Object Technology

Y. Narahari

Computer Science and Automation

Indian Institute of Science

Bangalore - 560 012

OUTLINE

1 Object Technology: History and Applications

2 OOA, OOD, and OOP

3 Classes and Objects

4 Object Model Characteristics

5 Benefits of OO-Approach

OBJECT TECHNOLOGY

- A sound paradigm to economically produce enduring and resilient industrial-strength software systems
- Representative Applications
  - Missile Control Software
  - ERP packages for industrial plants
  - Traffic control systems: Airlines, railways
  - Telecommunications
  - Industrial Process Control
  - Simulation
  - Database-intensive applications such as banking, transportation, service sectors
  - Office automation and workflow management systems
  - Health-care systems

Analysis and Design

- **Analysis**:
  - A disciplined process for generating a set of faithful models for a problem, without consideration of a technical solution
  - Examine the **What** of a problem
- **Design**:
  - A disciplined process that will describe how an analysis model may be implemented within a technical environment
  - A design model addresses the **how** of a problem and provides enough detail so that the system can be implemented in a programming language

Analysis and Design Methods

- **Method**:
  - A disciplined process for generating a set of models to describe a software system using a well-defined notation
- **Methodology**:
  - A collection of methods applied across the software development life-cycle and unified by a distinctive approach
- **Major Methods**:
  - Top-Down Structured Design (based on algorithmic decomposition)
  - Data-Driven Design (based on input-output relationships)
  - OO-Design (based on objects)

OO-Technology: History

- 1960s - Abstraction ideas - Dijkstra
- 1967 - Simula 67
- 1970s - Parnas (information hiding); Liskov and Guttag (abstract data types); Hoare (monitors); Chen (ER approach); Minsky (theory of frames)
- 1972 - Smalltalk; later versions in 74, 76, 80
- 1980s - Object Pascal, Ada, Eiffel, Objective C, CLOS, C++
- Early 1990s - Booch, Rumbaugh, Jacobson developed their distinctive methodologies; CASE tools
- Mid 1990s - UML, design patterns, OO-frameworks, distributed objects, unified process, components, etc.

OOA, OOD, and OOP

- **Object Oriented Programming**

  A method of implementation in which programs are organized as cooperative collections of objects (instances of classes), and whose classes are all members of a hierarchy of classes united via inheritance relationships.

- **Object Oriented Design**

  A method of design encompassing the process of object-oriented decomposition and a notation for depicting logical and physical as well as static and dynamic models of the system

- **Object Oriented Analysis**

  A method of analysis that examines requirements from the perspective of classes and objects

OOA, OOD, and OOP

- **OOA** provides a set of models from which one can carry out **OOD**
- **OOD** gives blueprints for implementing a system using **OOP** methods
- **OOP** leads to development of OO programs that implement the software system

CLASSES AND OBJECTS

- An object represents an individual, identifiable item, unit, or entity, either real or abstract, with a well-defined role in the problem domain
  - An object has **state, behavior, identity**
- The structure and behavior of similar objects are defined in their **class**.
  - A class is the same as an **Abstract Data Type**
  - An object is an instance of a class.
- Examples of Objects:
  - **Banking System**: Bank, Customer, Account, SB Account, FD Account, Manager, Employee, Transaction, Cash
  - **Simulation**: Resource, computer, disk, channel, random number, scheduling policy, job, etc.

ABSTRACT DATA TYPE

- An ADT is a set of well-defined elements, together with a collection of well-defined operations
  - Operands and results are not only instances of the ADT but could be other types of operands or instances of other ADTs
  - At least one of the operands or the result is of the ADT type in question
- An ADT Implementation is a translation into statements of a programming language:
  - the declarations that define the ADT elements (attributes) and the ADT operations (method)
  - An ADT implementation chooses a *Data Structure* to represent the ADT

Example: List ADT

- A list is a collection of elements of a particular type with representative operations such as:

  1. insert (x, p, L)
  2. locate (x, L)
  3. retrieve (p, L)
  4. delete (p, L)
  5. next (p, L)
  6. prev (p, L)
  7. makenull (L)
  8. first (L)
  9. printlist (L)

A Program Using List ADT

Problem: To eliminate all duplicates from a list

```
{
 p = first (L);
 while (p != end(L)) {
    q = next (p, L);
    while (q != end(L)) {
      if (same (retrieve (p, L),
           retrieve (q, L)))
          delete (q, L);
      else
          q = next (q, L);
    }
    p = next (p, L);
  }
}
```

Data Structure Independent

Characteristics of an Object Model

- **Major Characteristics**
  - Abstraction
  - Encapsulation
  - Modularity
  - Hierarchy
- **Minor Characteristics**
  - Typing
  - Concurrency
  - Persistence

ABSTRACTION

Essential characteristics of an object that distinguish it from all other objects.

- provides crisply defined conceptual boundaries for an object
- focuses on the outside view of an object
- serves to separate object's essential behavior from its implementation
- is a fundamental way to cope with complexity

Central problem: To decide upon the right set of abstractions for a given domain

ENCAPSULATION

Process of compartmentalizing the elements of an abstraction that constitute its structure and behavior.

- Complementary to abstraction:
  - abstraction focuses on observable behavior
  - encapsulation focuses on the implementation that gives rise to this behavior
- achieved through information hiding which is the process of hiding those aspects of the object behavior that are not relevant to the outside environment
- serves to separate interface of an abstraction and implementation of an abstraction

HIERARCHY

Represents a ranking or ordering of abstractions
Hierarchy can be:

1. **IS A** hierarchy (Inheritance, Generalization, Specialization)

2. **PART OF** hierarchy (Aggregation, composition)

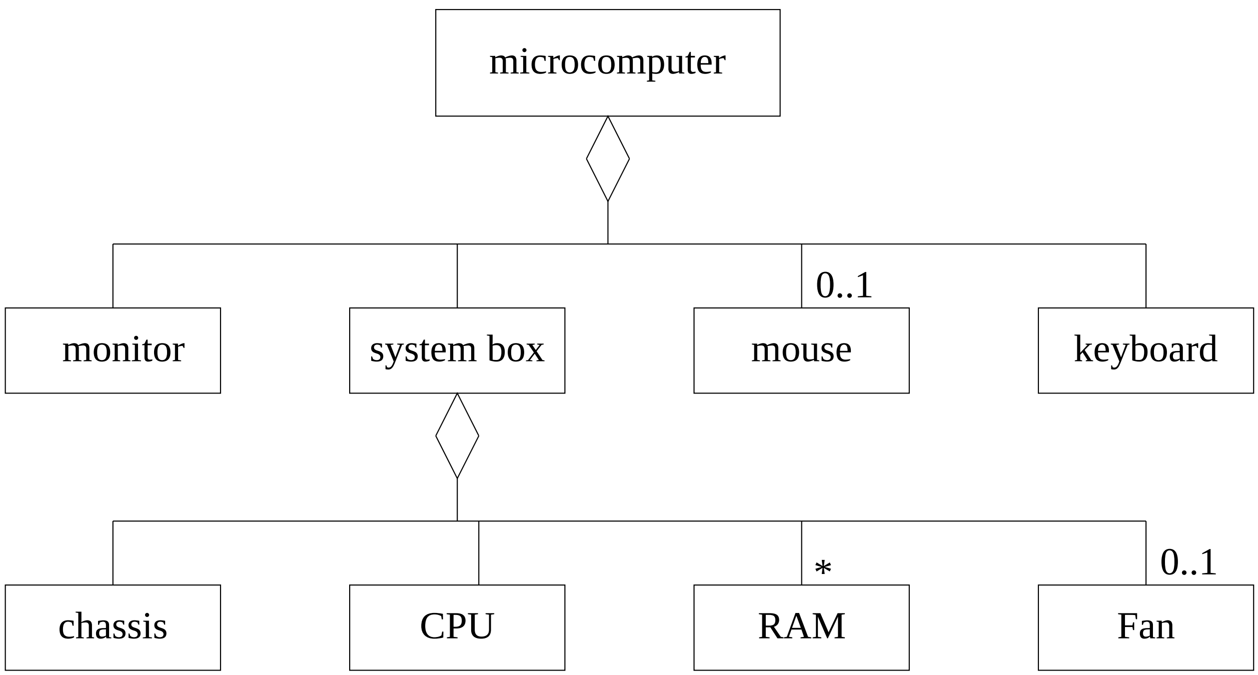
- Enables reuse

- Leads to a more natural model of the problem

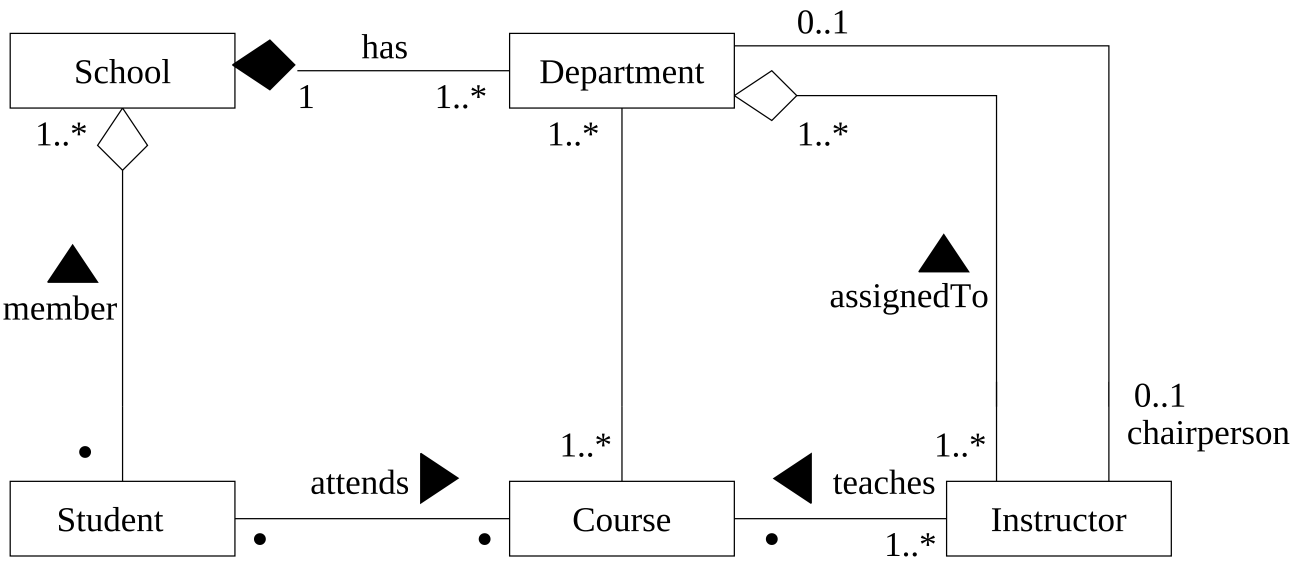
- Inheritance hierarchy enables polymorphism (ability to hide many different implementations behind a single interface)

- Class inheritance versus object composition is a very critical tradeoff in object oriented designs

Aggregation Relationships

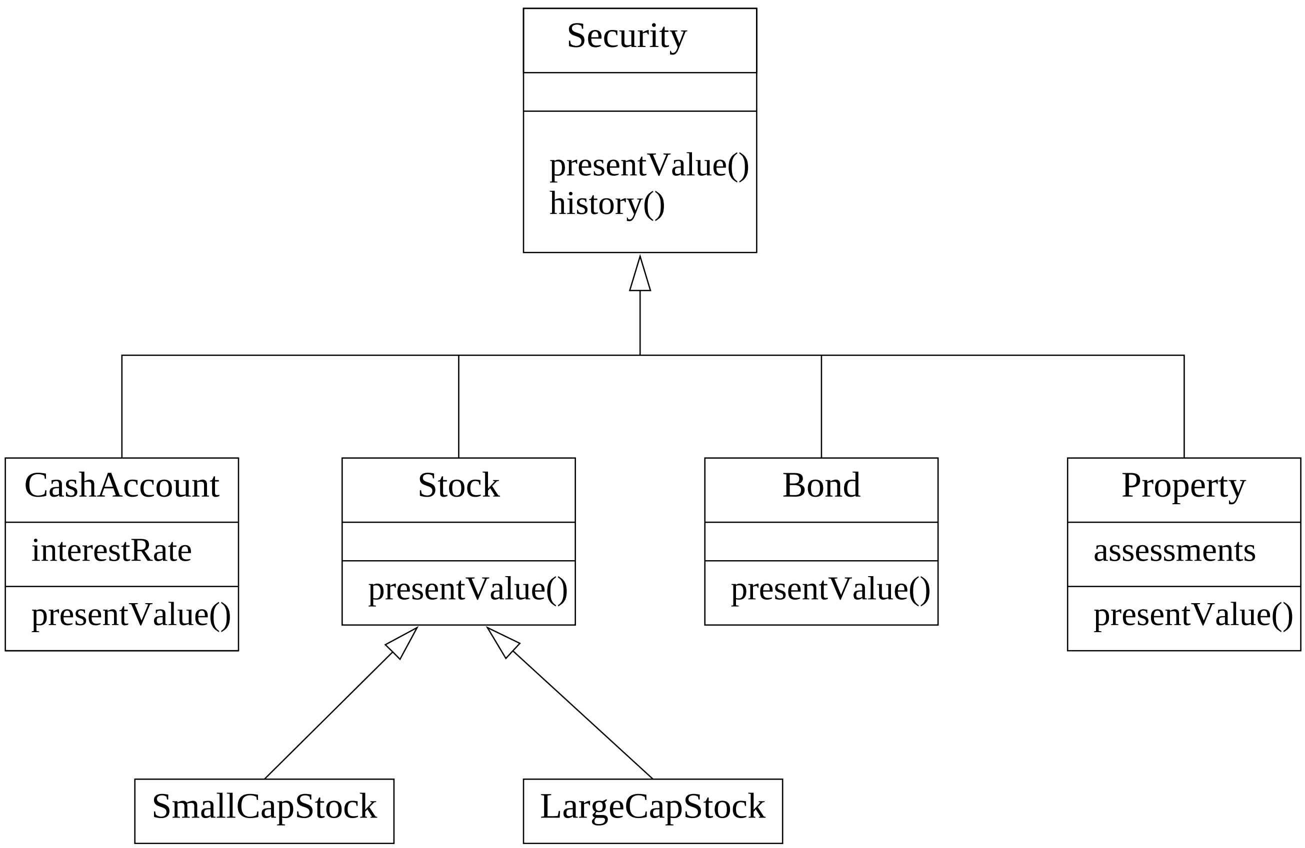


Structural Relationships



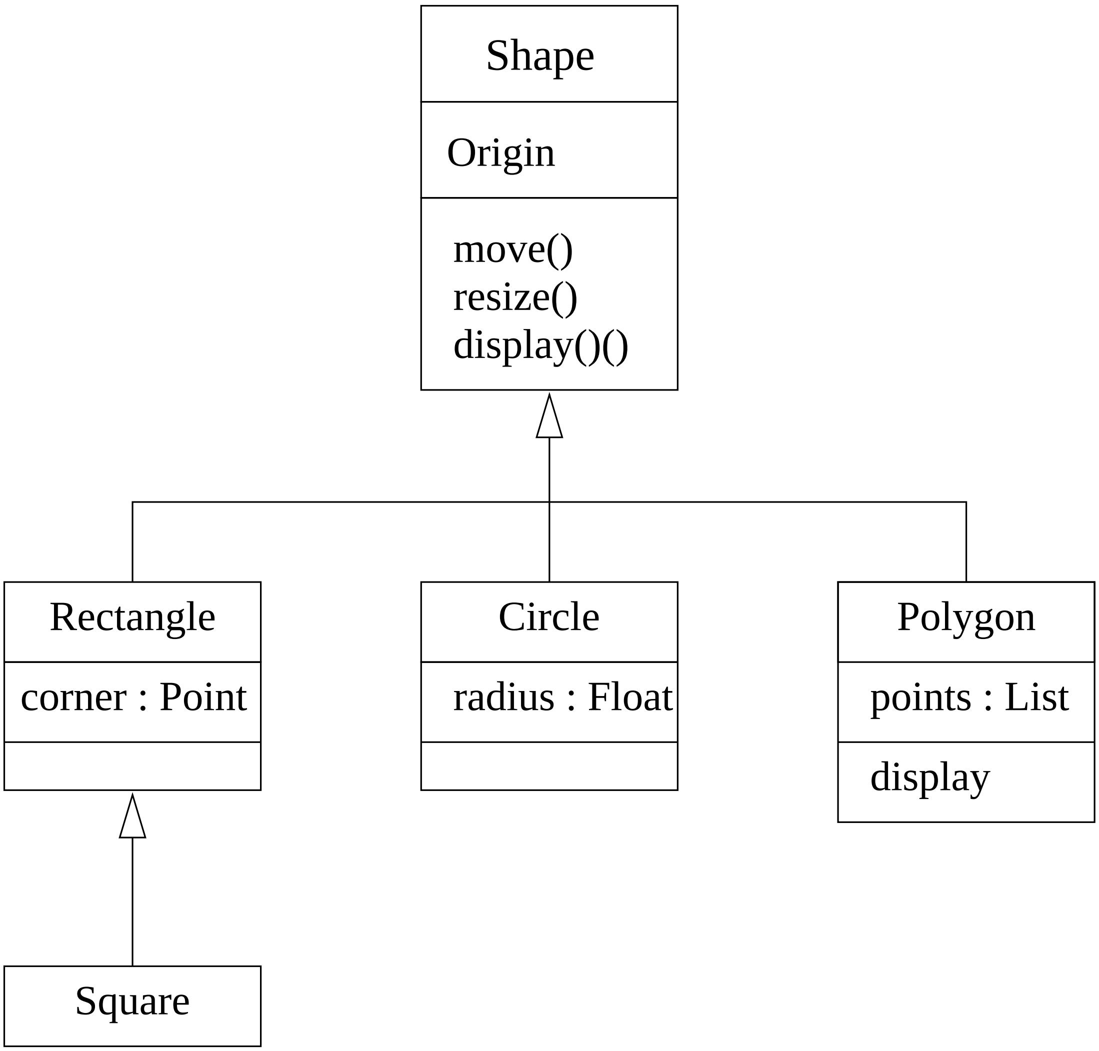
Structural Relationships

Inheritance Relationships



Inheritance Relationships

Generalization



Generalization

BENEFITS OF OO-APPROACH

1. Leads to more comprehensive analysis and better decompositions
2. Modeling based on the real world
   - Easier to understand and maintain
   - More durable and flexible
   - More accurate description of real-world processes
3. More thorough and more scientific large-scale design
   - Modularity and componentization
4. Reusable and extensible software
5. Provides a more natural approach to iterative software development

An ideal approach for large scale industrial strength software development

OOAD AND

PROCESS

Y. Narahari

Computer Science and Automation

Indian Institute of Science

Bangalore - 560 012

OUTLINE

1 Software Processes

2 OOAD Methodologies

3 OMT (Object Modeling Technique)

4 Rational Unified Process

Software Process

- Structured set of activities to transform user's requirements into a robust and scalable software system
- Defines *who* is doing *what, when,* and *how* towards building a software product
- An effective process:
  - provides guidelines for efficient development of quality software
  - reduces risk
  - increases predictability
  - promotes a common vision and culture
- An effective process should be capable of evolving through:
  - technologies
  - tools
  - people
  - organizational patterns

OOAD Methodologies

- OOAD methodologies proliferated during the late 1980's and early 1990's
- Prominent Methodologies:
  - Booch methodology
  - Object Modeling Technique (OMT)
  - Objectory (Object Factory)
  - Fusion Methodology
- Each methodology recommended its own modeling notation

OMT

- Developed by James Rumbaugh and co-workers
- Uses a notation called OMT
- OOAD in OMT has three main phases:
  1. **Analysis**: Develop a precise, concise, accurate, understandable, and correct model of the system
     - Object Modeling
     - Dynamic Modeling
     - Functional Modeling
  2. **System Design**: Create a high-level design or a system architecture
  3. **Object Design**: Implement classes and relationships using data structures and algorithms

Rational Unified Process (RUP)

- UML gives a standard way to visualize, specify, construct, document, and communicate the artifacts of a software-intensive system
- UML has to be used in the context of an end-to-end software process
- RUP is the recommended software process when UML is used as the modeling language
- RUP has evolved over a period of thirty years
  - Ericsson Approach (Late 1960s)
  - Objectory Process (Ivar Jacobson) (1987-1995)
  - Rational Objectory Process 4.1 (1996-1997)
  - Rational Unified Process (1998)

Unified Process: A Cosmic View

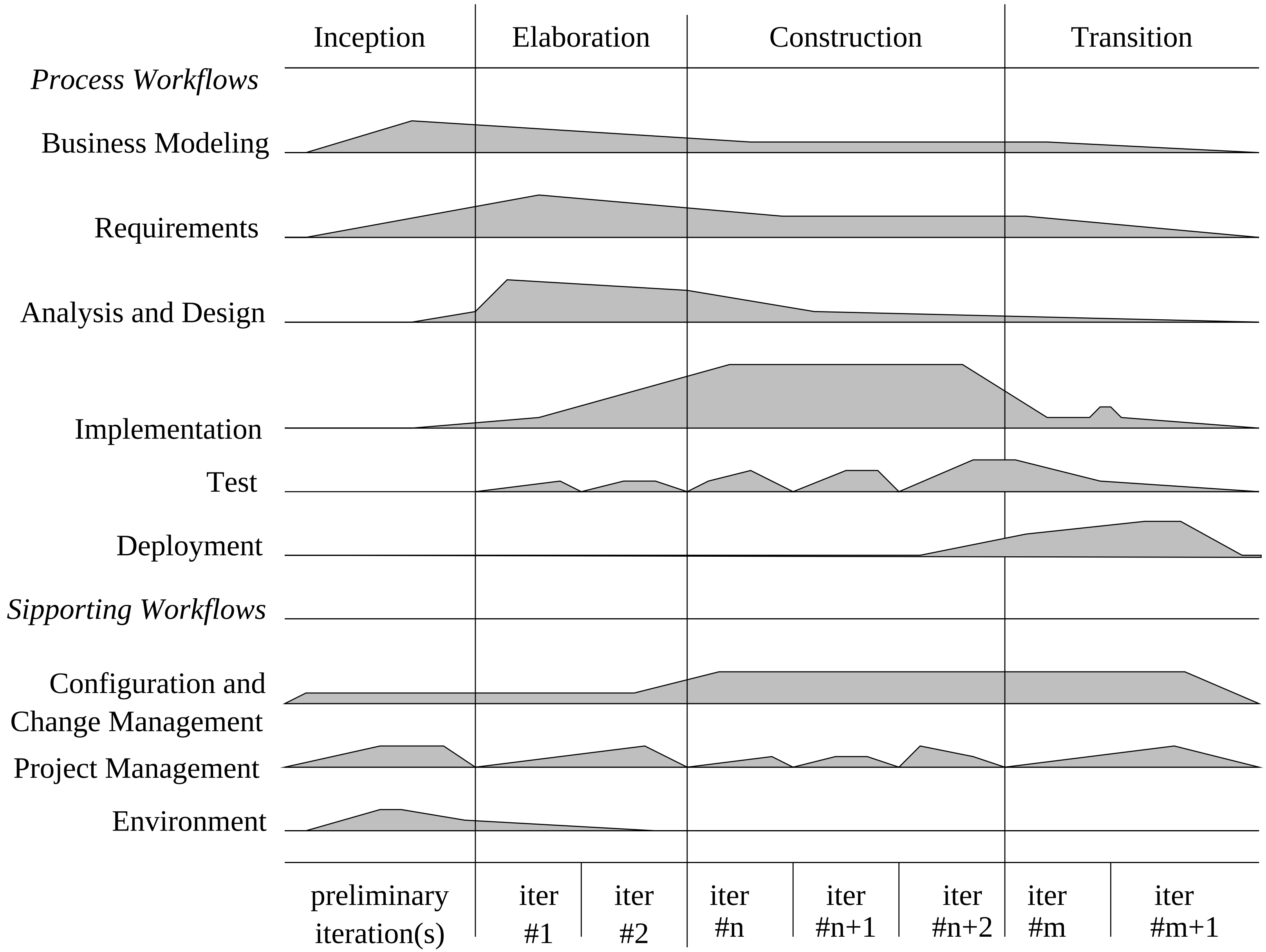
- A generic process framework that can be customized for:
  - a variety of software systems
  - different application areas
  - different types of organizations
  - different project sizes
- Distinctive Aspects:
  - Use-Case Driven
  - Architecture-Centric
  - Iterative and Incremental
  - Component-based
- Four Phase Process:
  - Inception
  - Elaboration
  - Construction
  - Transition

UML is an Integral Part of the Process

Workflows and Phases

- **Core Workflows**
  - Requirements Capture
  - Analysis
  - Design
  - Implementation
  - Test
- Four Phase Process:
  - Inception
  - Elaboration
  - Construction
  - Transition

UML is an Integral Part of the Unified Process

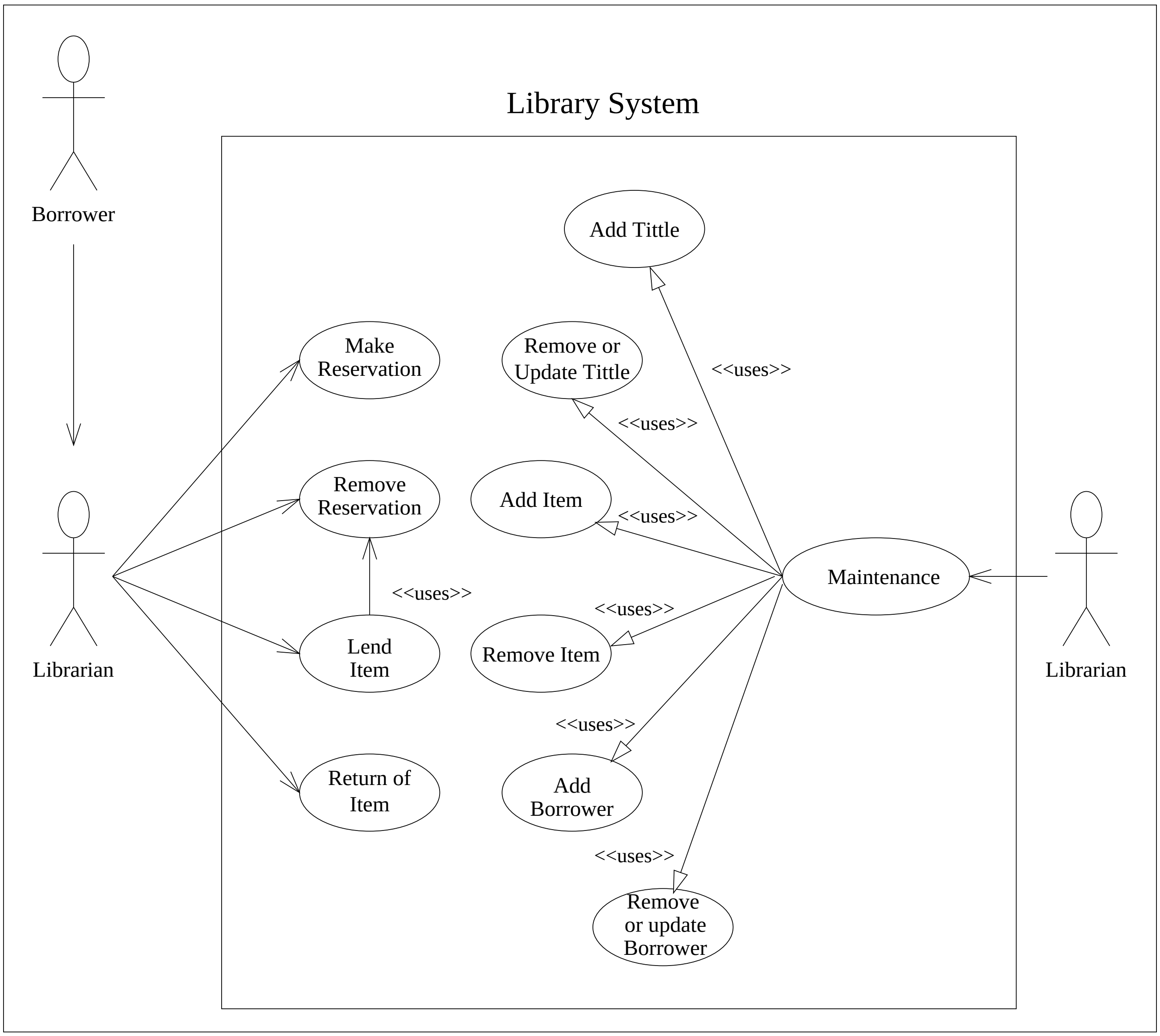


The Software Development Life Cycle

Use Case Driven

- Use Cases:
  - represent interactions between the user and system: *What does the system do for each user?*
  - capture functional requirements
- Developers create a series of analysis, design, and implementation models that realize the use cases
- Use cases drive the development process and bind the different phases of the process

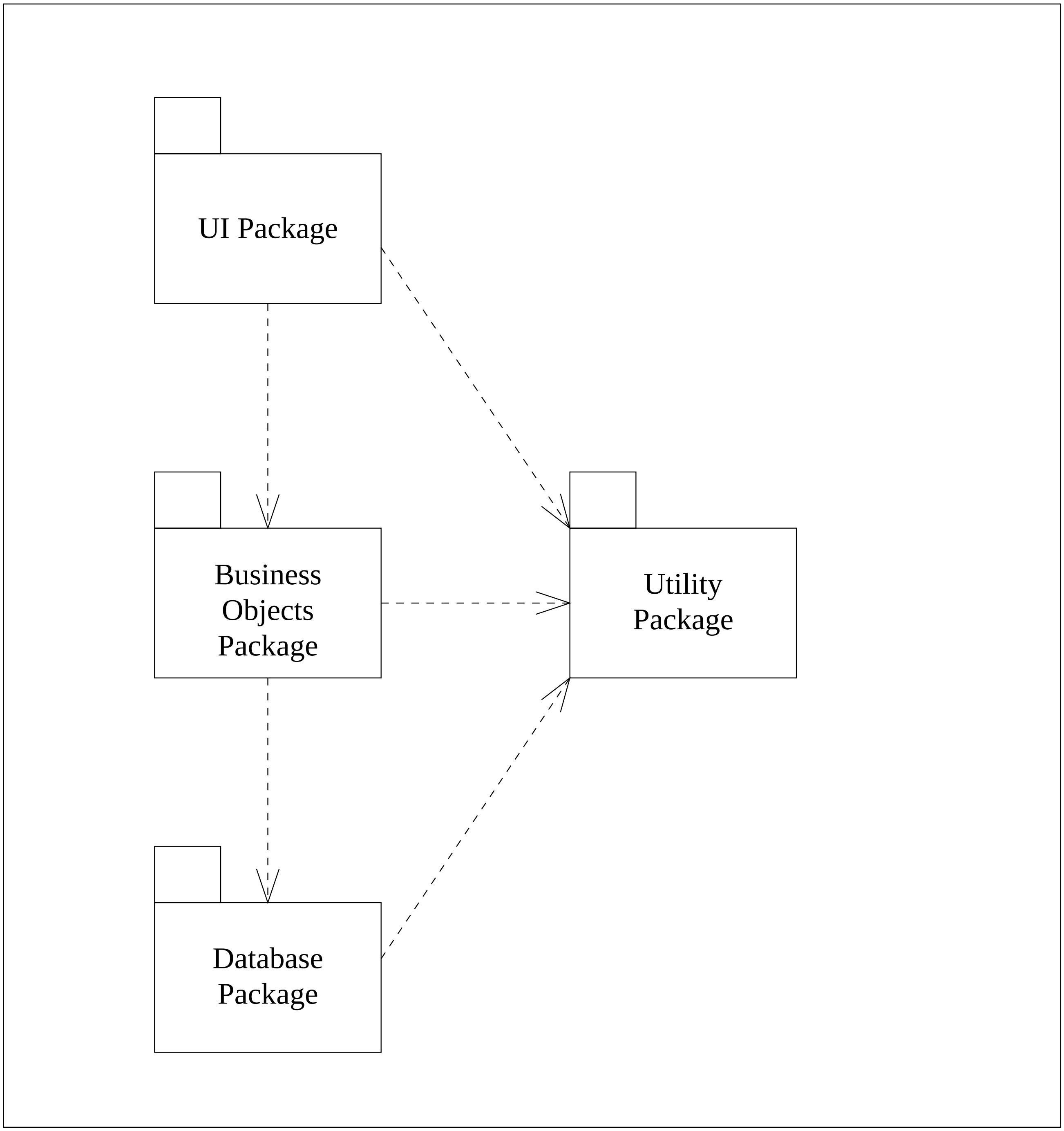
A Use Case Diagram



Architecture Centric

- A software architecture is an intermediate level abstraction that connects the characteristics of systems users need to the characteristics of the systems software engineers can build
- Software architecture embodies the most significant static and dynamic aspects of the systems
- Architecture can be evolved from key use cases
- Use cases represent the *function* and the architecture represents the *form* of a software product

A Typical Software Architecture Diagram



Iterative and Incremental

- A software development project is sliced into mini-projects; each mini-project is an iteration that results in an increment
- Iterations refers to steps in the work-flow
- Increments refer to growth in the product
- Each iteration deals with a group of use cases that together extend the usability of the product:
  - Developers identify and specify relevant use cases in the iteration
  - Create a design using chosen architecture
  - Implement the design in components
  - Verify that the components satisfy the use cases

Component Based

- An interface is a collection of operations that are used to specify the services of a class or component
- A physical and replaceable part of a system that conforms to and provides the realization of a set of interfaces
- Define crisp abstractions with well-defined interfaces, enabling to easily replace older components with newer, compatible ones
- Three types of components:
  - Deployment components: components necessary and sufficient to form an executable system
  - Work Product Components: source code files and data files from which deployment components are created
  - Execution Components: created as a consequence of an executing system

Inception

- Develop a good idea and vision of the end-product
- Present a business case for the project:
  - What is the system primarily going to do for its users?
  - What could an architecture look like?
  - What is the plan and what will it cost?
- Most important risks are identified
- The Elaboration Phase is planned in detail
- Broad estimation of resources and costs is done

Elaboration

- Specify in detail (most of the) use cases
- Design the system architecture
- Do a detailed risk analysis
- Realize the most important use cases to provide an architecture baseline
- Draw up a detailed plan of activities for the Construction phase (Set up a series of iterations for construction and assign use cases to iterations)
- Do an exhaustive estimation of resources and costs

Construction

- Build the system in a series of iterations
- Each iteration involves analysis, design, coding, testing, integration for the assigned use cases
- Incremental in function; builds on the use cases developed in the previous iteration
- Iterative: Rewrite existing code to make it more flexible

Transition

- Optimization and fine-tuning of the product
- Beta-testing
- Does not involve any development to add major functionality

UML Overview

Y. Narahari

Computer Science and Automation

Indian Institute of Science

Bangalore - 560 012

OUTLINE

1 Modeling Principles

2 UML Evolution

3 Bird's Eye View

4 UML Things

5 UML Relationships

6 UML Diagrams

Why Model?

- A model is a simplification of reality
- We build models so that we can better understand the system we are developing
- Models have four objectives:
  1. Help us to visualize a system as it is or as we want it to be
  2. Permit us to specify the structure and behavior of a system
  3. Provide us a template that guides us in constructing a system
  4. Document the decisions we have made

Principles of Modeling

1. The choice of what models to create has a profound influence on how a problem is approached and how a solution is evolved
2. Every model may be expressed at different levels of precision
3. The best models are connected to reality
4. No single model is sufficient. Every non-trivial system is best approached through a small set of nearly independent models

Unified Modeling Language

- OMG standard notation for object oriented modeling
- UML is a modeling language
- UML is a notation, not a methodology
- Developed jointly by: Booch, Rumbaugh, and Jacobson
- Version 0.8 in 1995; Version 1.0 in 1997; Version 1.2 was adopted as an OMG standard in September 1998
- Details can be downloaded from `www.rational.com`
- UML can be used in:
  - conceptual modeling
  - visualization
  - specification
  - constructing
  - documenting

UML: A Bird's Eye View

- UML has three building blocks:
  - Things
  - Relationships
  - Diagrams
- **Things**
  - Structural
  - Behavioral
  - Grouping
  - Annotational
- **Relationships**
  - Dependency
  - Association
  - Generalization
  - Realization

UML: A Bird's Eye View

- **Diagrams**
  - Class Diagram
  - Object Diagram
  - Use Case Diagram
  - Component Diagram
  - Deployment Diagram
  - Sequence Diagram
  - Collaboration Diagram
  - Statechart Diagram
  - Activity Diagram
- **Extensibility Mechanisms**
  - Stereotypes
  - Tagged Values
  - Constraints

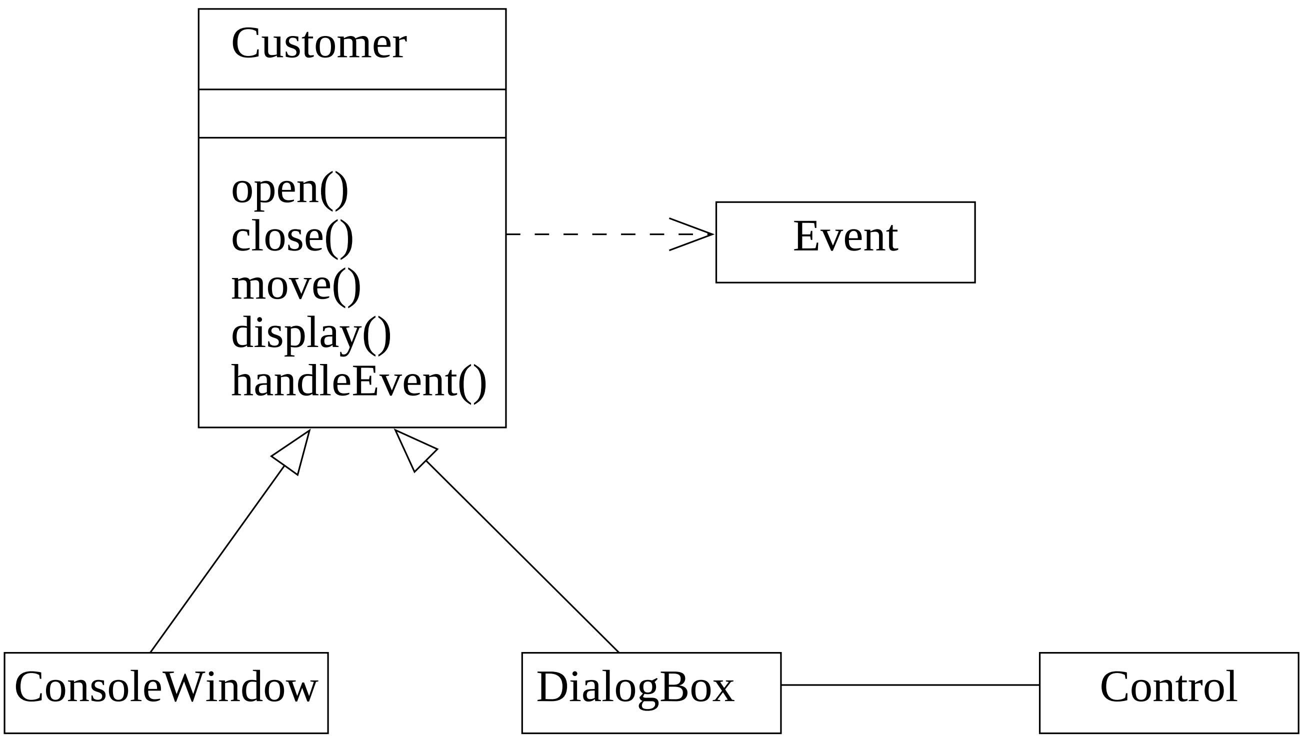
UML: Things

- **Structural Things**: Static parts of a model, either conceptual or physical.
  - Classes
  - Interfaces
  - Collaborations
  - Use Cases
  - Active classes
  - Components
  - Nodes
- **Behavioral Things**: Dynamic parts of UML models
  - Interaction
  - State machine
- **Grouping Things**: Organizational parts of UML models, for example, packages
- **Annotational Things**: Explanatory parts of UML models, for example, notes.

UML: Relationships

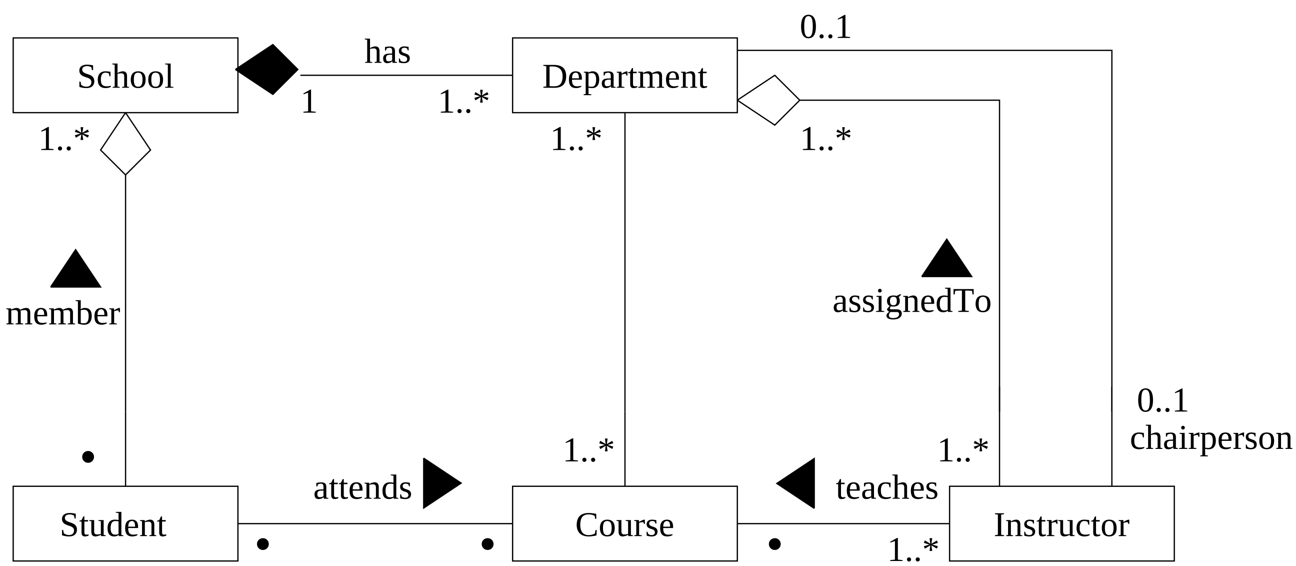
- **Dependency**: Semantic relationship between two things in which a change to one thing may affect the semantics of the other
- **Association**: Structural relationship that describes a connection among objects
  - Can be binary, ternary, etc.
  - Aggregation and composition
- **Generalization**: Relationship in which specialized objects (children) share the structure and behavior of the parent objects.
- **Realization**: Semantic relationship between classifiers, wherein one classifier specifies a contract that another classifier guarantees to carry out.
  - interfaces and classes
  - interfaces and components
  - use cases and collaborations

Relationships



Relationships

Structural Relationships



Structural Relationships

Architectural Views

- **Use Case View**: use case diagrams; activity diagrams
- **Design View**: class diagrams, interaction diagrams, state chart diagrams
- **Process View**: class diagrams, interaction diagrams, activity diagrams
- **Implementation View**: component diagrams
- **Deployment View**: deployment diagrams

Forward and Reverse Engineering

- **Forward Engineering** is the process of transforming a model to an implementation language
- **Reverse Engineering** is the process of transforming code into a model through a mapping from a specific implementation language
- (UML) models are semantically richer than code
- Forward engineering results in a loss of information; thus reverse engineering cannot completely recreate a model
- UML diagrams can be used in forward engineering and to some extent also in reverse engineering

UML Diagrams

Y. Narahari

Computer Science and Automation

Indian Institute of Science

Bangalore - 560 012

OUTLINE

1 Class Diagrams

2 Object Diagrams

3 Use Case Diagrams

4 Component Diagrams

5 Deployment Diagrams

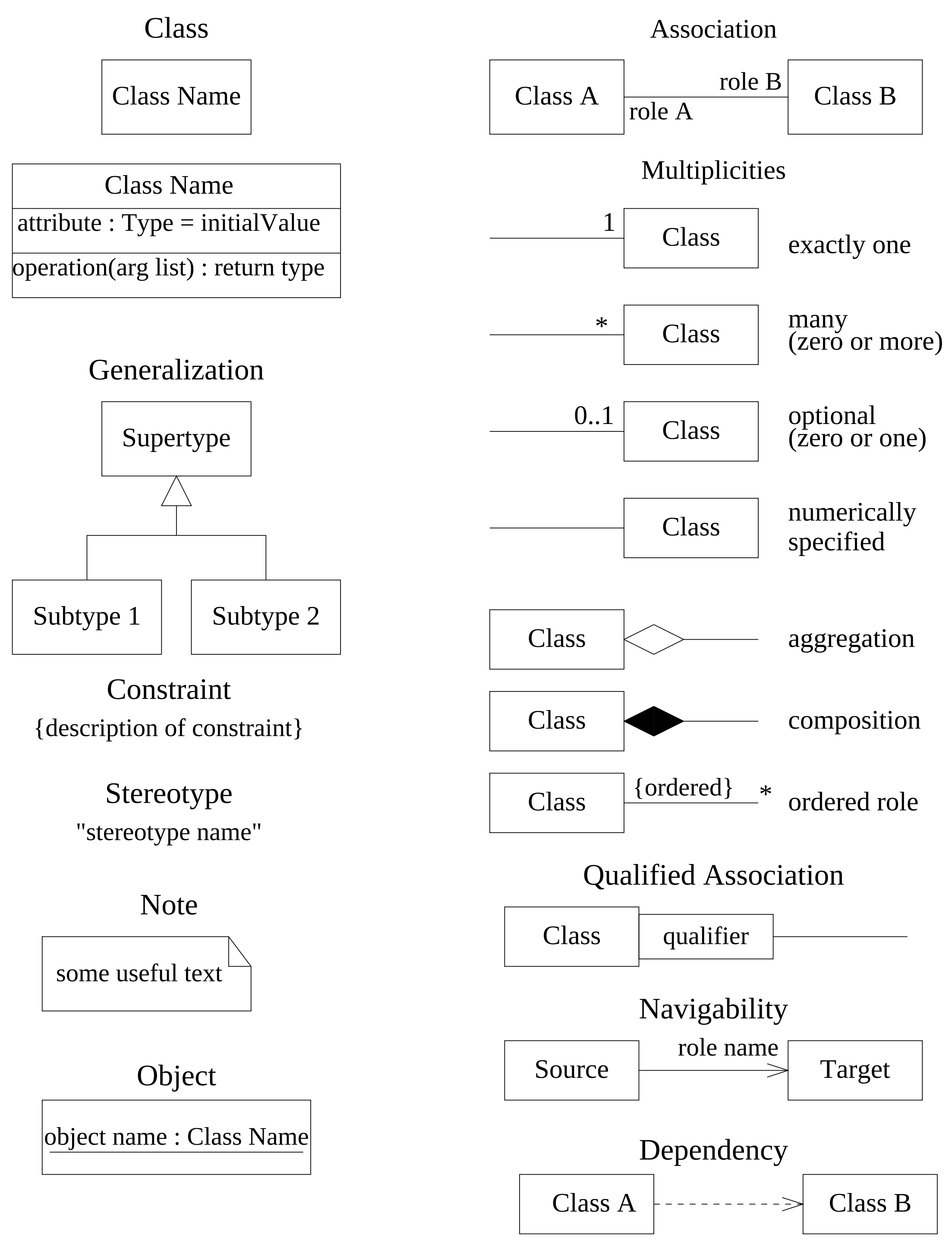
6 Sequence Diagrams

7 Collaboration Diagrams

8 Activity Diagrams

9 State Chart Diagrams

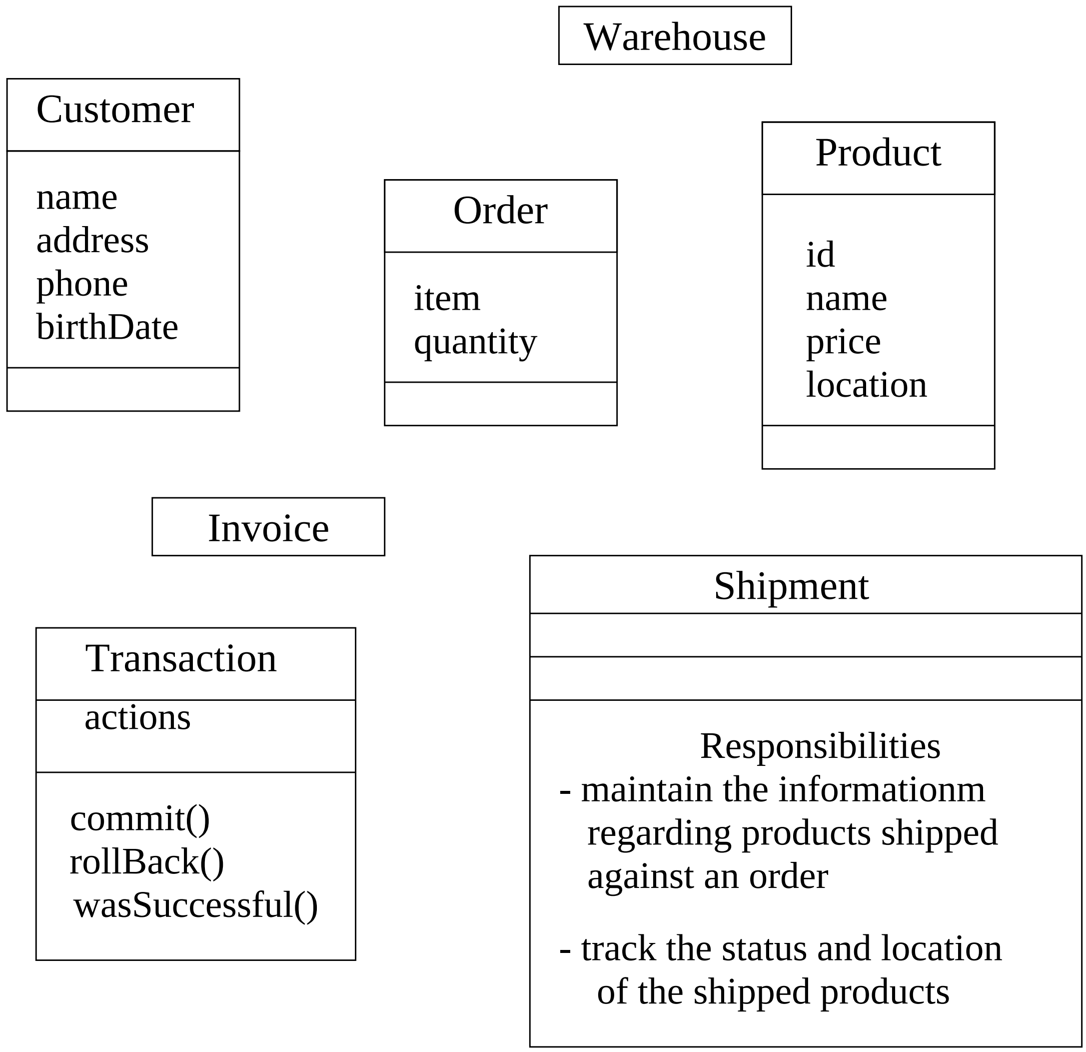
A Summary of UML Notation



Class Diagrams

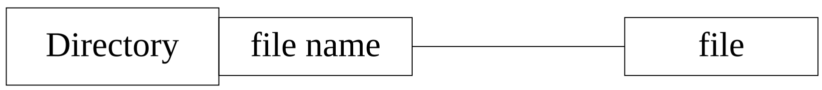
- Describes types of objects in the system and various kinds of relationships between the objects, such as:
  - Association
  - Aggregation
  - Generalization
- Interpretation of class diagrams can proceed along three perspectives:
  - **Conceptual**: Only the concepts in the domain are modeled here
  - **Specification**: Look into interfaces but not implementation
  - **Implementation**

Modeling the Vocabulary of a System



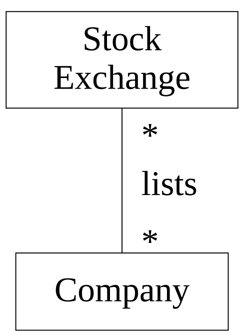
Modeling the Vocabulary of a System

Associations

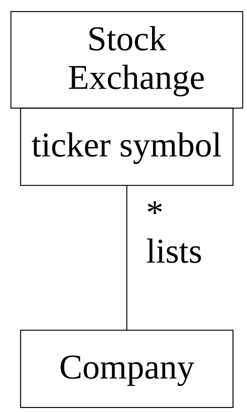


Qualified Association

- Improves semantic accuracy
- like a tennary association
- reduces effective multiplicity of an association

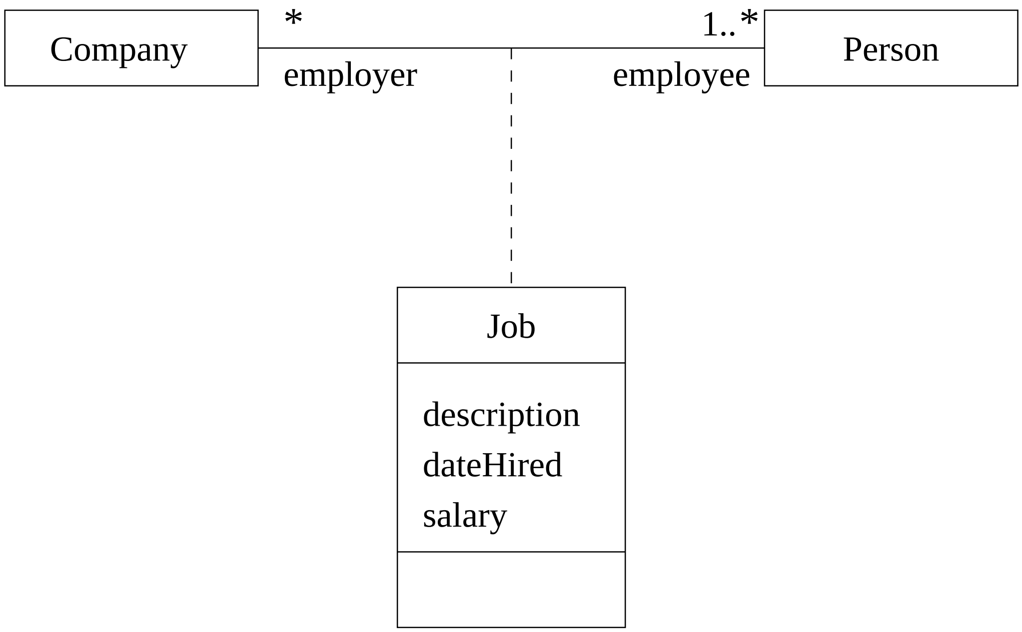


unqualified



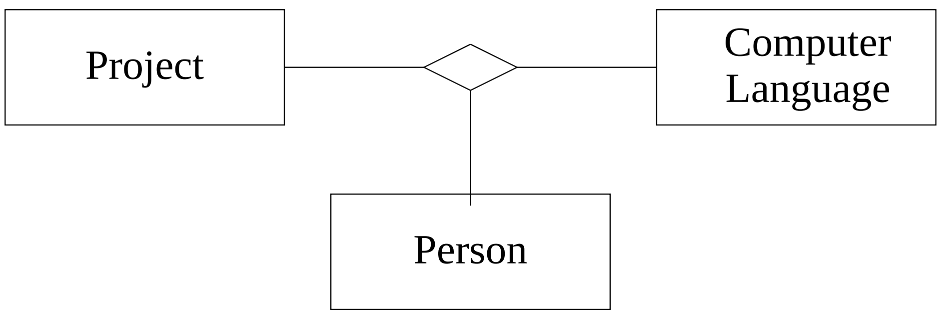
qualified

Association Class



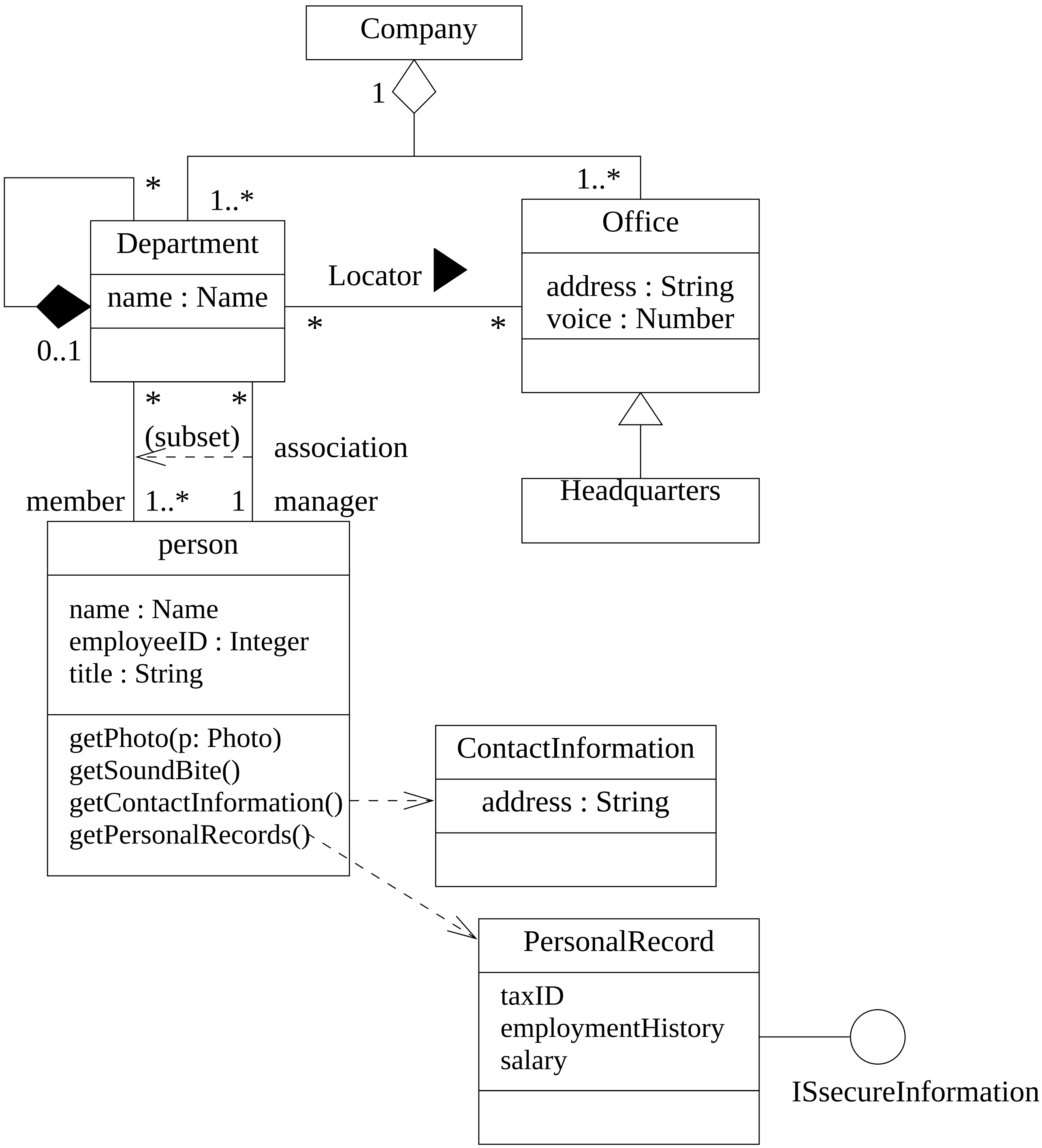
Association Classes

Ternary Association



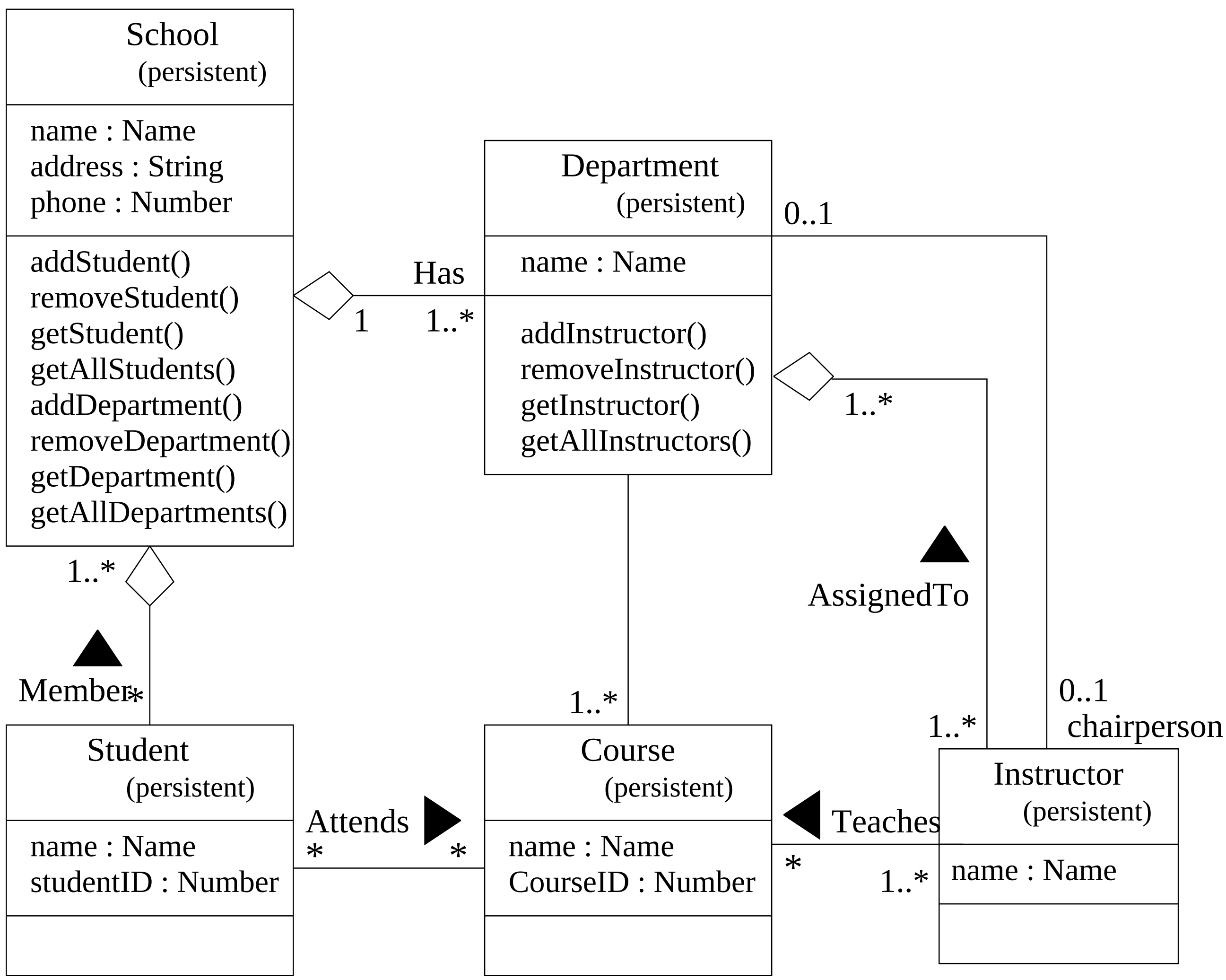
Tennary Association

Class Diagram



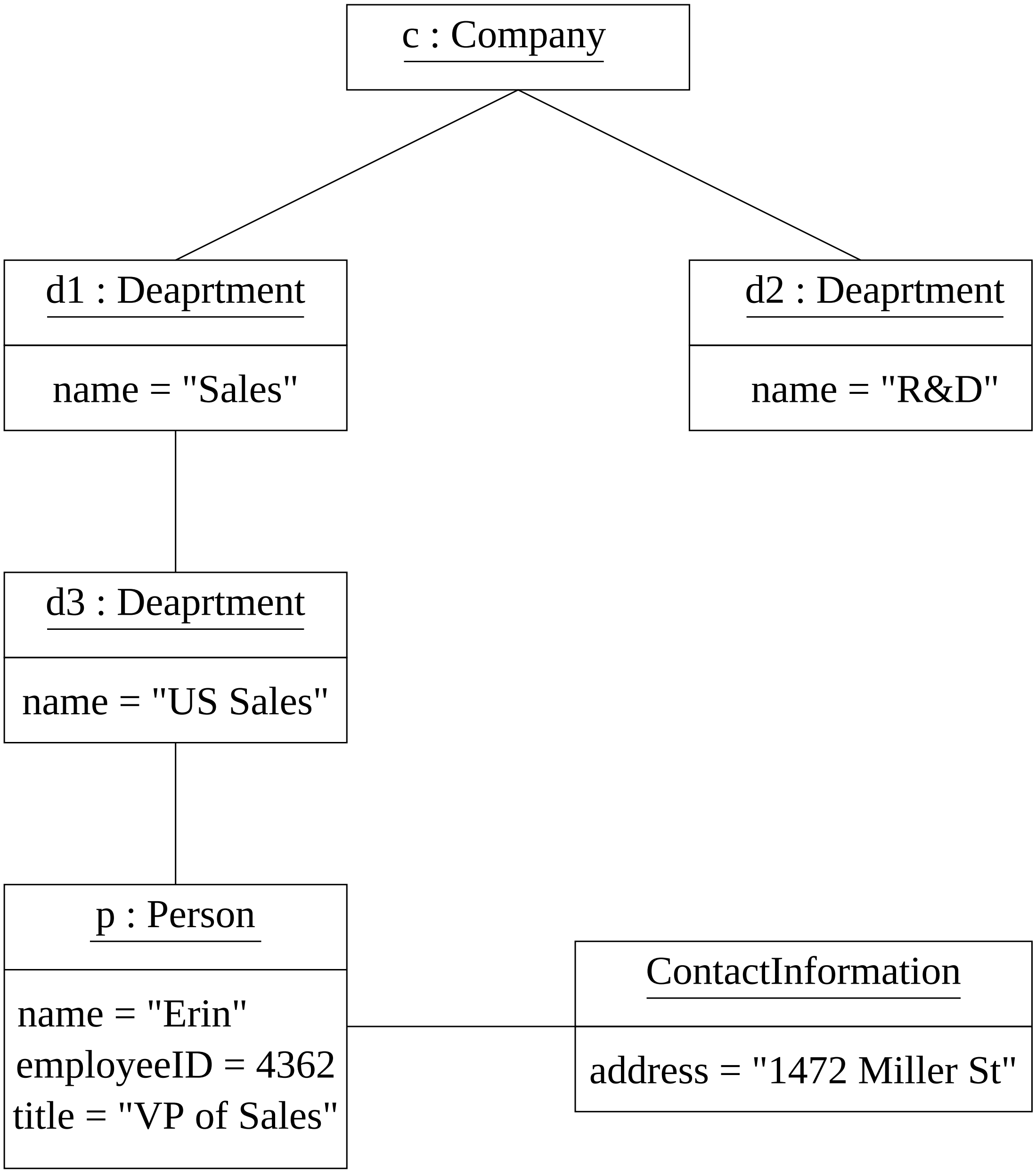
A Class Diagram

Another Class Diagram



Modeling a Schema

An Object Diagram

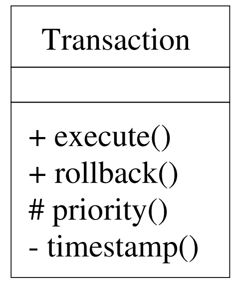


An Object Diagram

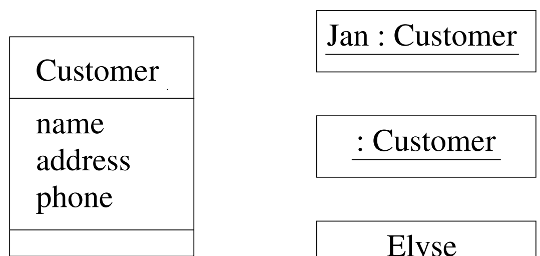
Common Mechanisms

1. **Specifications**
   - textual statement of the syntax and semantics of each building block (which supplements the graphical notation of the building block
2. **Adornments**
   - detail from an element's specification added to its basic graphical notation
3. **Common Divisions**
   - class-object dichotomy
   - interface-implementation dichotomy
4. **Extensibility Mechanisms**
   - Stereotypes
   - Tagged Values
   - Constraints

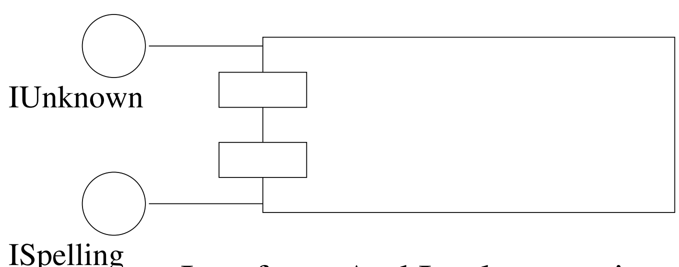
Common Mechanisms



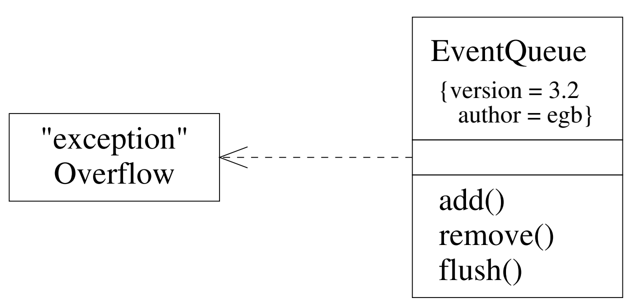
Adornments



Classes And Objects



Interfaces And Implementations



Extensibility Mechanisms

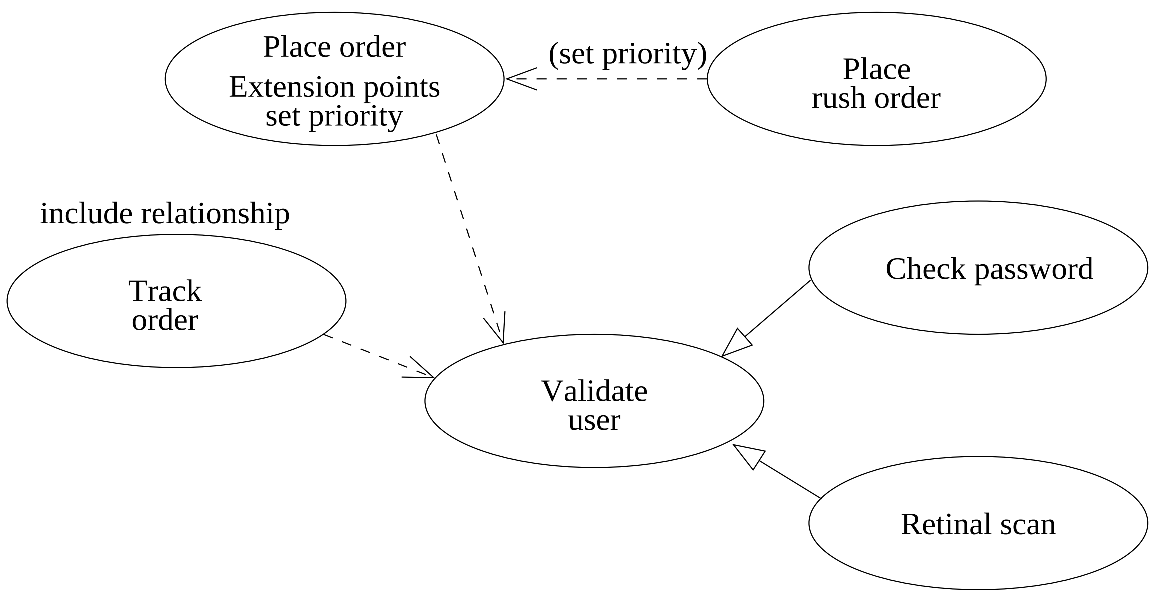
Use Cases

- Specify the behavior of a system or a part of a system and describe a set of actions that a system performs to yield an observable result of value to an actor
- Use cases are important to:
  - Capture intended behavior of the system being developed,without having to specify how that behavior is implemented
  - Provide a way for developers to come to a common understanding with the systems end users and domain experts
  - Help validate the architecture and verify the system as it evolves during development
  - Use cases are realized by collaborations whose elements work together to carry out each use case
- Rational Unified Process is use-case driven

Why Use Cases?

- They offer a systematic and intuitive means of capturing **functional requirements**, with a focus on value added to the user.
- They drive the whole development process:
  - Analysis, Design, and Testing are performed starting from the use cases
  - Design and Testing can be planned and coordinated in terms of use cases
- They help devise a suitable system architecture
- They facilitate an iterative and incremental process

Use Case Relationships

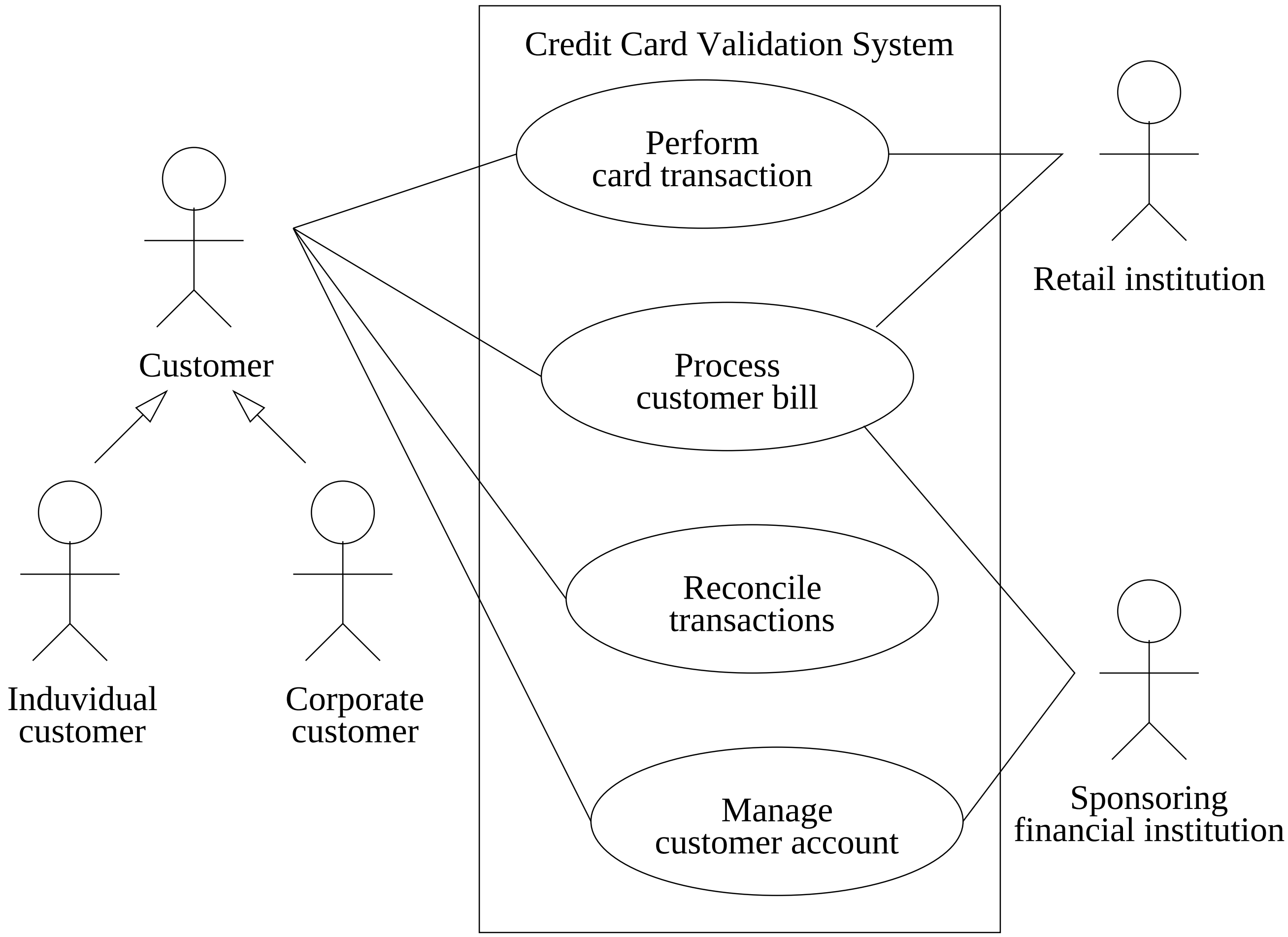


Generalization, Include, and Extend

Use Case Diagrams

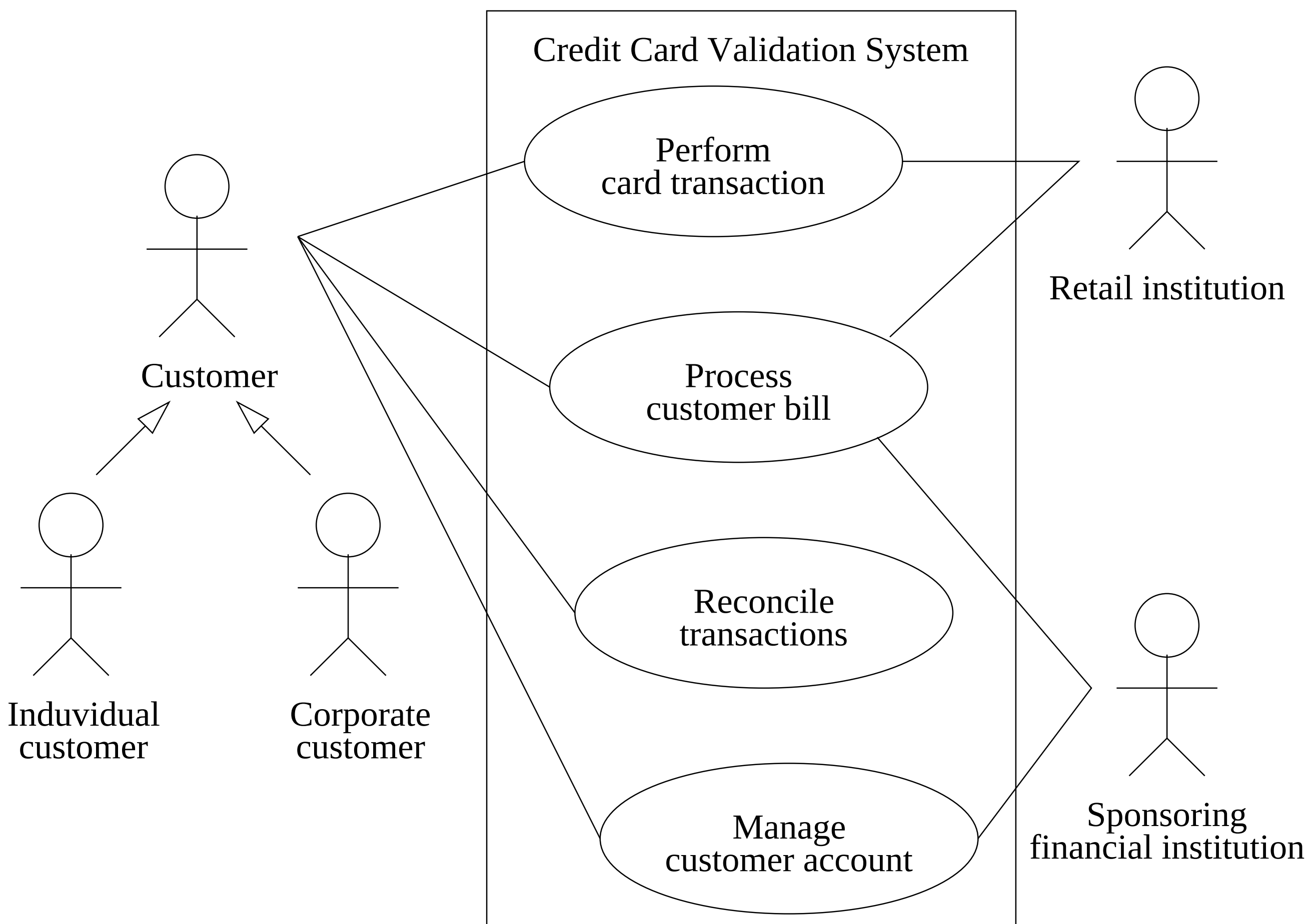
- A use-case diagram contains:
  - Use cases
  - Actors
  - Dependency, generalization, and association relationships
  - Notes and constraints
- Use case diagrams provide a static use case view
- Use case diagrams can be used to model:
  - context of a system
  - requirements of a system

A Use Case Diagram



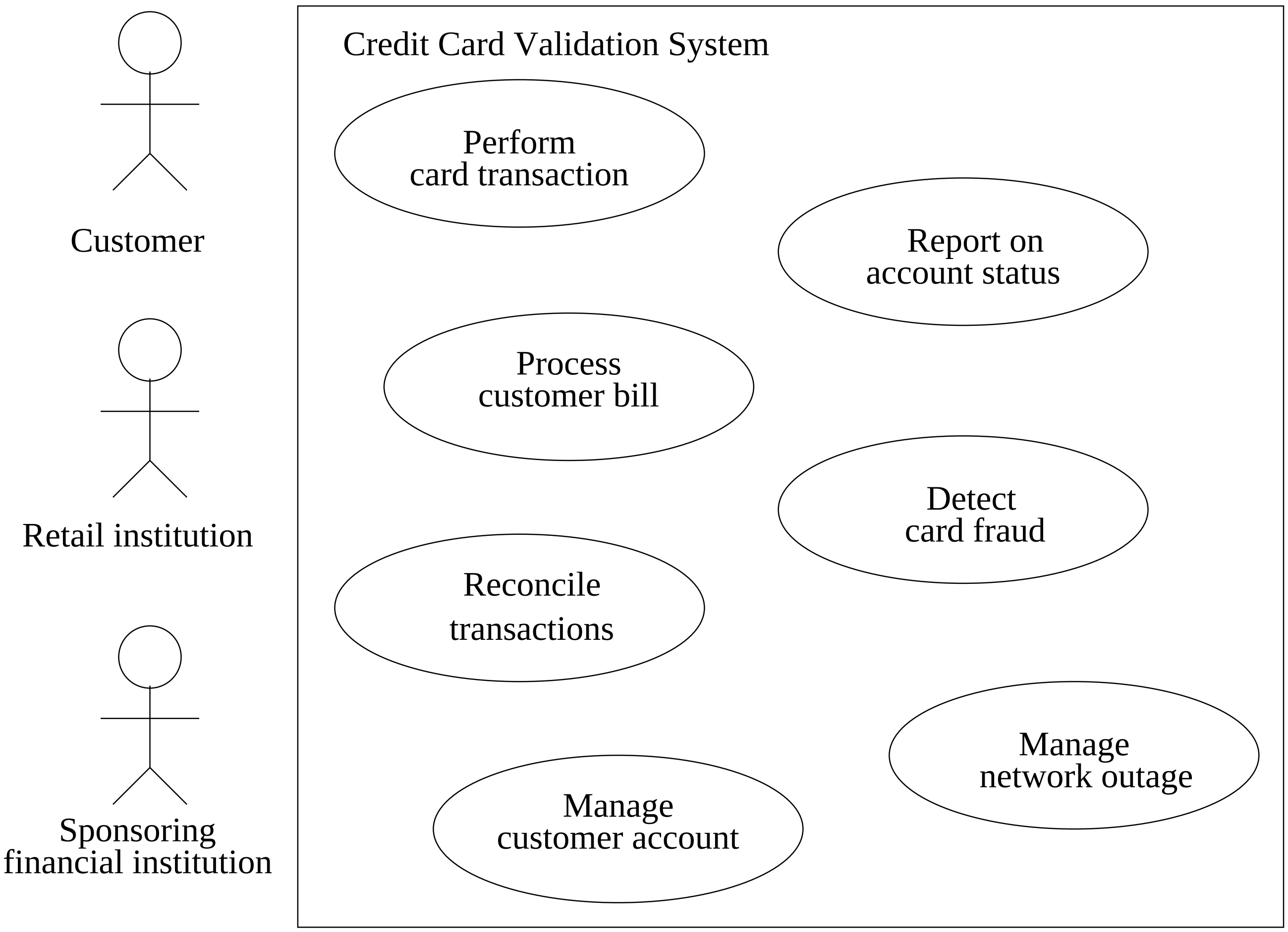
Modeling the Context of a System

Modeling Context of a System



Modeling the Context of a System

Modeling Requirements of a System



Modeling the Requirements of a System

Interfaces

- An interface is a collection of operations that are used to specify a service of a class or a component
- **Export Interface**: an interface that a component realizes
  - A component may provide many export interfaces
- **Import Interface**: an interface that a component uses
  - A component may conform to many import interfaces

Components

- A component is a physical and replaceable part of a system that conforms to and provides the realization of a set of interfaces
  - model : executables, libraries, tables, files, documents, APIs, source code, etc.
  - represent physical packaging of otherwise logical elements such as classes, interfaces, and collaborations
  - higher level of abstraction than classes
- Define crisp abstractions with well-defined interfaces, enabling to easily replace older components with newer, compatible ones
- Components only have operations which are reachable only through their interfaces

Types of Components

- **Deployment components**: components necessary and sufficient to form an executable system, such as dynamic libraries and executables; Examples - COM, CORBA, Enterprise Java Beans
- **Work Product Components**: source code files and data files from which deployment components are created
- **Execution Components**: created as a consequence of an executing system, for example a COM+ object that is instantiated from a DLL

Component Diagrams

- Shows the organization and dependencies among a set of components
- Comprises:
  - Components
  - Interfaces
  - Dependency, generalization, association, and realization relationships
  - notes and constraints
- Models static implementation view of a system
- Can be used:
  - to model source code
  - to model executable releases
  - to model physical databases
  - to model adaptable systems

Deployment

- A node is a physical element that exists at run time and represents a computational resource and usually has memory and processing capability
  - A *processor* is a node that has processing capability and therefore can execute a component
  - A *device* is a node with no processing capability and provides only an interface to the real world
- Nodes represent physical deployment of components and are responsible for executing components
- A component may be deployed on multiple nodes; also a component need not be statically located in a given node

Deployment Diagrams

- Shows the configuration of run time processing nodes and the components that live on them
- Models the static deployment view of the system (model the topology of the hardware on which the system executes)
- Comprises:
  - Nodes and components
  - Dependency and association relationships
  - Notes and constraints
- Not necessary in some situations
- Very useful in modeling: embedded systems, client/server systems, and fully distributed systems

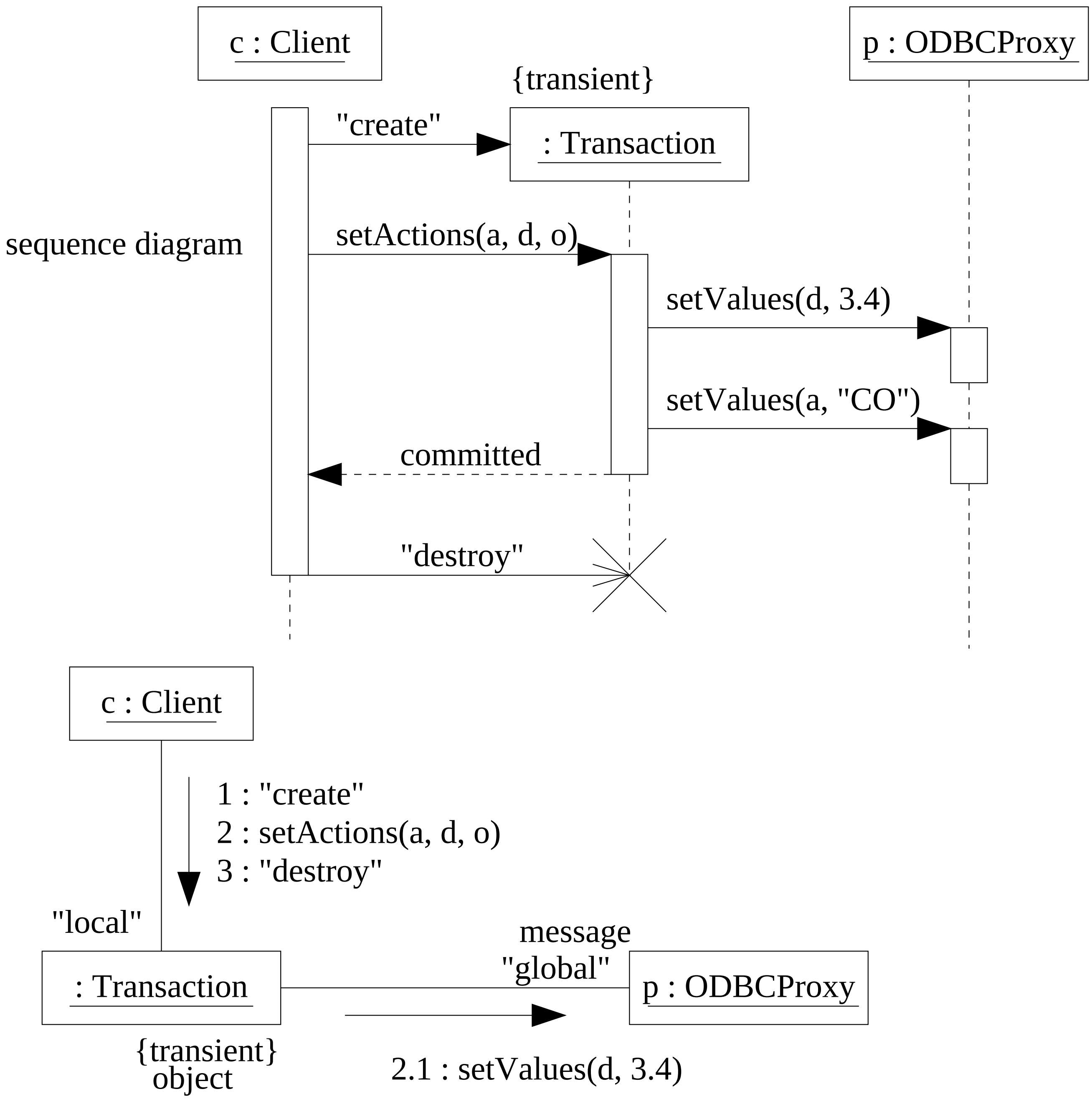
Interactions

- An **interaction** is a behavior that comprises a set of messages exchanged among a set of objects within a context to accomplish a purpose
- **Link**: A semantic connection among objects; an instance of an association
- **Message**: A specification of a communication between objects that conveys information with the expectation that activity will ensue; Messages could be in the form of
  - call
  - return
  - send
  - create
  - destroy

Interaction Diagrams

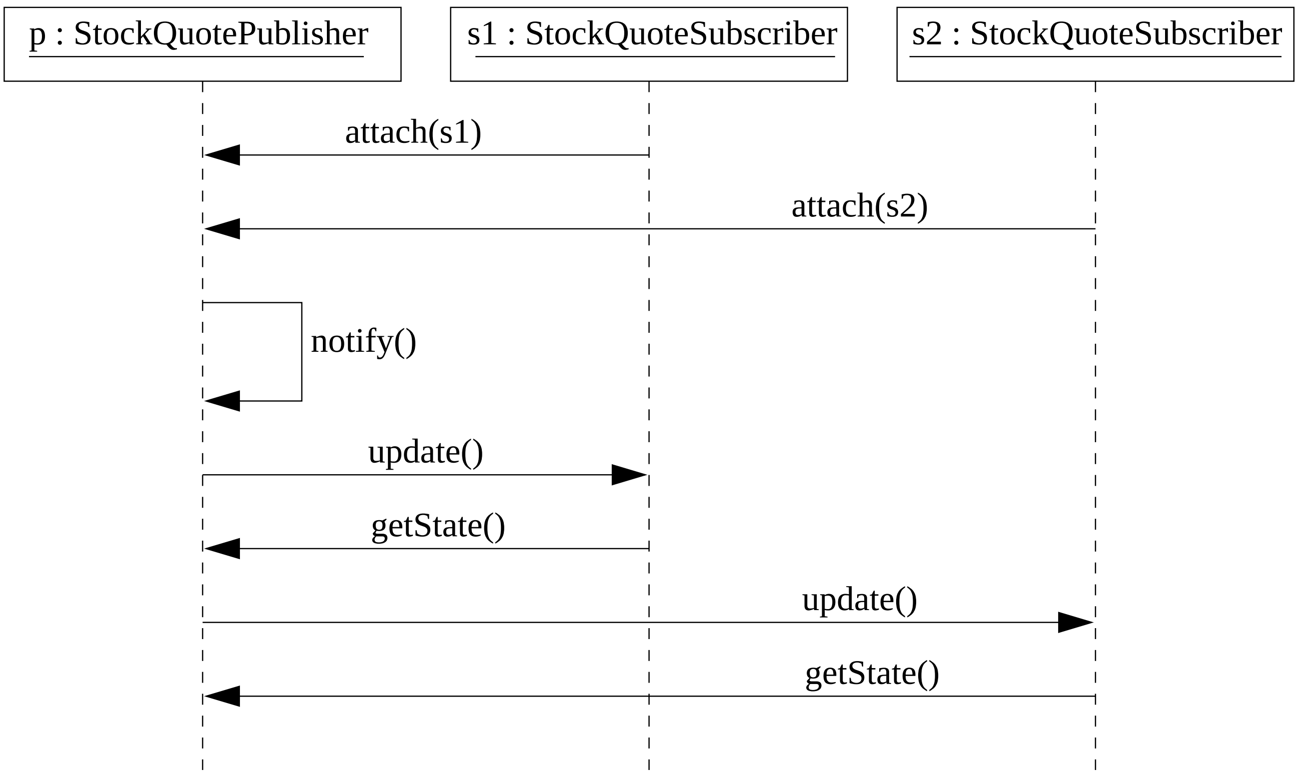
- Shows an interaction, consisting of a set of objects and their relationships, including the messages that may be dispatched among them
- Involves modeling concrete instances of classes, interfaces, components, and nodes, along with the messages that are dispatched among them, all in the context of a scenario
- Interaction diagrams are of two types:
  - Sequence diagrams
  - Collaboration diagrams
- Sequence diagram shows time ordering of messages (flow of control by time ordering)
- Collaboration diagram shows structural organization of objects that send and receive messages (flow of control by organization)
- semantically equivalent

Interactions



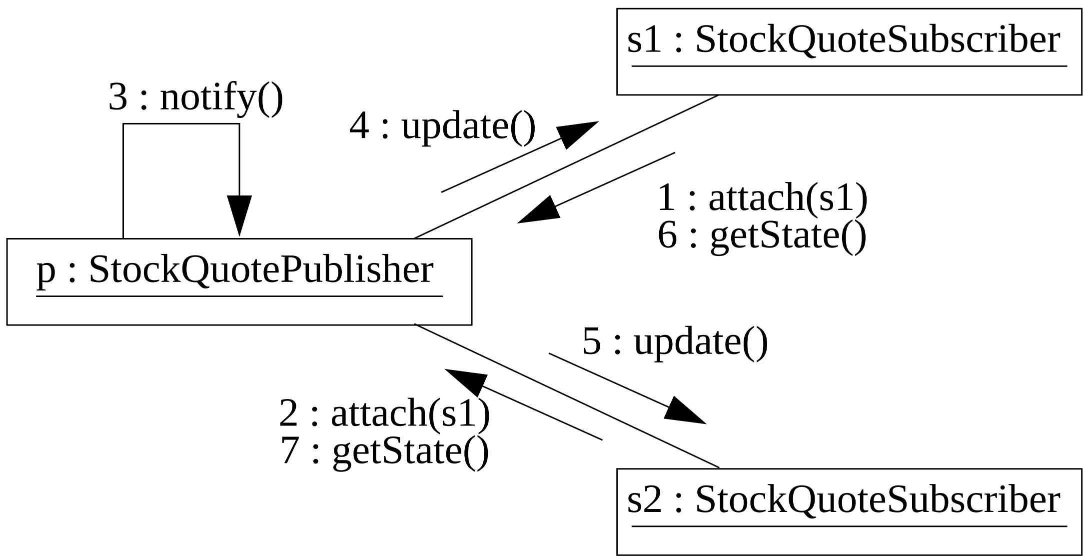
Interaction Diagrams

Flow of Control by Time



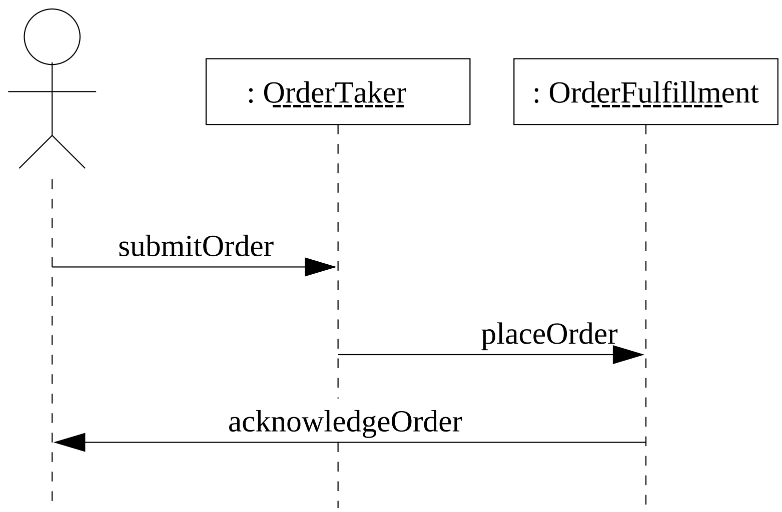
Flow of Control by Time

Flow of Control by Organization



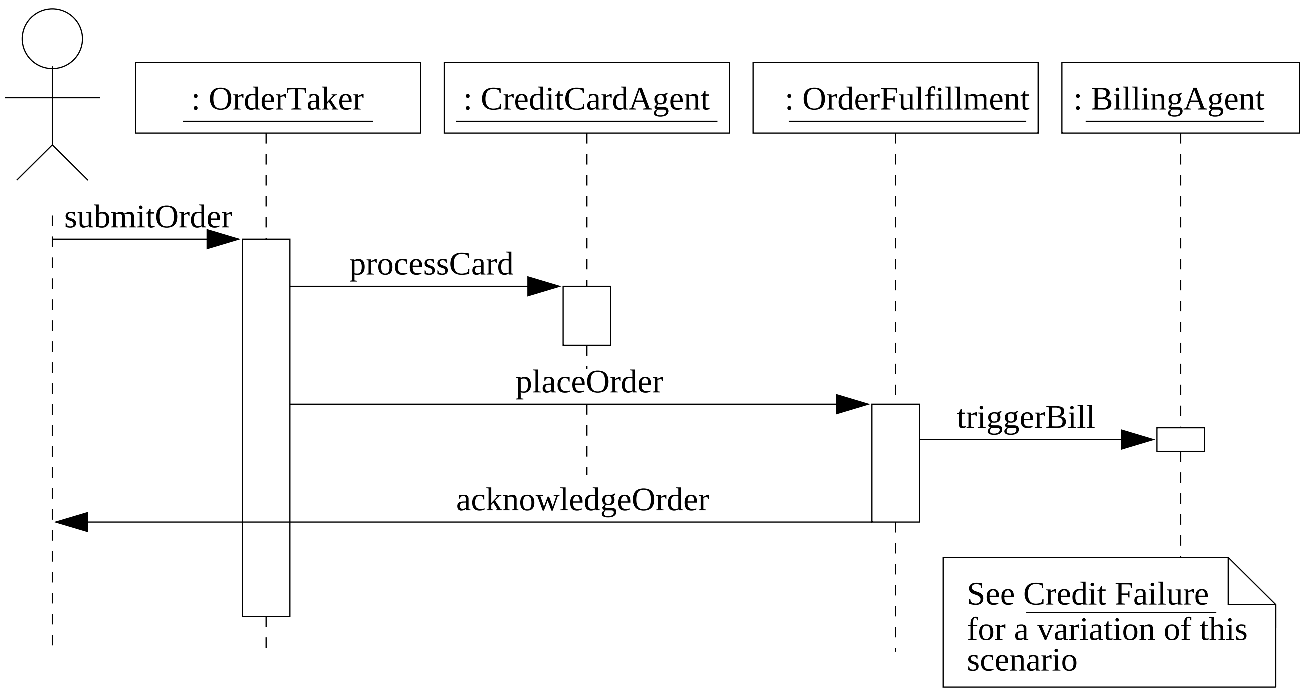
Flow of Control by Organization

Interaction at a High Level



Interaction Diagram at a High Level of Abstraction

Interaction at a Lower Level



Interaction Diagram at a Low Level of Abstraction

Events and Signals

- An **event** is the specification of a significant occurrence that has a location in time and space; can trigger a state transition
- A **signal** is a kind of event that represents the specification of an asynchronous stimulus communicated between instances
- Kinds of Events:
  - Signal: a named object that is dispatched (thrown) asynchronously by one object and then received (caught) by another
    - Exceptions are a common kind of internal signals
  - Call: represents the dispatch of an operation (synchronous)
  - Time event: represents passage of time
  - Change event: represents a change in state or the satisfaction of a condition

Exceptions

- Exceptions are kinds of signals (internal)
- Modeled as stereotyped classes
- Specify the kinds of exceptions that on object may throw through its operations
- Exceptions can be arranged in a hierarchy
- An important part of visualizing, specifying, and documenting the
- An important part of visualizing, specifying, and documenting the behavior of a class or an interface

State Machines

- Specifies the sequences of states an object goes through during its lifetime in response to events, together with its responses to those events
- A state is a condition or situation during the life of an object during which it satisfies some condition, performs some activity, or waits for some event
- Commonly used to specify the behavior of objects or instances that must respond to asynchronous stimulus or whose current behavior depends on the past
- Two kinds of state machines:
  - **Activity Diagrams**: emphasize flow of control from activity to activity
  - **Statechart Diagrams**: emphasize potential states of the objects and transitions among those states

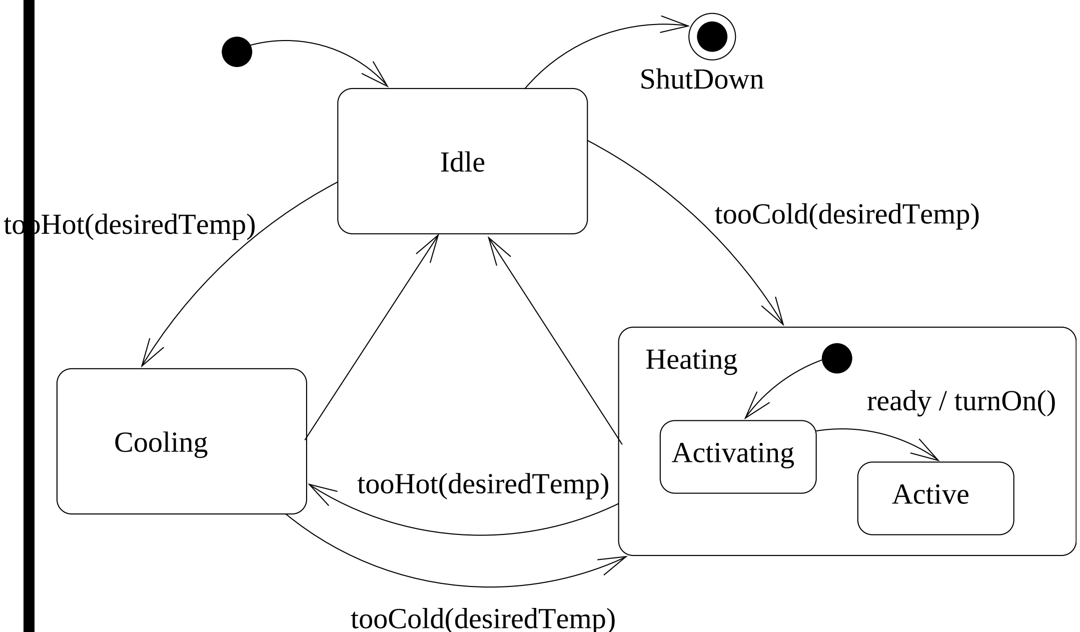
States and Transitions

- States have the following parts:
  - Name
  - Entry/exit actions
  - Internal transitions (transitions that do not cause a change in state)
  - Substates
    - sequential substates
    - concurrent substates
  - Deferred events
- A transition has five parts:
  - Source state
  - Event trigger
  - Guard condition
  - Action
  - Target state

Statechart Diagrams

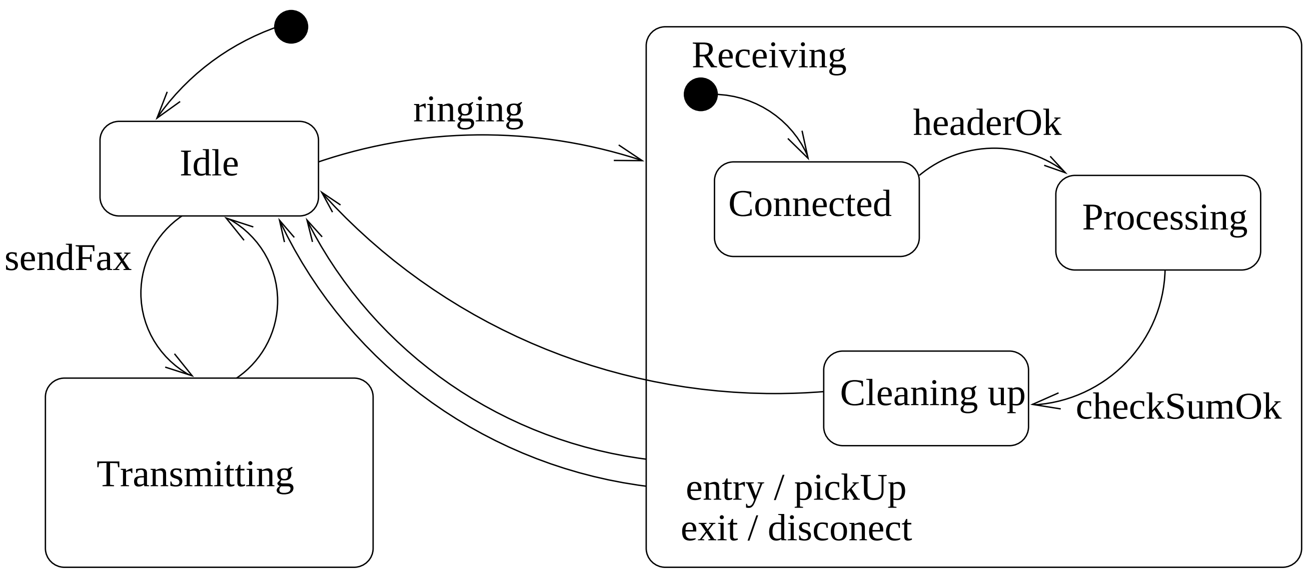
- Model the event-ordered behavior of reactive objects
- Provide a most natural way to visualize, specify, construct, and document the behavior of interesting, non-trivial objects and instances
- Can be attached to classes, use cases, or entire systems
- A natural tool to model reactive (event-driven) objects
  - objects whose behavior is best characterized by response to events dispatched from outside their context
- Can be used for constructing executable systems through forward and reverse engineering

A State Machine



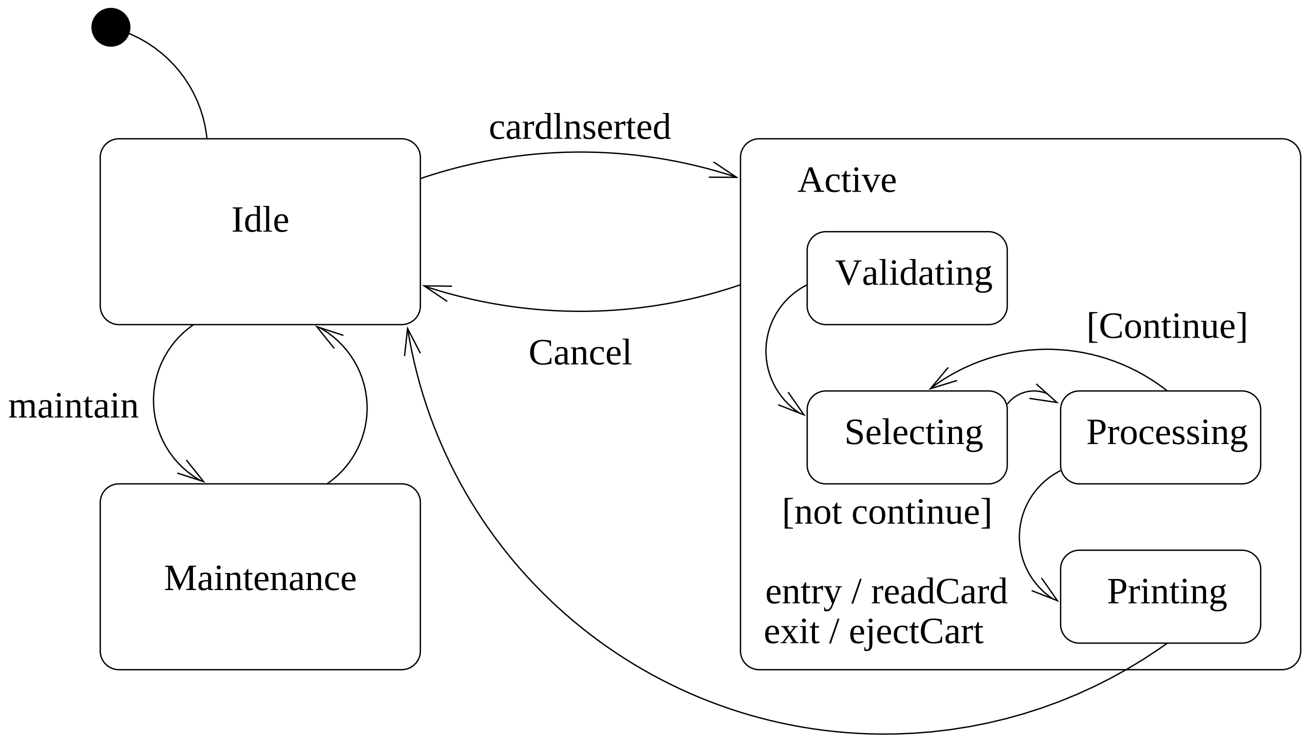
State Machines

A State Chart Diagram



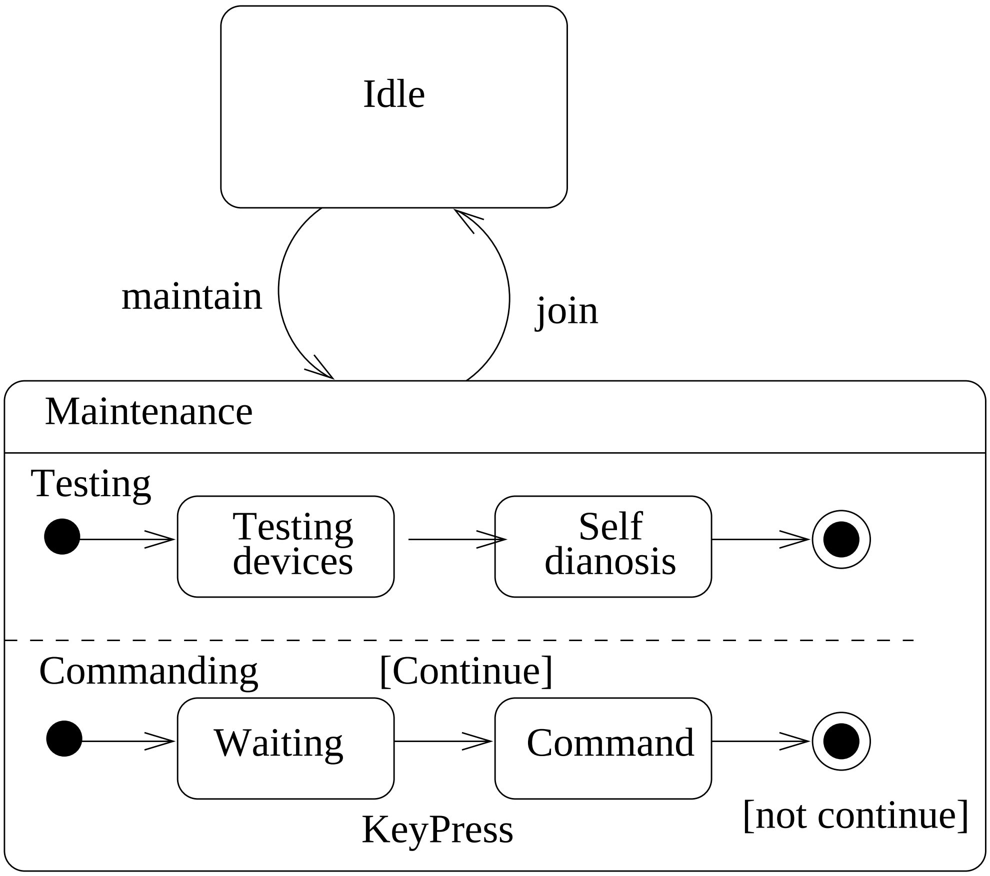
Statechart Diagram

Sequential Substates



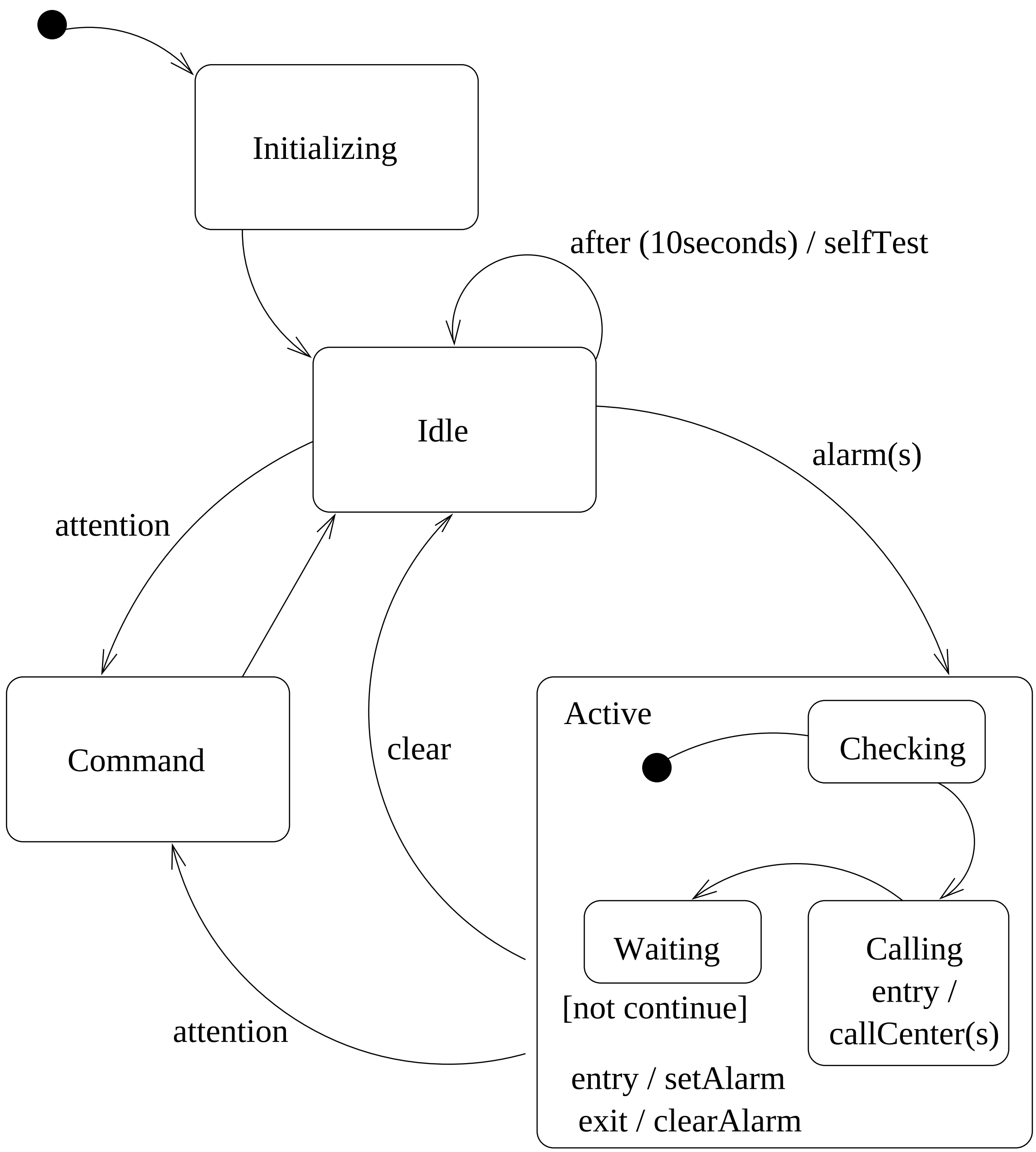
Sequential Substates

Concurrent Substates



Cuncurrent Substances

Modeling the Lifetime of an Object

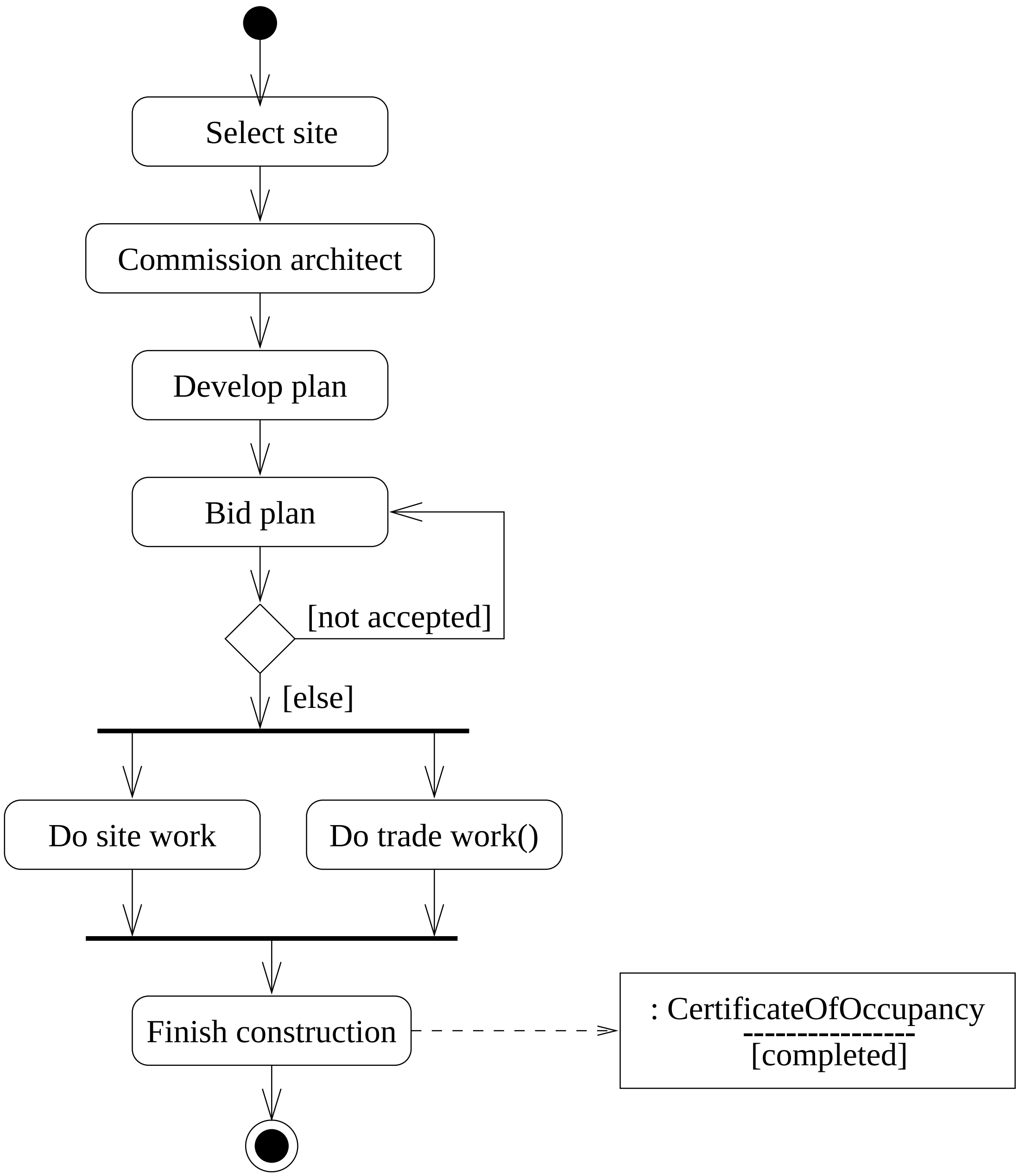


Modeling the Lifetime of An Object

Activity Diagrams

- Shows flow of control from activity to activity and models:
  - dynamics of a society of objects through sequential and concurrent steps in a process
  - flow of an object as it moves from one state to another
  - flow of control of an operation
- **Activity**: an ongoing non-atomic execution within a state machine: an activity results in some action
- An **action** is made up of executable atomic computations that result in a change of the state of system or the return of a value
  - calling another operation
  - sending a signal
  - creating or destroying an object
  - a pure computation

An Activity Diagram

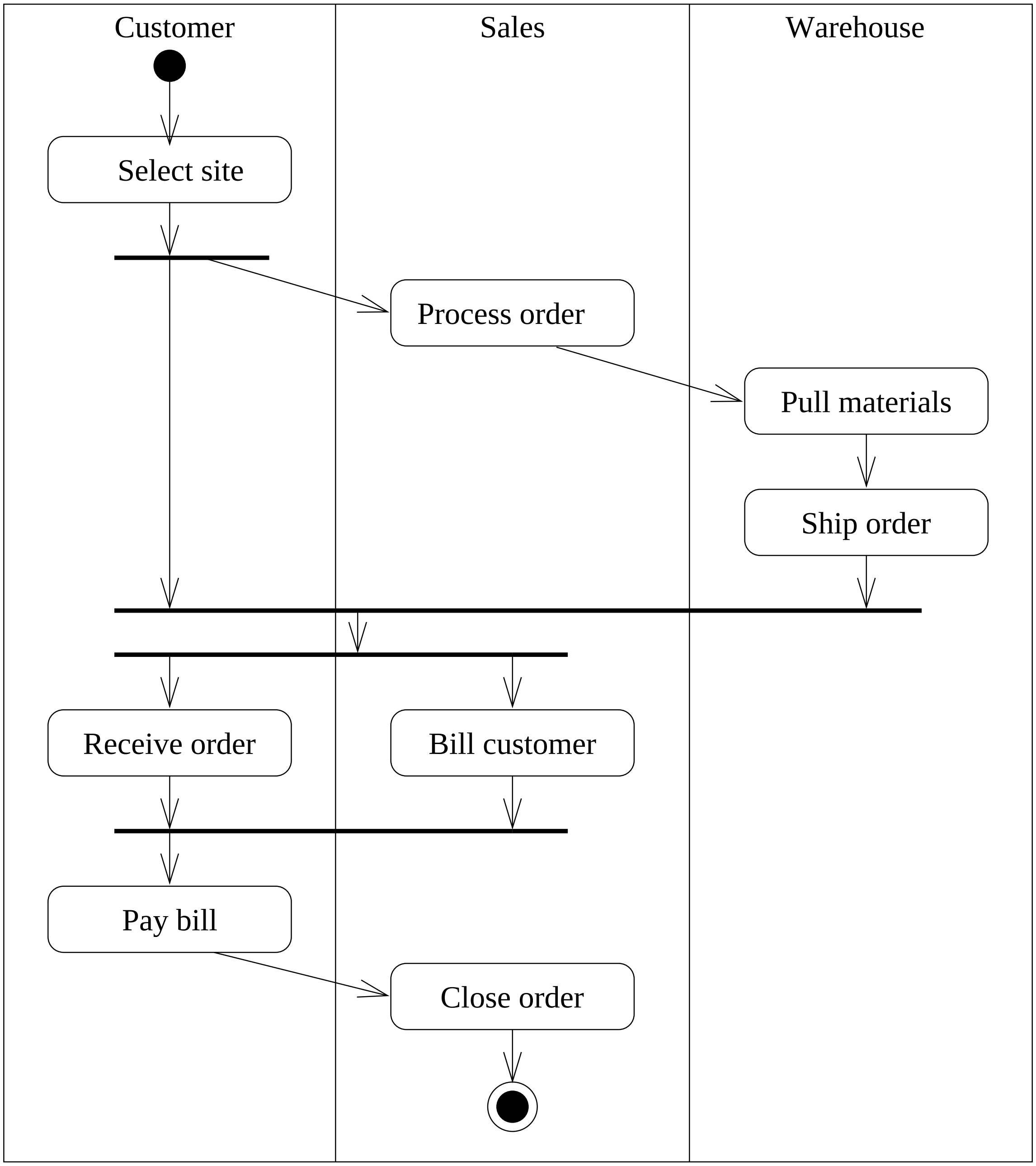


Activity Diagrams

Activity Diagrams

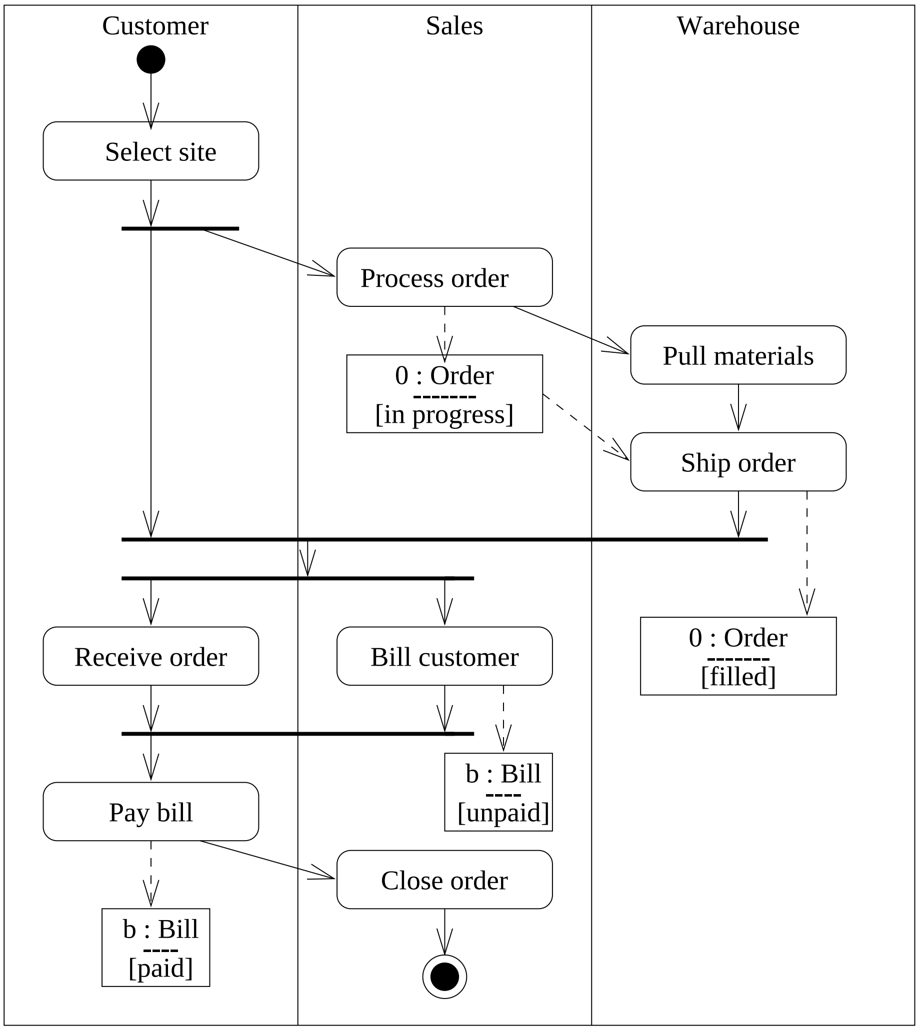
- An activity diagram is a state machine in which
  1. almost all states are activity states
  2. almost all transitions are triggered by completion of activities in the source state
- Important features that can be modeled:
  - Sequential execution
  - Concurrency (forking)
  - Synchronization (joining)
  - Swimlanes
  - Object flow
- Primary uses:
  - Modeling of workflows and business processes
  - Model an operation (like a flowchart)
  - Forward and reverse engineering

Swimlanes in an Activity Diagram



Swimlanes

Object Flow in an Activity Diagram



Object Flow

Processes and Threads

- **Active Object**: an object that owns a process or thread and can initiate control activity
- **Active Class**: a class whose instances are active objects
- **Process**: a heavyweight flow that can execute concurrently with other processes
  - runs in an independent address space known to the operating system
- **Thread**: a lightweight flow that can execute concurrently with other threads in the same process
  - most often, hidden inside a heavier-weight process and runs inside the address space of an enclosing process
- An active class represents a process or thread that is the root of an independent flow of control

Communication and Synchronization

- **Communication**:
  - Passive object to passive object
  - Active object to active object
    (inter-process communication)
    * synchronous (rendezvous)
    * asynchronous (mailbox)
  - Active object to passive object
  - Passive object to active object
- **Synchronization**: This problem arises when two or more flows of control are in the same object at the same time
  - Sequential approach
  - Guarded semantics
  - Concurrent approach

Time and Space

- UML provides modeling infrastructure for real-time and distributed systems:
  - *Timing Mark*: a denotation for the time at which an event occurs
  - *Time Expression*: an expression that evaluates to an absolute or relative value of time
  - *Timing Constraint*: a semantic statement about the relative or absolute value of time
  - *Location*: placement of a component on a node
- A well-structured UML model:
  - exposes all and only those time and space properties that capture the desired behavior of the system
  - centralizes the use of those properties so that they are easy to find and easy to modify

A Case Study

Y. Narahari

Computer Science and Automation

Indian Institute of Science

Bangalore - 560 012

Case Study: A Library Support System

A Requirements Specification

- The library lends books and magazines to borrowers, who are registered in the system.
- The library handles purchase of new titles. Popular titles are bought in multiple copies. Old books and magazines are often removed.
- The librarian interacts with the customers
- A borrower can reserve a book or magazine that is not currently available in the library and will get a notification when the book is returned or purchased. The reservation is canceled in appropriate conditions.
- The library can create, update, and delete information about titles, borrowers, loans, and reservations
- The system can run on popular technical environments (Unix, Windows, OS/2, etc.) and has a modern GUI.

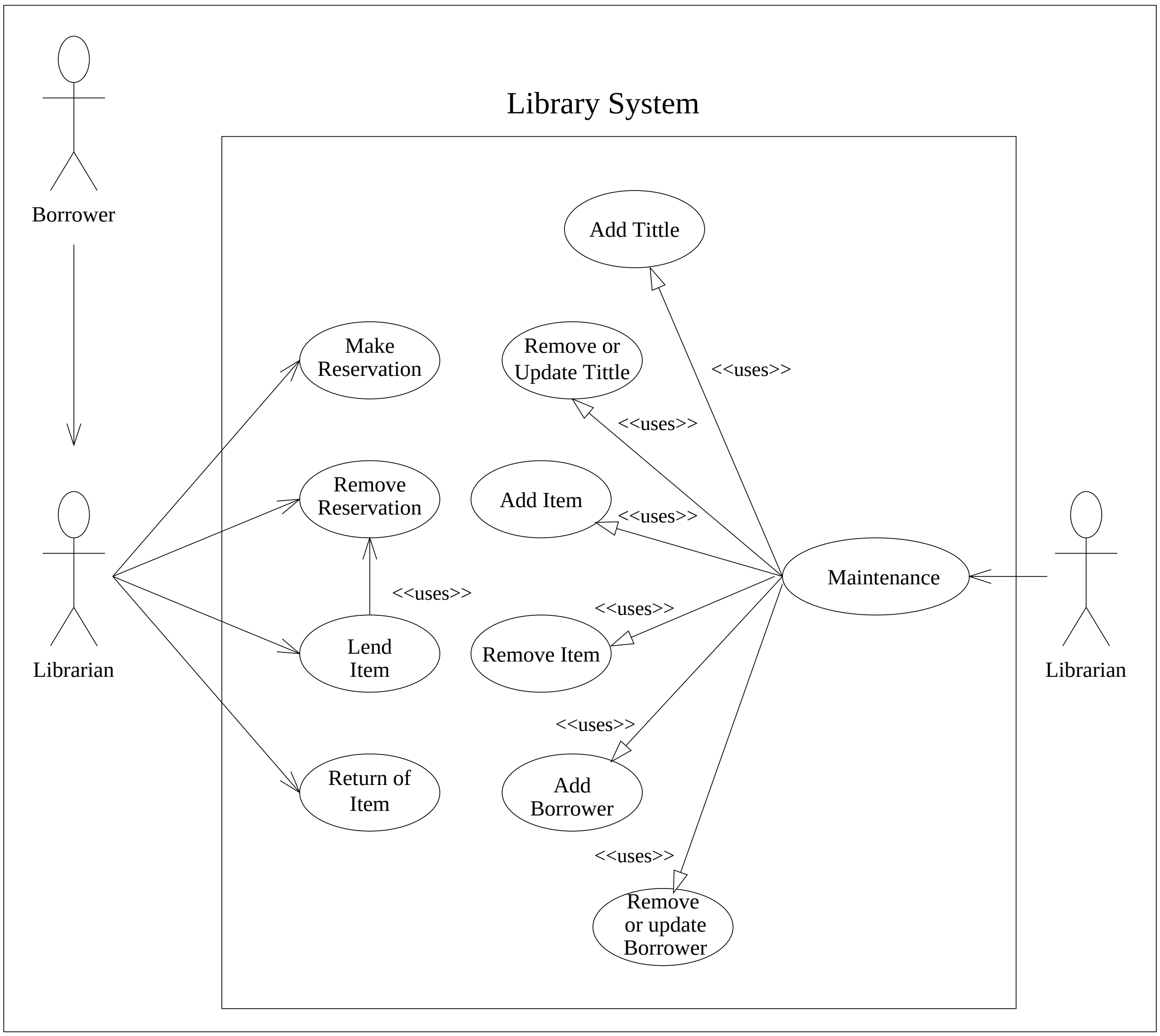
Different Steps in the Process

- **Analysis**: capture and describe all the requirements of the system, and to create a model that defines the key domain classes
  - Requirements Analysis: Use-case Diagrams
  - Domain Analysis: Class Diagrams, Interaction Diagrams, State Machines
- **Design**: Specify a working solution that can be transformed into programming code
  - Architectural Design
  - Detailed Design
- **Implementation**: Develop or generate the code
- **Test and Deployment**

Requirements Analysis

- Use cases describe what the library system provides in terms of functionality
- Actors: Librarians, Borrowers
- Use cases:
  - Lend Item
  - Return Item
  - Make Reservation
  - Remove Reservation
  - Add Title
  - Update or Remove Title
  - Add Item
  - Remove Item
  - Add Borrower
  - Update or Remove Borrower
  - Maintenance
- Each use-case is documented with text

Use Case Diagram



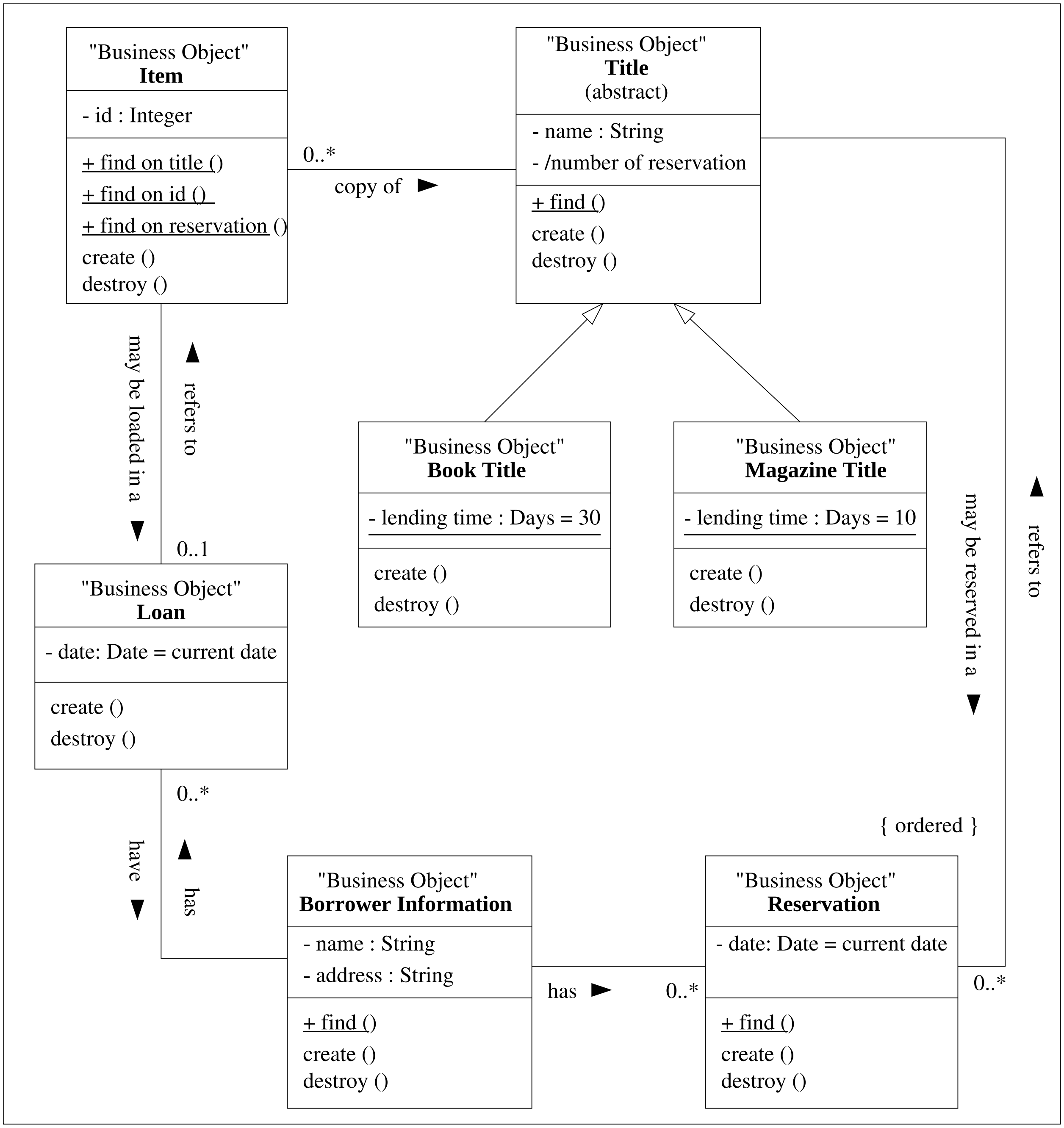
Use Case: Lending Item

1. If the borrower has no reservation:
   - A title is identified
   - An available item of the title is identified
   - The borrower is identified
   - The library lends the item
   - A new loan is registered
2. If the borrower has a reservation:
   - The borrower is identified
   - The title is identified
   - An available item of the title is identified
   - The library lends the item
   - The reservation is removed

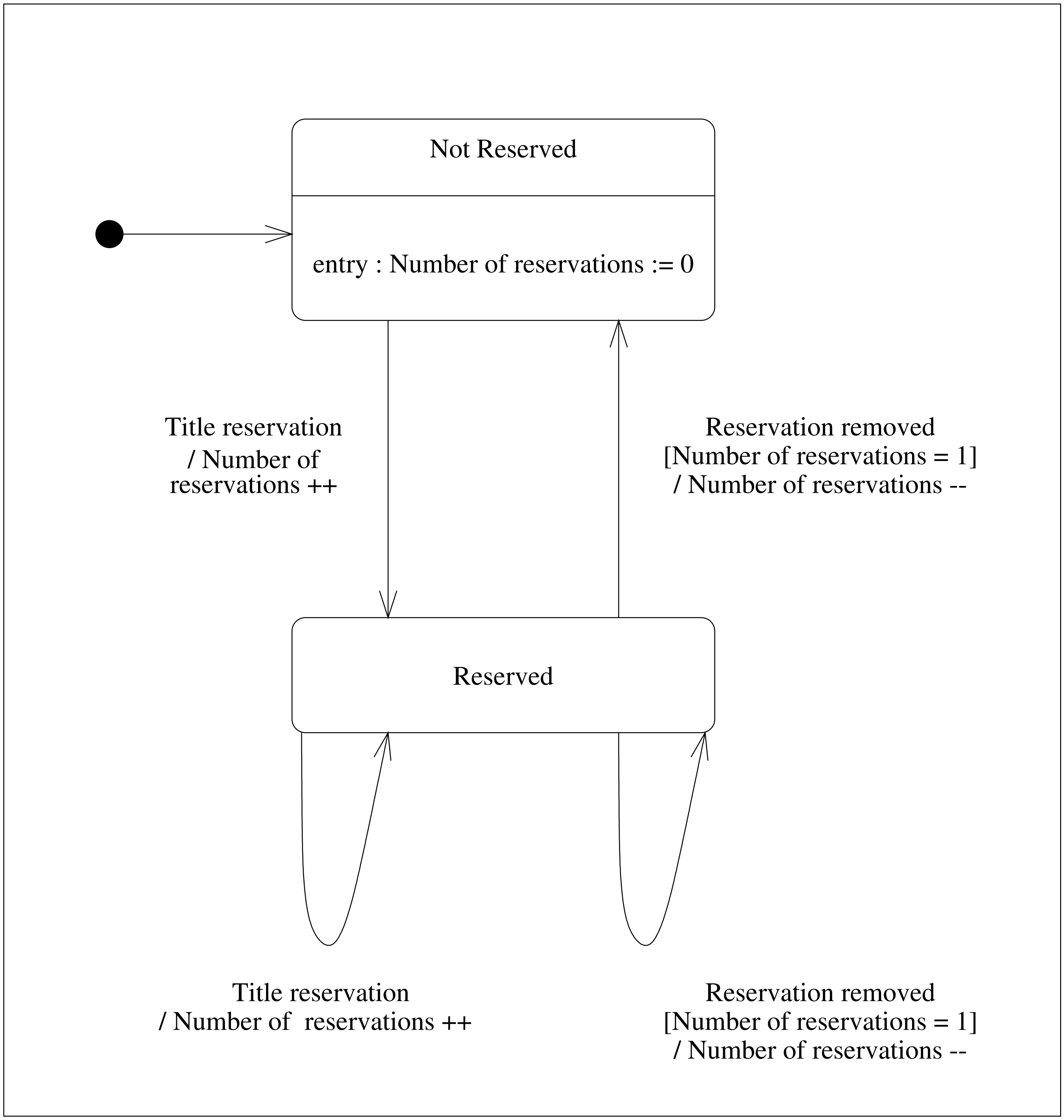
Domain Analysis

- Identify the classes from the specifications and the use cases
- Domain classes: BorrowerInformation, Title, Book Title, Magazine Title, Item, reservation, and Loan
- The stereotype **Business Object** specifies that the object is a key domain class and should be stored persistently in the system
- Some broad issues regarding GUI may have to be considered during the analysis stage

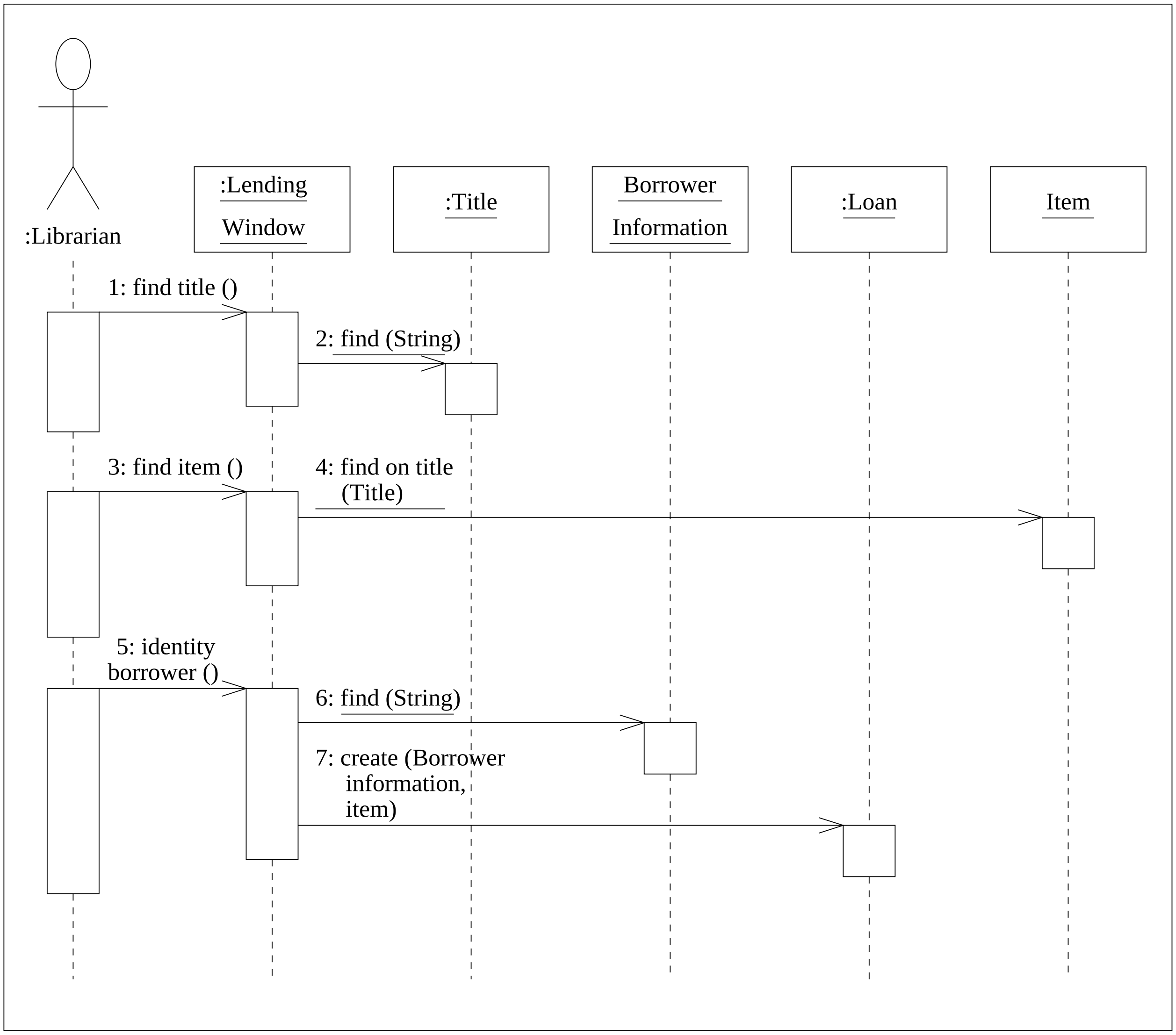
Domain Class Diagram



State Diagram for the Title Class



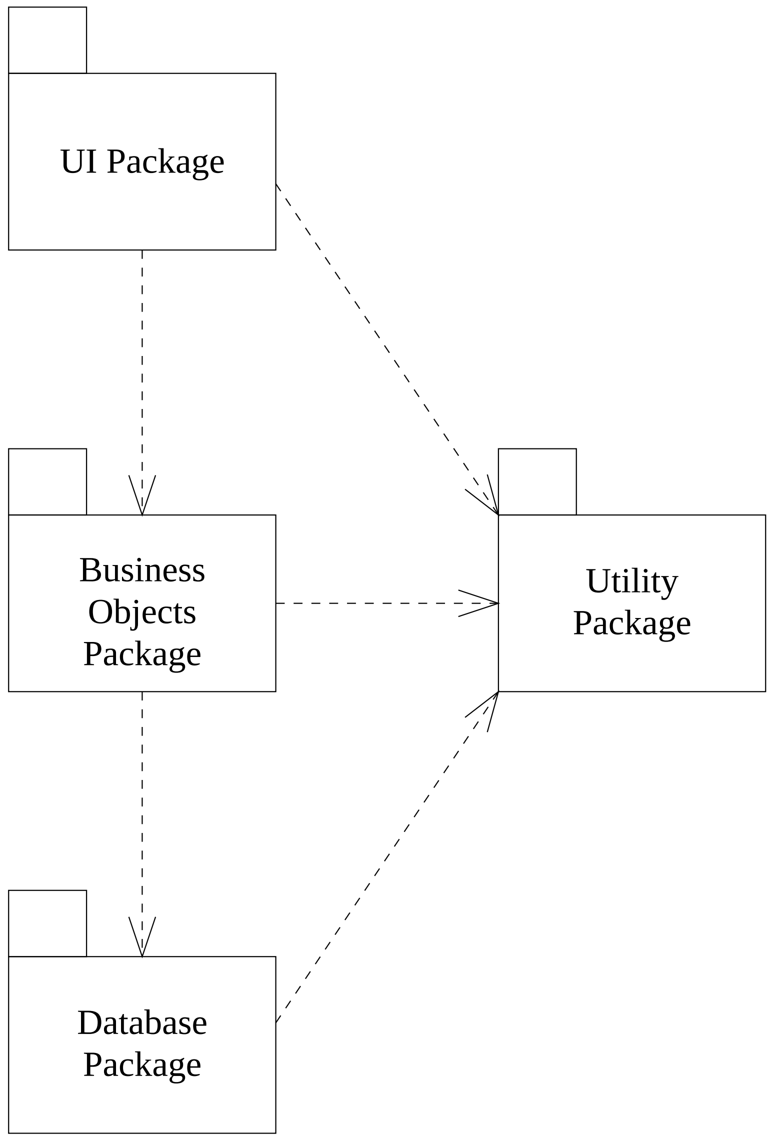
Sequence Diagram for Lend Item Use Case



Architecture Design

- High level design where subsystems (packages) are defined, including dependencies and communication mechanisms between between the packages
- A well-designed architecture is the foundation for an extensible and changeable system
- Packages in the Library System:
  - User Interface Package: based on the Java AWT package
  - Business Objects Package: includes domain classes
  - Database Package: provides persistence to business objects
  - Utility Package: services that are used in other packages

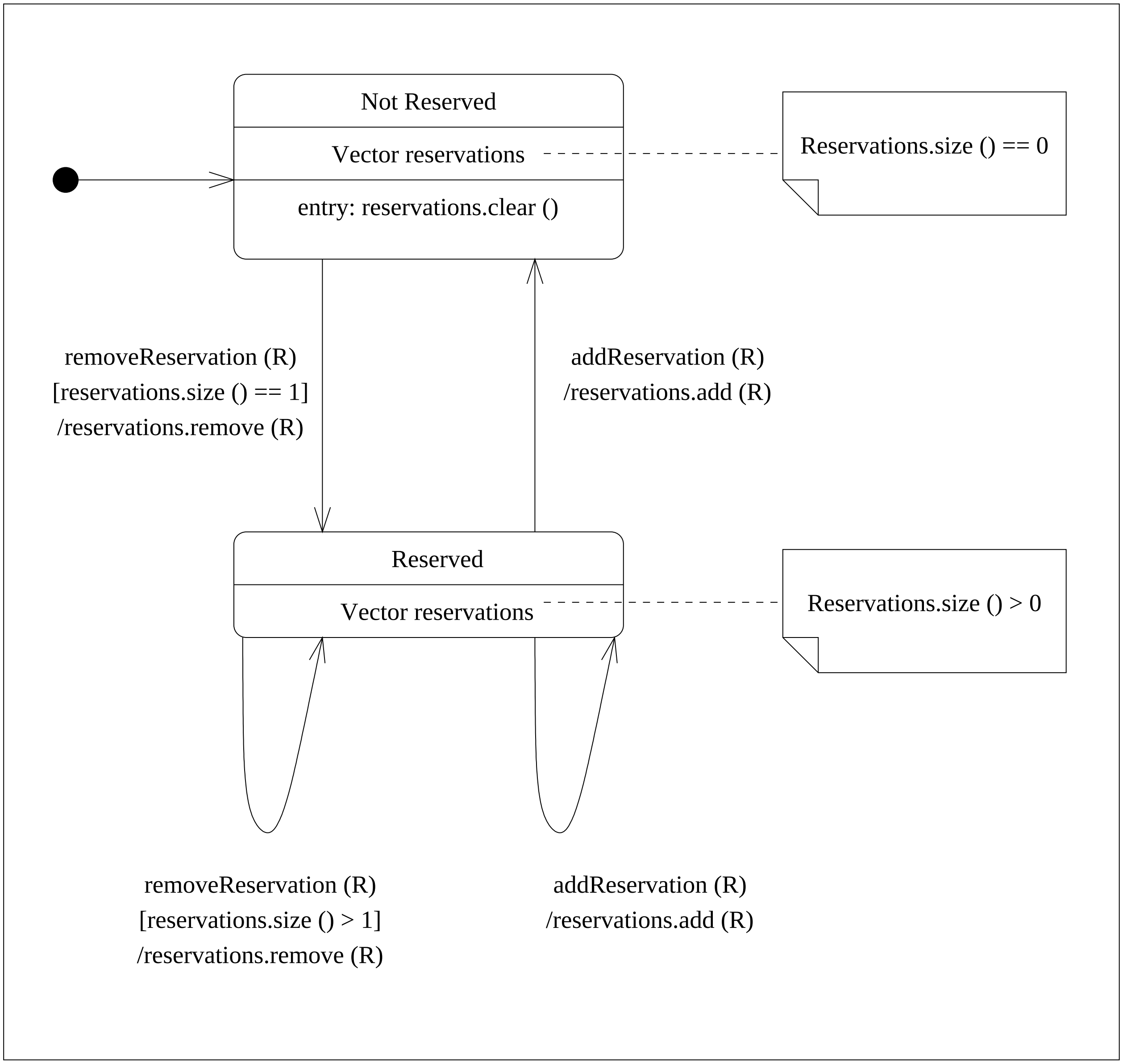
Architectures of Subsystems



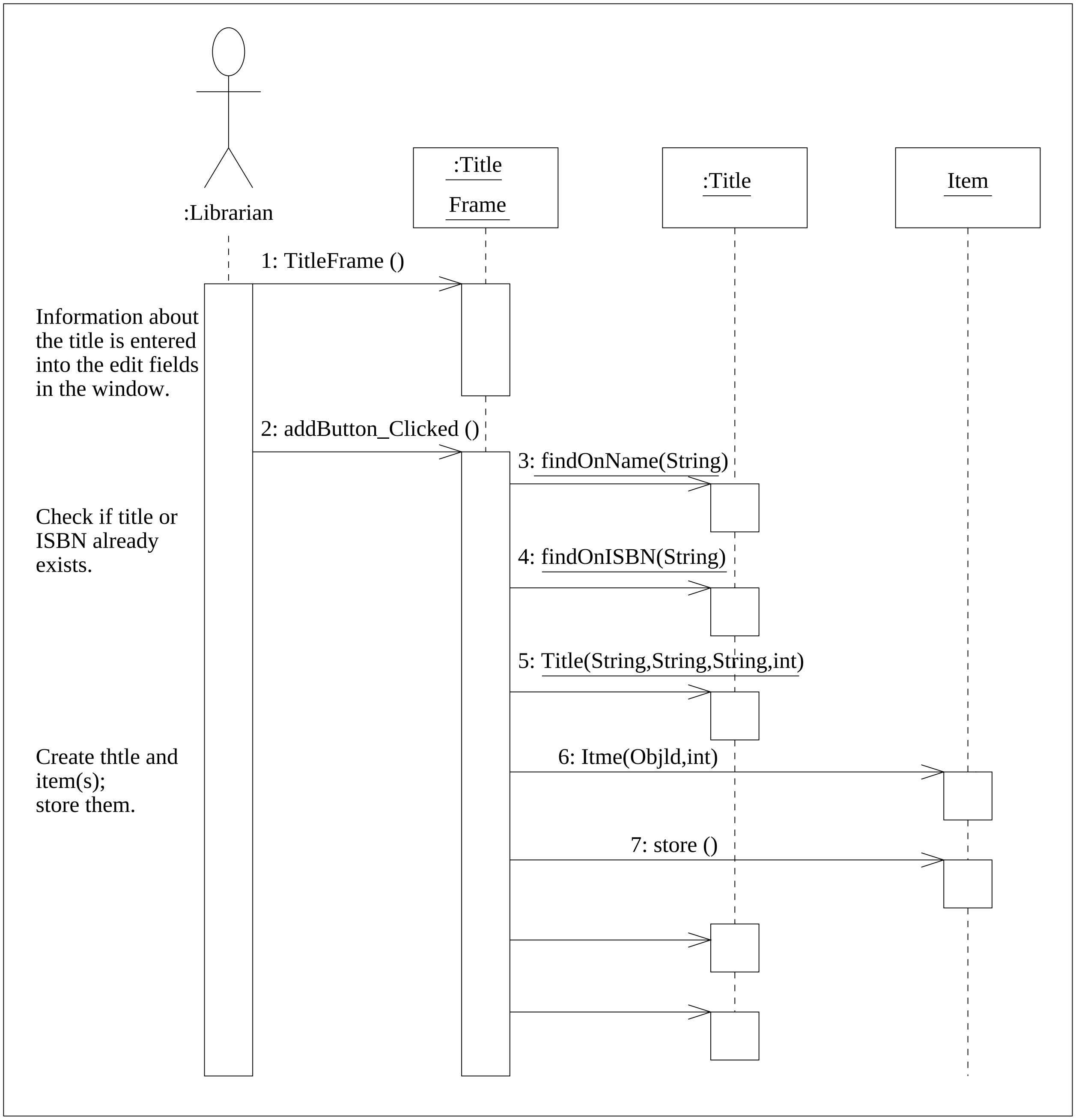
Detailed Design

- Describe the new technical classes; expand and detail the descriptions of business object classes; (through more detailed UML diagrams)
- **Database Package**:
  - *Persistent* is a class that all classes that need persistent objects must inherit
- **Utility Package**:
  - *ObjId* is a class whose objects are used to refer to any persistent object in the system; used by all packages in the system
- **Business Objects Package**:
  - Class descriptions are detailed
  - Diagrams are refined further taking into account design-level details
- **User Interface Package**

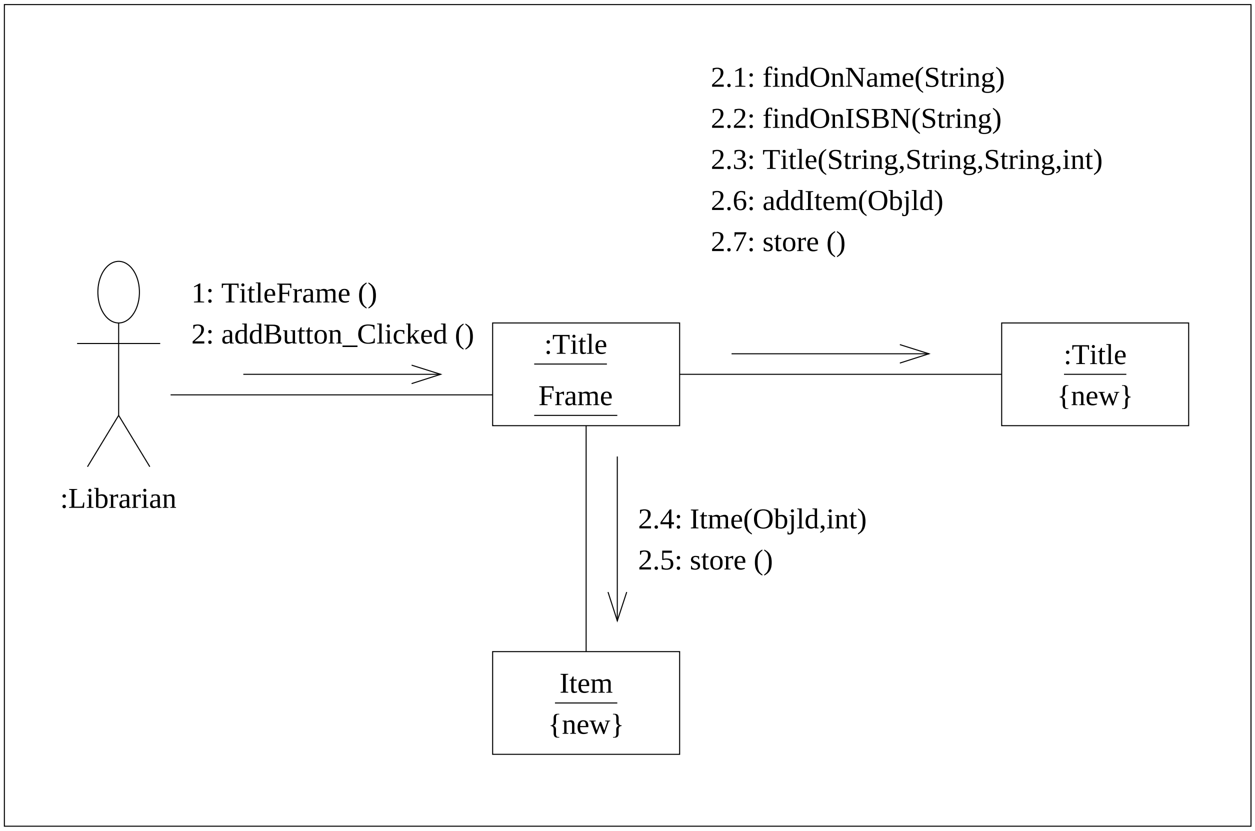
Design State Diagram for Title Class



Design Level Sequence Diagram



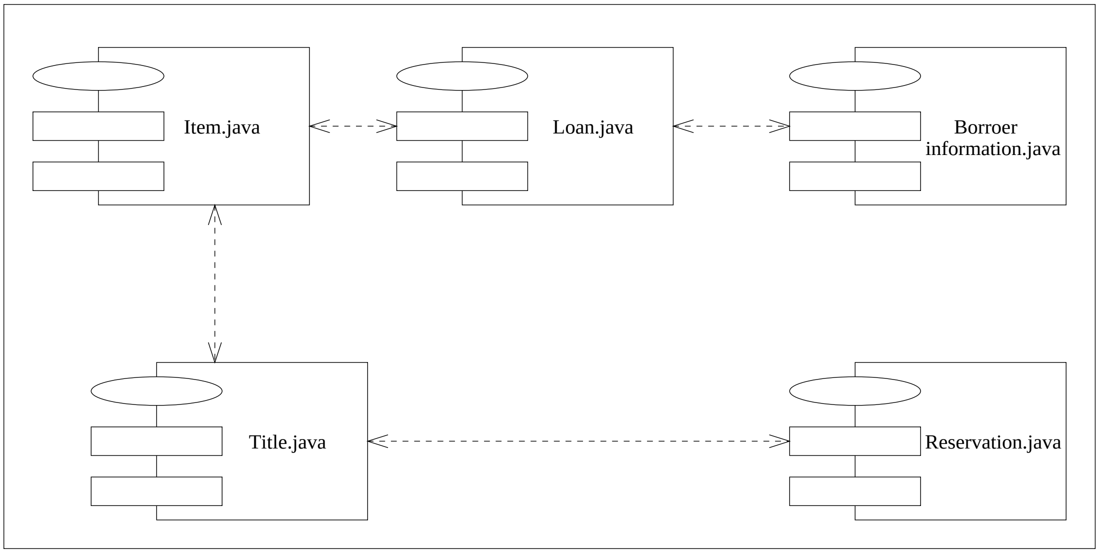
Design Level Collaboration Diagram



User Interface Design

- Windows for functions such as lending and returning items, and making reservations of titles
- Windows for viewing information in the system, about titles and borrowers
- Windows for maintenance functions such as, adding, updating, and removing
- User Interface classes:
  - MainWindow
  - LendingItemFrame
  - CancelReservationFrame
  - ReturnItemFrame
  - ReservationFrame

Component Diagram



Deployment Diagram