Advanced Software Engineering
(CS6401)

Autumn Semester (2022-2023)

Dr. Judhistir Mahapatro
Department of Computer Science and Engineering
National Institute of Technology Rourkela

Object-Oriented Software Design

Organization of this Lecture

- Introduction to object-oriented concepts
- Object modelling using Unified Modelling Language (UML)
- Object-oriented software development and patterns
- Summary

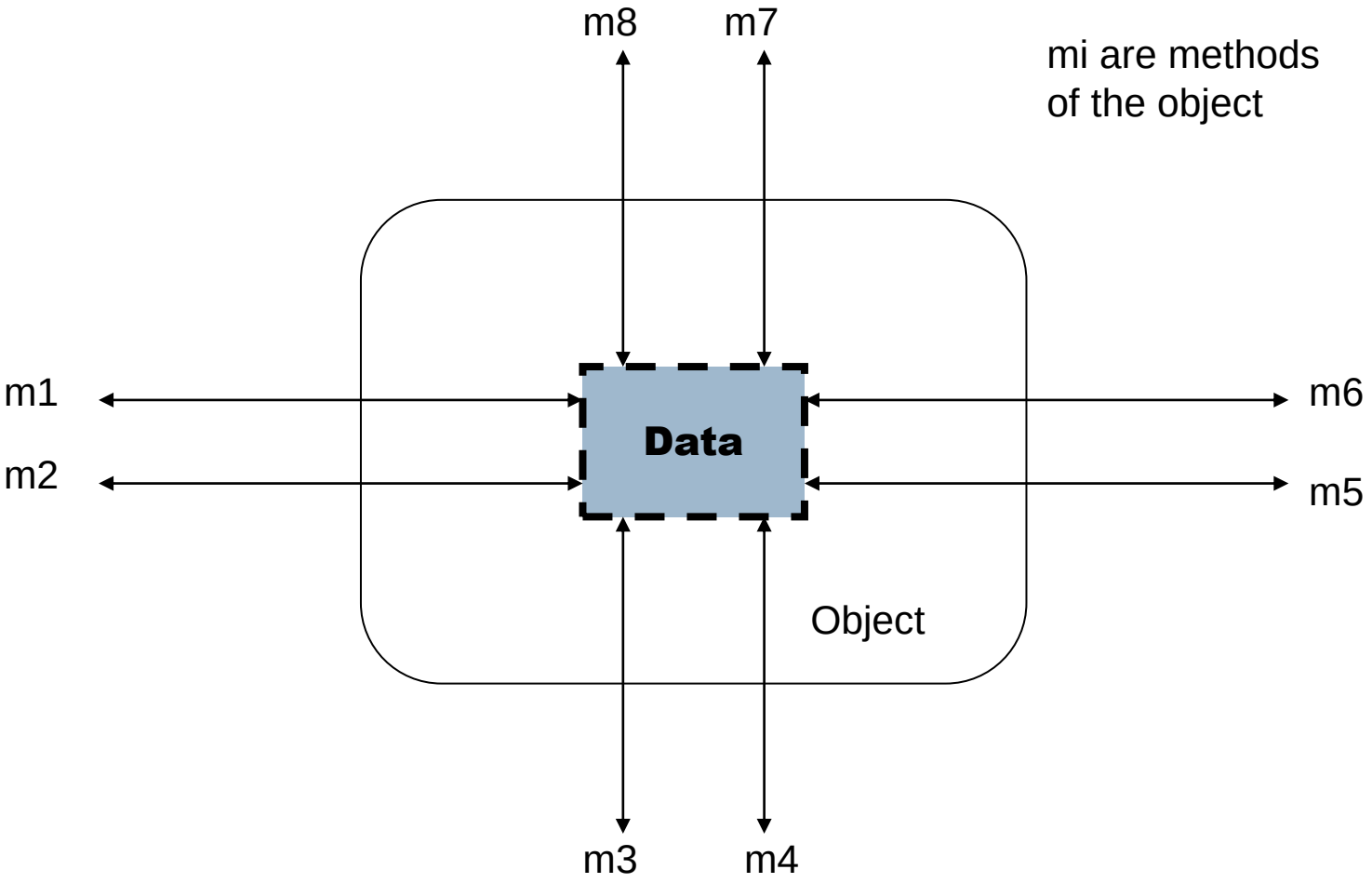
Object-oriented Concepts

- Object-oriented (OO) design techniques are becoming popular:
  - Inception in early 1980's and nearing maturity.
  - Widespread acceptance in industry and academics
  - Unified Modelling Language (UML) poised to become a standard for modelling OO systems

Object-oriented Concepts

- Basic Mechanisms:
  - Objects:
    - A real-world entity.
    - A system is designed as a set of interacting objects.
    - Consists of data (attributes) and functions (methods) that operate on data
    - Hides organization of internal information (Data abstraction)
    - Examples: an employee, a book etc.

Object-oriented Concepts



Model of an object

Object-oriented Concepts

- Class:
  - Instances are objects
  - Template for object creation
  - Sometimes not intended to produce instances (abstract classes)
  - Considered as abstract data type (ADT)
  - Examples: set of all employees, different types of book

Object-oriented Concepts

- Methods and message:
  - Operations supported by an object
  - Means for manipulating the data of other objects
  - Invoked by sending message
  - Examples: calculate_salary, issue-book, member_details, etc.

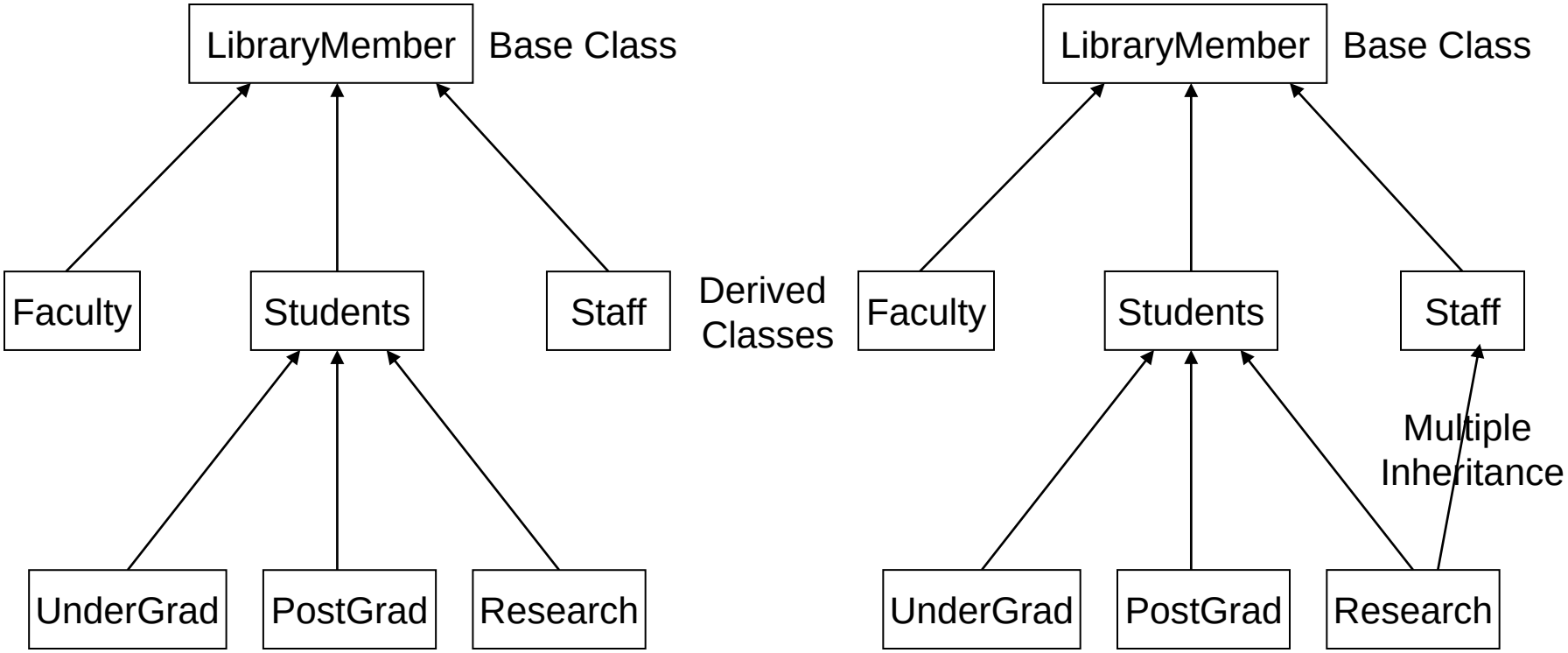
Object-oriented Concepts

- Inheritance:
  - Allows to define a new class (derived class) by extending or modifying existing class (base class)
  - Represents Generalization-specialization relationship
  - Allows redefinition of the existing methods (method overriding)

Object-oriented Concepts

- Multiple Inheritance:
  - Subclass can inherit attributes and methods from more than one base class
  - Multiple inheritance is represented by arrows drawn from the subclass to each of the base classes

Object-oriented Concepts



Object-oriented Concepts

- Key Concepts:
  - Abstraction:
    - Consider aspects relevant for certain purpose
    - Suppress non-relevant aspects
    - Supported at two levels i.e. class level where base class is an abstraction & object level where object is a data abstraction entity

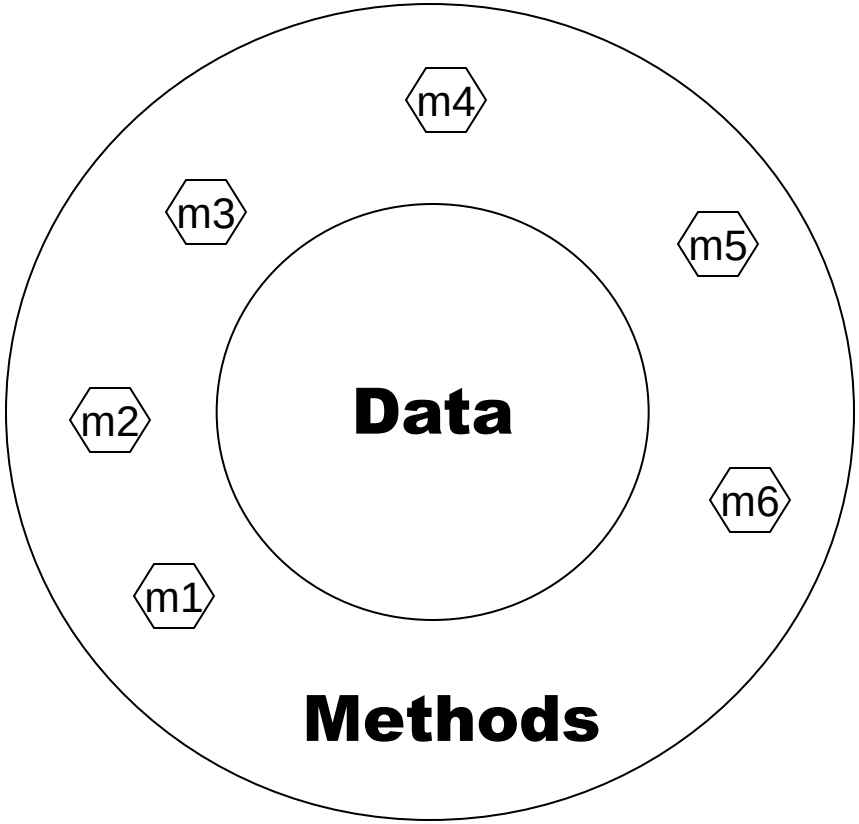
Object-oriented Concepts

- Advantages of abstraction:
  - Reduces complexity of software
  - Increases software productivity
- It is shown that software productivity is inversely proportional to software complexity

Object-oriented Concepts

- Encapsulation:
  - Objects communicate outside world through messages
  - Objects data encapsulated within its methods

Object-oriented Concepts



Concept of encapsulation

Object-oriented Concepts

- Polymorphism:
  - Denotes to poly (many) morphism (forms)
  - Same message result in different actions by different objects (static binding)

Object-oriented Concepts

- Example of static binding:

```
Class Circle{
    private float x, y, radius;
    private int fillType;

    public create ();
    public create (float x, float y, float centre);
    public create (float x, float y, float centre, int fillType);
        }
```

Object-oriented Concepts

- In this example:
  - A class named Circle has three definitions for create operation
  - Without any parameter, default
  - Centre and radius as parameter

Object-oriented Concepts

- In this example:
  - Centre, radius and filltype as parameter
  - Depending upon parameters given, method will be invoked
  - Method create is overloaded

Object-oriented Concepts

- Dynamic binding:
  - In inheritance hierarchy, an object can be assigned to another object of its ancestor class
  - A method call to an ancestor object would result in the invocation of appropriate method of object of the derived class

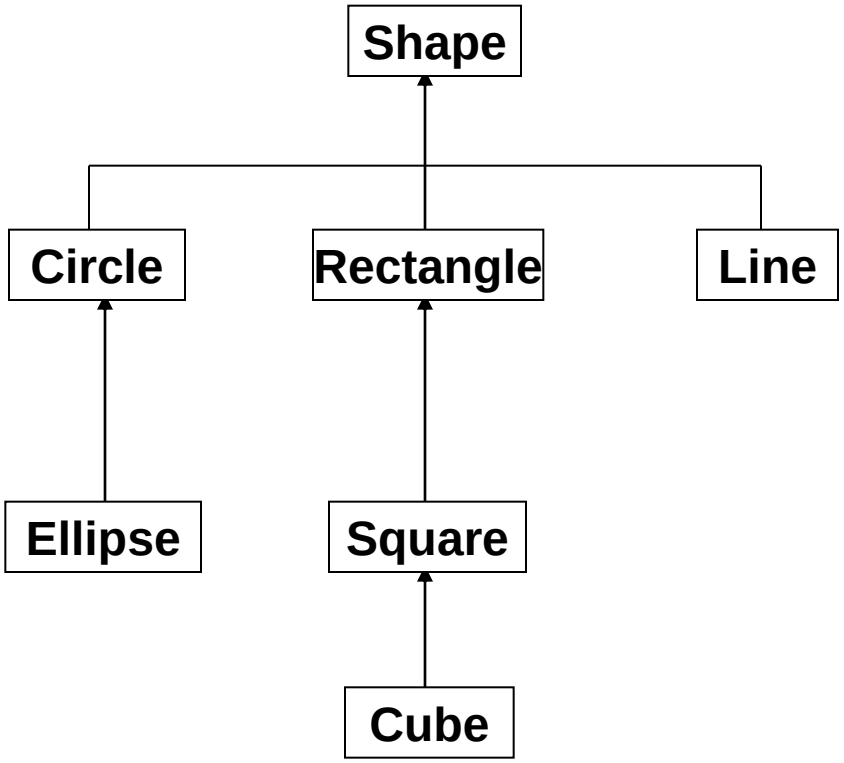
Object-oriented Concepts

- Dynamic binding:
  - Exact method cannot be known at compile time
  - Dynamically decided at runtime

Object-oriented Concepts

- Example of dynamic binding:
  - Consider class hierarchy of different geometric objects
  - Now display method is declared in the shape class and overridden in each derived class
  - A single call to the display method for each object would take care displaying appropriate element

Object-oriented Concepts



Class hierarchy of geometric objects

Object-oriented Concepts

Traditional code

```
If (shape == Circle) then
        draw_circle();
else if (shape == Rectangle) then
        draw_rectangle();

            -
            -
            -
            -
```

Object-oriented code

```
Shape.draw();

            -
            -
            -
            -
```

Traditional code and OO code using dynamic binding

Object-oriented Concepts

- Advantages of dynamic binding:
  - Leads to elegant programming
  - Facilitates code reuse and maintenance
  - New objects can be added with minimal changes to existing objects

Object-oriented Concepts

- **Composite objects:**
  - Object containing other objects
  - Composition limited to tree hierarchy i.e. no circular inclusion relation
  - Inheritance hierarchy different from containment hierarchy

Object-oriented Concepts

- **Composite objects:**
  - Inheritance hierarchy, different object types with similar features
  - Containment allows construction of complex objects

Object-oriented Concepts

- **Genericity:**
  - Ability to parameterize class definitions
  - Example: class stack of different types of elements such as integer, character and floating point stack
  - Generacity permits to define generic class stack and later instantiate as required

Advantages of Object-oriented design

- Code and design reuse
- Increased productivity
- Ease of testing & maintenance
- Better understandability
- Its agreed that increased productivity is chief advantage

Advantages of Object-oriented design

- Initially incur higher costs, but after completion of some projects reduction in cost become possible
- Well-established OO methodology and environment can be managed with 20-50% of traditional cost of development

Object modelling using UML

- UML is a modelling language
- Not a system design or development methodology
- Used to document object-oriented analysis and design
- Independent of any specific design methodology

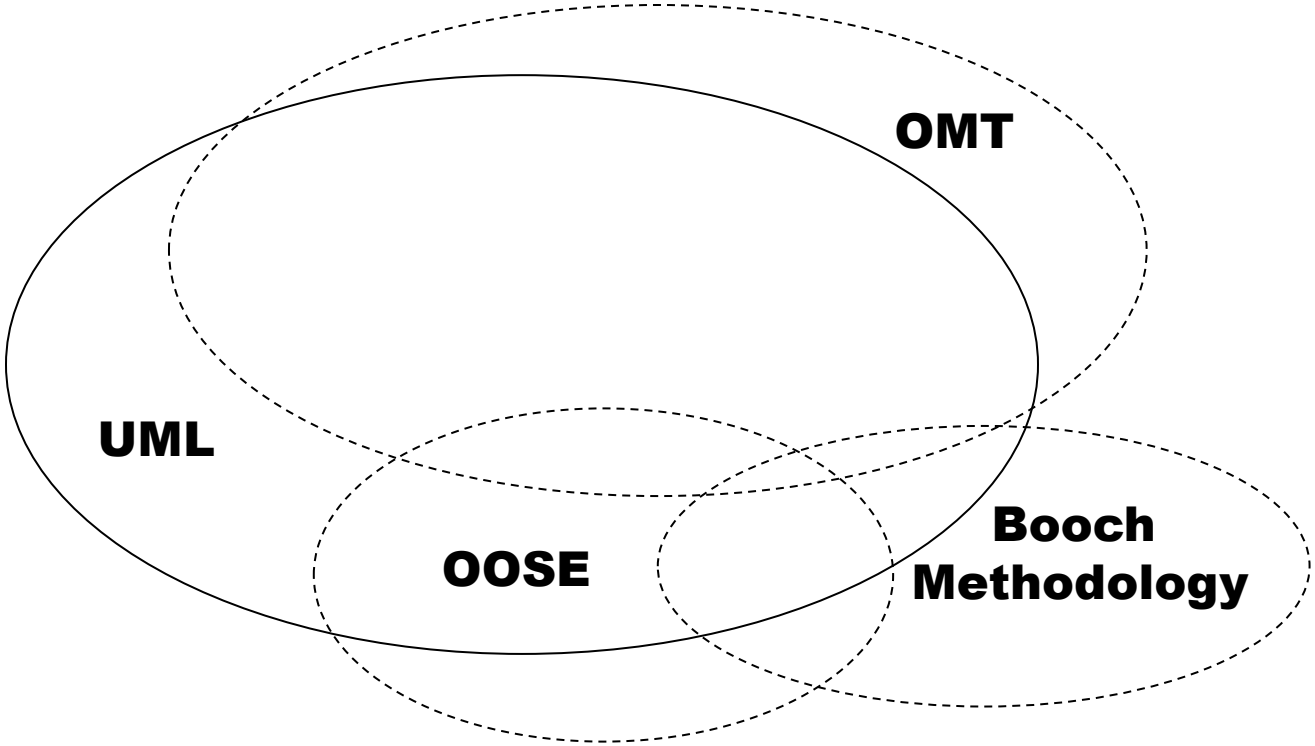
Unified Modelling Language (UML)

- Origin
  - In late 1980s and early 1990s different software development houses were using different notations
  - Developed in early 1990s to standardize the large number of object-oriented modelling notations

UML

- Based Principally on
  - OMT [Rumbaugh 1991]
  - Booch's methodology[Booch 1991]
  - OOSE [Jacobson 1992]
  - Odell's methodology[Odell 1992]
  - Shlaer and Mellor [Shlaer 1992]

UML



Different object modelling techniques in UML

UML

- As a Standard
  - Adopted by Object Management Group (OMG) in 1997
  - OMG an association of industries
  - Promote consensus notations and techniques
  - Used outside software development, example car manufacturing

Why UML is required?

- Model is required to capture only important aspects
- UML a graphical modelling tool, easy to understand and construct
- Helps in managing complexity

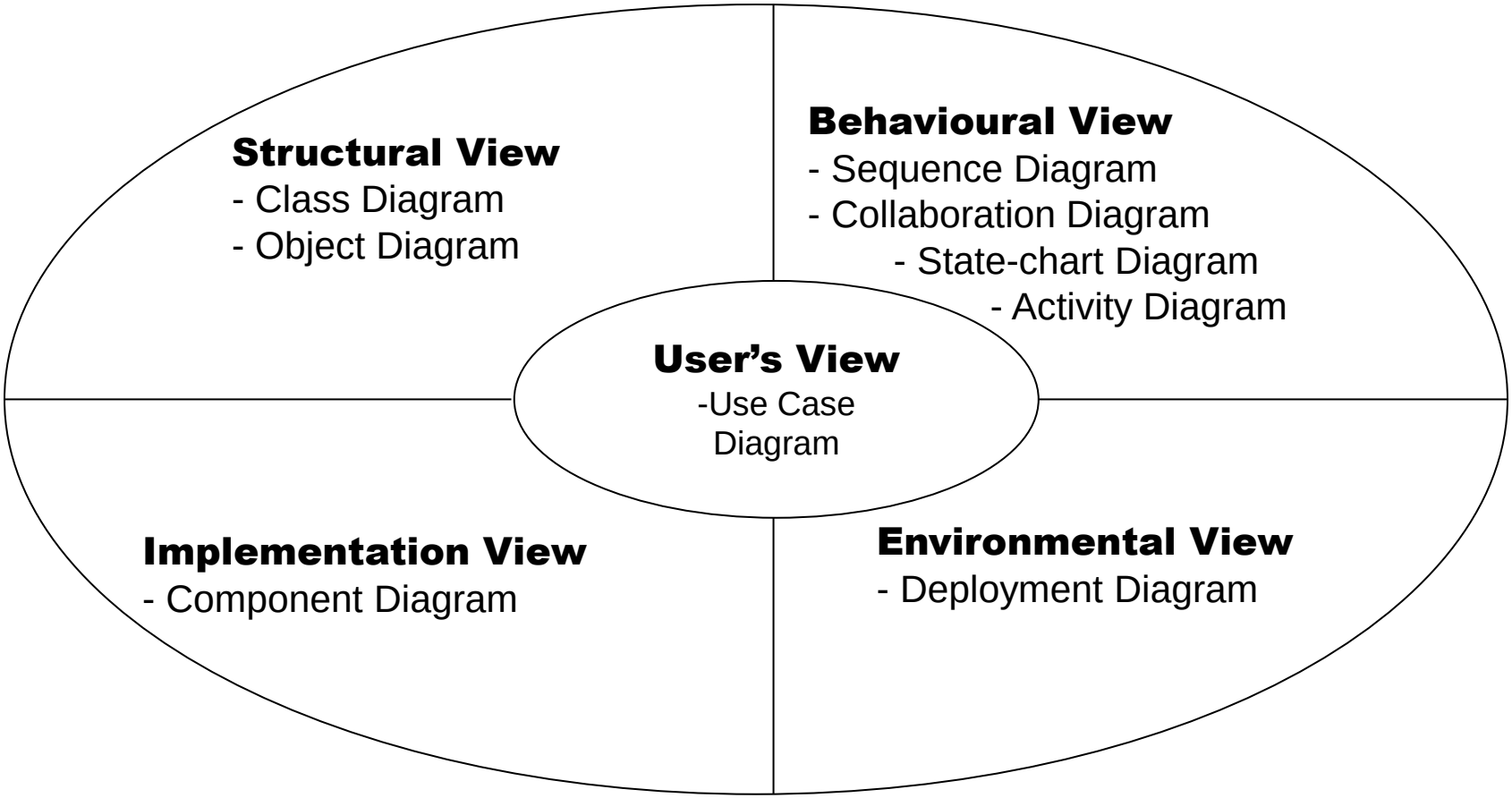
UML diagrams

- Nine diagrams to capture different views of a system
- Provide different perspectives of the software system
- Diagrams can be refined to get the actual implementation of the system

UML diagrams

- Views of a system
  - User’s view
  - Structural view
  - Behavioral view
  - Implementation view
  - Environmental view

UML diagrams



Diagrams and views in UML

UML diagrams

- User’s view
  - It captures the view of the system in terms of the functionalities offered by the system to its user
  - It is a black-box view of the system
  - Dynamic behavior of the components, the implementation etc are not captured.

UML diagrams

- Structural view
  - Defines the structure of the problem (or the solution) in terms of the objects (or classes) important to the understanding of the working of a system and its implementation.
  - It captures the relationship among the classes (or objects)
  - Called the static model, since the structure of a system does not change with time.

UML diagrams

- Behavioural view
  - Captures how objects interact with each other in time to realize the system behavior.
  - System behavior captures the time-dependent (dynamic) behavior.
  - It constitutes the dynamic model of the system

UML diagrams

- Implementation view
  - Captures important components of the system and their interdependencies.
  - Example, implementation view might show the GUI part, the middleware, and the database parts and would capture their interdependencies.

UML diagrams

- Environmental view
  - This view models how the different components are implemented on different pieces of hardware.

Are all views required?

- NO
- Use case model, class diagram and one of the interaction diagram for a simple system
- State chart diagram in case of many state changes
- Deployment diagram in case of large number of hardware components

Use Case model

- Consists of set of “use cases”
- An important analysis and design artifact
- Other models must confirm to this model
- Not really an object-oriented model
- Represents a functional or process model

Use Cases

- Different ways in which system can be used by the users
- Corresponds to the high-level requirements
- Represents transaction between the user and the system
- Define behavior without revealing internal structure of system
- Set of related scenarios tied together by a common goal

Use Cases

- Normally, use cases are independent of each other
- Implicit dependencies may exist
- Example: In Library Automation System, renew-book & reserve-book are independent use cases. But in actual implementation of renew-book, a check is made to see if any book has been reserved using reserve-book

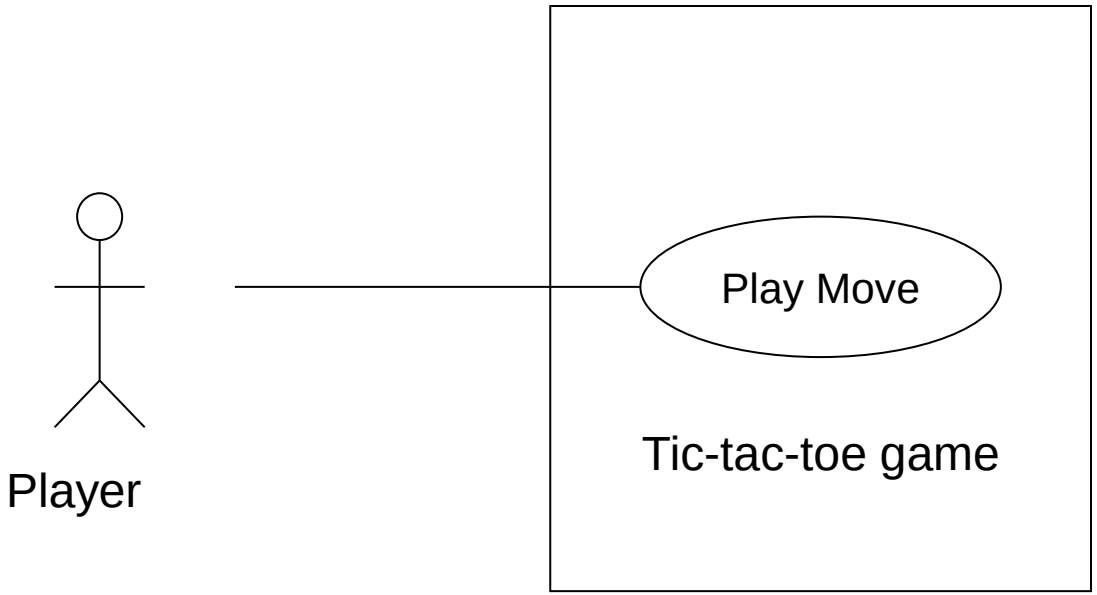
Example of Use Cases

- For library information system
  - issue-book
  - Query-book
  - Return-book
  - Create-member
  - Add-book, etc.

Representation of Use Cases

- Represented by use case diagram
- Use case is represented by ellipse
- System boundary is represented by rectangle
- Users are represented by stick person icon (actor)
- Communication relationship between actor and use case by line
- External system by stereotype

Example of Use Cases



Use case model

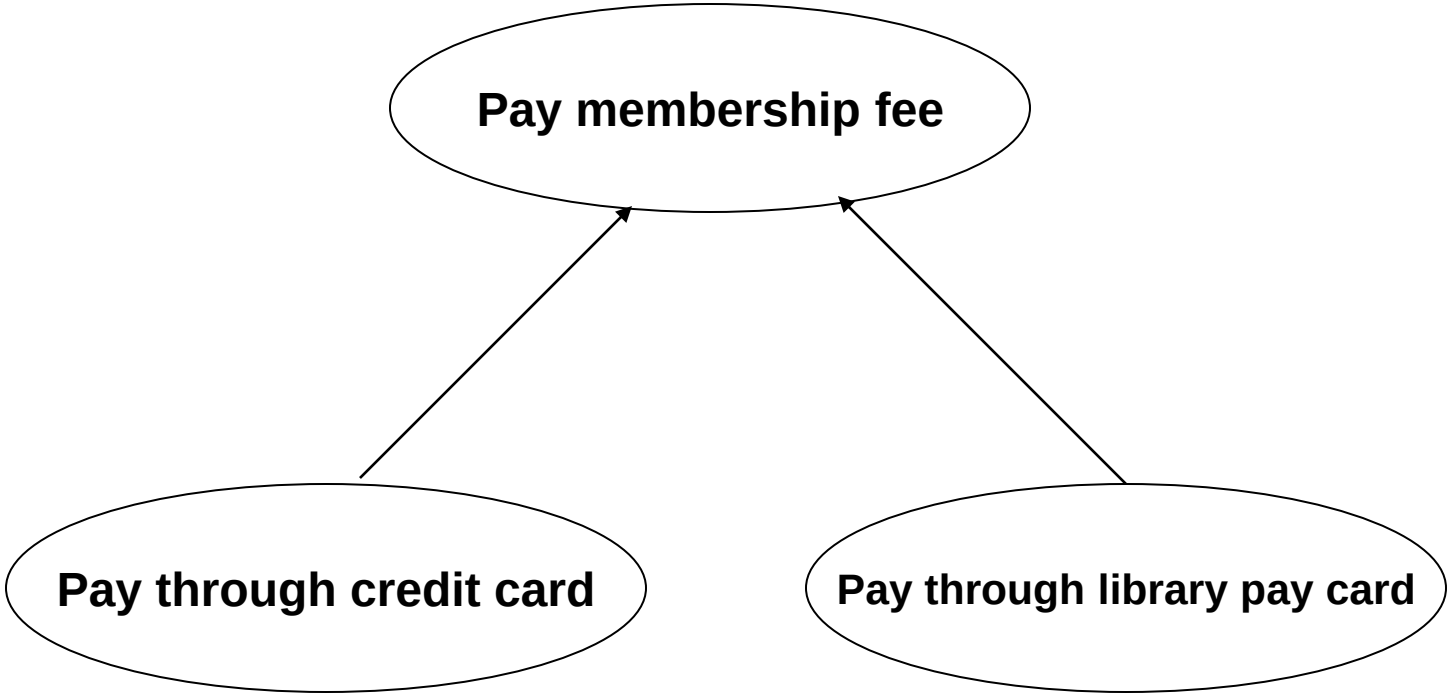
Why develop Use Case diagram?

- Serves as requirements specification
- Users identification helps in implementing security mechanism through login system
- Another use in preparing the documents (e.g. user's manual)

Factoring Use Cases

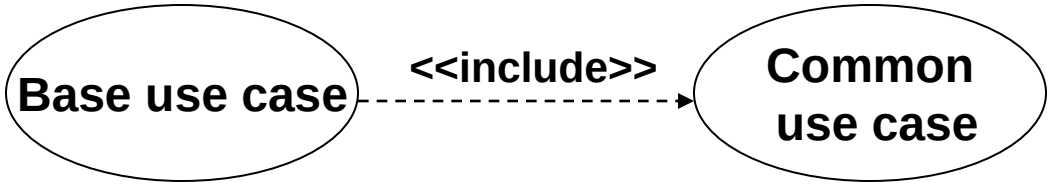
- Complex use cases need to be factored into simpler use cases
- Represent common behavior across different use cases
- Three ways of factoring
  - Generalization
  - Includes
  - Extends

Factoring Using Generalization

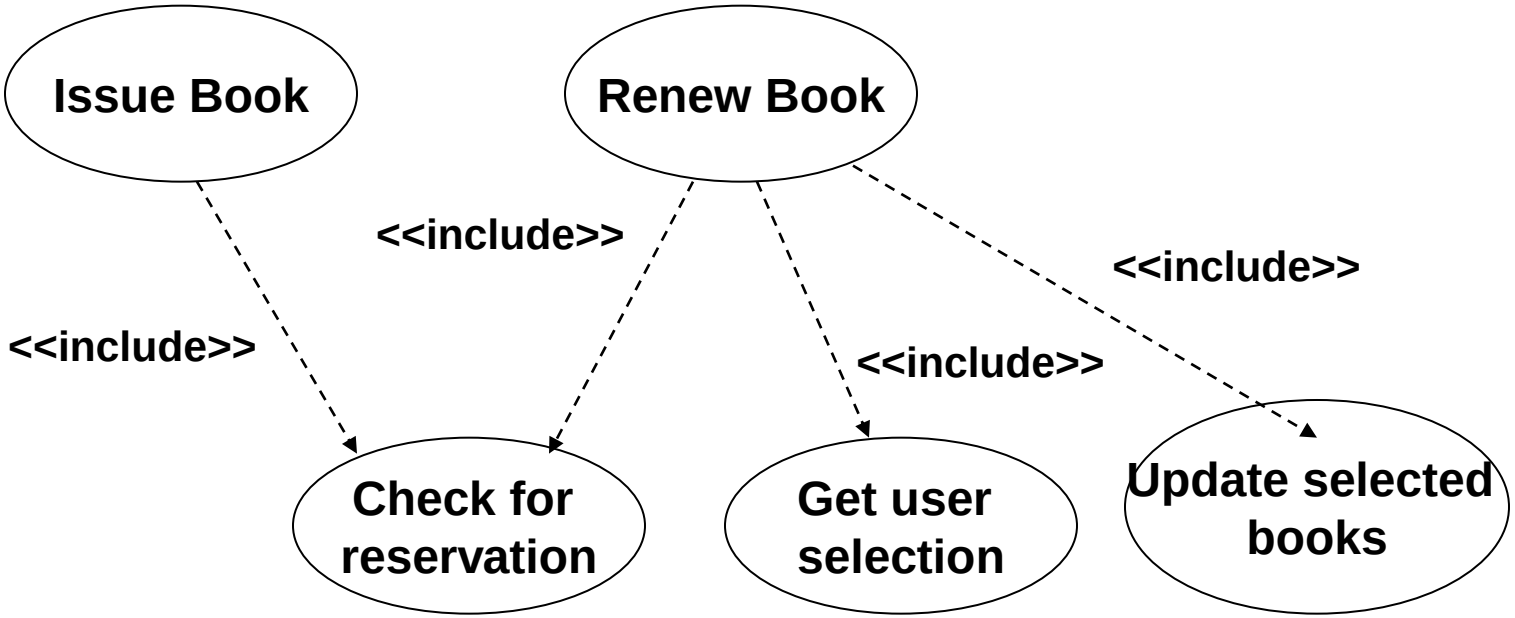


Use case generalization

Factoring Using Includes



Use case inclusion

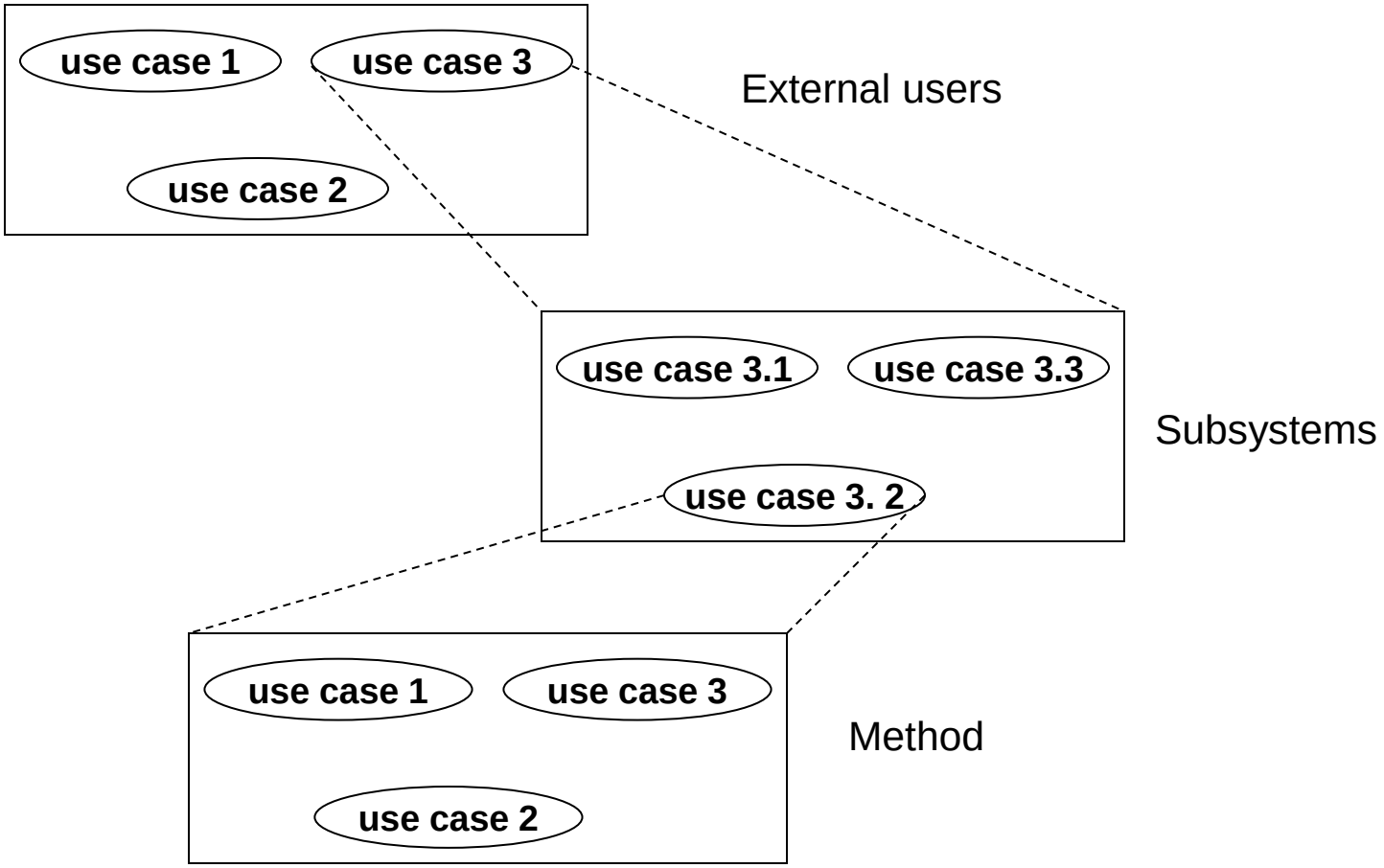


example

Factoring Using Extends

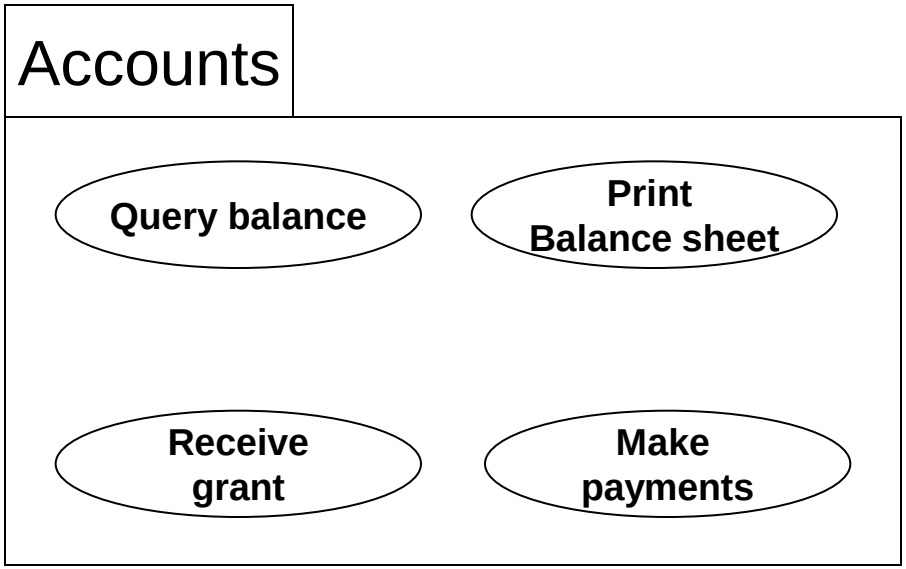
Use case extension

Hierarchical Organization of Use Cases



Hierarchical organization of use cases

Use Case Packaging



Use case packaging