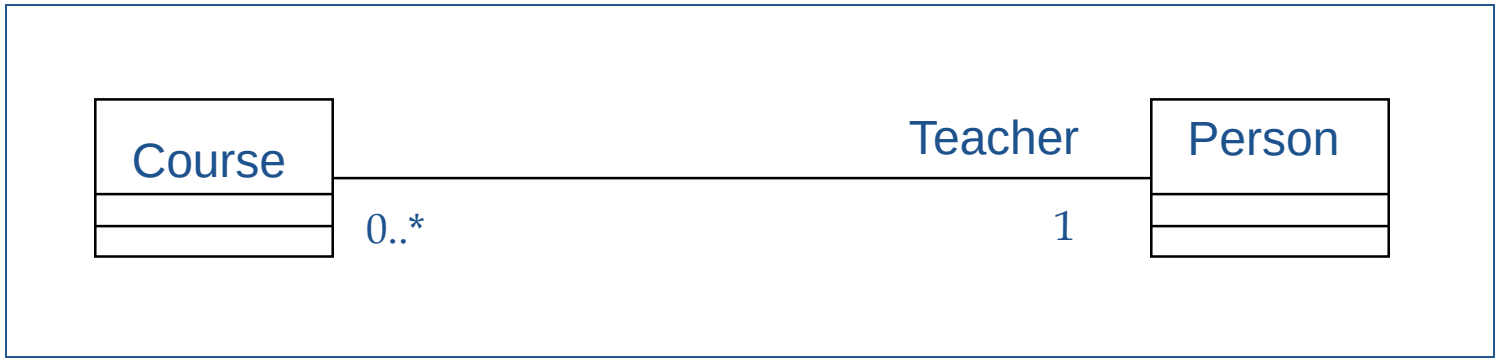
Example: Multiplicity

- Multiplicity decisions expose many hidden assumptions about the problem being modeled
  - Can a teacher be on sabbatical?
  - Can a course have two teachers?



What Does Multiplicity Mean?

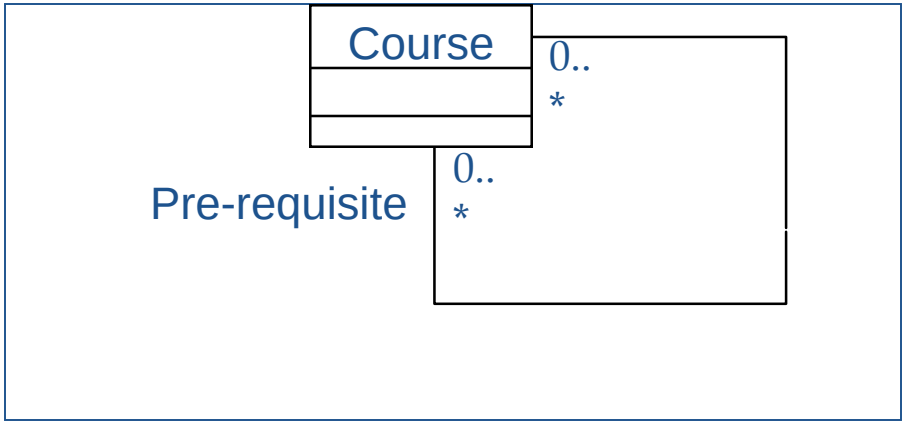
- Multiplicity answers two questions
  - Is the association mandatory or optional?
  - What is the minimum and maximum number of instances that can be linked to one instance?



What does this diagram tell you?

Reflexive Associations

- In a reflexive association, objects in the same class are related
  - Indicates that multiple objects in the same class collaborate together in some way



A course may have many pre-requisites
A course may be a pre-requisite for many other courses

Associations

Heuristics for identifying associations

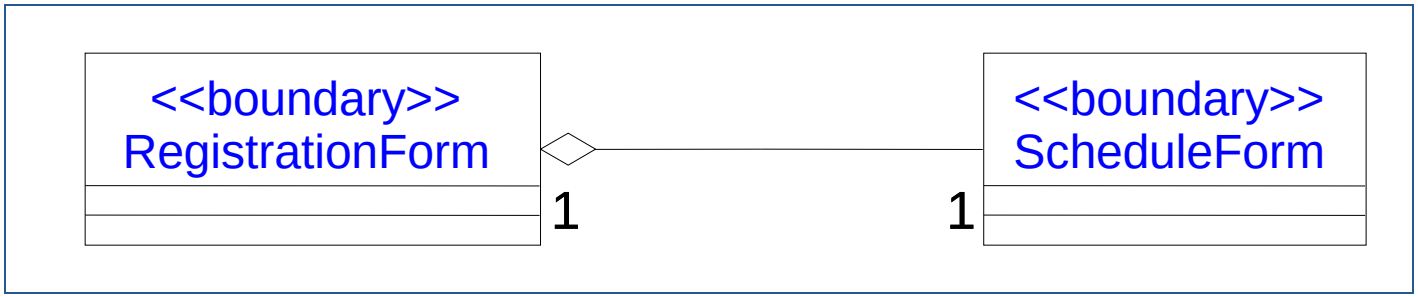
- Examine verb phrases.
- Name associations and roles precisely.
- Use qualifiers as often as possible to identify namespaces and key attributes.
- Eliminate any association that can be derived from other associations.
- Do not worry about multiplicity until the set of associations is stable.
- Too many associations make a model unreadable.

Relationships

- **Types of relationship**
  - Association (Kết hợp)
  - **Aggregation (Thu nạp)**
  - Composition (Hợp thành)
  - Dependency (Phụ thuộc)
  - Generalization/Inheritance (Kế thừa)
  - Realization (Hiện thực hóa)

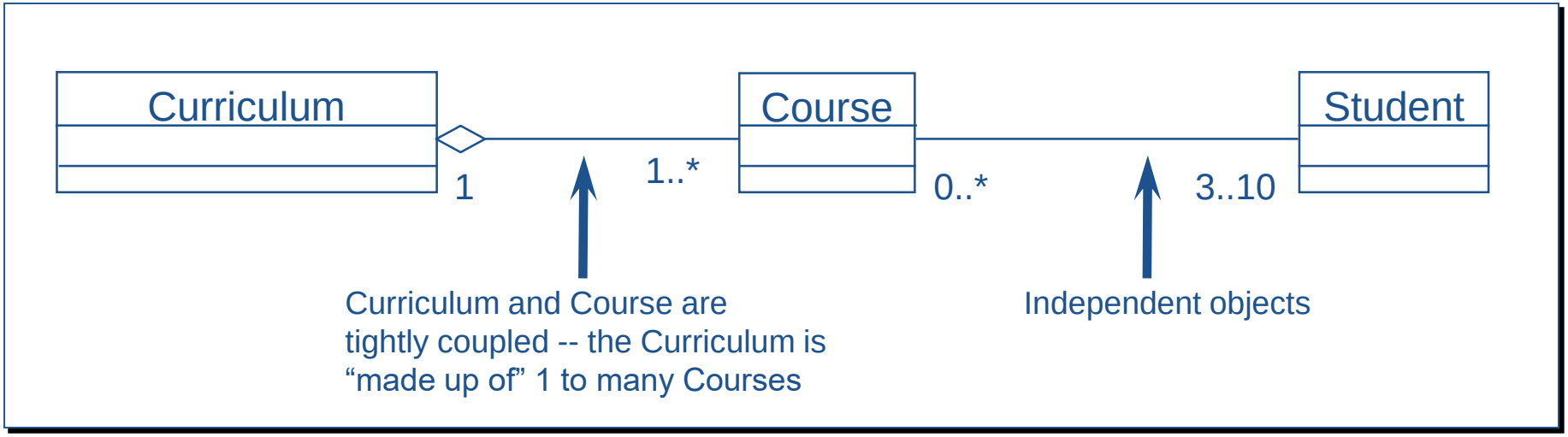
Aggregation

- Aggregation is a specialized form of association in which a whole is related to its part(s)
  - Aggregation is known as a "part-of" or containment relationship
- An aggregation is represented as an association with a diamond next to the class denoting the aggregate (whole)
- Multiplicity is represented in the same manner as other associations



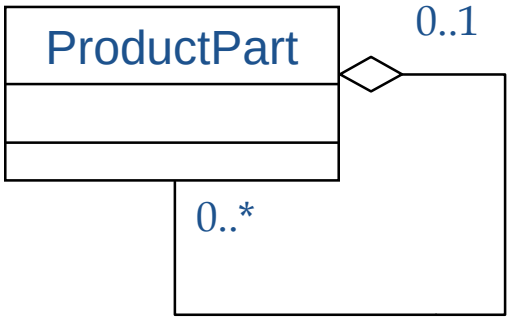
Association or Aggregation?

- If two objects are tightly bound by a whole-part relationship
  - The relationship is an aggregation
- If two objects are usually considered as independent, even though they are often linked
  - The relationship is an association



Reflexive Aggregates

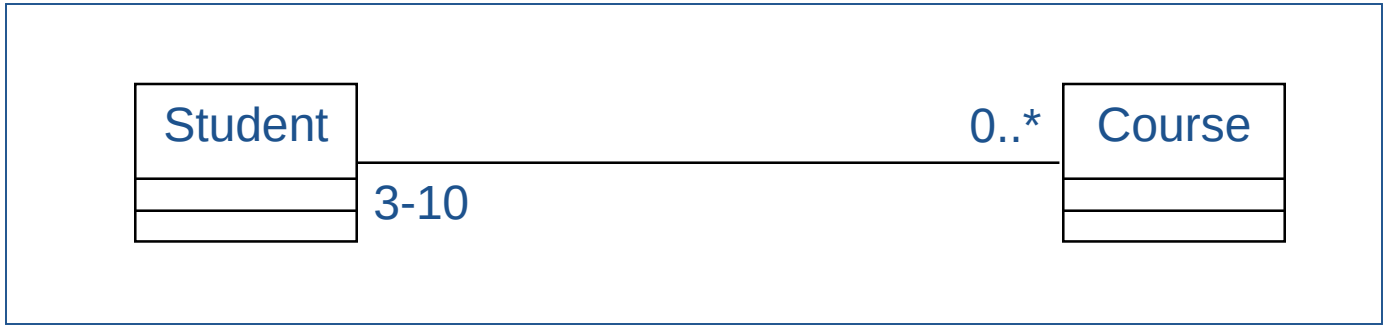
- Aggregates can also be reflexive
  - Classic bill of materials type problem
- This indicates a recursive relationship



One ProductPart object contains
zero or more ProductPart objects

Association Classes

- We wish to track the grades for all courses a student has taken
- The relationship between student and Course is a many-to-many relationship
- Where do we place the attribute grade?

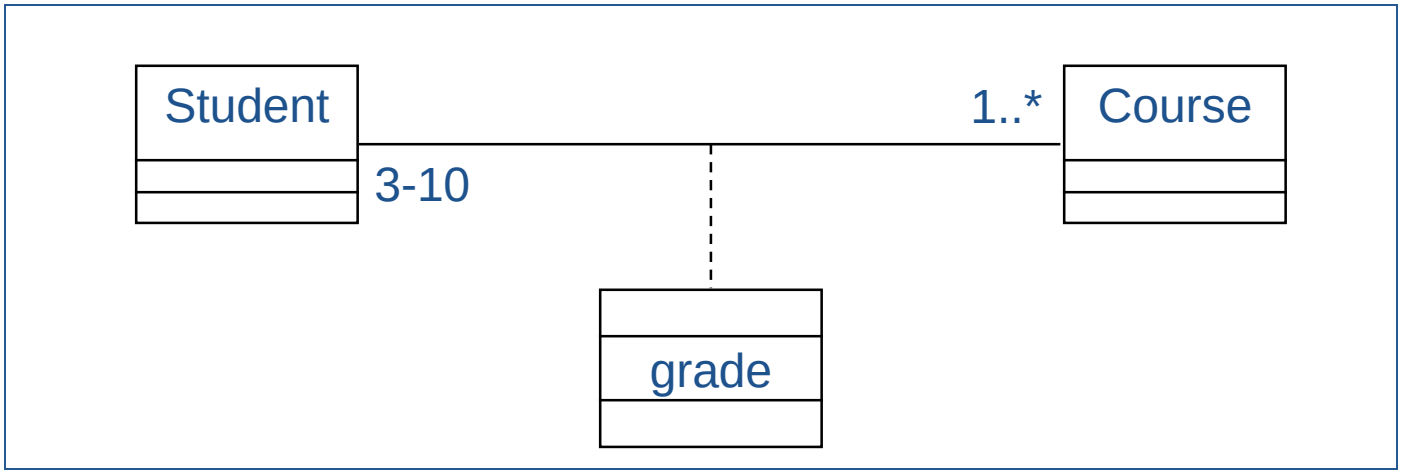


Association Classes (cont.)

- The attribute grade cannot be placed in the Course class because there are (potentially) many links to many Student objects
- The attribute grade cannot be placed in the Student class because there are (potentially) many links to many Course objects
- Therefore, the attribute really belongs to the individual Student-Course link
- An association class is used to hold the link information

Drawing Association Classes

- Create an association class using the class icon
- Connect the class icon to the association line using a dashed line
- The association class may include multiple properties of the association
- Only one association class is permitted per association

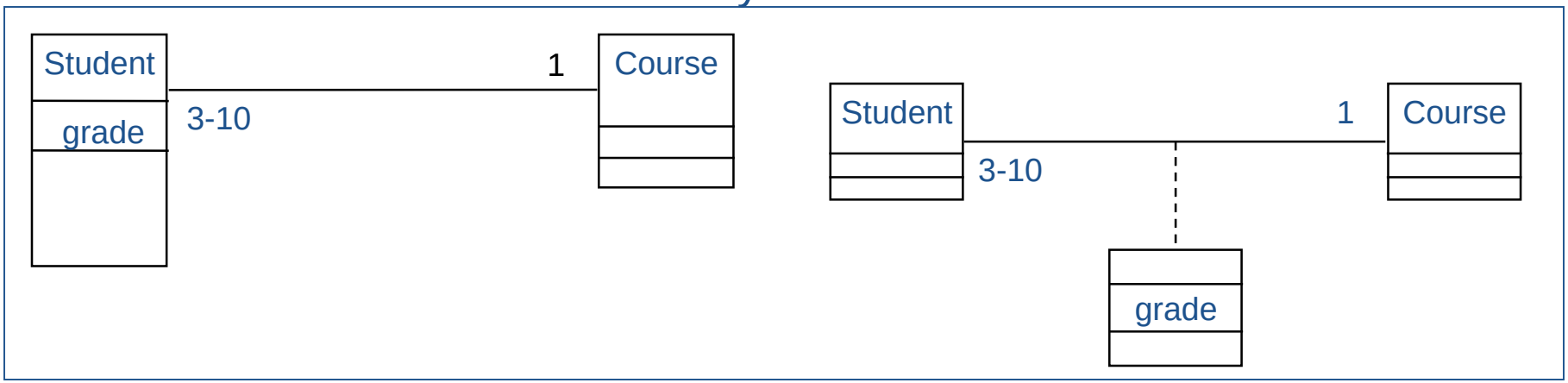


Association Classes and Multiplicity

- Association classes are often used for many-to-many associations
- If the multiplicity at either end of an association is "to-one"
  - The attribute may be placed within the class on the many side of the relationship

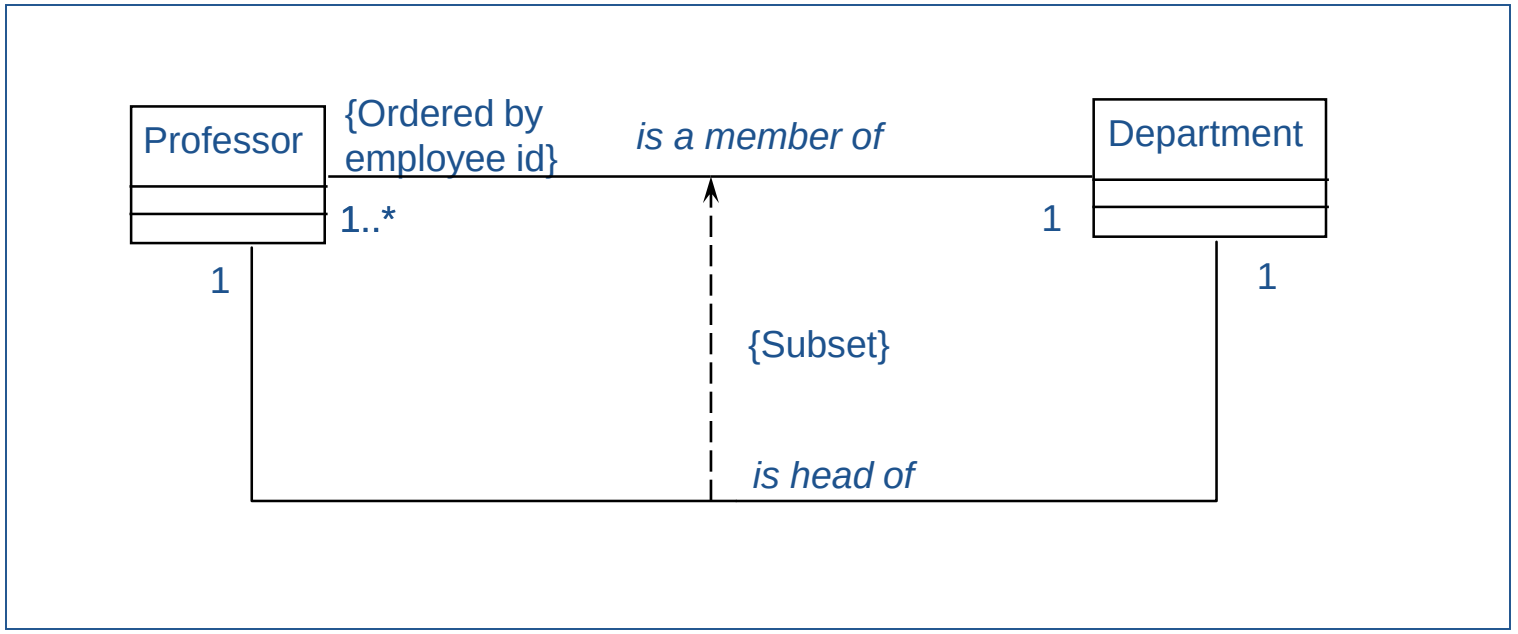
OR

  - An association class may still be used



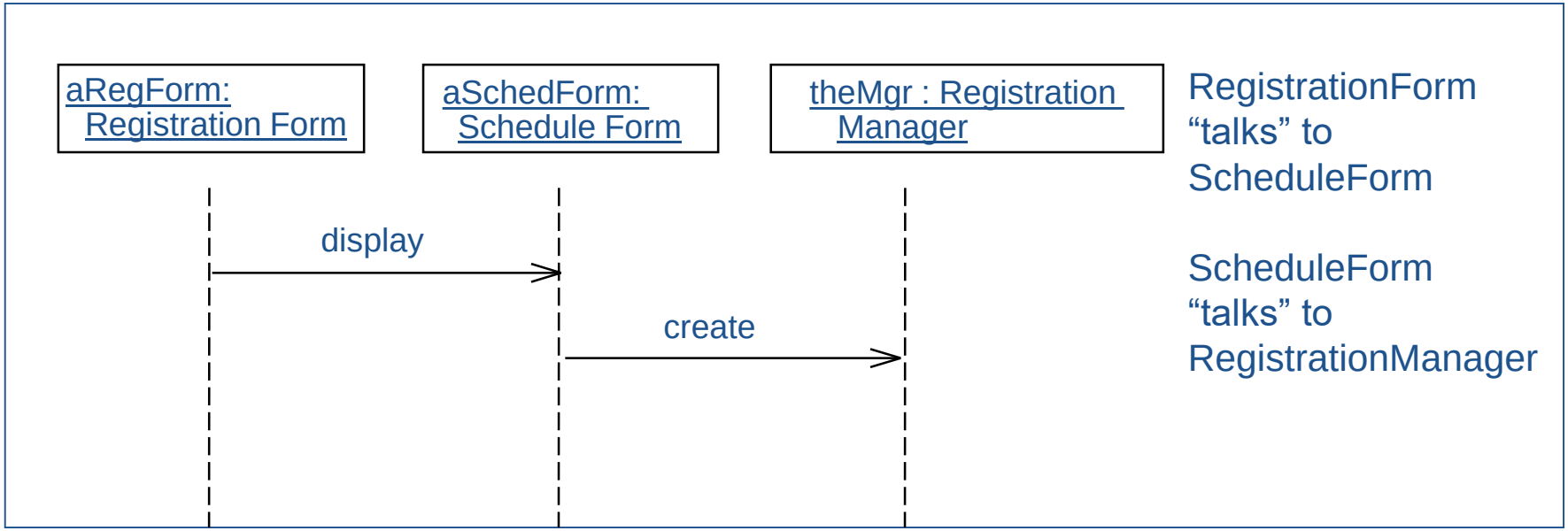
Constraints

- A constraint is the expression of some condition that must be preserved
  - A constraint is shown within curly braces



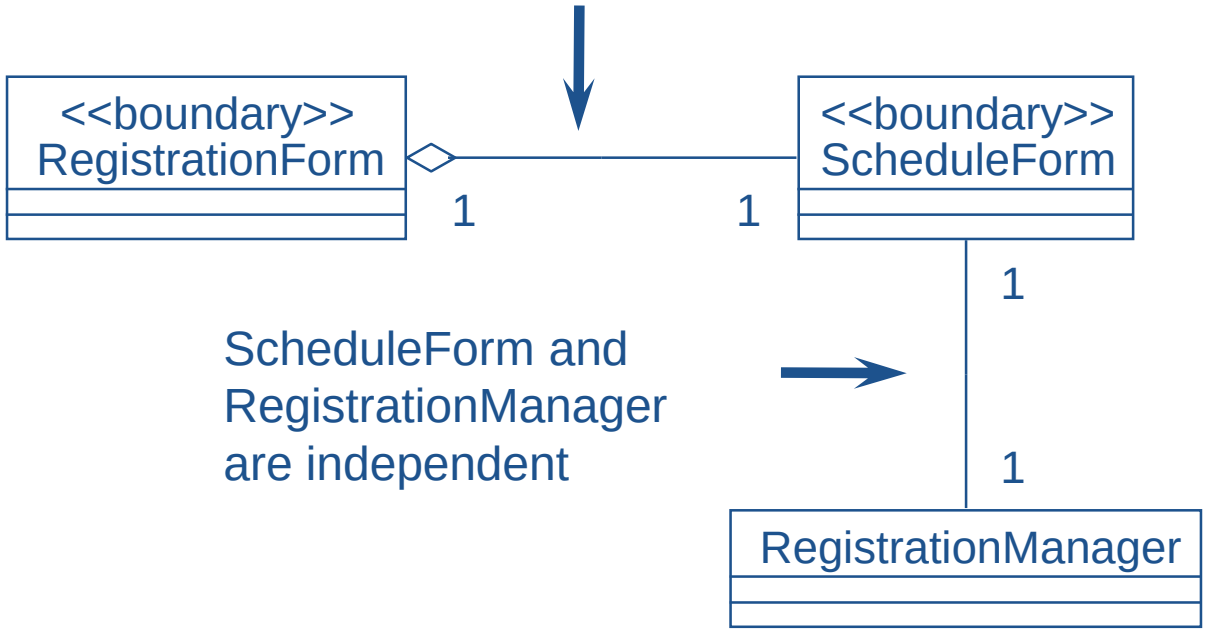
Finding Associations and Aggregations

- Scenarios may be examined to determine if a relationship should exist between two classes
  - Two objects can communicate only if they “know” one another
- Associations and/or aggregations provide a pathway for communication



Association or Aggregation?

RegistrationForm and ScheduleForm are tightly coupled -- a ScheduleForm is “part of” the RegistrationForm



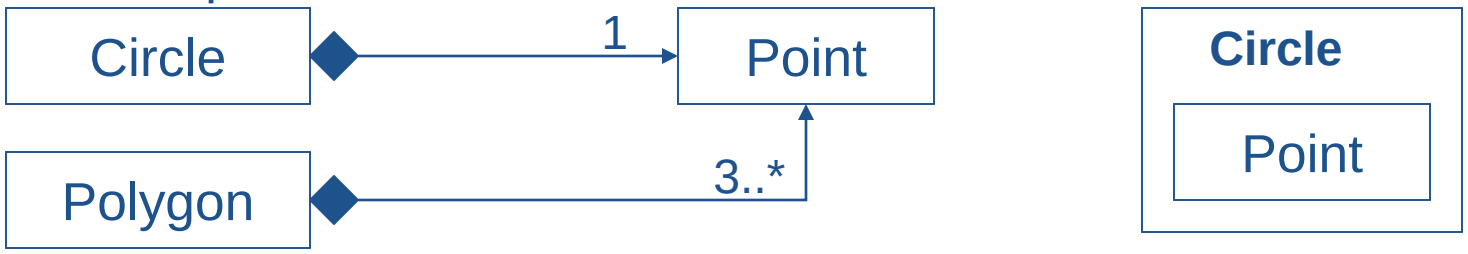
Relationships

- **Types of relationship**
  - Association (Kết hợp)
  - Aggregation (Thu nạp)
  - **Composition (Hợp thành)**
  - Dependency (Phụ thuộc)
  - Generalization/Inheritance (Kế thừa)
  - Realization (Hiện thực hóa)

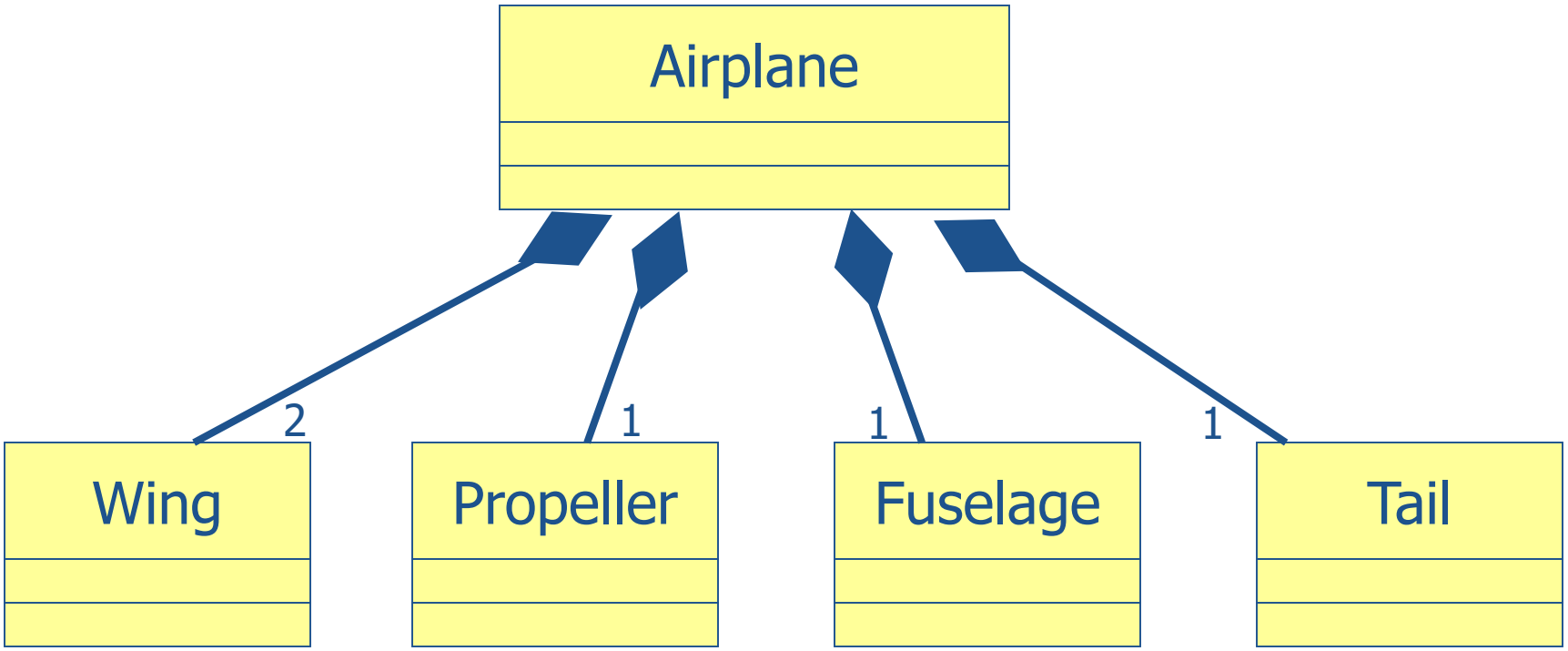
Composition

A strong form of aggregation

- A **composition aggregation** indicates that the existence of the parts depends on the whole
- 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.



Composition



Relationships

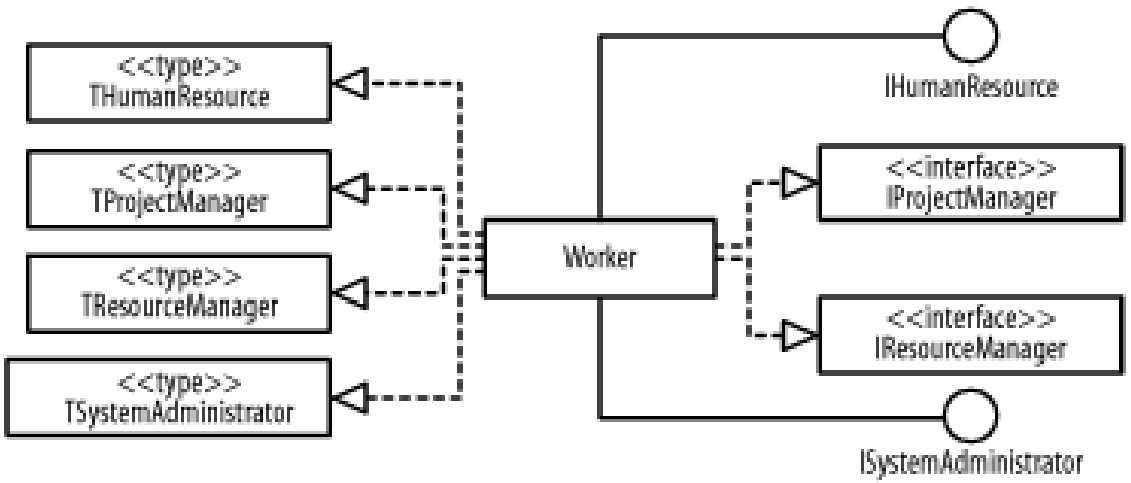
- **Types of relationship**
  - Association (Kết hợp)
  - Aggregation (Thu nạp)
  - Composition (Hợp thành)
  - Dependency (Phụ thuộc)
  - Generalization/Inheritance (Kế thừa)
  - **Realization (Hiện thực hóa)**

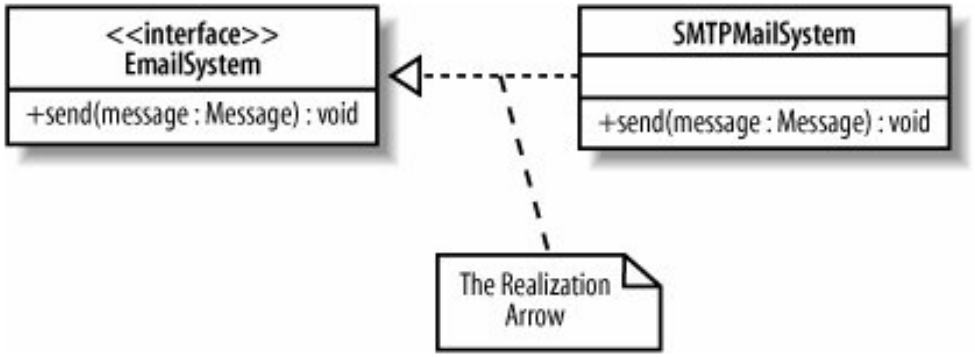
Realization

- **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**

Realization

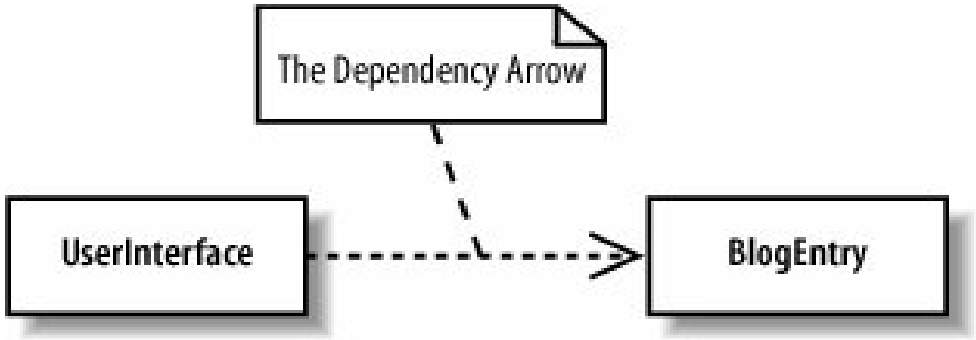
Figure 3-34. Realizations for the Worker class





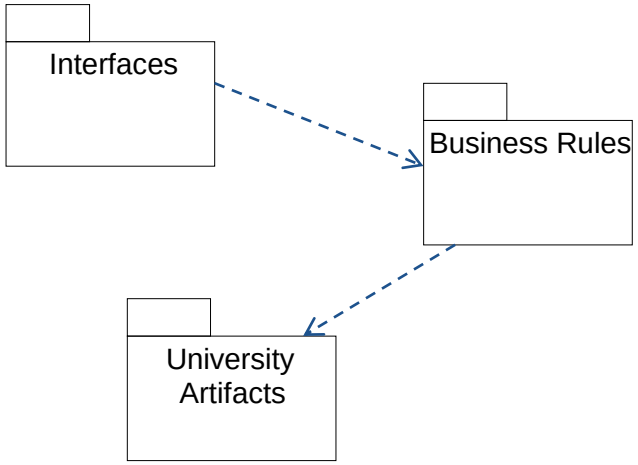
Dependency

- **A dependency indicates a semantic relation between two or more classes in which a change in one may force changes in the other although there is no explicit association between them.**



Package Relationships

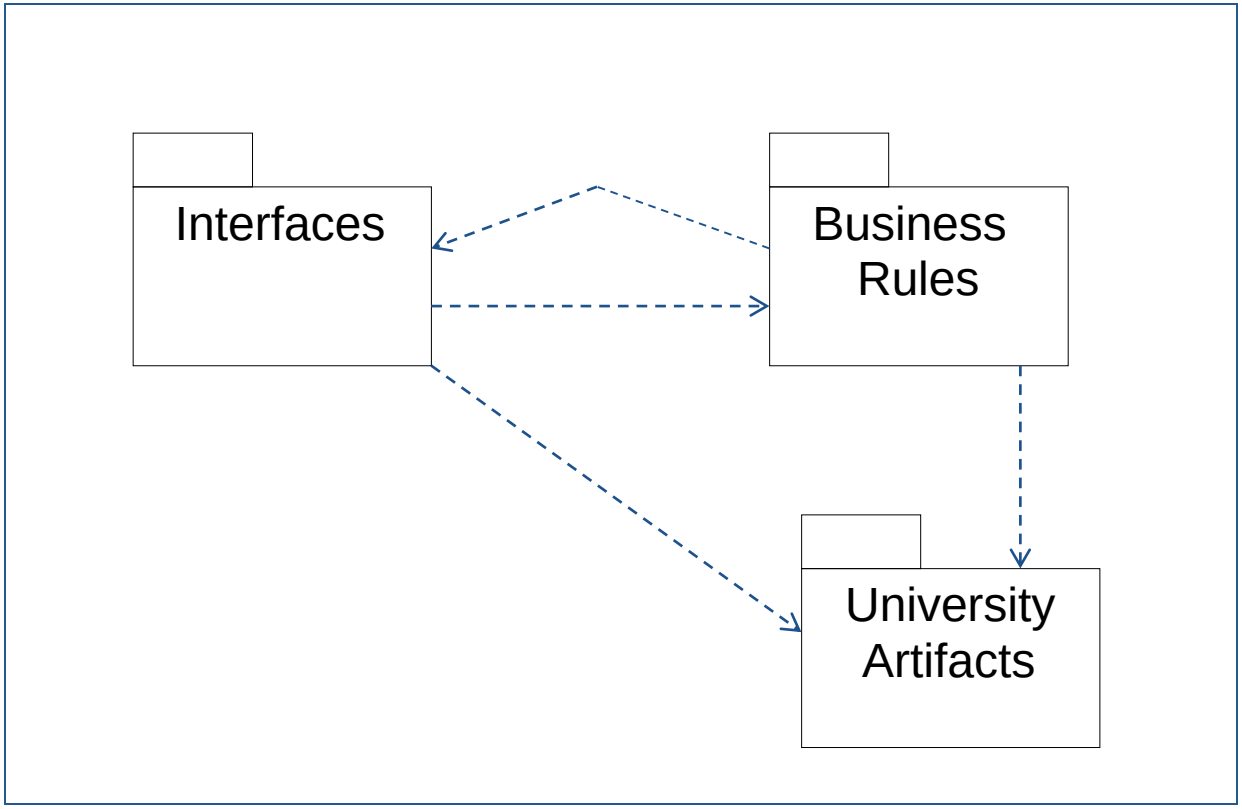
- Packages are related to one another using a dependency relationship
- If a class in one package “talks” to a class in another package then a dependency relationship is added at the package level



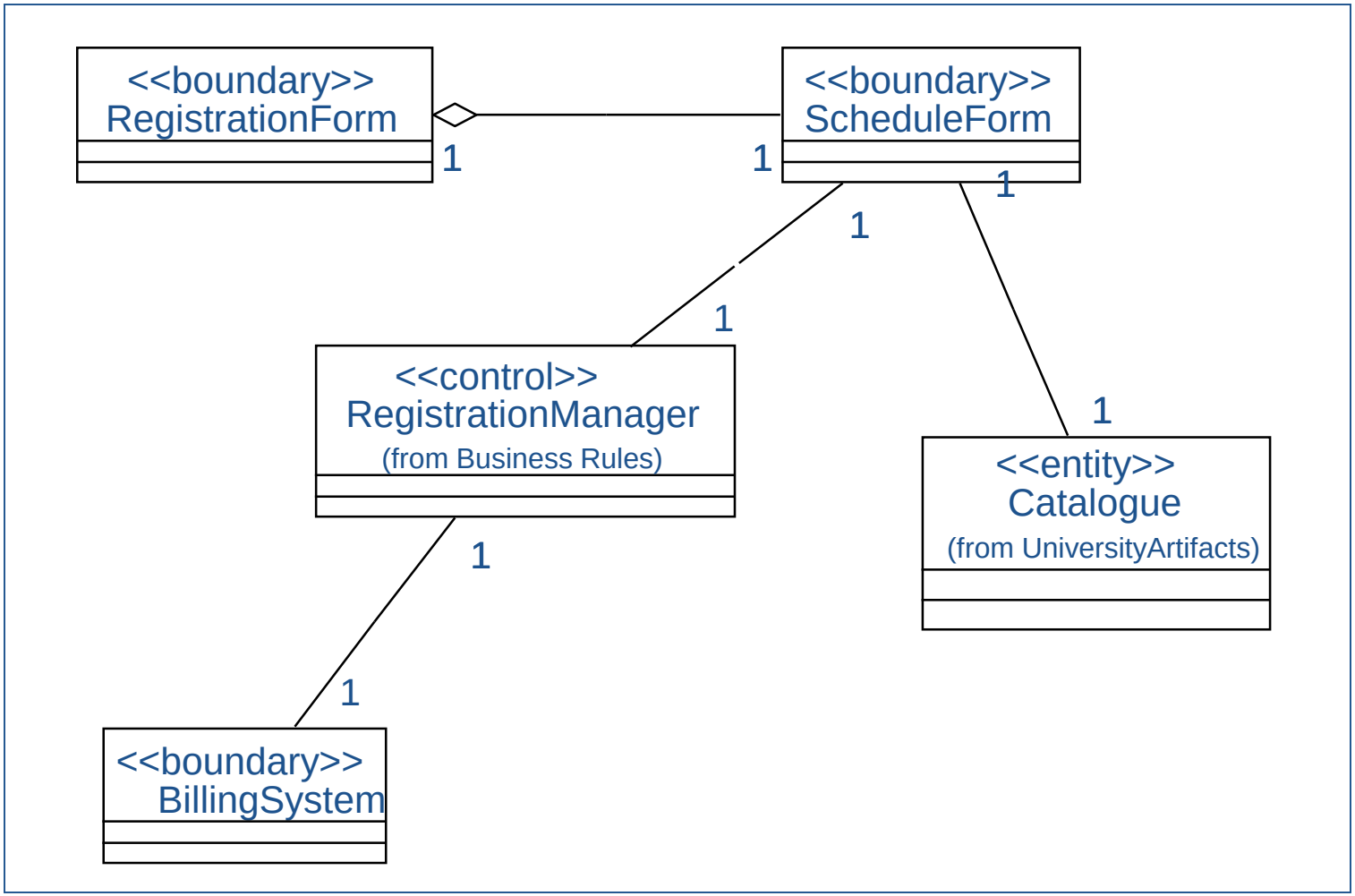
Relationships During Analysis and Design

- During analysis, establish connections (associations and aggregations) among classes
  - These connections exist because of the nature of the classes, not because of a specific implementation
  - Make an initial estimate of multiplicity in order to expose hidden assumptions
- Class diagrams are updated to show the added relationships
- During design:
  - Multiplicity estimates are refined and updated
  - Associations and aggregations are evaluated and refined
  - Package relationships are re-evaluated and refined
  - Class diagrams are matured

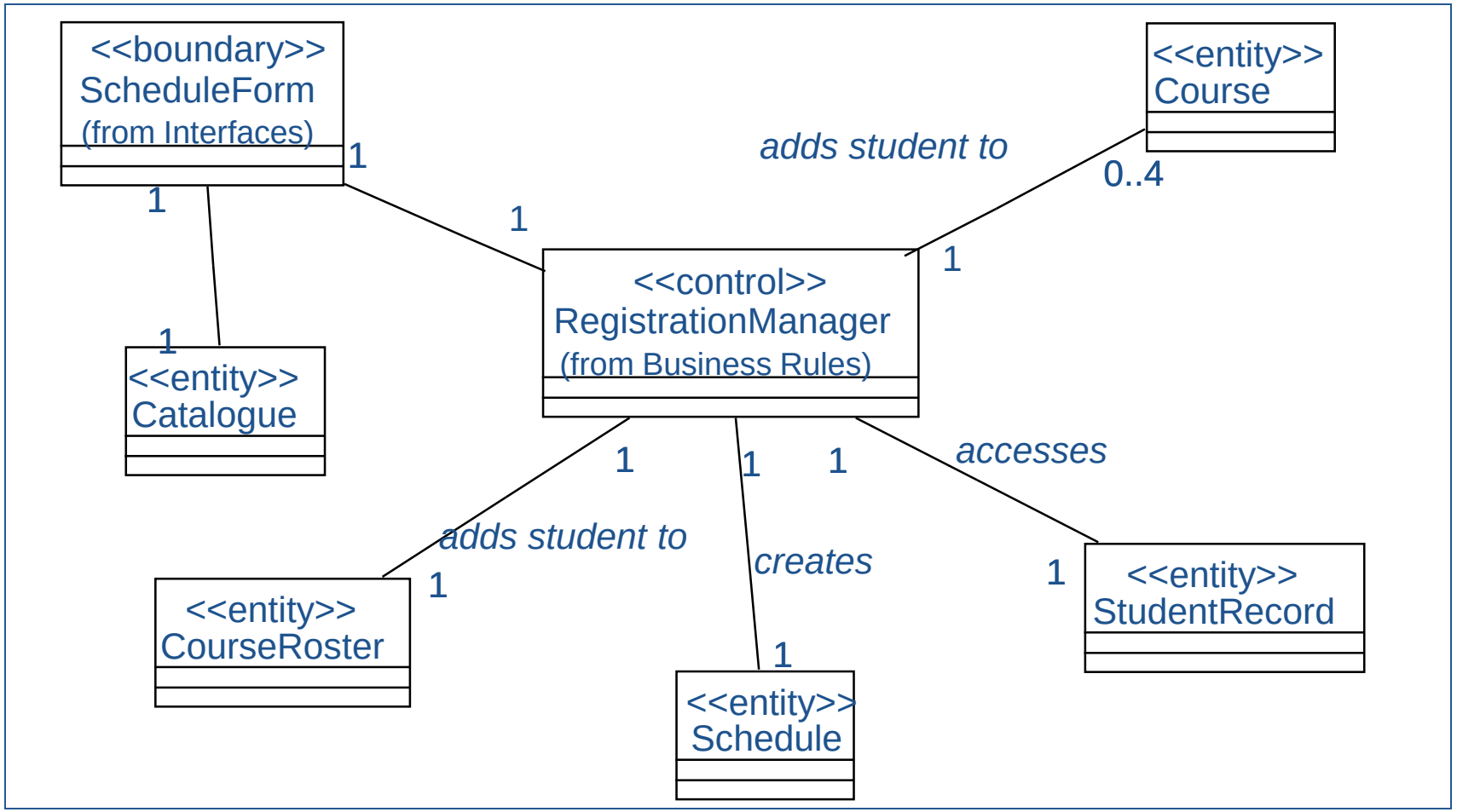
Updated Main Class Diagram for the Registration System



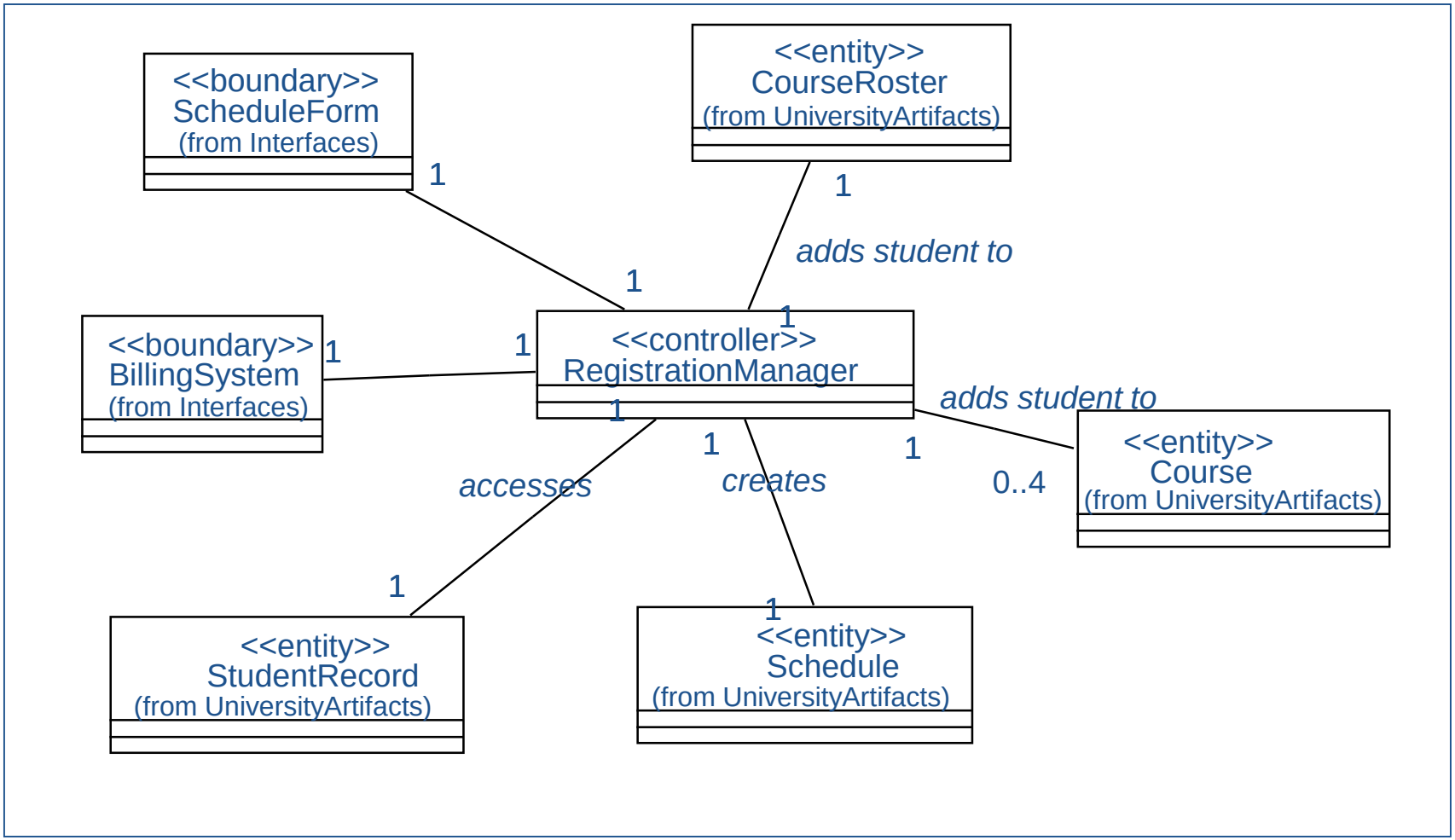
Updated Interfaces Main Class Diagram



Updated UniversityArtifacts Main Class Diagram



Updated Business Rules Main Class Diagram



Relationships

- **Types of relationship**
  - Association (Kết hợp)
  - Aggregation (Thu nạp)
  - Composition (Hợp thành)
  - Dependency (Phụ thuộc)
  - **Generalization/Inheritance (Kế thừa)**
  - Realization (Hiện thực hóa)

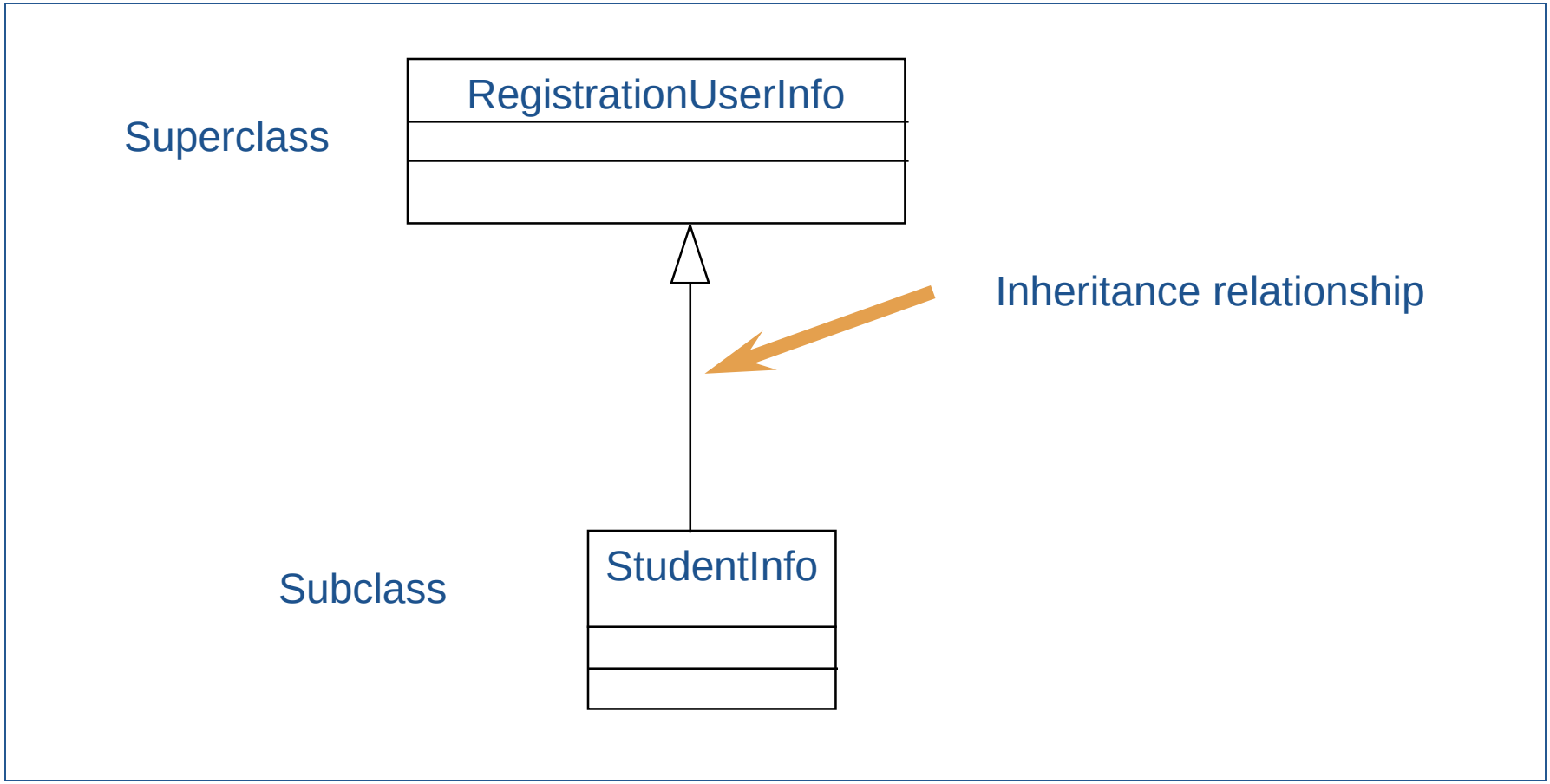
Bài tập

- **Một nhóm 2 SV**
  - Chọn 1 nghiệp vụ cụ thể, vẽ các lược đồ sau:
    - 1 Usecase diagram (viết scenario): có ít nhất 1 usecase
    - 1 Sequence diagram
    - 1 Class diagrams
    - *Không làm chức năng đăng ký, đăng nhập, đăng xuất*
    - *Viết ra giấy (nộp vào cuối buổi)*

Inheritance

- Inheritance defines a relationship among classes where one class shares the structure and/or behavior of one or more classes
- Inheritance defines a hierarchy of abstractions in which a subclass inherits from one or more superclasses
  - With single inheritance, the subclass inherits from only one superclass
  - With multiple inheritance, the subclass inherits from more than one superclass
- Inheritance is an “is a” or “kind of” relationship

Drawing an Inheritance Hierarchy

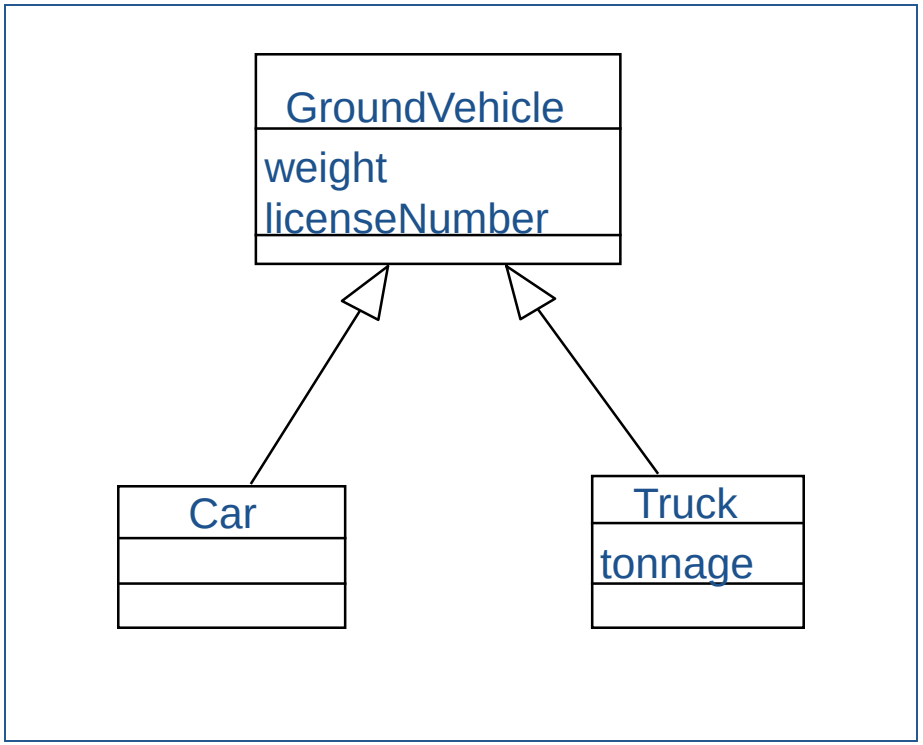


What Gets Inherited?

- A subclass inherits its parent's:
  - Attributes
  - Operations
  - Relationships
- A subclass may:
  - Add additional attributes, operations, relationships
  - Redefine inherited operations (use caution!)

Inheriting Attributes

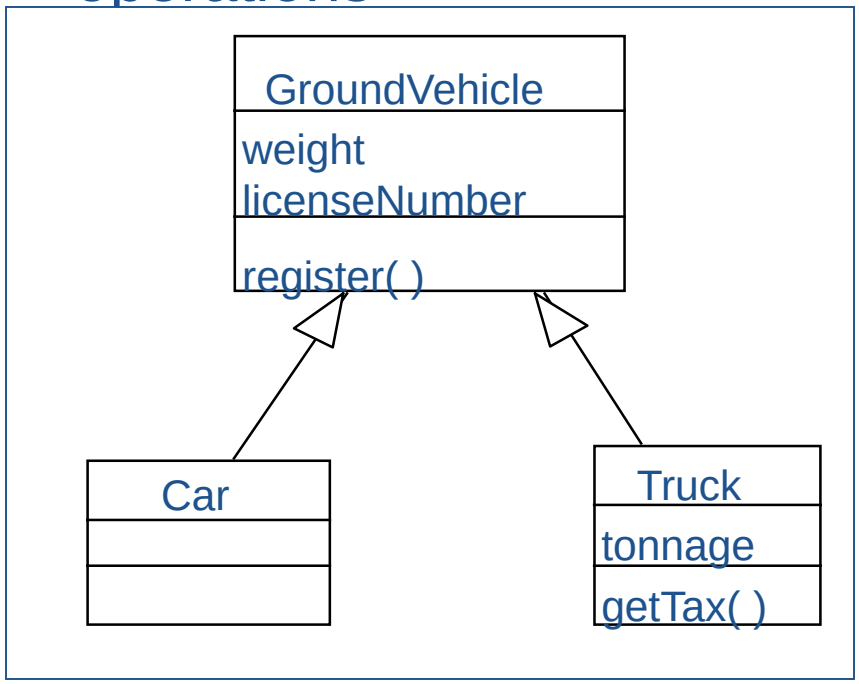
- Attributes are defined at the highest level in the inheritance hierarchy at which they are applicable
- Subclasses of a class inherit all attributes
- Each subclass may add additional attributes



A truck has three attributes:
- licenseNumber
- weight
- tonnage

Inheriting Operations

- Operations are defined at the highest level in the inheritance hierarchy at which they are applicable
- Subclasses of a class inherit all operations
- Each subclass may augment or redefine inherited operations

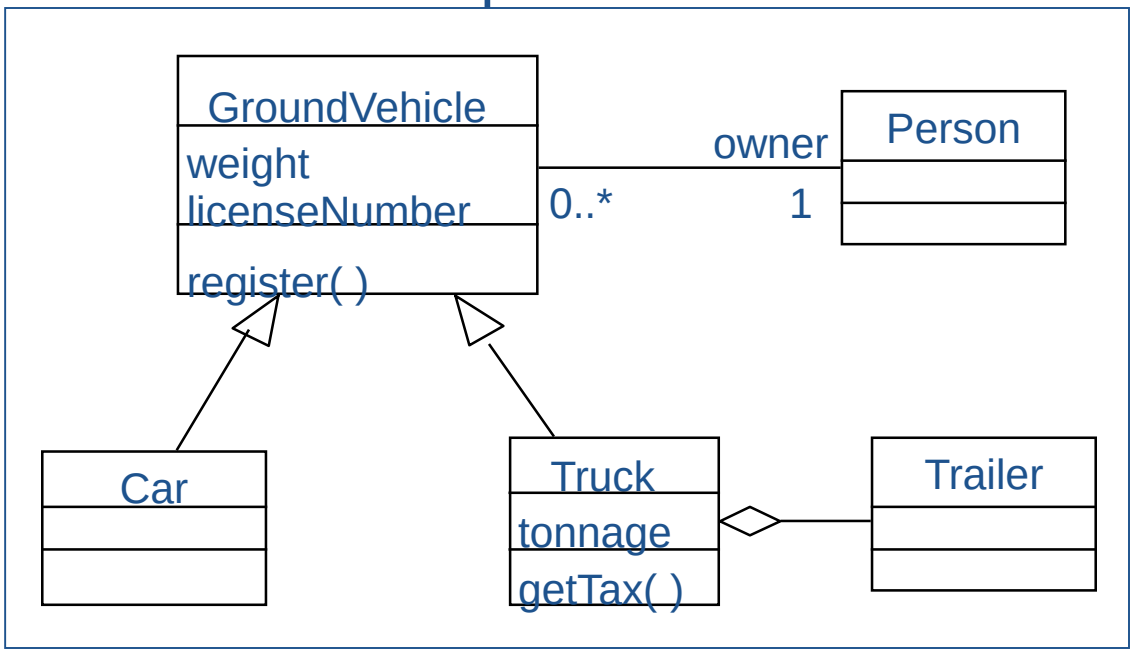


A truck has three attributes:
- licenseNumber
- weight
- tonnage

and two operations:
- register()
- getTax()

Inheriting Relationships

- Relationships are also inherited and should be defined at the highest level in the inheritance hierarchy at which they are applicable
- Subclasses of a class inherit all relationships
- Each subclass may also participate in additional relationships

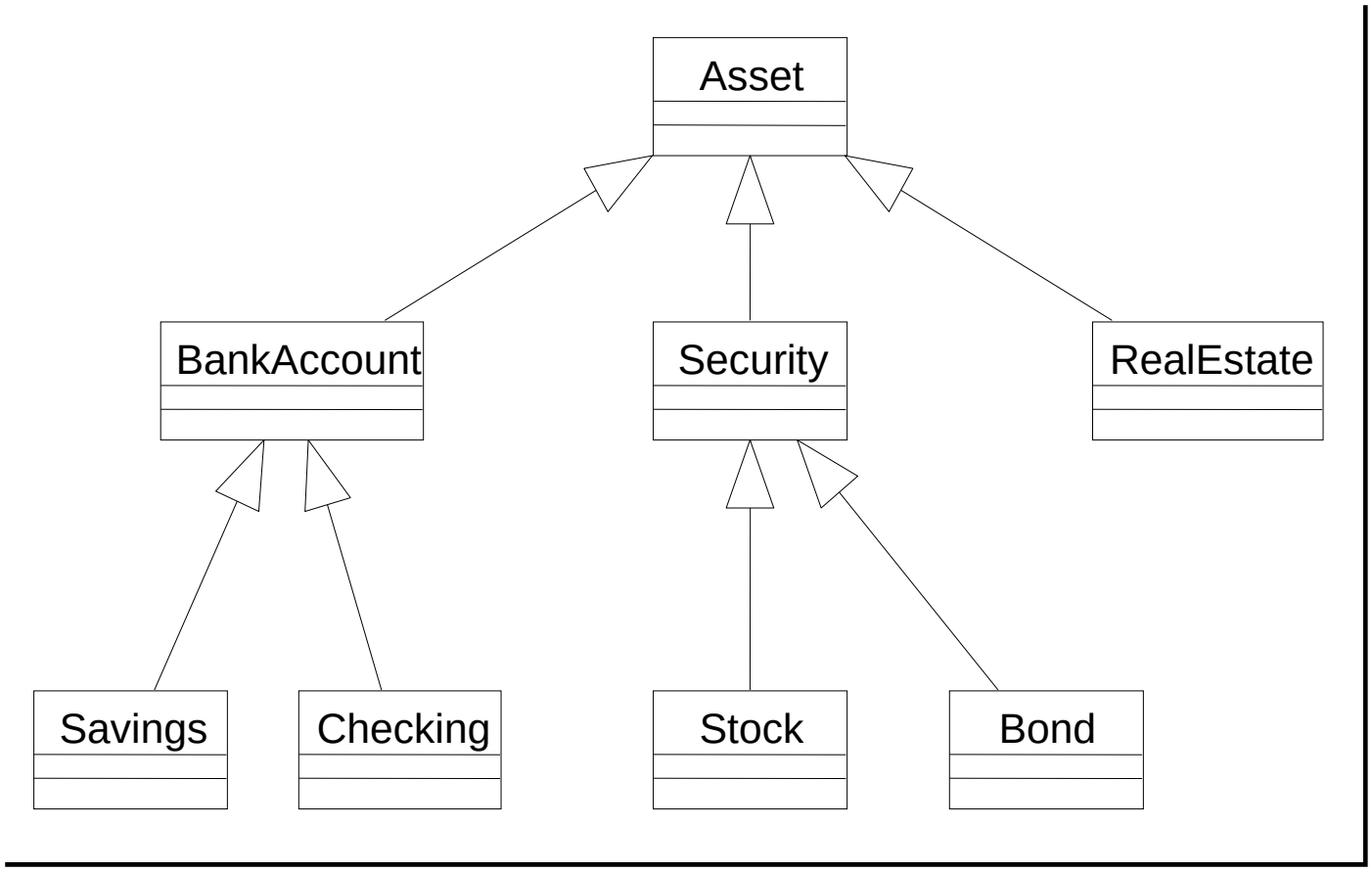


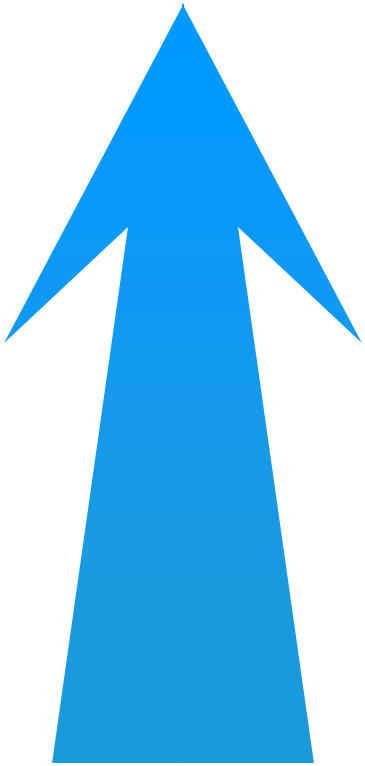
car is related to an owner
A truck is related to an owner
A truck also has a trailer

Generalization of Classes

- Generalization provides the capability to create superclasses that encapsulate structure and/or behavior common to several subclasses
- Generalization procedure
  - Identifying similarity of structure/behavior among several classes
  - Creating a superclass to encapsulate the common structure/behavior
  - The original classes are subclassed off of the new superclass
- Superclasses are more abstract than their subclasses

Example of Generalization



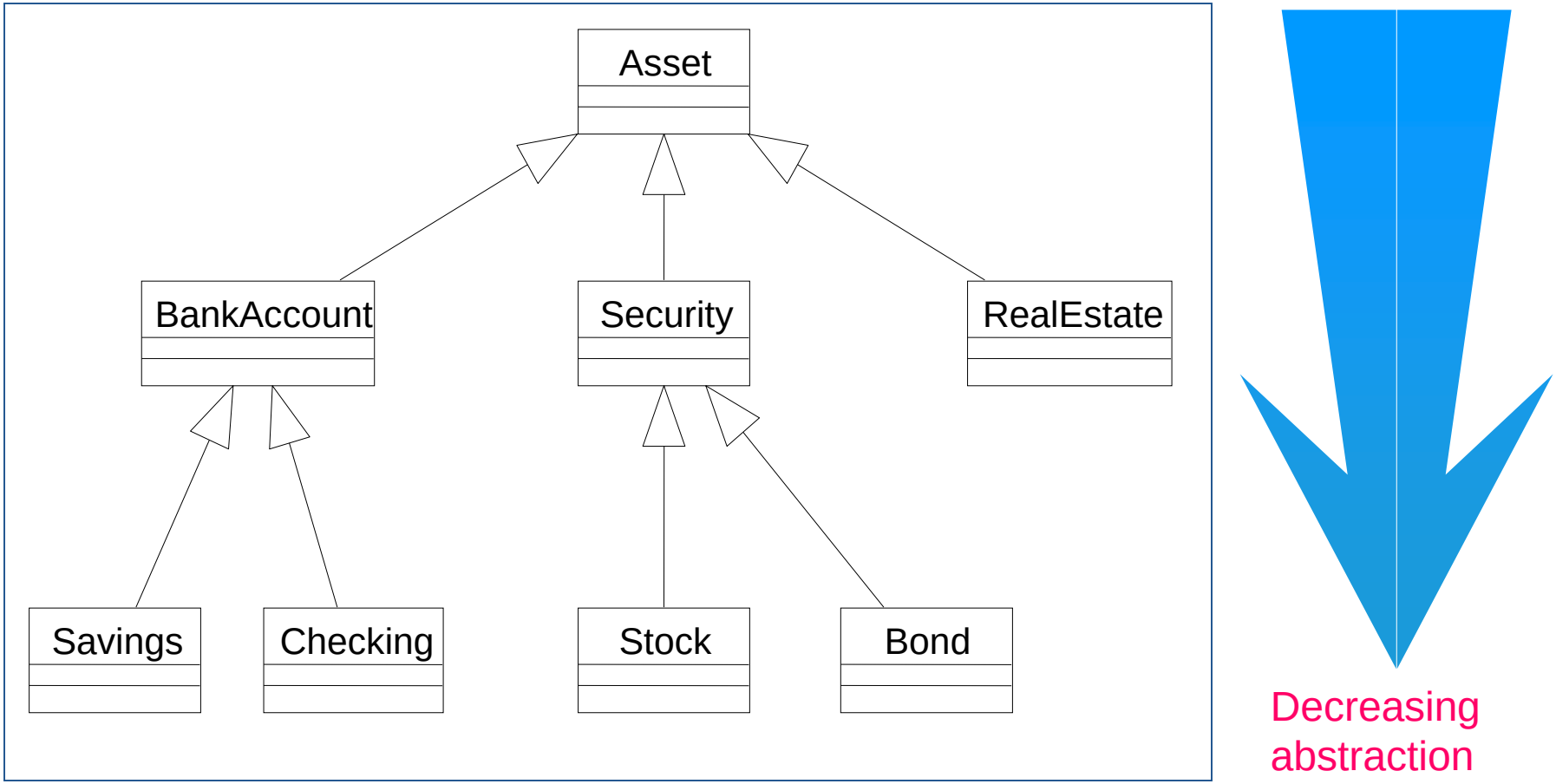


Increasing abstraction

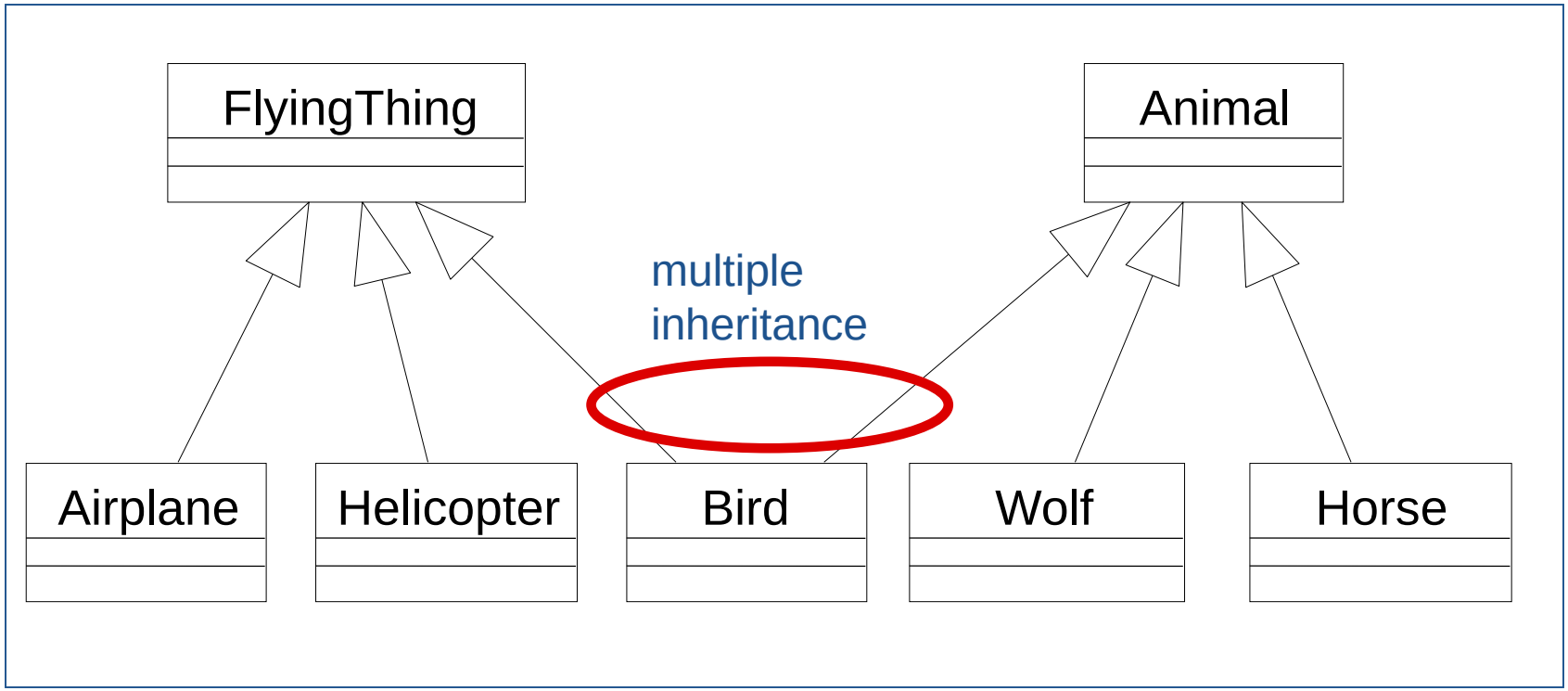
Specialization of Classes

- Specialization provides the capability to create subclasses that represent refinements in which structure and/or behavior from the superclass are added or modified
- Specialization procedure
  - Noticing that some instances exhibit specialized structure or behavior
  - Creating subclasses to group instances according to their specialization
- Subclasses are less abstract than their superclasses

Example of Specialization



Multiple Inheritance



Bird inherits from both FlyingThing and Animal

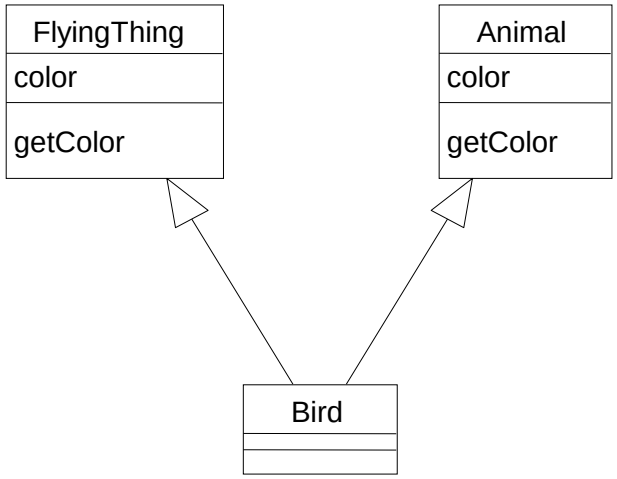
Multiple Inheritance Concepts

- Conceptually straightforward and necessary for modeling the real world accurately
- In practice, may lead to difficulties in implementation
  - Not all object-oriented programming languages support multiple inheritance directly

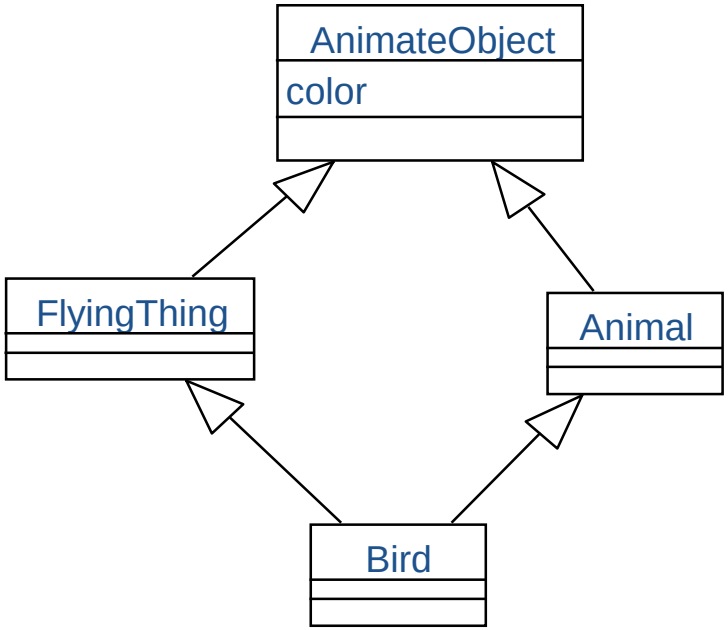
Use multiple inheritance only when needed, and
always with caution !

Multiple Inheritance: Problems

Name clashes on attributes or operations



Repeated inheritance



Each programming language/environment chooses ways to resolve these difficulties

Finding Inheritance

- It is important to evaluate all classes for possible inheritance
  - Look for common behavior (operations) and state (attributes) in classes
- Addition technique
  - Add new operations/attributes to the subclass(es)
- Modification technique
  - Redefine operations
    - Must be careful not to change the semantics

Inheritance vs. Aggregation

- Inheritance and aggregation are often confused
  - Inheritance represents an “is-a” or “kind-of” relationship
  - Aggregation represents a “part-of” relationship

The keywords “is a” and “part of” will help determine the correct relationship

Inheritance vs. Aggregation

Inheritance	Aggregation
Keywords “is a”	Keywords “has a”
One object	Relates objects in different classes
Represented by an arrow	Represented by a diamond

II. Analysis activities

1. Identifying Objects
2. Mapping Usecase to Objects (with Sequence diagrams)
3. Identifying Class relationship
4. **Identifying Attributes**
5. Modeling State-dependent Behavior of Objects

4. Identifying Attributes

- **Attributes are properties of individual objects.**
- **Atribute has:**
  - Name
  - type