Object-Oriented Analysis and Design Using UML

Module 1

Examining Object-Oriented Concepts and Terminology

Objectives

Upon completion of this module, you should be able to:

- Describe the important object-oriented (OO) concepts
- Describe the fundamental OO terminology

Examining Object Orientation

OO concepts affect the whole development process:

- Humans think in terms of nouns (objects) and verbs (behaviors of objects).
- With OOSD, both problem and solution domains are modeled using OO concepts.
- The *Unified Modeling Language* (UML) is a de facto standard for modeling OO software.
- OO languages bring the implementation closer to the language of mental models. The UML is a good bridge between mental models and implementation.

Examining Object Orientation

"Software systems perform certain actions on objects of certain types; to obtain flexible and reusable systems, it is better to base their structure on the objects types than on the actions." (Meyer page vi)

OO concepts affect the following issues:

- Software complexity
- Software decomposition
- Software costs

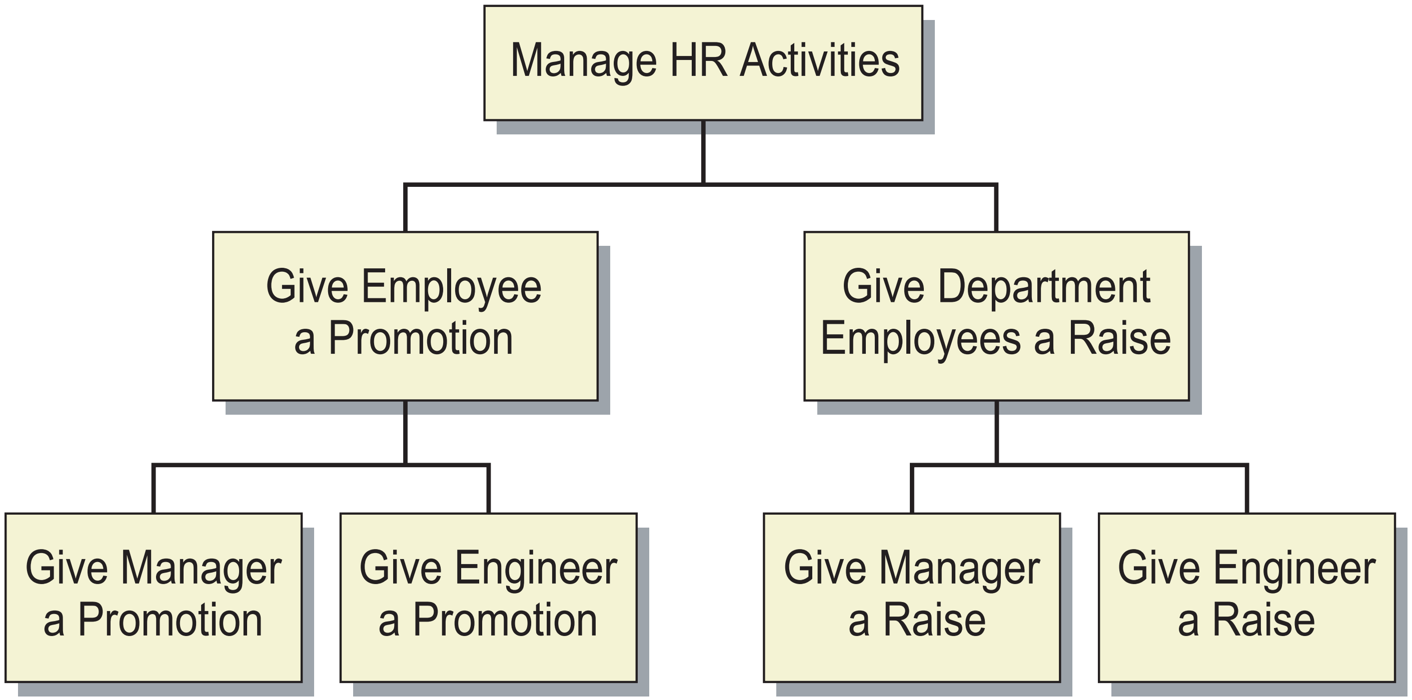
Software Complexity

Complex systems have the following characteristics:

- They have a *hierarchical structure*.
- The choice of *which components are primitive* in the system is arbitrary.
- A system can be split by intra- and inter-component relationships. This *separation of concerns* enables you to study each part in relative isolation.
- Complex systems are usually composed of only a *few types of components in various combinations*.
- A successful, complex system invariably *evolves from a simple working system*.

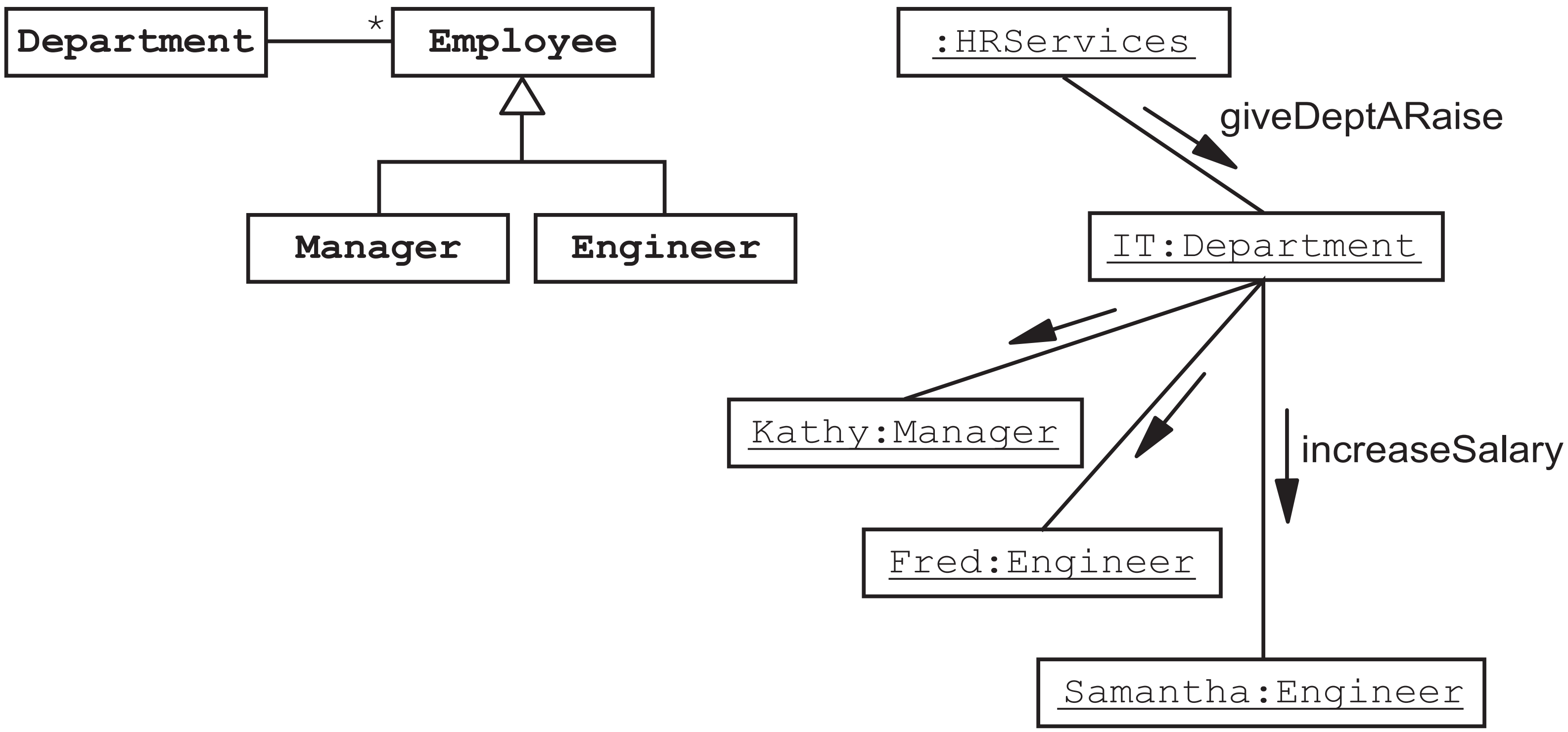
Software Decomposition

In the Procedural paradigm, software is decomposed into a hierarchy of procedures or tasks.



Software Decomposition

In the OO paradigm, software is decomposed into a hierarchy of interacting components (usually objects).



Software Costs

Development:

- OO principles provide a natural technique for modeling business entities and processes from the early stages of a project.
- OO-modeled business entities and processes are easier to implement in an OO language.

Maintenance:

- Changeability, flexibility, and adaptability of software is important to keep software running for a long time.
- OO-modeled business entities and processes can be adapted to new functional requirements.

Comparing the Procedural and OO Paradigms

	Procedural Paradigm	**OO Paradigm**
Organizational structure	Focuses on hierarchy of procedures and subprocedures Data is separate from procedures	Network of collaborating objects Methods (processes) are often bound together with the state (data) of the object
Protection against modification or access	Data is difficult to protect against inappropriate modifications or access when it is passed to or referenced by many different procedures.	The data and internal methods of objects can be protected against inappropriate modifications or access by using encapsulation.

Comparing the Procedural and OO Paradigms

	Procedural Paradigm	**OO Paradigm**
Ability to modify software	Can be expensive and difficult to make software that is easy to change, resulting in many “Brittle” systems	Robust software that is easy to change, if written using good OO principles and patterns
Reuse	Reuse of methods is often achieved by copy-and-paste or 1001 parameters.	Reuse of code by using generic components (one or more objects) with well-defined interfaces. This is achieved by extension of classes (or interfaces) or by composition of objects.

Comparing the Procedural and OO Paradigms

	Procedural Paradigm	**OO Paradigm**
Configuration of special cases	Often requires `if` or `switch` statements. Modification is risky because it often requires altering existing code. So, modifications must be done with extreme care apart from requiring extensive regression testing. These factors make even minor changes costly to implement.	Polymorphic behavior can facilitate the possibility of modifications being primarily additive, subtractive, or substitution of whole components (one or more objects); thereby, reducing the associated risks and costs.

Surveying the Fundamental OO Concepts

- Objects
- Classes
- Abstraction
- Encapsulation
- Inheritance
- Interfaces
- Polymorphism
- Cohesion
- Coupling
- Class associations and object links
- Delegation

Objects

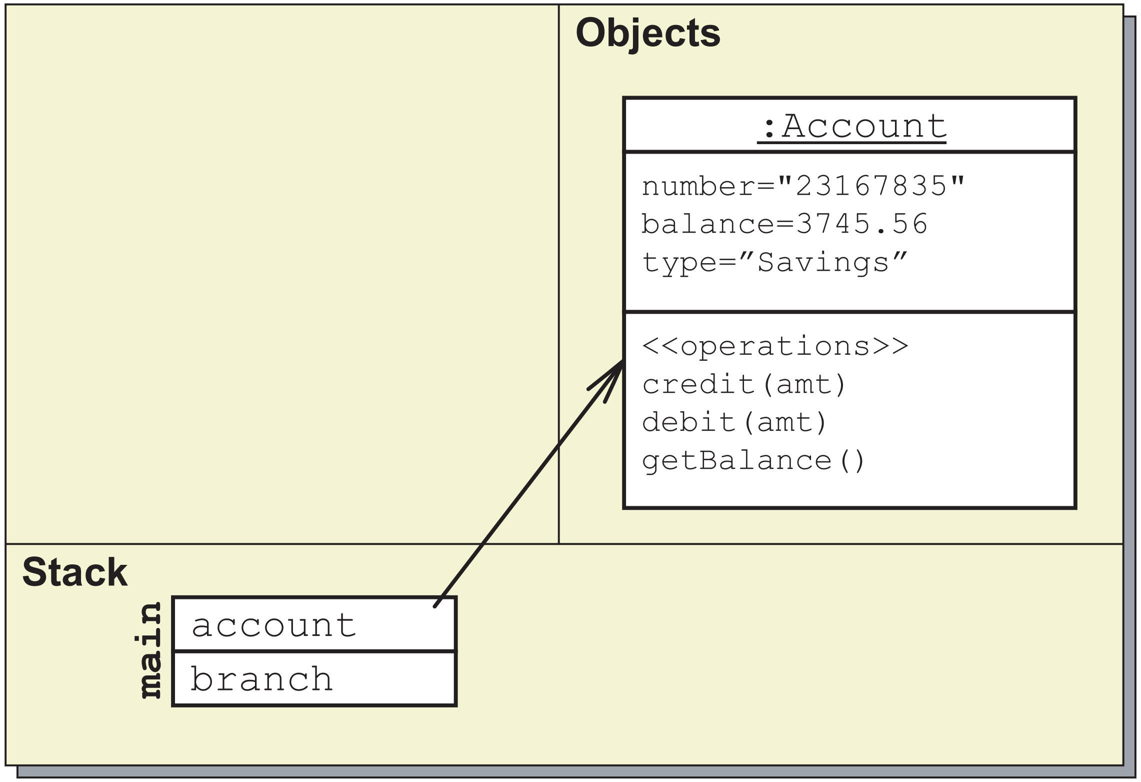
object = state + behavior

“An object has state, behavior, and identity; the structure and behavior of similar objects are defined in their common class.” (Booch Object Solutions page 305)

Objects:

- Have identity
- Are an instance of only one class
- Have attribute values that are unique to that object
- Have methods that are common to the class

Objects: Example



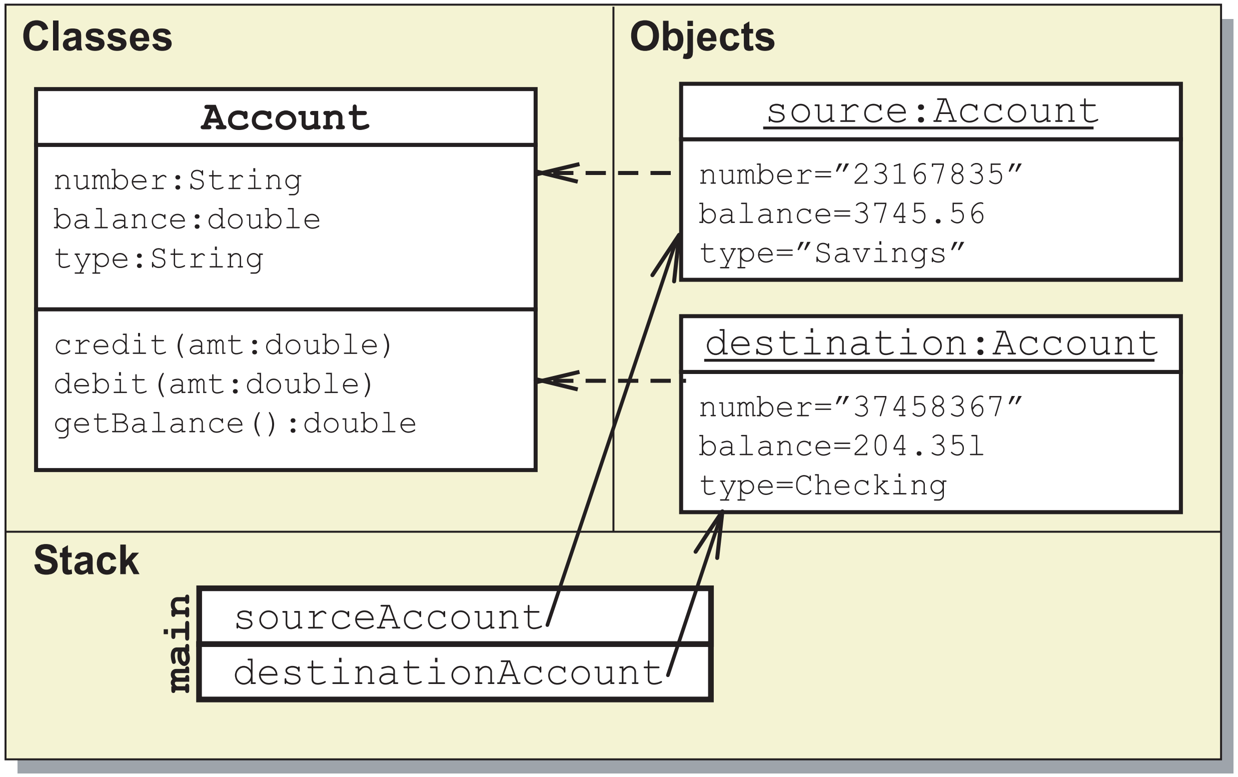
Classes

A class is a blueprint or prototype from which objects are created. (The Java™ Tutorials)

Classes provide:

- The metadata for attributes
- The signature for methods
- The implementation of the methods (usually)
- The constructors to initialize attributes at creation time

Classes: Example



Abstraction

In OO software, the concept of abstraction enables you to create a simplified, but relevant view of a real world object within the context of the problem and solution domains.

- The abstraction object is a representation of the real world object with irrelevant (within the context of the system) behavior and data removed.
- The abstraction object is a representation of the real world object with currently irrelevant (within the context of the view) behavior and data hidden.

Abstraction: Example

Engineer
fname:String lname:String salary:Money
increaseSalary(amt) designSoftware() implementCode()

Engineer
fname:String lname:String salary:Money fingers:int toes:int hairColor:String politicalParty:String
increaseSalary(amt) designSoftware() implementCode() eatBreakfast() brushHair() vote()

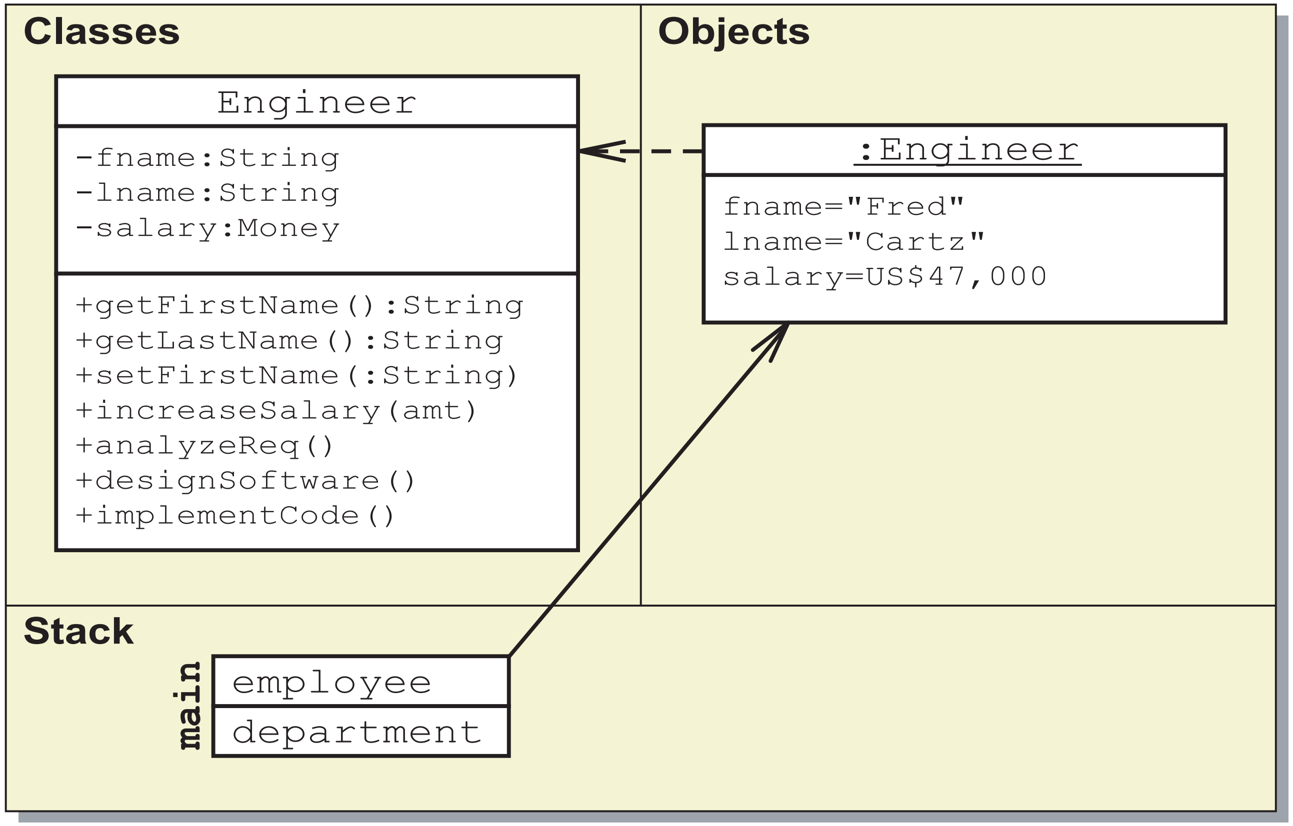
Encapsulation

Encapsulation means "to enclose in or as if in a capsule"
(Webster New Collegiate Dictionary)

Encapsulation is essential to an object. An object is a capsule that holds the object's internal state within its boundary.

In most OO languages, the term encapsulation also includes *information hiding,* which can be defined as: "hide implementation details behind a set of non-private methods".

Encapsulation: Example



✗ `name = employee.fname;`

✗ `employee.fname = "Samantha";`

✓ `name = employee.getFirstName();`

✓ `employee.setFirstName("Samantha");`

Inheritance

Inheritance is “a mechanism whereby a class is defined in reference to others, adding all their features to its own.” (Meyer page 1197)

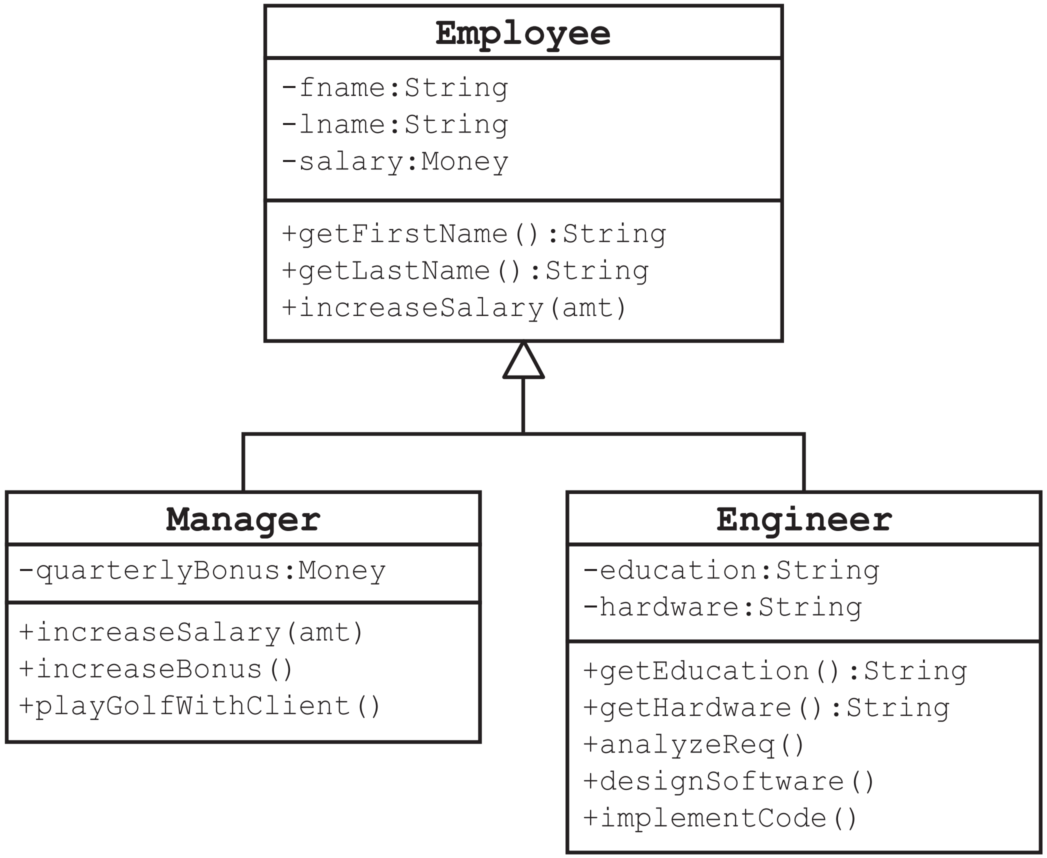
Features of inheritance:

- Attributes and methods from the superclass are included in the subclass.
- Subclass methods can override superclass methods.
- The following conditions must be true for the inheritance relationship to be plausible:
  - A subclass object *is a (is a kind of)* the superclass object.
  - Inheritance should conform to Liskov’s Substitution Principle (LSP).

Inheritance

- Specific OO languages allow either of the following:
  - Single inheritance, which allows a class to directly inherit from only one superclass (for example, Java).
  - Multiple inheritance, which allows a class to directly inherit from one or more superclasses (for example, C++).

Inheritance: Example



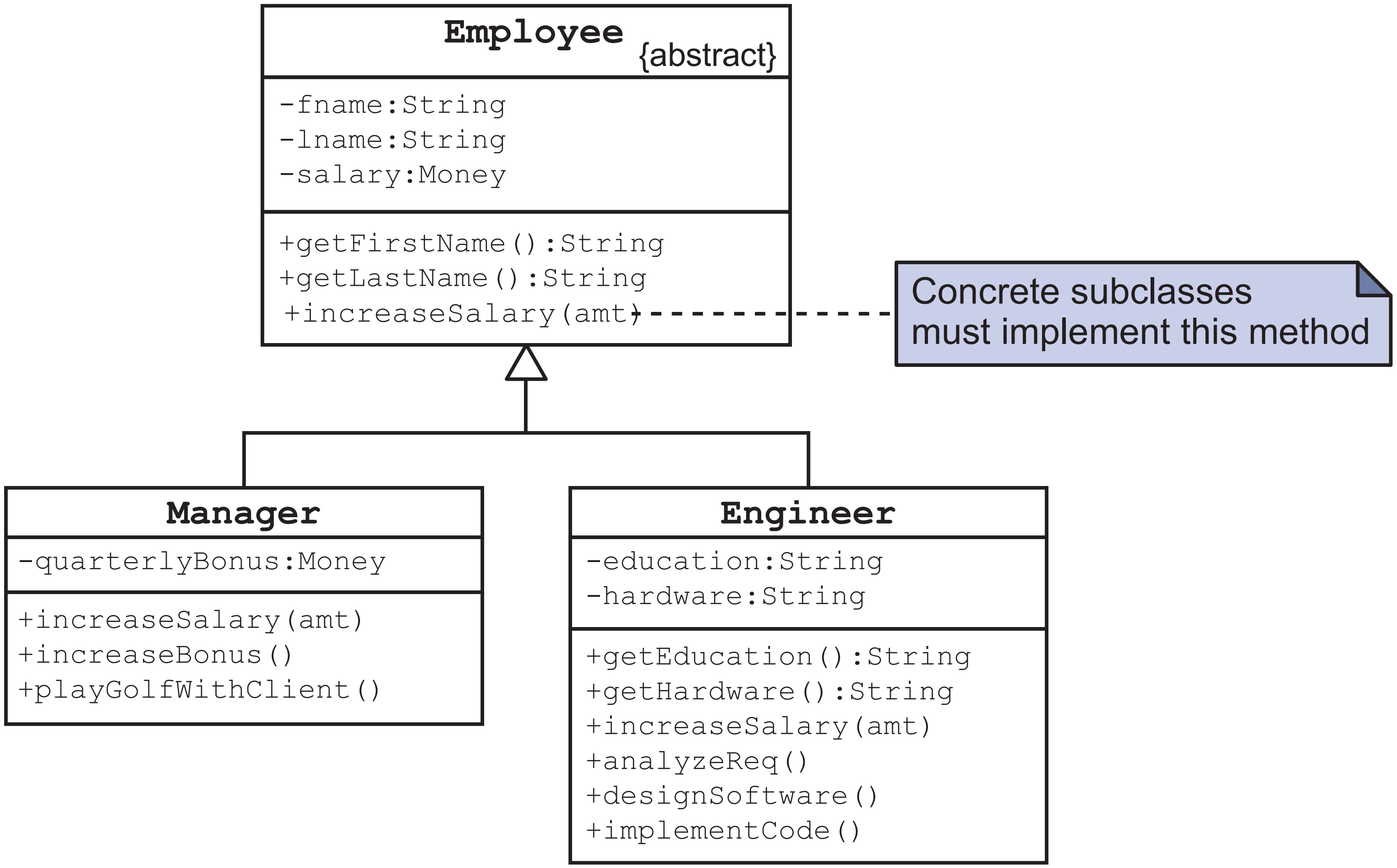
Abstract Classes

A class that contains one or more abstract methods, and therefore can never be instantiated. (Sun Glossary)

Features of an abstract class:

- Attributes are permitted.
- Methods are permitted and some might be declared abstract.
- Constructors are permitted, but no client may directly instantiate an abstract class.
- Subclasses of abstract classes must provide implementations of all abstract methods; otherwise, the subclass must also be declared abstract.
- In the UML, a method or a class is denoted as abstract by using italics, or by appending the method name or class name with `{abstract}`.

Abstract Classes: Example



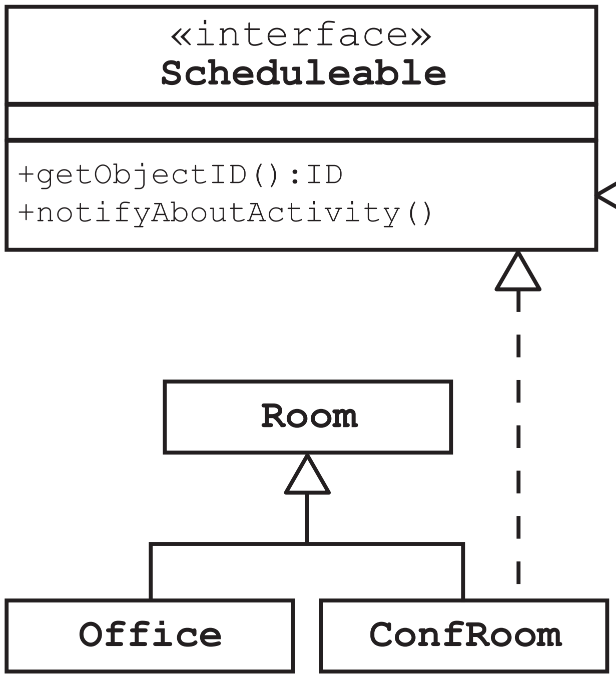
Interfaces

Features of Java technology interfaces:

- Attributes are not permitted (except constants).
- Methods are permitted, but they must be abstract.
- Constructors are not permitted.
- Subinterfaces may be defined, forming an inheritance hierarchy of interfaces.

A class may implement one or more interfaces.

Interfaces: Example



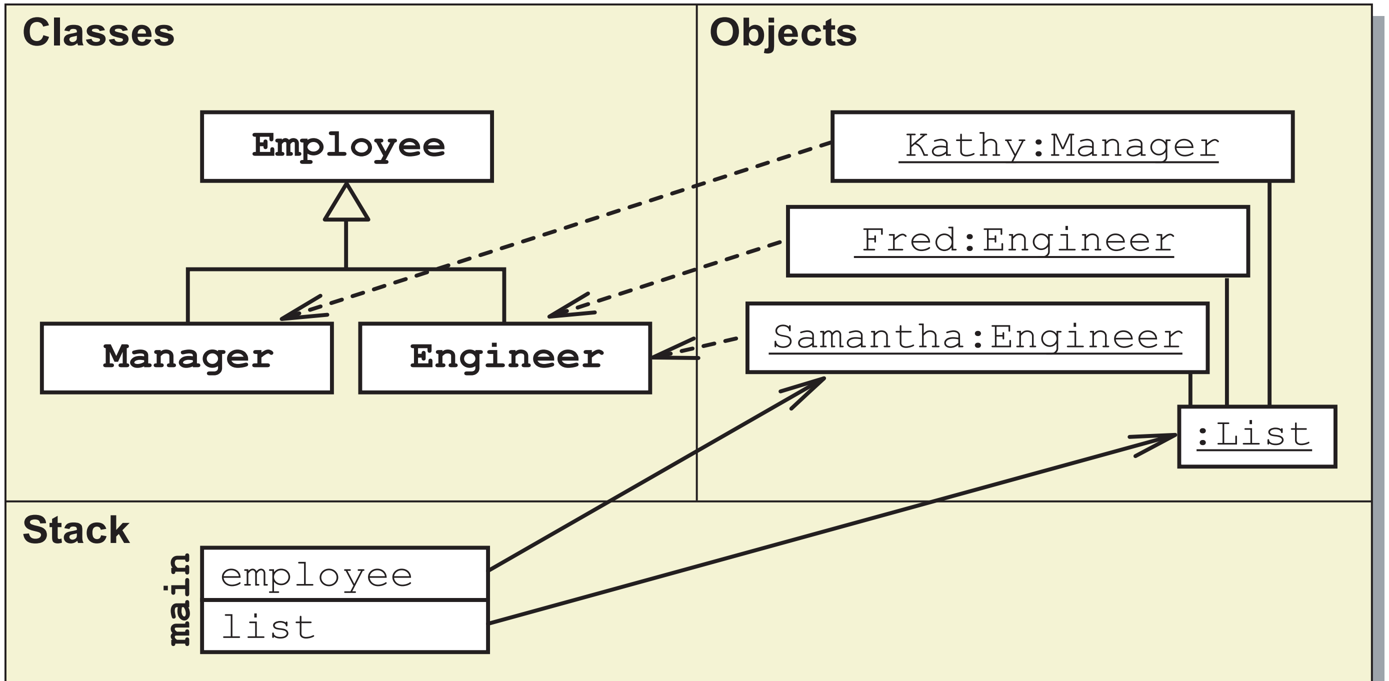
Polymorphism

Polymorphism is "a concept in type theory, according to which a name (such as a variable declaration) may denote objects of many different classes that are related by some common superclass [type]." (Booch OOAD page 517)

Aspects of polymorphism:

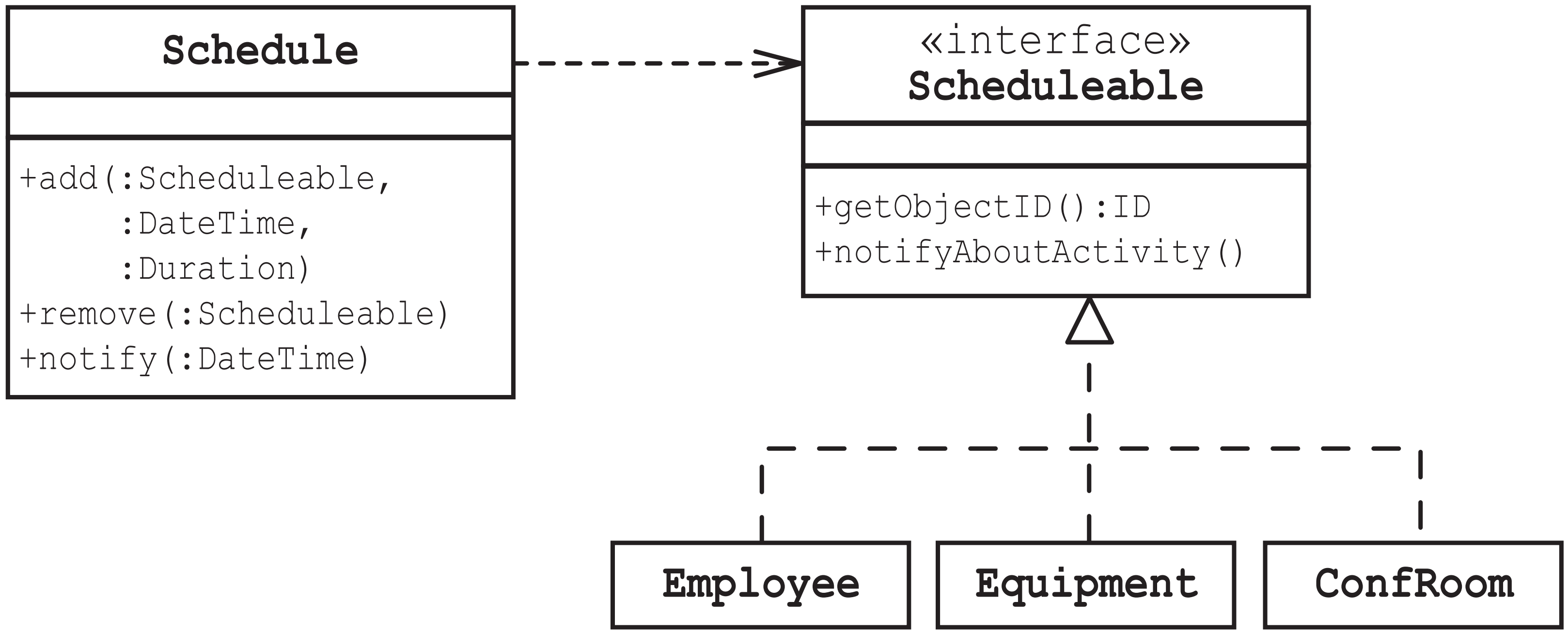
- A variable can be assigned different types of objects at runtime provided they are a subtype of the variable's type.
- Method implementation is determined by the type of object, not the type of the declaration (dynamic binding).
- Only method signatures defined by the variable type can be called without casting.

Polymorphism: Example




```
List list = getProjectTeam();
for ( int i=0; i<list.size(); i++ ) {
  Employee employee = (Employee) list.get(i);
  employee.increaseSalary(0.10); //10%
}
```

Polymorphism: Example

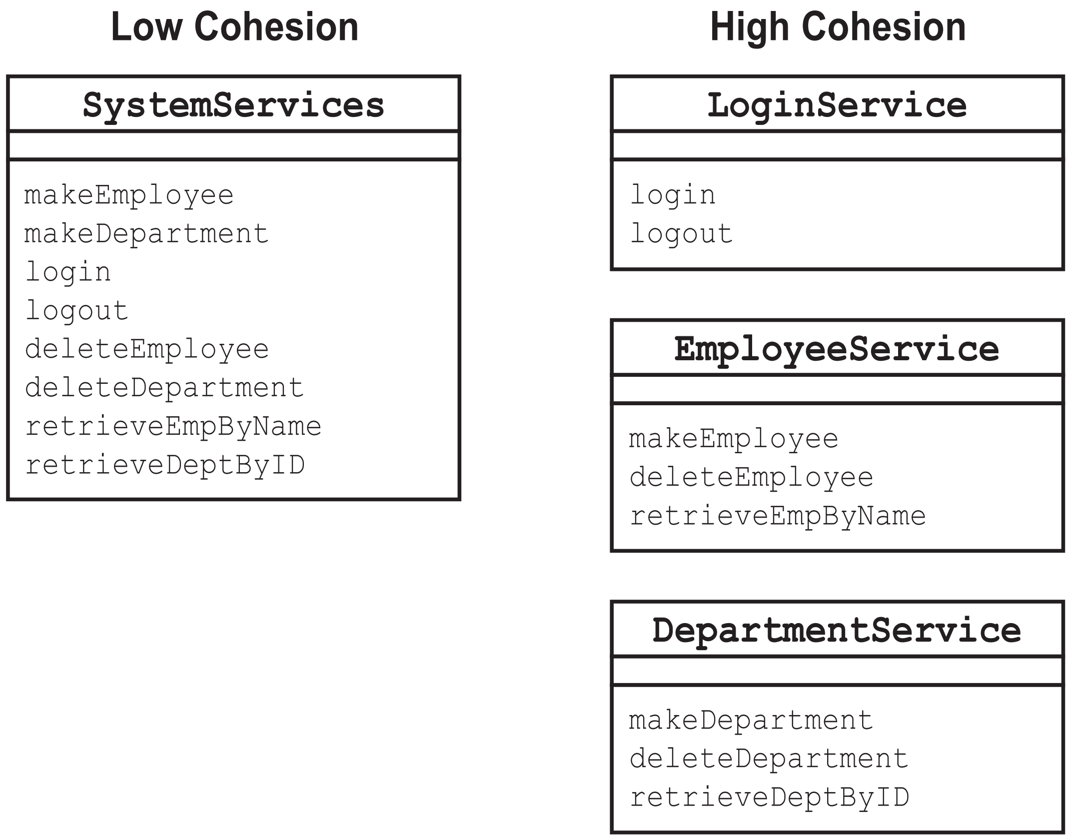


Cohesion

In software, the concept of cohesion refers to how well a given component or method supports a single purpose.

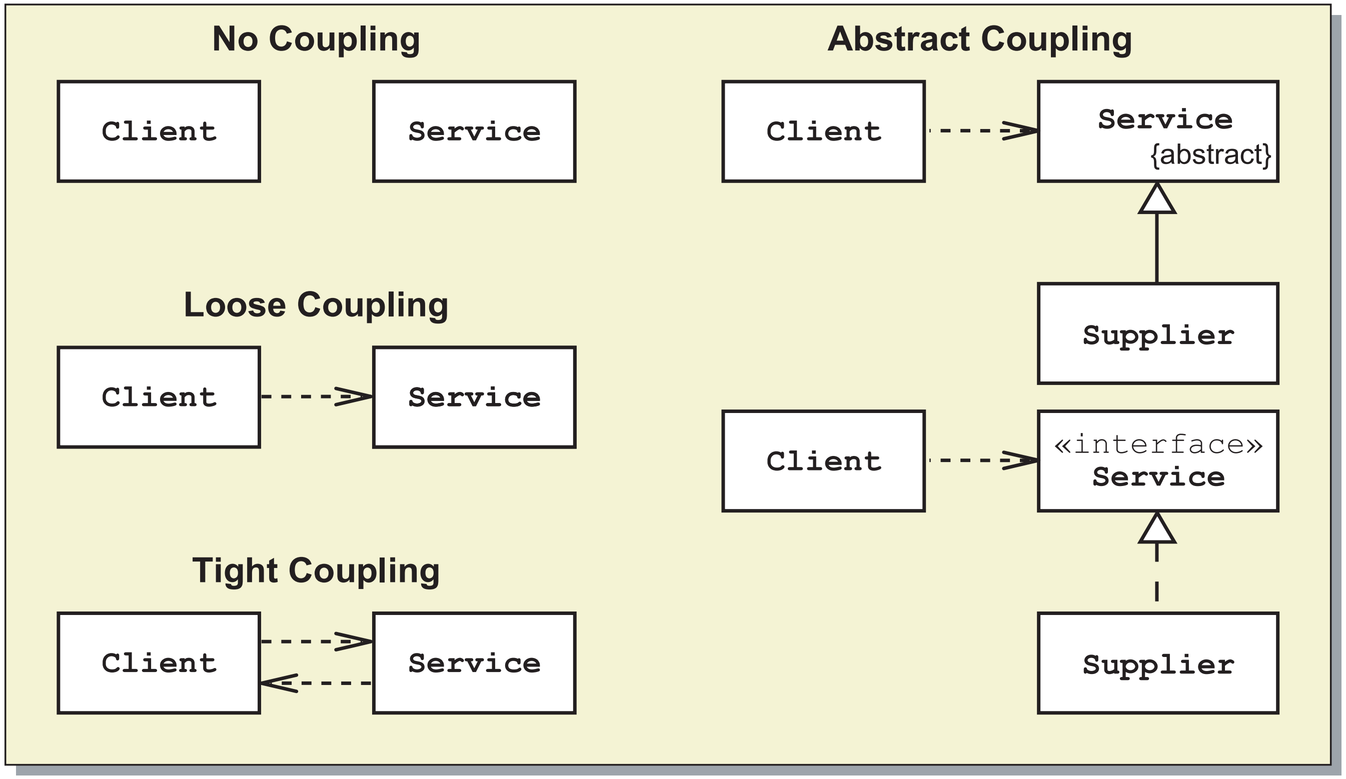
- Low cohesion occurs when a component is responsible for many unrelated features.
- High cohesion occurs when a component is responsible for only one set of related features.
- A component includes one or more classes. Therefore, cohesion applies to a class, a subsystem, and a system.
- Cohesion also applies to other aspects including methods and packages.
- Components that do everything are often described with the Anti-Pattern term of Blob components.

Cohesion: Example



Coupling

Coupling is “the degree to which classes within our system are dependent on each other.” (Knoernschild page 174)



Class Associations and Object Links

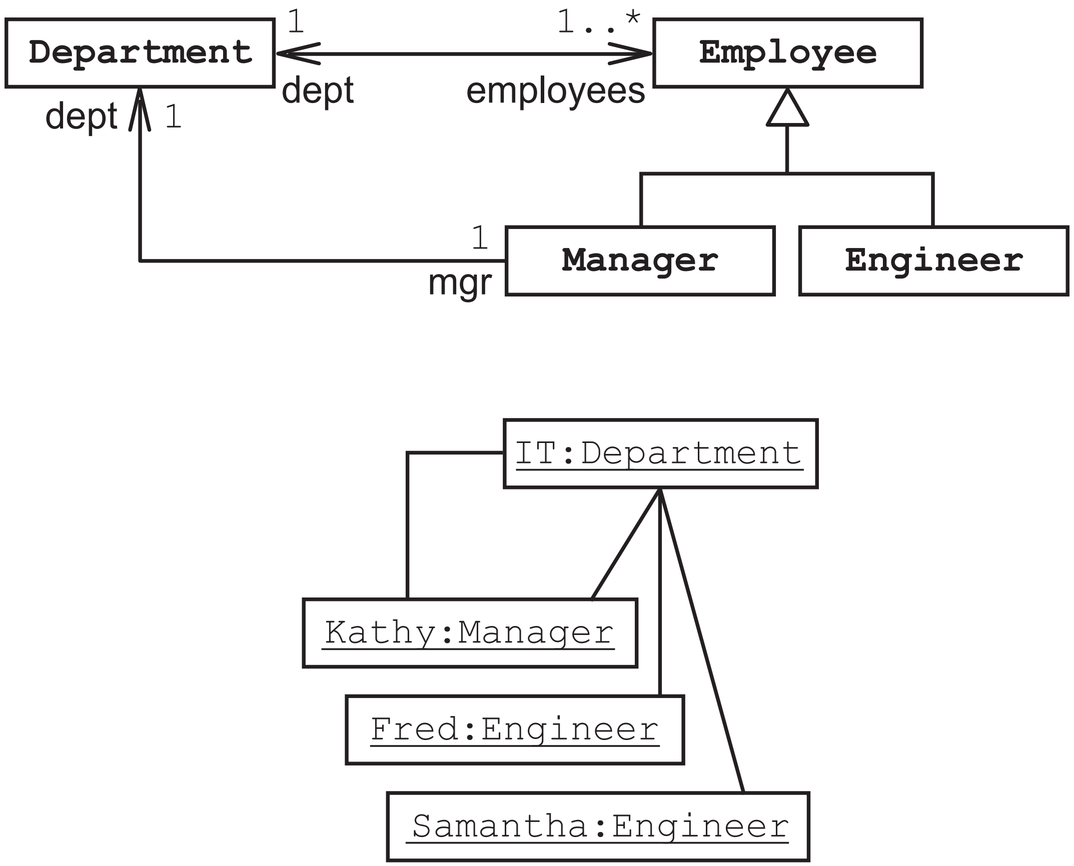
Dimensions of associations include:

- The roles that each class plays
- The multiplicity of each role
  - `1` denotes exactly one
  - `1..*` denotes one or more
  - `0..*` or `*` denotes zero or more
- The direction (or navigability) of the association

Object links:

- Are instances of the class association
- Are one-to-one relationships

Class Associations and Object Links: Example



Delegation

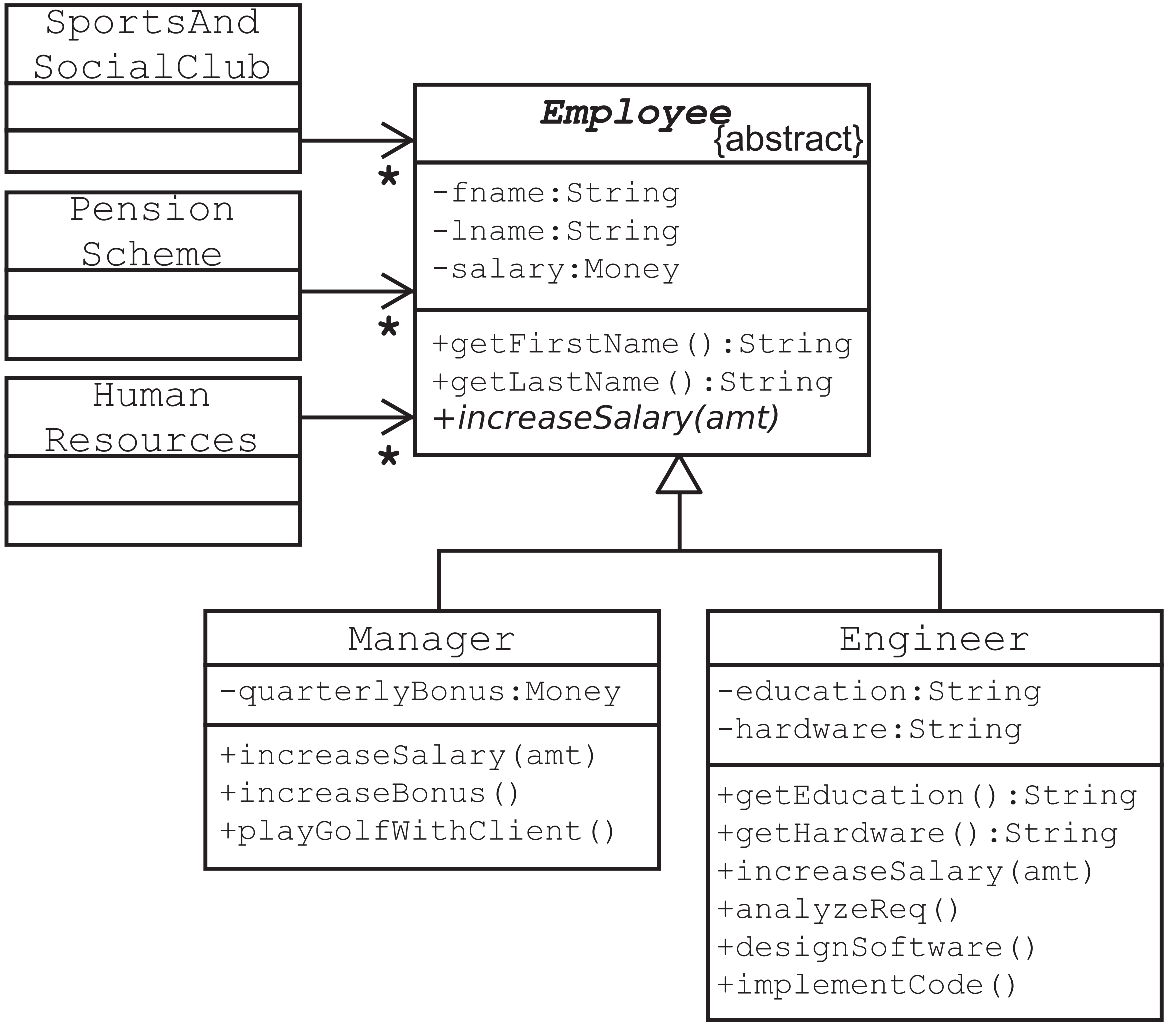
Many computing problems can be easily solved by delegation to a more cohesive component (one or more classes) or method.

- Delegation is similar to how we humans behave.
  - A manager often delegates tasks to an employee with the appropriate skills.
  - You often delegate plumbing problems to a plumber.
  - A car delegates accelerate, brake, and steer messages to its subcomponents, who in turn delegate messages to their subcomponents. This delegation of messages eventually affects the engine, brakes, and wheel direction respectively.
- OO paradigm frequently mimics the real world.

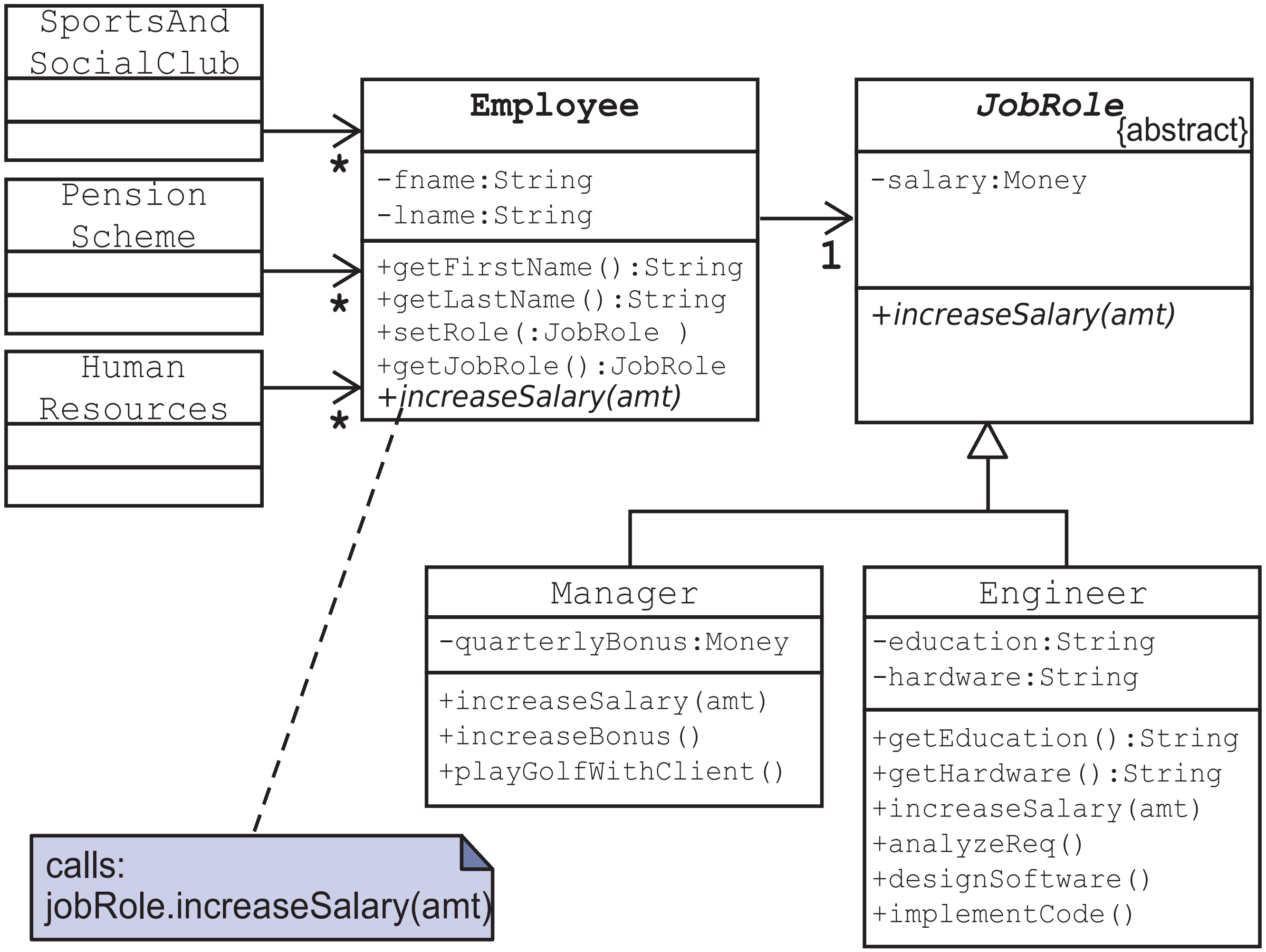
Delegation

- The ways you delegate in OO paradigm include delegating to:
  - A more cohesive linked object
  - A collection of cohesive linked objects
  - A method in a subclass
  - A method in a superclass
  - A method in the same class

Delegation: Example Problem



Delegation: Example Solution



Summary

- Object orientation is a model of computation that is closer to how humans think about problems.
- OO paradigm provides a set of useful concepts.

Module 2

Introducing Modeling and the Software Development Process

Objectives

Upon completion of this module, you should be able to:

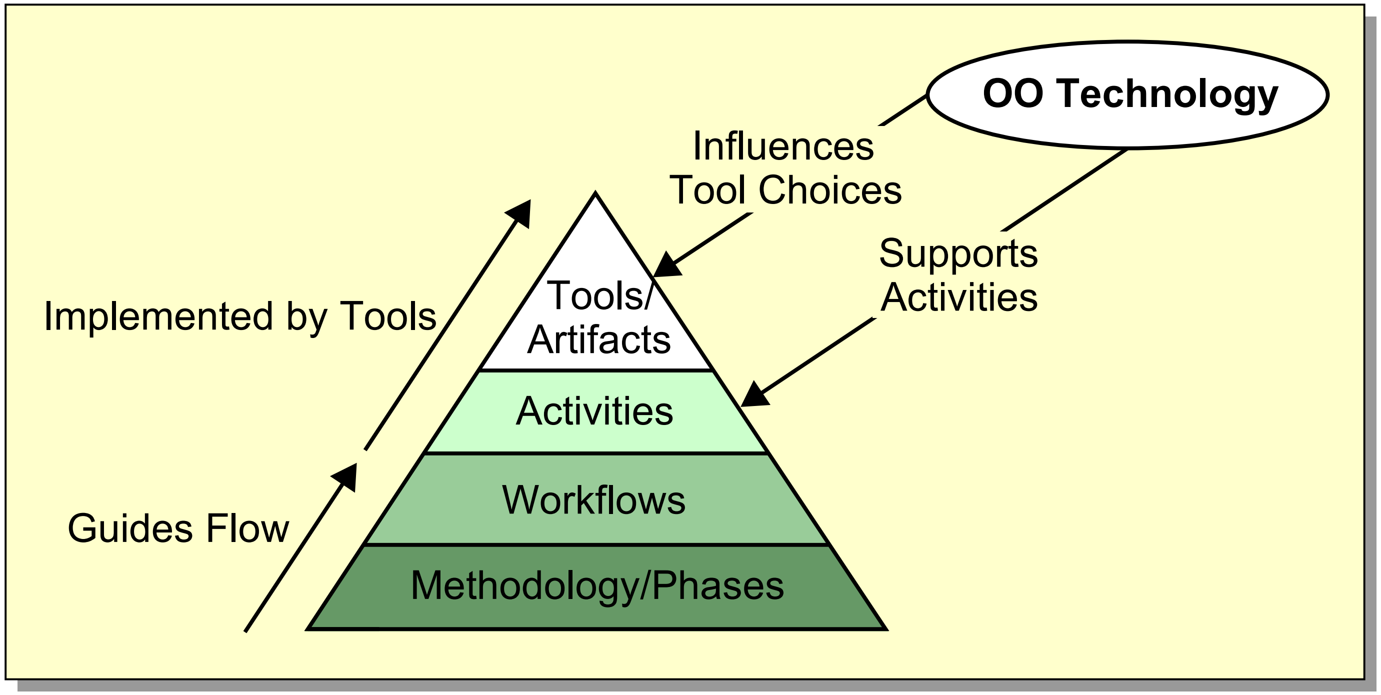
- Describe the Object-Oriented Software Development (OOSD) process
- Describe how modeling supports the OOSD process
- Describe the benefits of modeling software
- Explain the purpose, activities, and artifacts of the following OOSD workflows: Requirements Gathering, Requirements Analysis, Architecture, Design, Implementation, Testing, and Deployment

Describing Software Methodology

A methodology is "a body of methods, rules, and postulates employed by a discipline" [Webster New Collegiate Dictionary]

- In OOSD, methodology refers to the highest-level organization of a software project.
- This organization can be decomposed into medium-level phases. Phases are decomposed into workflows (disciplines). Workflows are decomposed into activities.
- Activities transform the artifacts from one workflow to another. The output of one workflow becomes the input into the next.
- The final artifact is a working software system that satisfies the initial artifacts: the system requirements.

The OOSD Hierarchy



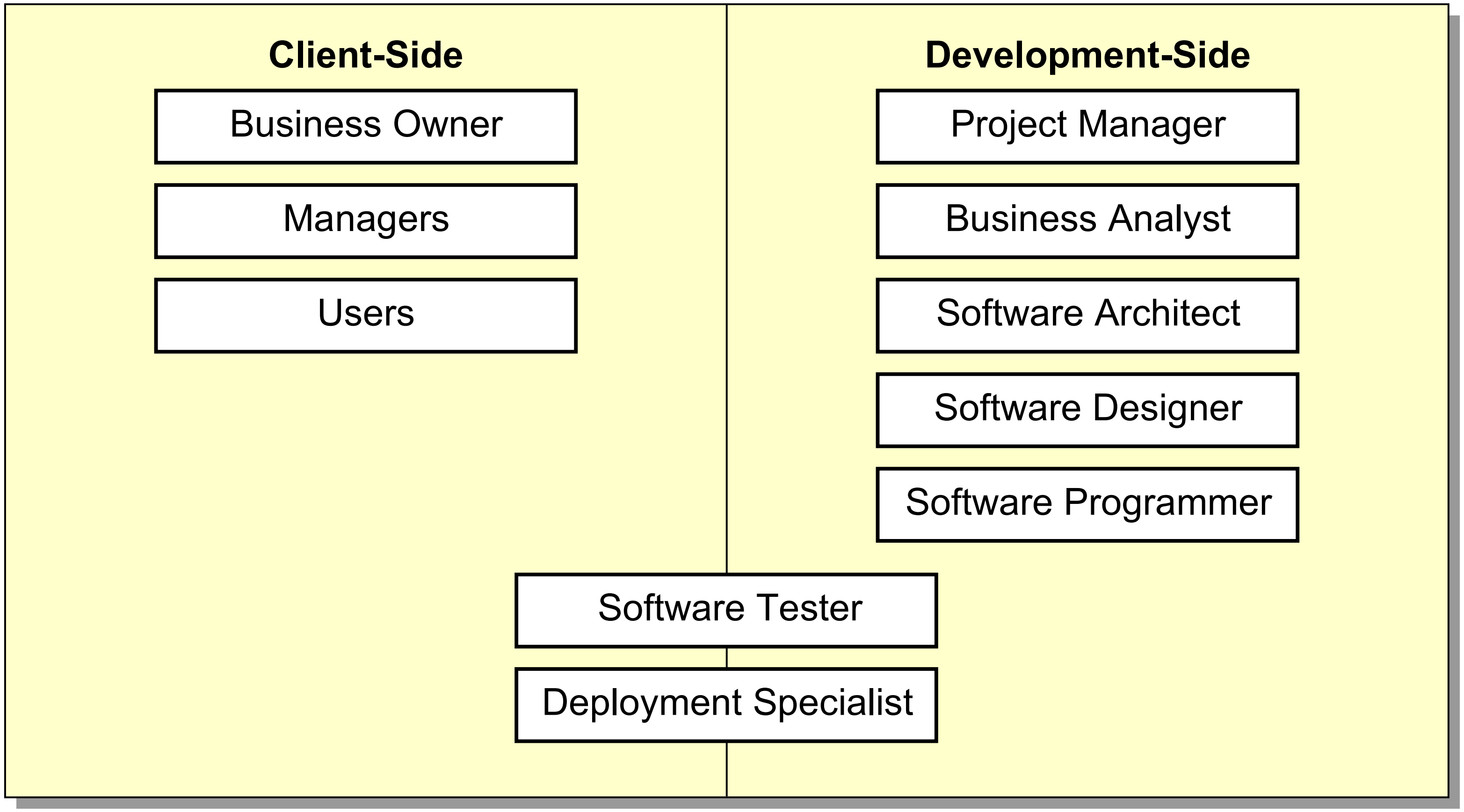
Listing the Workflows of the OOSD Process

Software development has traditionally encompassed the following workflows:

- Requirements Gathering
- Requirements Analysis
- Architecture
- Design
- Implementation
- Testing
- Deployment

Describing the Software Team Job Roles

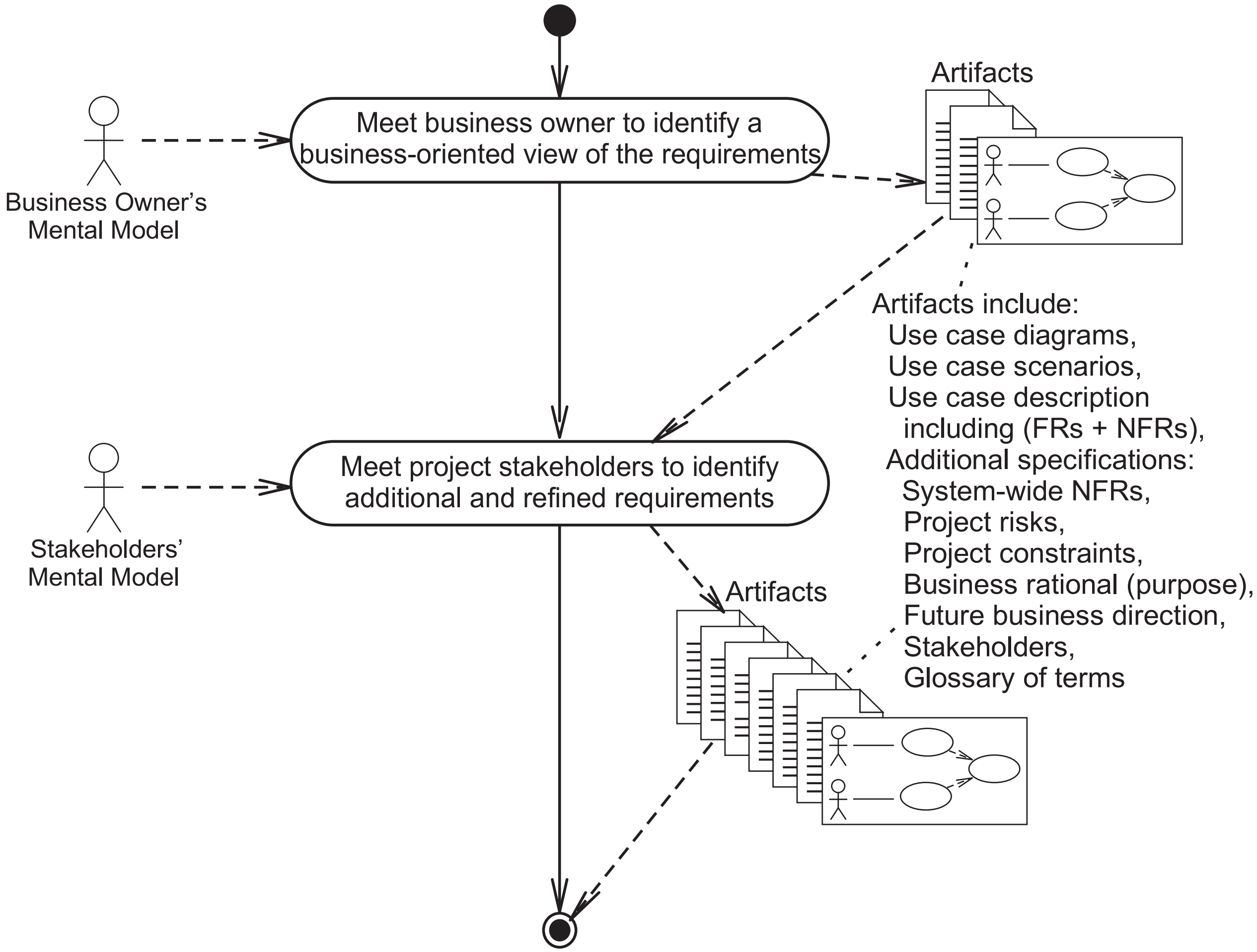
Project Stakeholders



Exploring the Requirements Gathering Workflow

Workflow	**Purpose**	**Description**
Requirements Gathering	Determine *what* the system must do	Determine: • With whom the system interacts (actor) • What behaviors (called use cases) that the system must support • Detailed behavior of each use case, which includes the low-level functional requirements (FRs) • Non-functional requirements (NFRs)

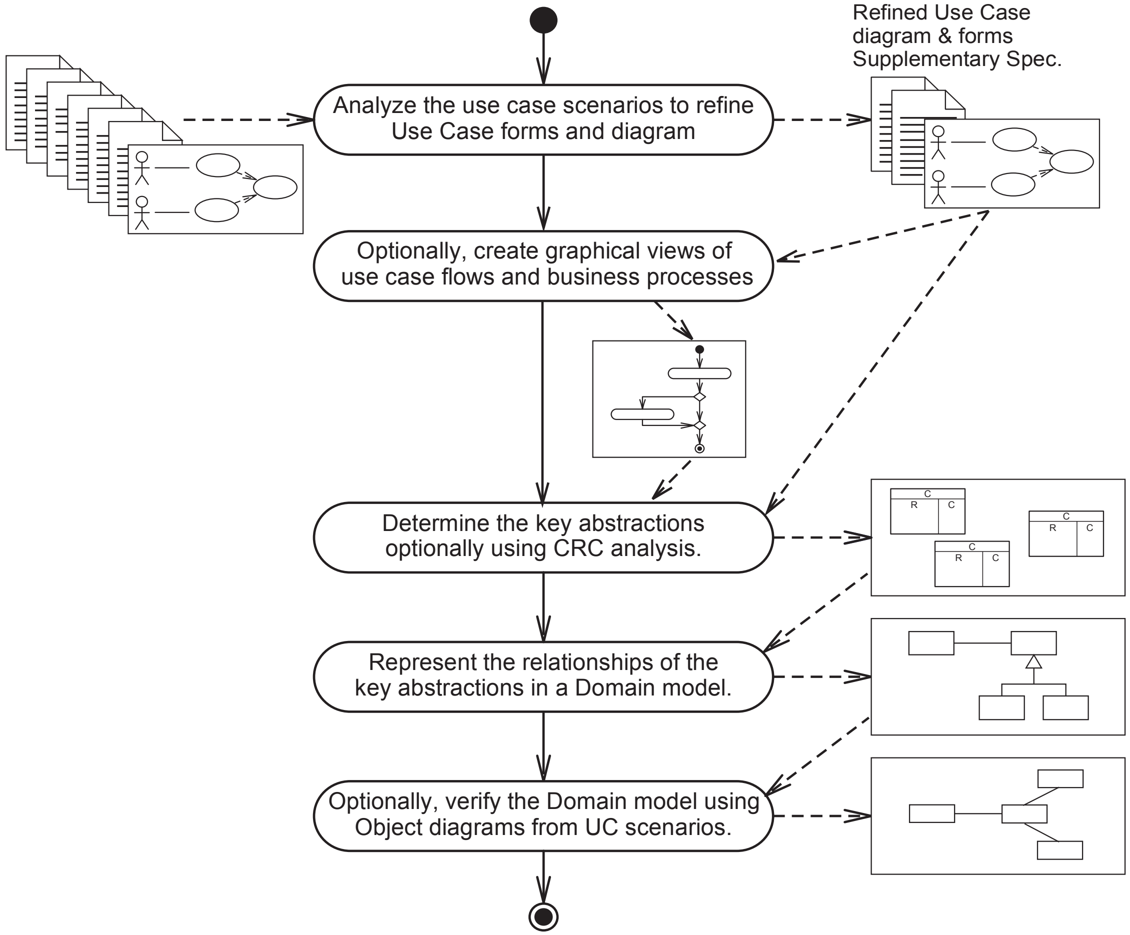
Activities and Artifacts of the Requirements Gathering Workflow



Exploring the Requirements Analysis Workflow

Workflow	**Purpose**	**Description**
Requirements Gathering	Determine *what* the system must do	
Requirements Analysis	Model the existing business processes	Determine: • The detailed behavior of each use case • Supplementary use cases • The key abstractions that exist in the current increment of the problem domain • A business domain class diagram

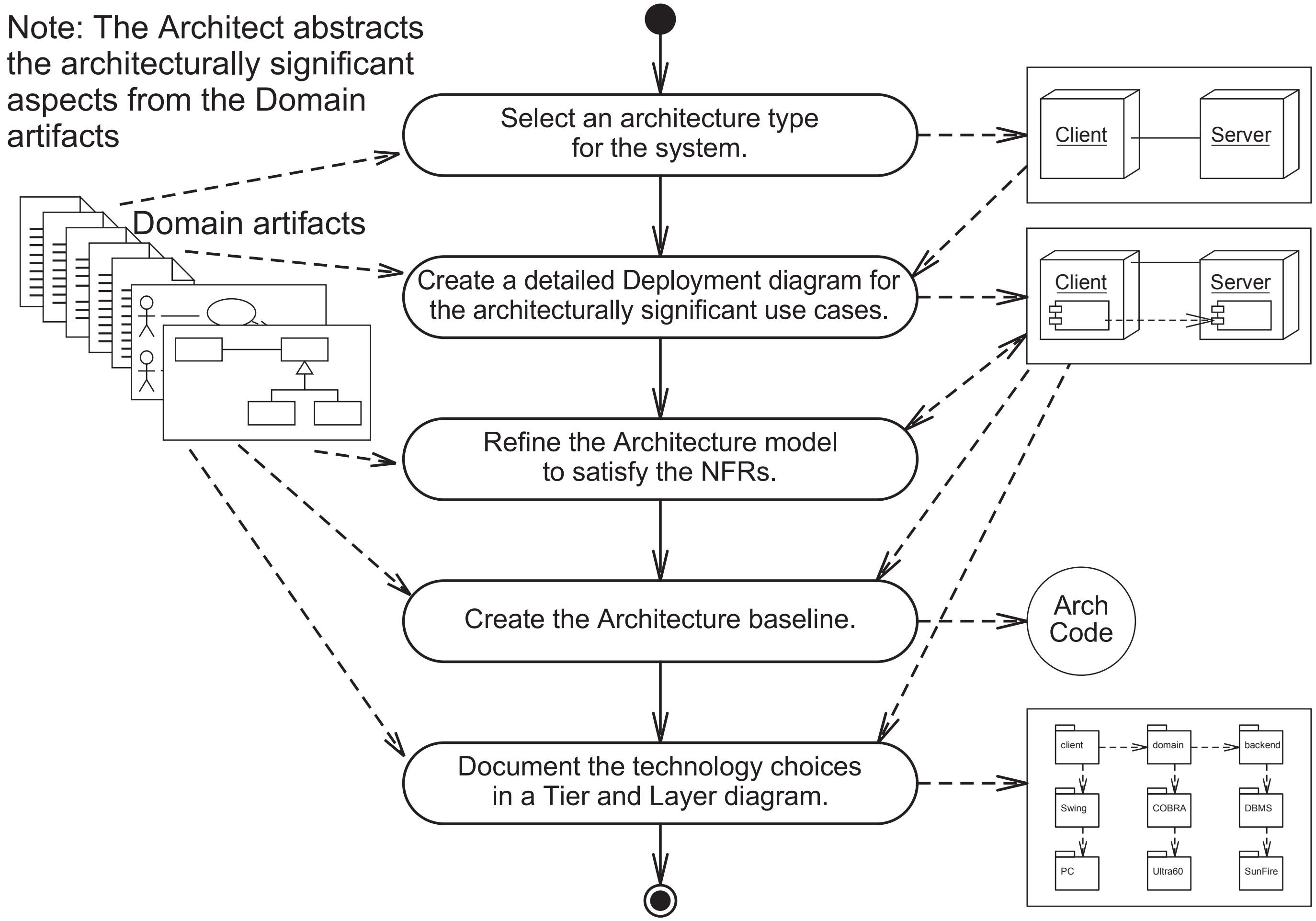
Activities and Artifacts of the Requirements Analysis Workflow



Exploring the Architecture Workflow

Workflow	Purpose	Description
Requirements Gathering	Determine *what* the system must do	
Requirements Analysis	Model the existing business processes	
Architecture	Model the high-level system structure to satisfy the NFRs	• Develop the highest-level structure of the software solution • Identify the technologies that will support the Architecture model • Elaborate the Architecture model with Architectural patterns to satisfy NFRs

Activities and Artifacts of the Architecture Workflow



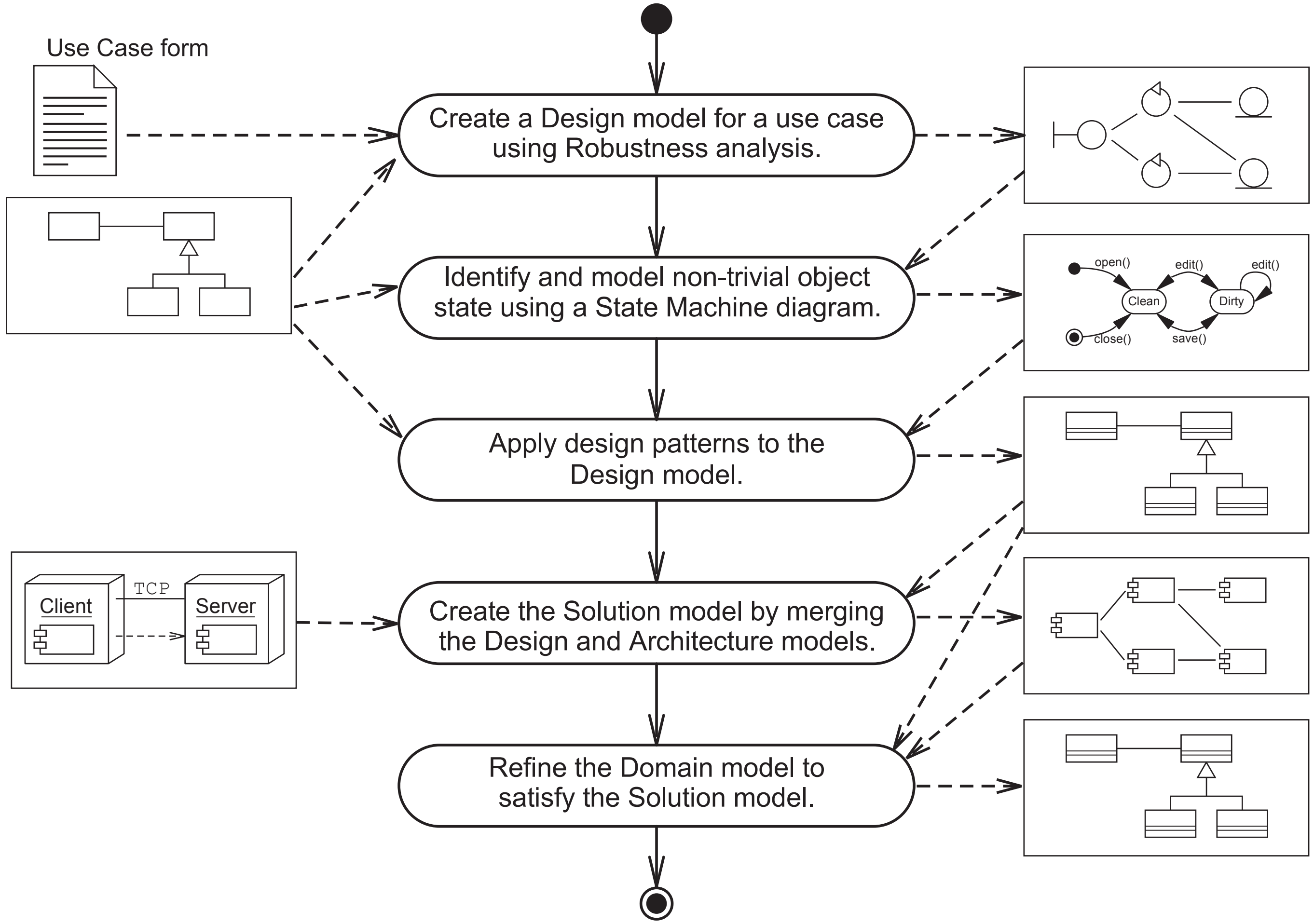
Exploring the Design Workflow

Workflow	**Purpose**	**Description**
Requirements Gathering	Determine *what* the system must do	
Requirements Analysis	Model the existing business processes	
Architecture	Model the high-level system structure to satisfy the NFRs	

Exploring the Design Workflow

Workflow	**Purpose**	**Description**
Design	Model *how* the system will support the use cases	• Create a Design model for a use case using Interaction diagrams • Identify and model objects with non-trivial states using a State Machine diagram • Apply design patterns to the Design model • Create a Solution model by merging the Design and Architecture models • Refine the Domain model

Activities and Artifacts of the Design Workflow



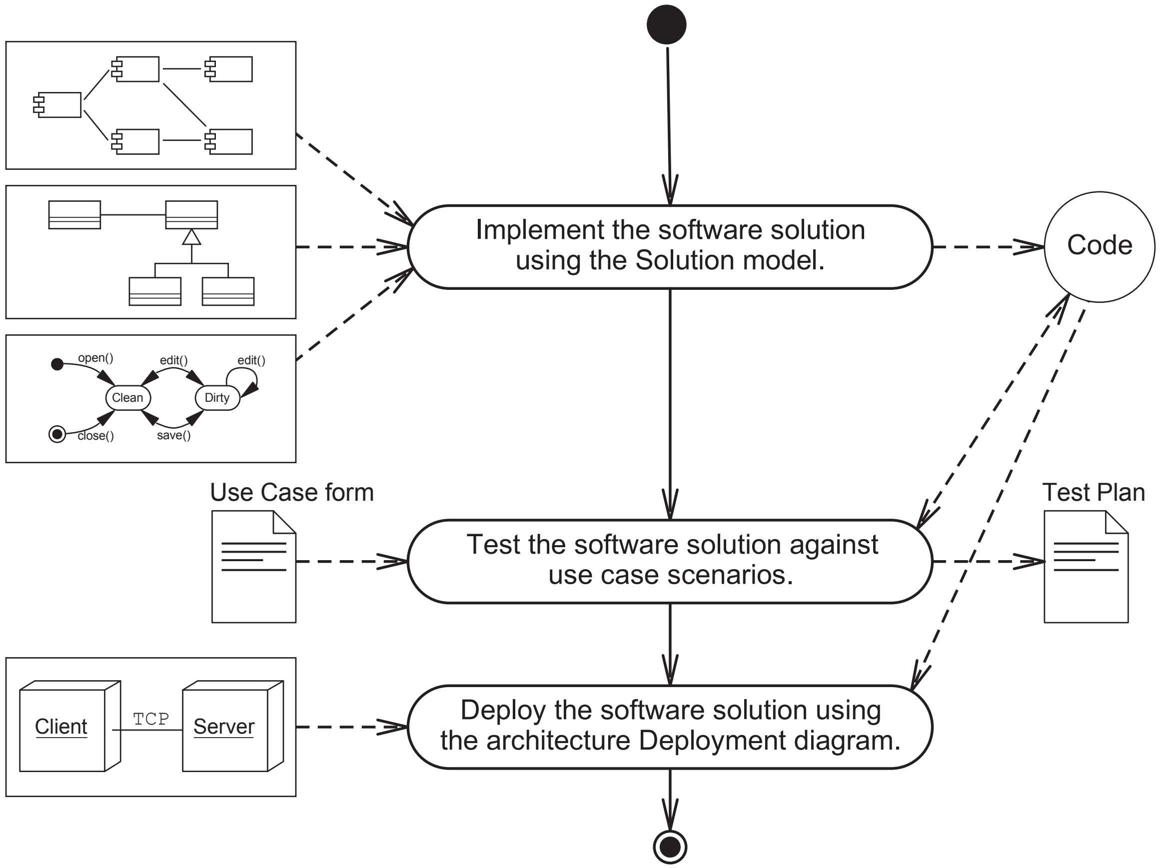
Exploring the Implementation, Testing, and Deployment Workflows

Workflow	**Purpose**	**Description**
Requirements Gathering	Determine *what* the system must do	
Requirements Analysis	Model the existing business processes	
Architecture	Model the high-level system structure to satisfy the NFRs	
Design	Model *how* the system will support the use cases	

Exploring the Implementation, Testing, and Deployment Workflows

Workflow	Purpose	Description
Implementation, Testing, and Deployment	Implement, test, and deploy the system	• Implement the software • Perform testing • Deploy the software to the production environment

Activities and Artifacts of the Implementation, Testing, and Deployment Workflows



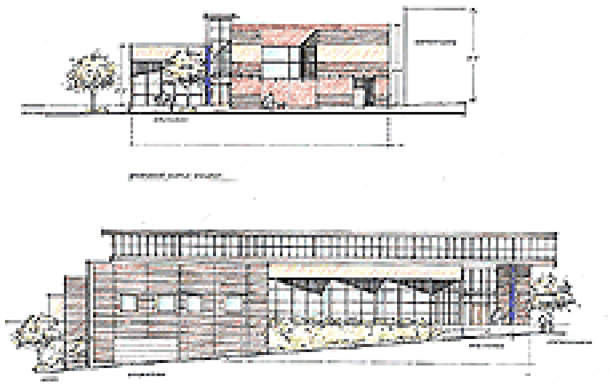
Exploring the Benefits of Modeling Software

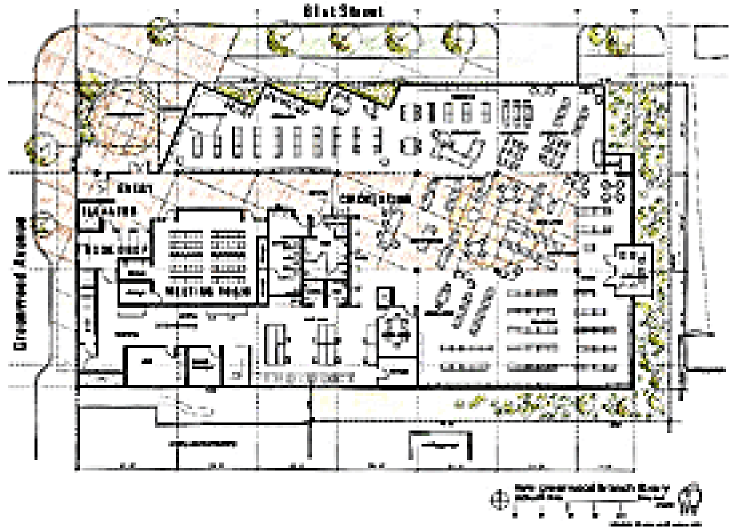
The inception of every software project starts as an idea in someone's mind.

To construct a realization of that idea, the development team must create a series of conceptual models that transform the idea into a production system.

What is a Model?

"A model is a simplification of reality." (Booch UML User Guide page 6)





(Buffalo Design © 2002. Images used with permission.)

- A model is an abstract conceptualization of some entity (such as a building) or a system (such as software).
- Different views show the model from different perspectives.

Why Model Software?

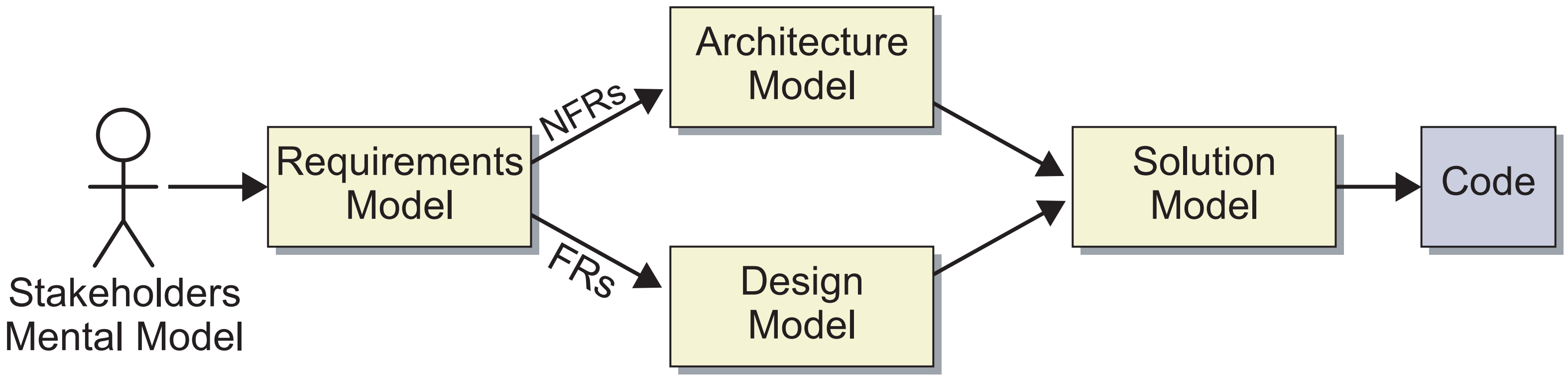
"We build models so that we can better understand the system we are developing." (Booch UML User Guide page 6)

Specifically, modeling enables us to:

- Visualize new or existing systems
- Communicate decisions to the project stakeholders
- Document the decisions made in each OOSD workflow
- Specify the structure (static) and behavior (dynamic) elements of a system
- Use a template for constructing the software solution

OOSD as Model Transformations

Software development can be viewed as a series of transformations from the Stakeholder’s mental model to the actual code:



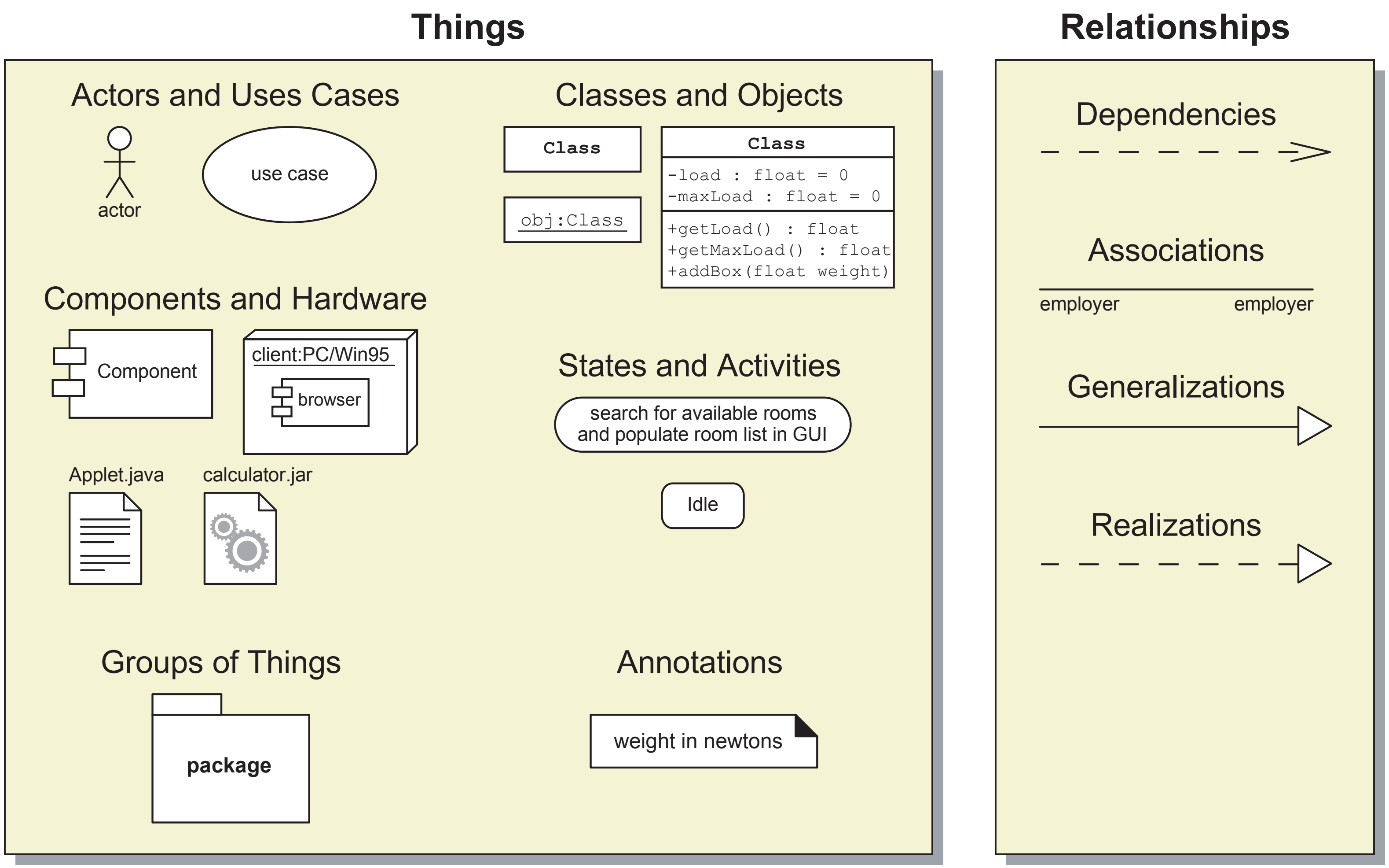
Defining the UML

"The Unified Modeling Language (UML) is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system." (UML v1.4 page xix)

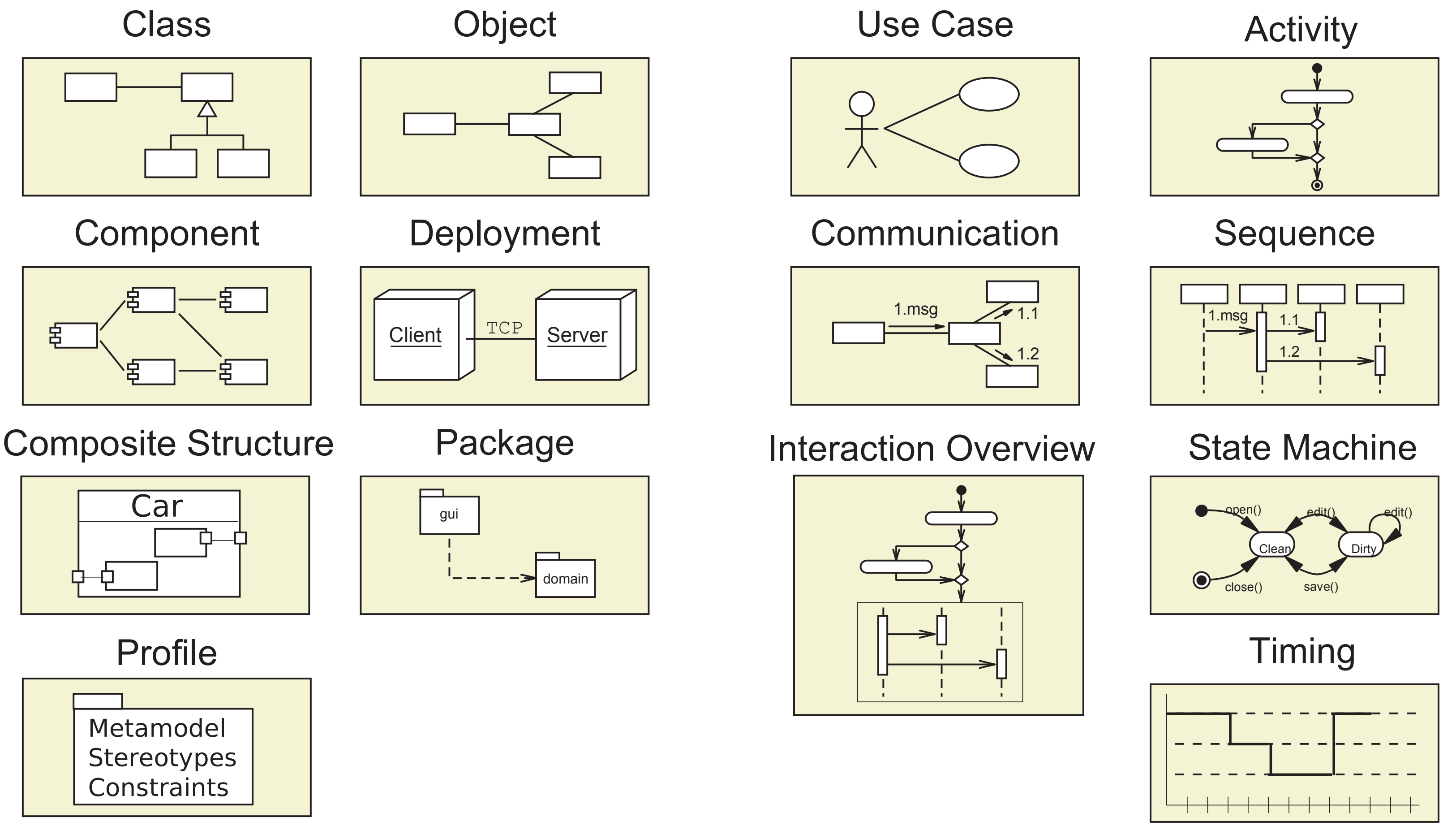
Using the UML, a model is composed of:

- Elements (things and relationships)
- Diagrams (built from elements)
- Views (diagrams showing different perspectives of a model)

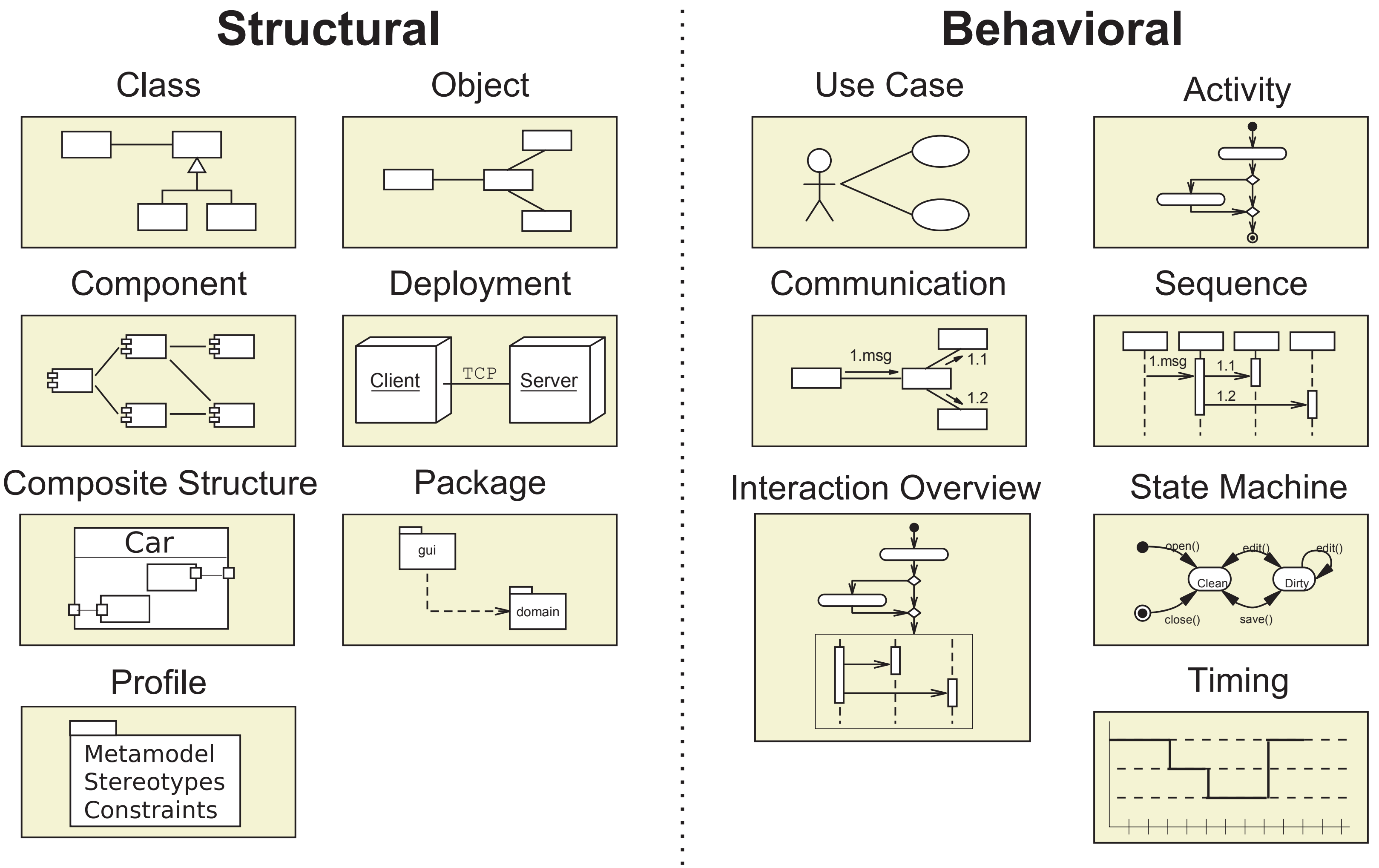
UML Elements



UML Diagrams



UML Diagram Categories



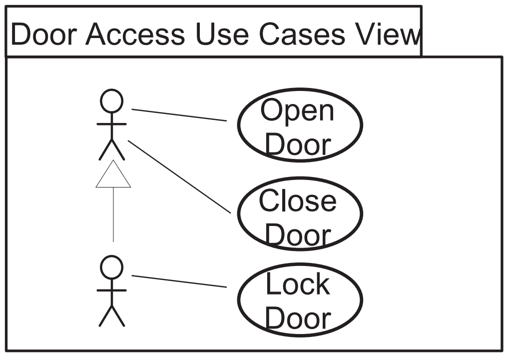
Common UML Elements and Connectors

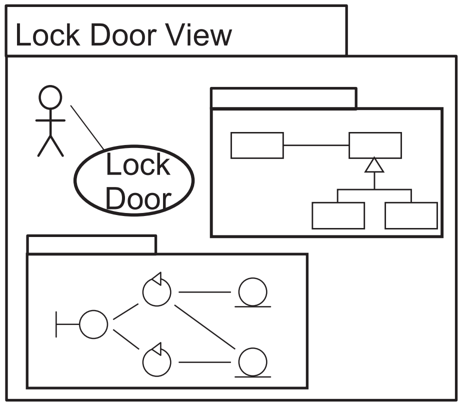
UML has a few elements and connectors that are common across UML diagrams. These include:

- Package
- Note
- Dependency
- Stereotypes

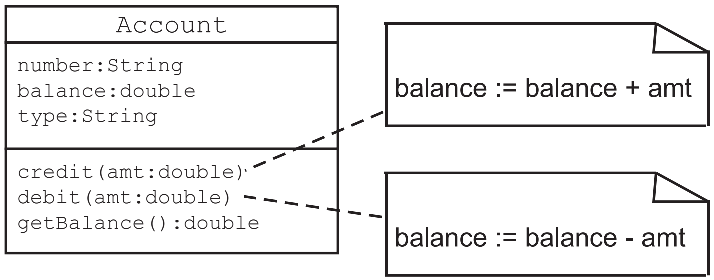
Packages and Notes

Package

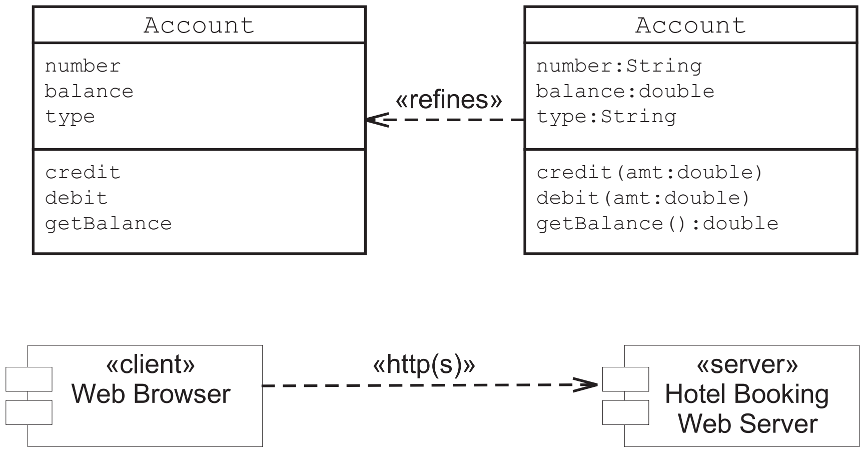




Notes



Dependency and Stereotype



What UML Is and Is Not

UML is not:	But it:
Used to create an executable model	Can be used to generate code skeletons
A programming language	Maps to most OO languages
A methodology	Can be used as a tool within the activities of a methodology

UML Tools

UML itself is a tool. You can create UML diagrams on paper or a white board. However, software tools are available to:

- Provide computer-aided drawing of UML diagrams
- Support (or enforce) semantic verification of diagrams
- Provide support for a specific methodology
- Generate code skeletons from the UML diagrams
- Organize all of the diagrams for a project
- Automatic generation of modeling elements for design patterns, Java™ Platform, Enterprise Edition (Java™ EE platform) components, and so on

Summary

- The OOSD process starts with gathering the system requirements and ends with deploying a working system.
- Workflows define the activities that transform the artifacts of the project from the requirements model to the implementation code (the final artifact).
- The UML supports the creation of visual artifacts that represent views of your models.

Module 3

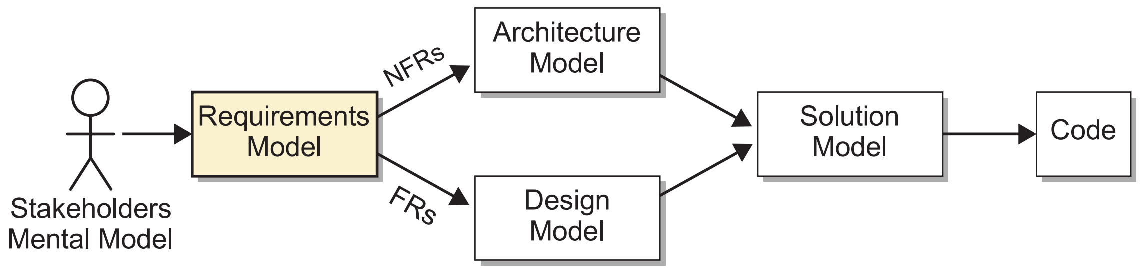
Creating Use Case Diagrams

Objectives

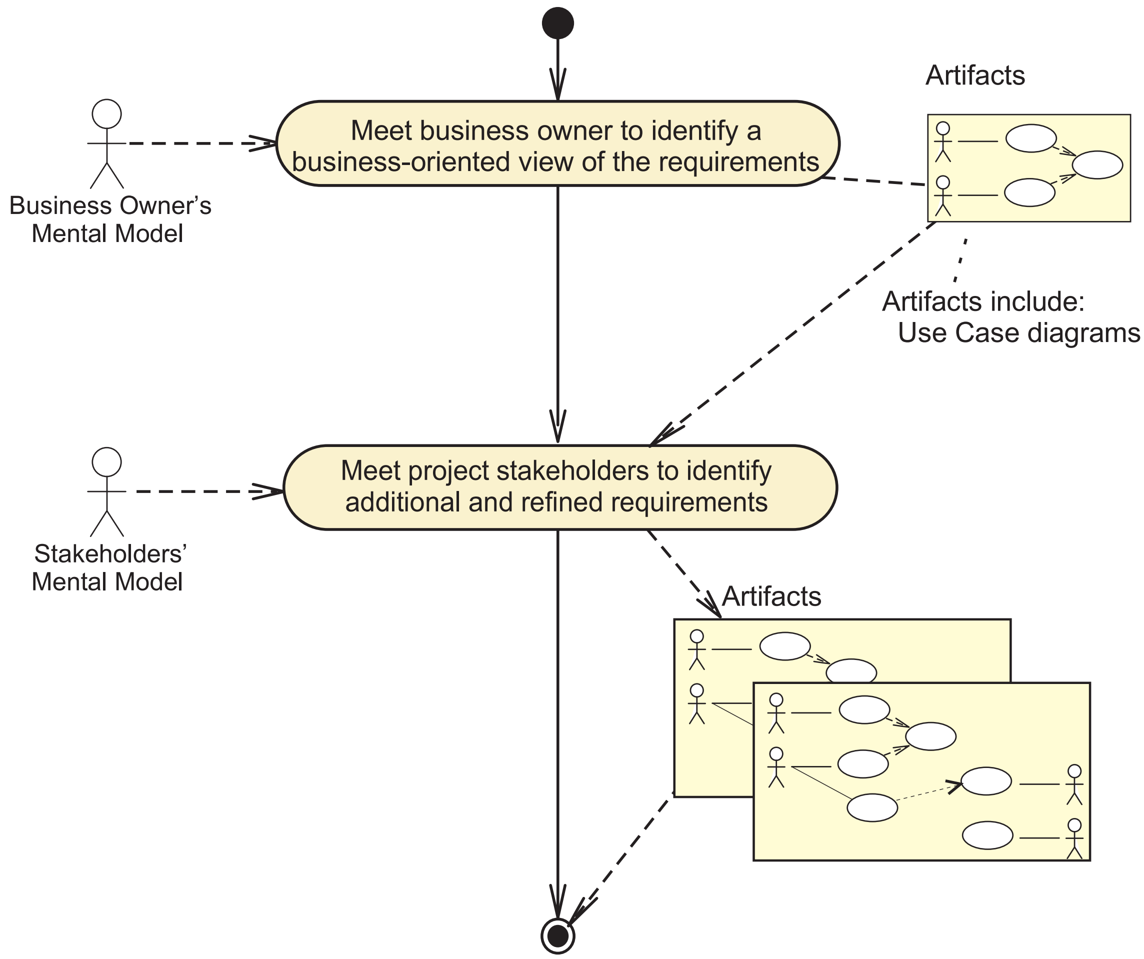
Upon completion of this module, you should be able to:

- Justify the need for a Use Case diagram
- Identify and describe the essential elements in a UML Use Case diagram
- Develop a Use Case diagram for a software system based on the goals of the business owner
- Develop elaborated Use Case diagrams based on the goals of all the stakeholders
- Recognize and document use case dependencies using UML notation for extends, includes, and generalization
- Describe how to manage the complexity of Use Case diagrams by creating UML packaged views

Process Map



Stakeholders Mental Model
Requirements Model
NFRs
FRs
Architecture Model
Design Model
Solution Model
Code



Business Owner's Mental Model
Meet business owner to identify a business-oriented view of the requirements
Artifacts
Artifacts include: Use Case diagrams
Stakeholders' Mental Model
Meet project stakeholders to identify additional and refined requirements
Artifacts

Justifying the Need for a Use Case Diagram

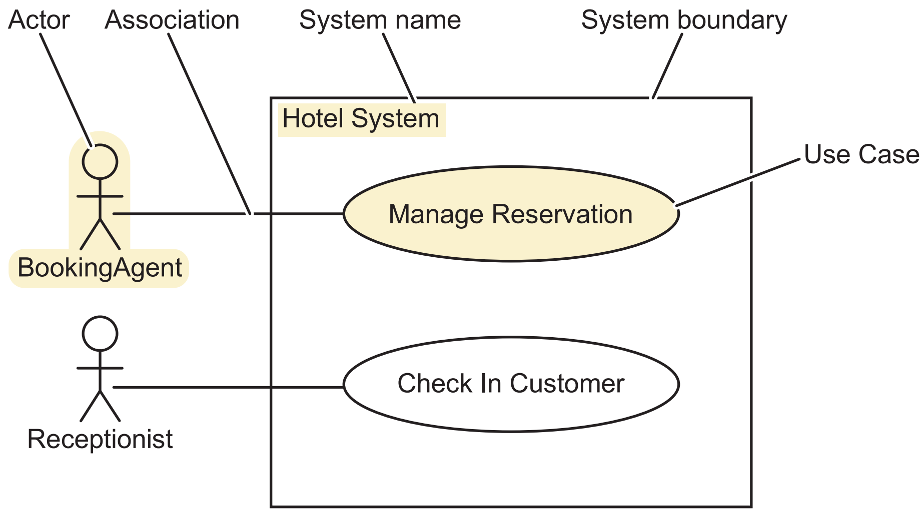
Following are reasons a Use Case diagram is necessary:

- A Use Case diagram enables you to identify—by modeling—the high-level functional requirements (FRs) that are required to satisfy each user's goals.
- The client-side stakeholders need a big picture view of the system.
- The use cases form the basis from which the detailed FRs are developed.
- Use cases can be prioritized and developed in order of priority.
- Use cases often have minimal dependencies, which enables a degree of independent development.

Identifying the Elements of a Use Case Diagram

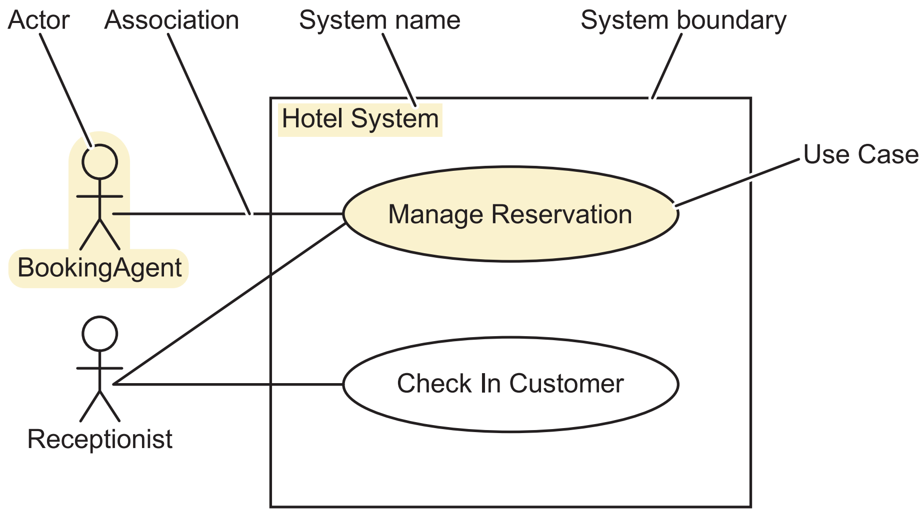
A Use Case diagram shows the relationships between actors (roles) and the goals they wish to achieve.

A physical job title can assume multiple actors (roles).



Identifying the Elements of a Use Case Diagram

This diagram illustrates an alternate style that explicitly shows an association between the Receptionist actor (role) and the Manage Reservation use case.



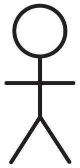
Actors

An actor:

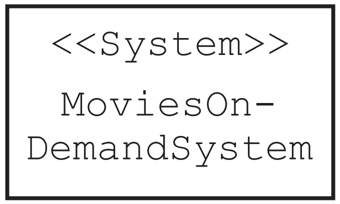
- Models a type of role that is external to the system and interacts with that system
- Can be a human, a device, another system, or time
- Can be primary or secondary
  - Primary: Initiates and controls the whole use case
  - Secondary: Participates only for part of the use case

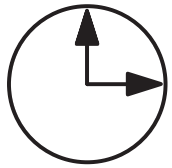
A single physical instance of a human, a device, or a system may play the role of several different actors.

Actors



BookingAgent





Time

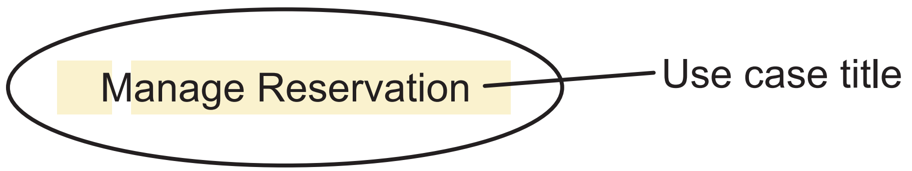
This icon represents a human actor (user) of the system.

This icon can represent any actor, but is usually used to represent external systems, devices, or time.

This icon represents a time-trigger mechanism that activates a use case.

Use Cases

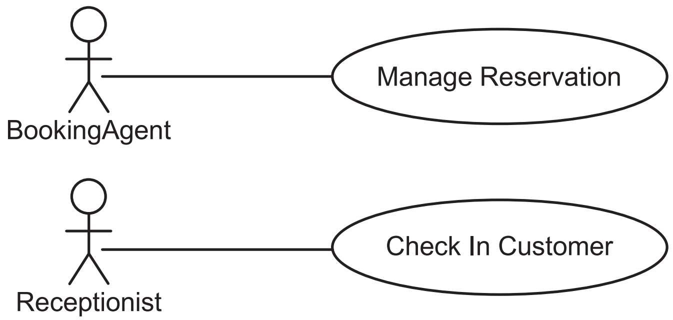
A use case describes an interaction between an actor and the system to achieve a goal.

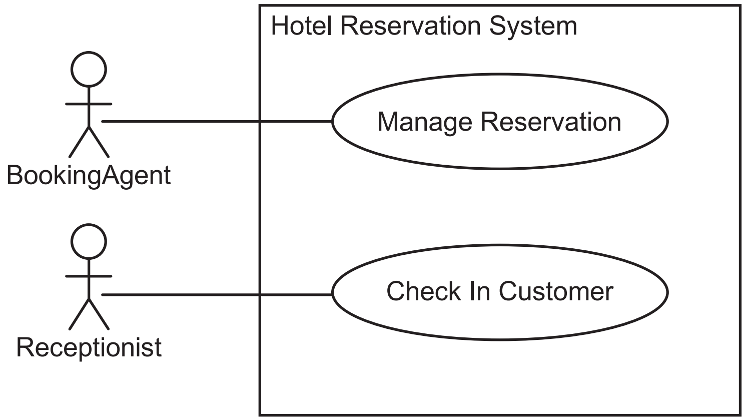


- A use case encapsulates a major piece of system behavior with a definable outcome.
- A use case is represented as an oval with the use case title in the center.
- A good use case title should consist of a brief but unambiguous verb-noun pair.
- A use case can often be UI independent.

System Boundary

The use cases may optionally be enclosed by a rectangle that represents the system boundary.



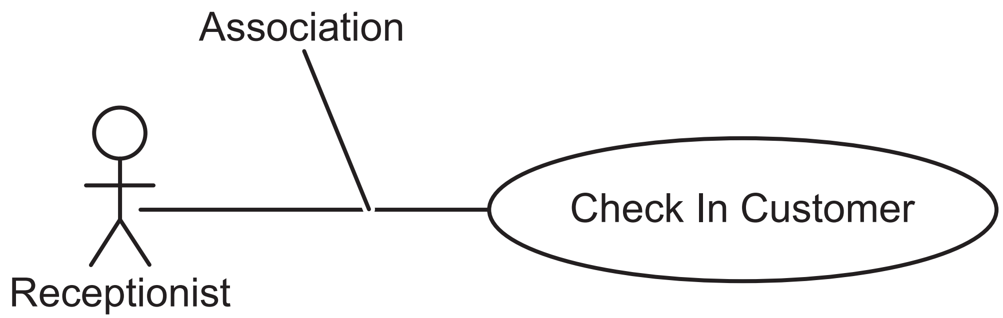


The system boundary box is optional.

This equivalent Use Case diagram shows the system boundary for clarity.

Use Case Associations

A use case association represents “the participation of an actor in a use case.” (UML v1.4 spec. page 357)



- An actor must be associated with one or more use cases.
- A use case must be associated with one or more actors.
- An association is represented by a solid line with no arrowheads.However, some UML tools use arrows by default.

Creating the Initial Use Case Diagram

One of the primary aims of the initial meeting with the project's business owner is to identify the business-significant use cases.

- A use case diagram may be created during the meeting.
- Alternatively, the diagrams can be created after the meeting from textual notes.

The next two slides present some text showing an abstract of the use-case-specific topics discussed during the meeting.

Creating the Initial Use Case Diagram

The booking agent (internal staff) must be able to manage reservations on behalf of customers who telephone or e-mail with reservation requests. The majority of these requests will make a new reservation, but occasionally they will need to amend or cancel a reservation. A reservation holds one or more rooms of a room type for a single time period, and must be guaranteed by either an electronic card payment or the receipt of a purchase order for corporate customers and travel agents. These payment guarantees must be saved for future reference.

A reservation can also be made electronically from the Travel Agent system and also by customers directly via the internet.

Creating the Initial Use Case Diagram

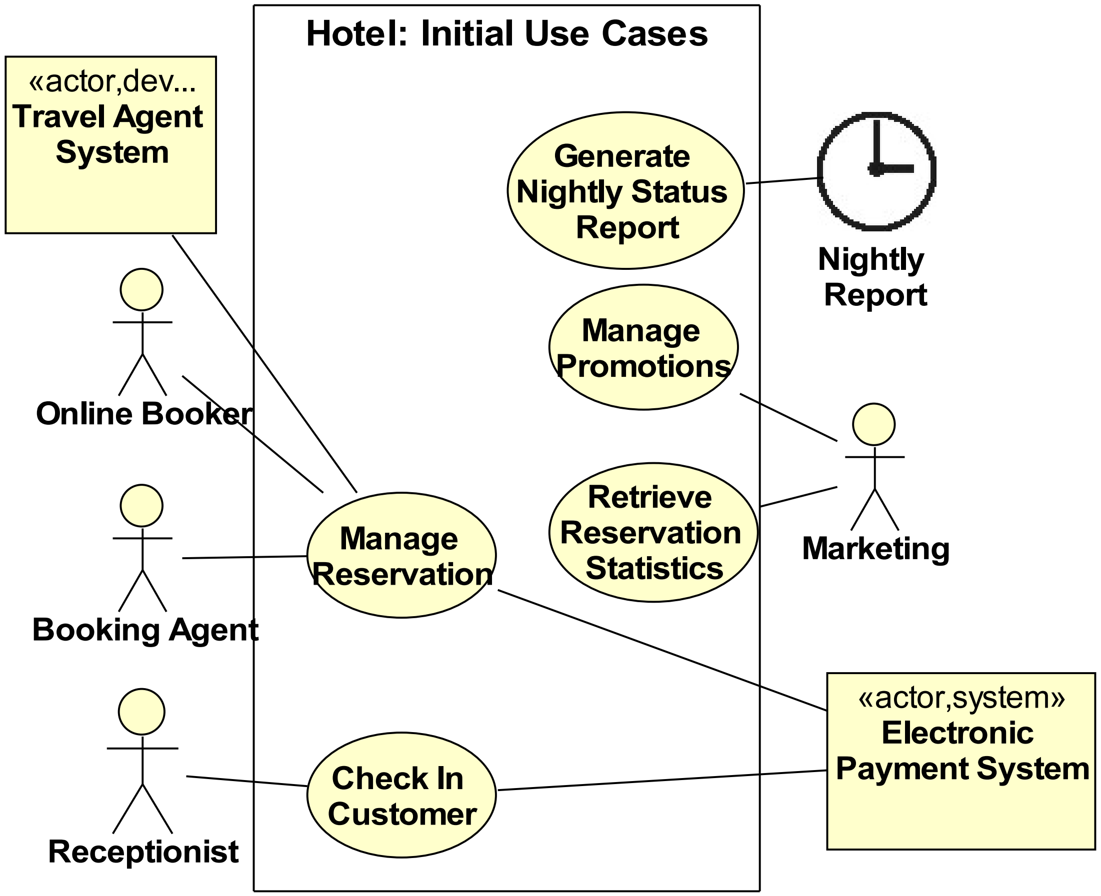
The receptionist must be able to check in customers arriving at the hotel. This action will allocate one or more rooms of the requested type. In most cases, a further electronic card payment guarantee is required.

Most receptionists will be trained to perform the booking agent tasks for customers who arrive without a booking or need to change a booking.

The marketing staff will need to manage promotions (special offers) based on a review of past and future reservation statistics. The marketing staff will elaborate on the detailed requirements in a subsequent meeting.

The management needs a daily status report, which needs to be produced when the hotel is quiet. This activity is usually done at 3 a.m.

Creating the Initial Use Case Diagram



Identifying additional Use Cases

During the meeting with the business owner, you will typically discover 10 to 20 percent of the use cases needed for the system.

During the meeting with the other stakeholders, you will discover many more use case titles that you can add to the diagram. For example:

- Maintain Rooms
  - Create, Update, and Delete
- Maintain RoomTypes
  - Create, Update, and Delete

Identifying additional Use Cases

The time of discovery depends upon the development process.

- In a non-iterative process:
  - You ideally need to discover all of the remaining use case titles, bringing the total to 100 percent.
  - However, this is a resource-intensive task and is rarely completely accurate.

Identifying additional Use Cases

- In an iterative/incremental development process, an option is to:
  - Discover a total of 80 percent of the use case titles in the next few iterations for 20 percent of the effort. This is just one of the many uses of the 80/20 rule.
  - Discover the remaining 20 percent of use case titles in the later iterations for minimal effort.

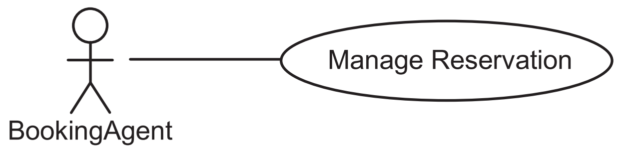
  This process works well with software that is built to accommodate change.

Use Case Elaboration

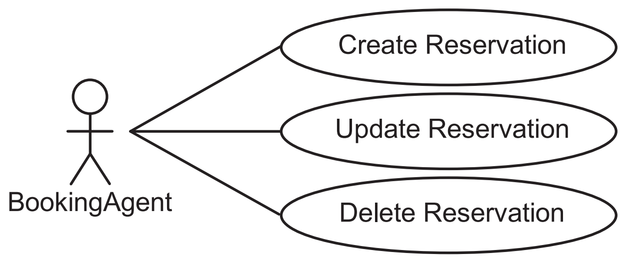
During the meeting with the other stakeholders, you will discover many more use cases that you can add to the diagram.

You might also find that some use cases are too high-level. In this case, you can introduce new use cases that separate the workflows.

Example:



Becomes:

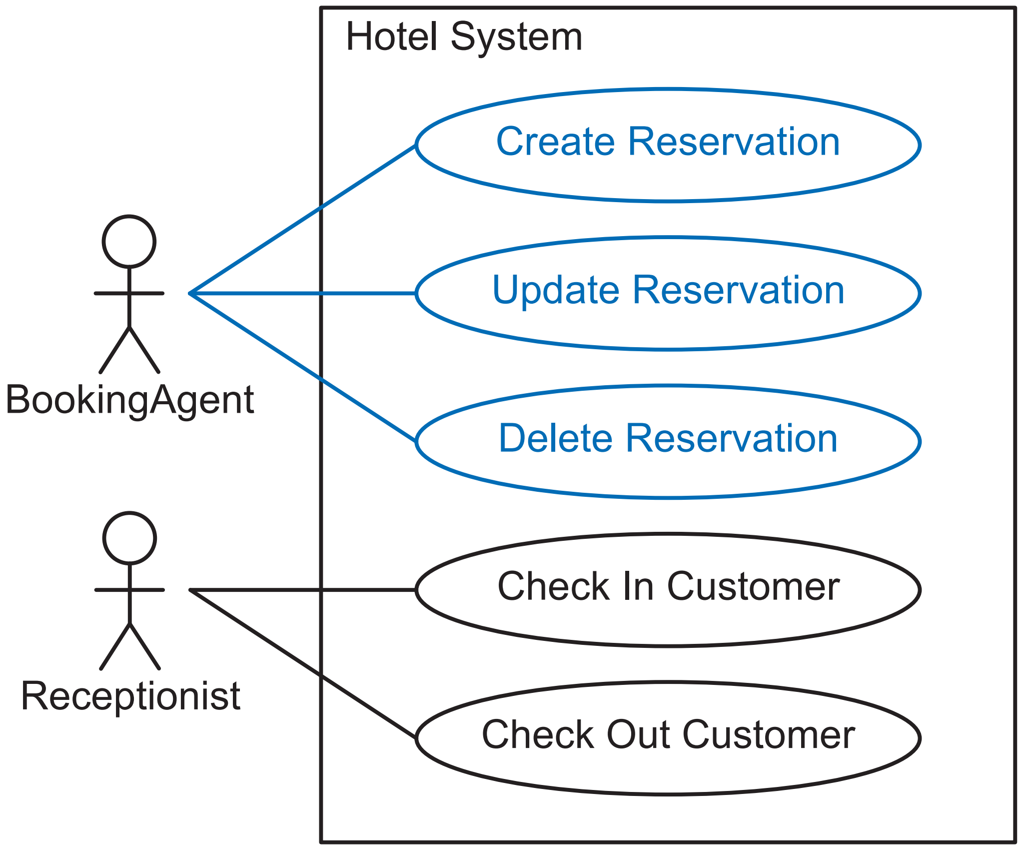


Expanding High-Level Use Cases

- Typically, *managing an entity* implies being able to Create, (Retrieve), Update, and Delete an entity (so called, CRUD operations). Other keywords include:
  - Maintain
  - Process
- Other high-level use cases can occur. Identify these by analyzing the use case scenarios and look for significantly divergent flows.
- If several scenarios have a different starting point, these scenarios might represent different use cases.

Expanding High-Level Use Cases

- The expanded diagram:



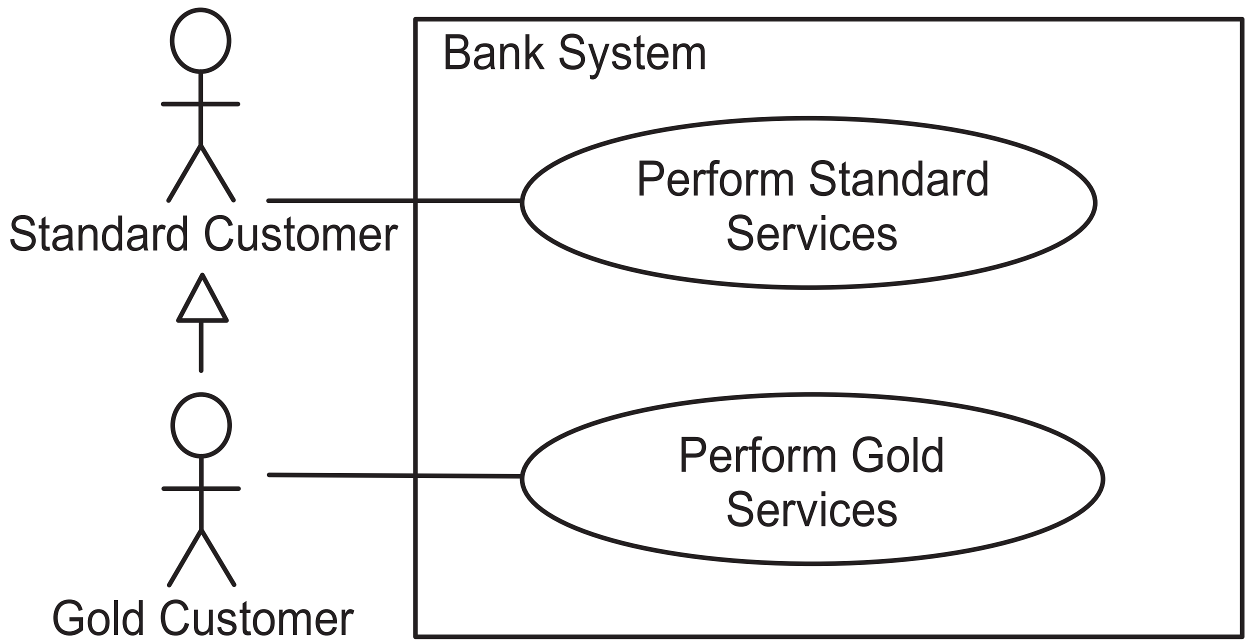
Analyzing Inheritance Patterns

Inheritance can occur in Use Case diagrams for both actors and use cases:

- An actor can inherit all of the use case associations from the parent actor.
- A use case can be *subclassed* into multiple, specialized use cases.

Actor Inheritance

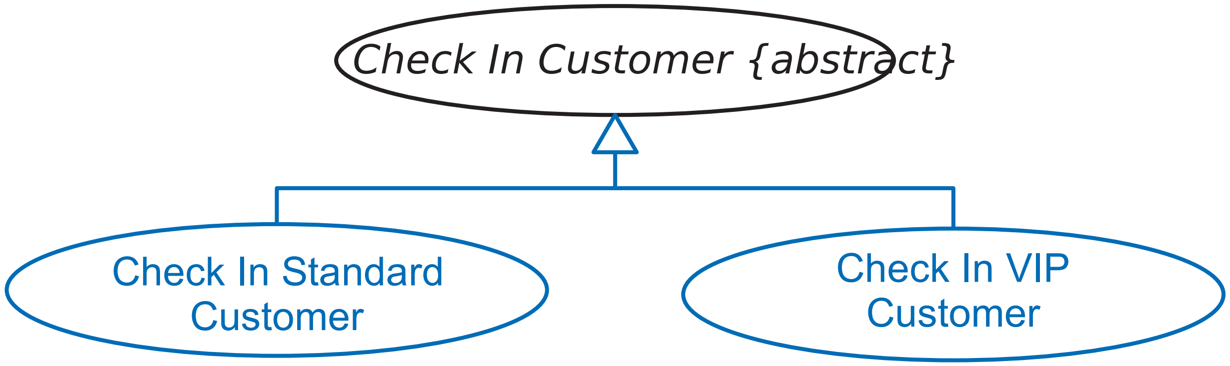
An actor can inherit all of the use case associations from the parent actor.



This inheritance should be used only if you can apply the *"is a kind of"* rule between the actors.

Use Case Specialization

A use case can be *subclassed* into multiple, specialized use cases:



- Use case specializations are *usually* identified by significant variations in the use case scenarios.
- If the base use case cannot be instantiated, you must mark it as abstract.

Analyzing Use Case Dependencies

Use cases can depend on other use cases in two ways:

- One use case (a) *includes* another use case (i).

  This means that the one use case (a) requires the behavior of the other use case (i) and *always* performs the included use case.

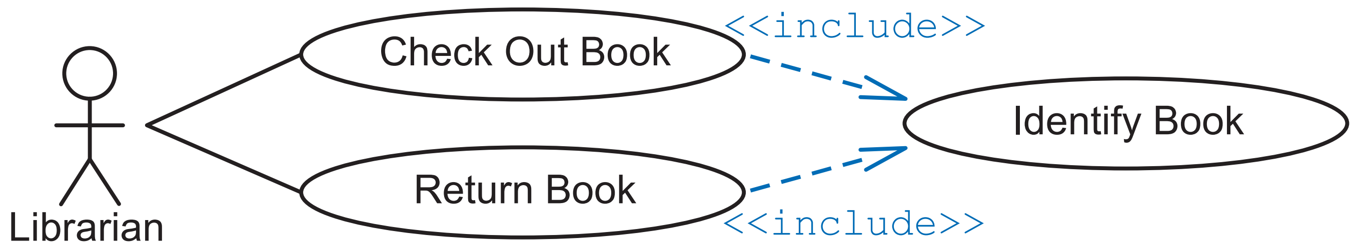
- One use case (e) can *extend* another use case (b).

  This means that the one use case (e) can (optionally) extend the behavior of the other use case (b).

The «include» Dependency

The include dependency enables you to identify behaviors of the system that are common to multiple use cases.

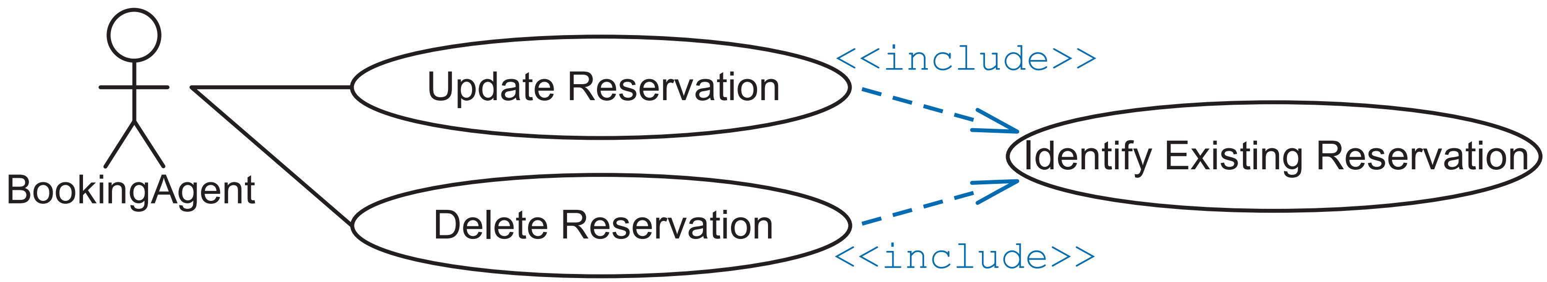
This dependency is drawn like this:



The «include» Dependency

Identifying and recording common behavior:

- Review the use case scenarios for common behaviors.
- Give this behavior a name and place it in the Use Case diagram with an«include» dependency.



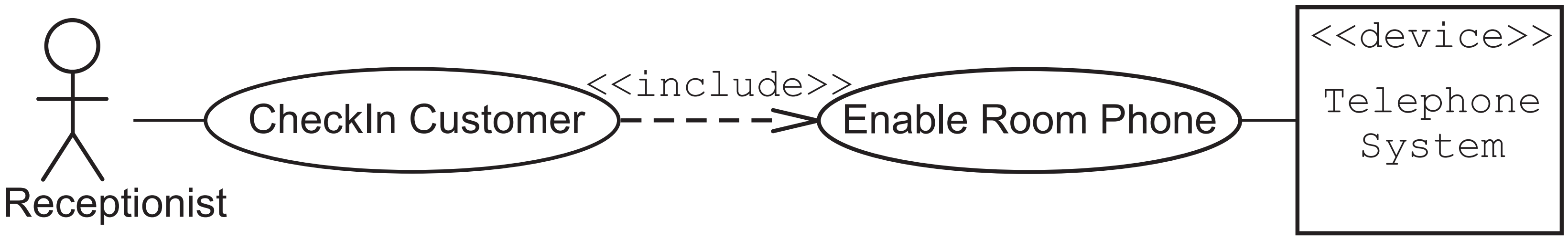
The «include» Dependency

Identifying behavior associated with a secondary actor:

- Review the use case scenarios for significant behavior that involves a secondary actor.

The «`include`» Dependency

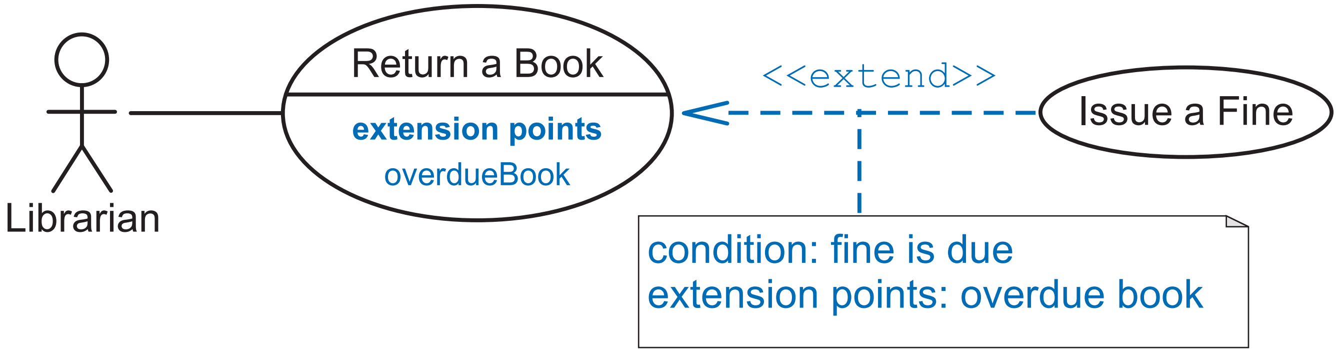
- Split the behavior that interacts with this secondary actor. Give this behavior a Use Case title, and place it in the Use Case diagram with an «`include`» dependency.



The «extend» Dependency

The extend dependency enables you to identify behaviors of the system that are not part of the primary flow, but exist in alternate scenarios.

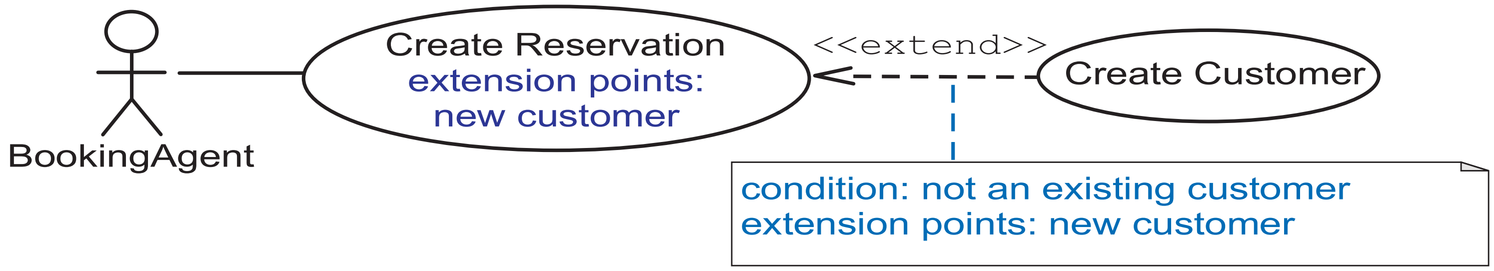
This dependency is drawn like this:



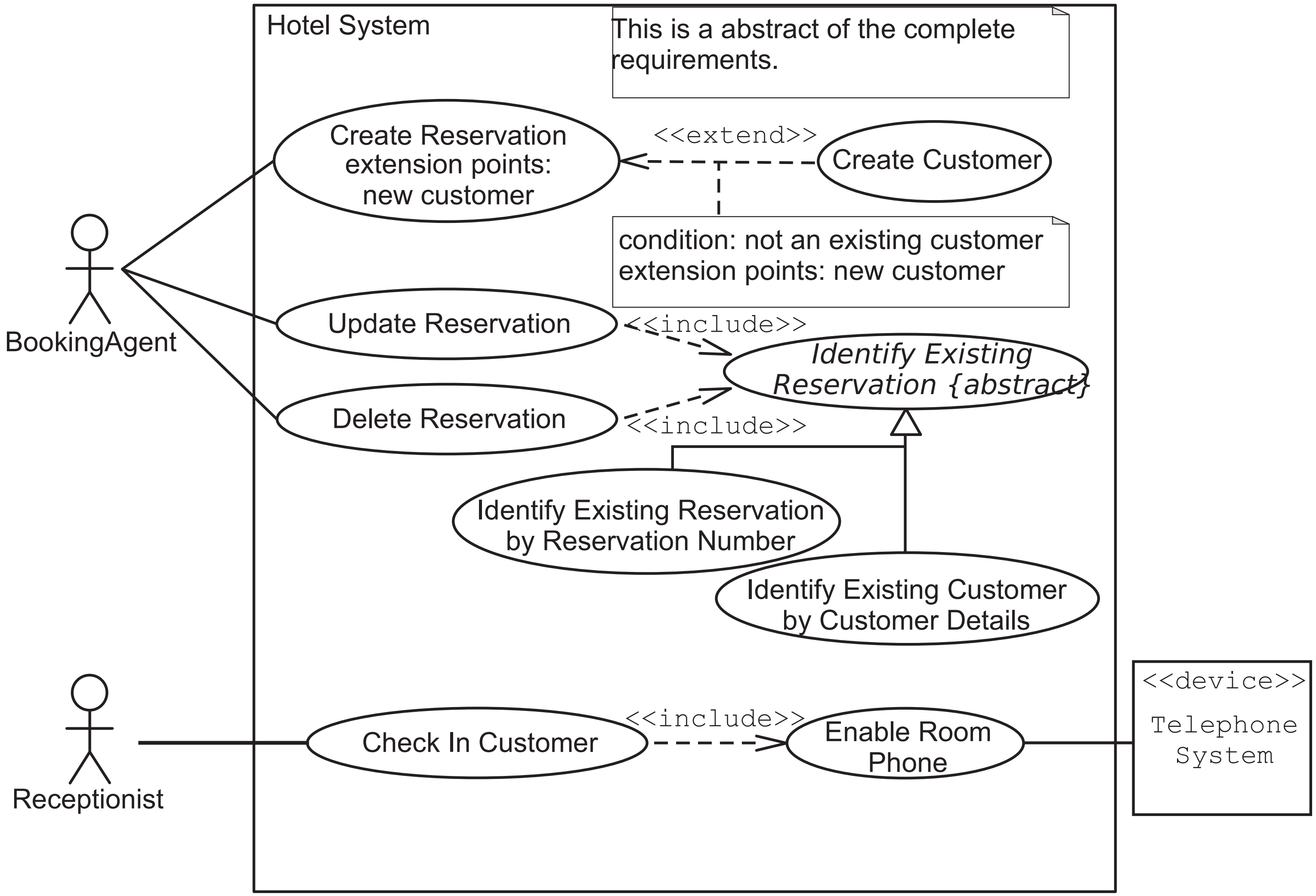
The «extend» Dependency

Identifying and recording behaviors associated with an alternate flow of a use case:

- Review the use case scenarios for significant and cohesive sequences of behavior.
- Give this behavior a name and place it in the Use Case diagram with a «extend» dependency.



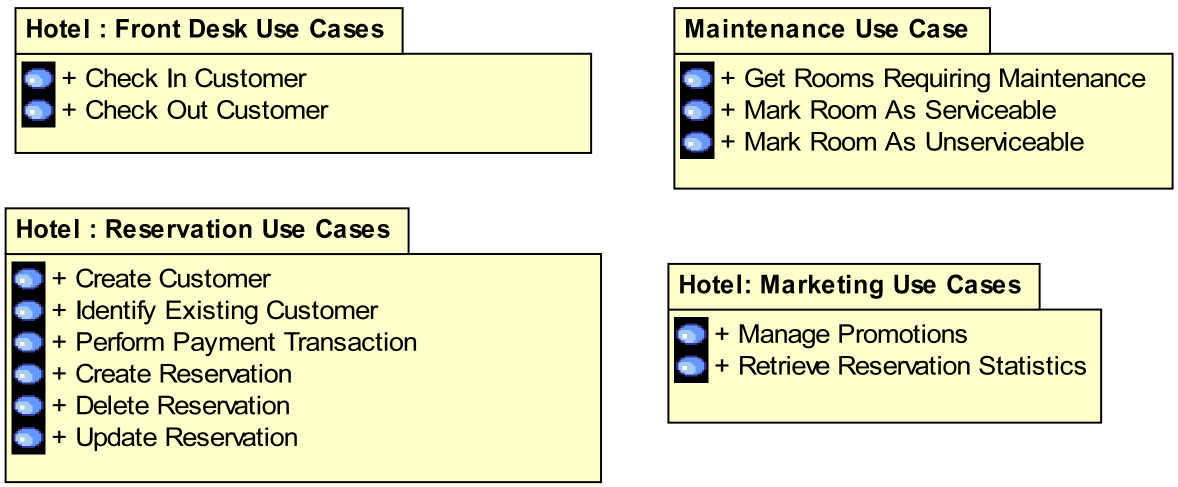
A Combined Example



Packaging the Use Case Views

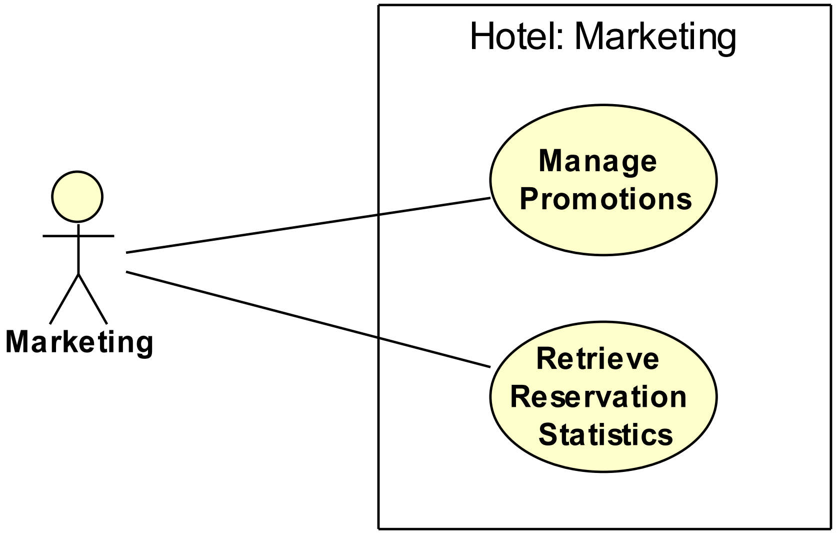
It should be apparent that any non-trivial software development would need more use cases than could be viewed at one time. Therefore, you need to be able to manage this complexity.

One way of managing this complexity is to break down the use cases into packages.

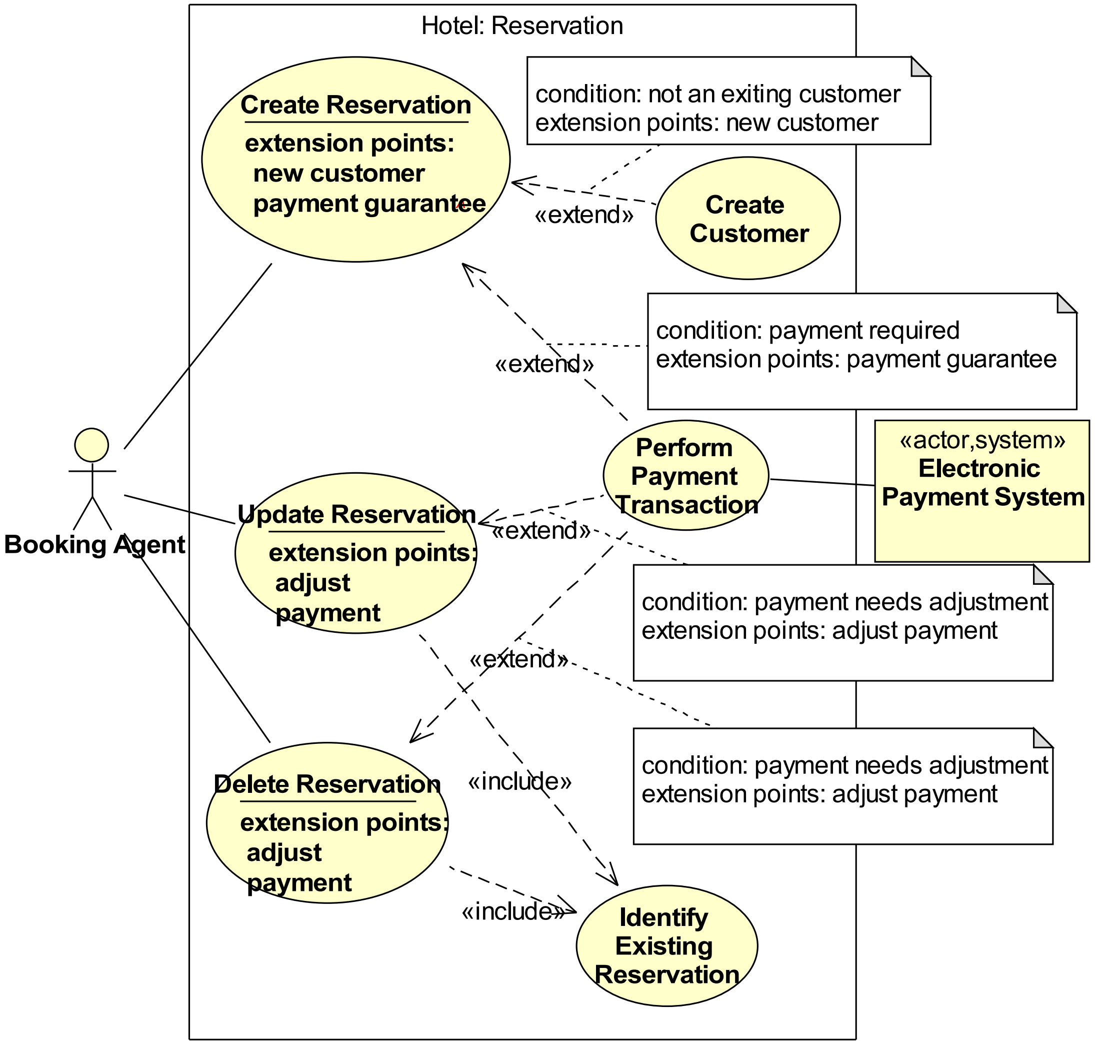


Packaging the Use Case Views

- You can look inside each package to reveal the detailed content.
- A use case element may exist in multiple packages, where it participates in multiple views.



Packaging the Use Case Views



Summary

- A Use Case diagram provides a visual representation of the big-picture view of the system.
- The Use Case diagram represents the actors that use the system, the use cases that provide a behavior with a definable goal for an actor, and the associations between them.
- Use Case diagrams can be elaborated to show a software system based on the goals of the business owner and all the other stakeholders

Summary

- Use Case diagrams can be elaborated to show use case dependencies by using UML notation for extends, includes, and generalization.
- Complex Use Case diagrams can be broken down into views by using UML packages.

Module 4

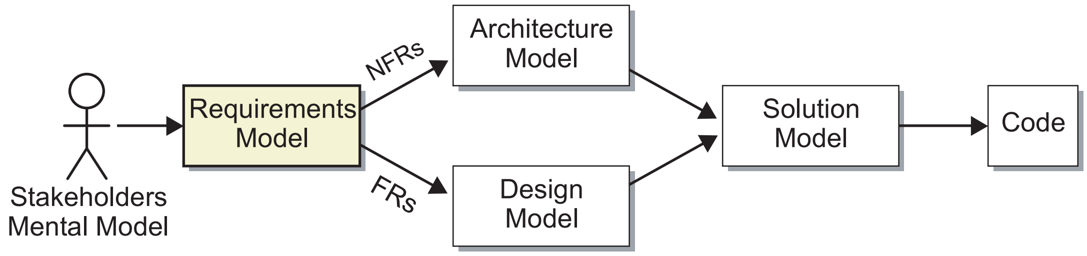
Creating Use Case Scenarios and Forms

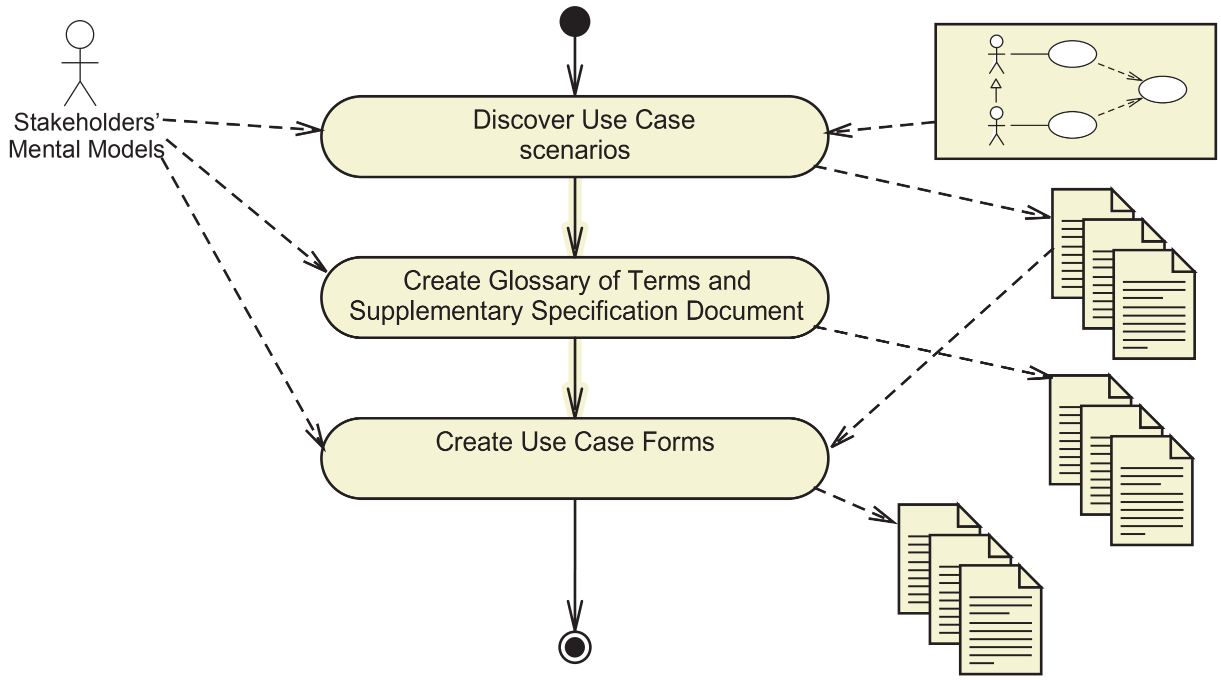
Objectives

Upon completion of this module, you should be able to:

- Identify and document scenarios for a use case
- Create a Use Case form describing a summary of the scenarios in the main and alternate flows
- Describe how to reference included and extending use cases.
- Identify and document non-functional requirements (NFRs), business rules, risks, and priorities for a use case
- Identify the purpose of a Supplementary Specification Document

Process Map


Stakeholders
Mental Model
Requirements
Model
NFRs
FRs
Architecture
Model
Design
Model
Solution
Model
Code


Stakeholders'
Mental Models
Discover Use Case
scenarios
Create Glossary of Terms and
Supplementary Specification Document
Create Use Case Forms

Recording Use Case Scenarios

A Use Case scenario is a concrete example of a use case.

A Use Case scenario should:

- Be as specific as possible
- Never contain conditional statements
- Begin the same way but have different outcomes
- Not specify too many user interface details
- Show successful as well as unsuccessful outcomes (in different scenarios)

Use Case scenarios drive several other OOAD workflows.

Selecting Use Case Scenarios

While it is ideal to have multiple scenarios for all use cases, doing so would take a lot of time. Therefore, you can select appropriate scenarios by the following criteria:

- The use case involves a complex interaction with the actor.
- The use case has several potential failure points, such as interaction with external systems or a database.

There are two types of scenarios:

- Primary (Happy) scenarios record successful results.
- Secondary (Sad) scenarios record failure events.

Writing a Use Case Scenario

A Use Case scenario is a story that:

- Describes how an actor uses the system and how the system responds to the actions of the actor.
- Has a beginning, a middle, and an end.

Primary Use Case Scenario: Example

The beginning:

The use case begins when the booking agent receives a request to make a reservation for rooms in the hotel.

Primary Use Case Scenario: Example

The middle:

The booking agent enters the arrival date, the departure date, and the quantity of each type of room that is required. The booking agent then submits the entered details. The system finds rooms that will be available during the period of the reservation and allocates the required number and type of rooms from the available rooms. The system responds that the specified rooms are available, returns the provisional reservation number, and marks the reservation as “held”. The booking agent accepts the rooms offered.

Primary Use Case Scenario: Example

More of the middle:

The booking agent selects that the customer has visited one of the hotels in this group before, and enters the zip code and customer name. The system finds and returns a list of matching customers with full address details. The booking agent selects one of the customers as being the valid customer. The system assigns this customer to the reservation. The booking agent performs a payment guarantee check. This check is successful.

Primary Use Case Scenario: Example

The end:

The system assigns the payment guarantee to the reservation and changes the state of the reservation to “confirmed”. The system returns the reservation ID and booking details.

Secondary Use Case Scenario: Example

The beginning:

The use case begins when the booking agent receives a request to make a reservation for rooms in the hotel.

The middle:

The booking agent enters the arrival date, the departure date, and the quantity of each type of room that is required. The booking agent then submits the entered details. The system responds that there are no rooms available of any type for the date range specified in the request.

The end:

The use case ends.

Supplementary Specifications

Some of the project information that you gather cannot be stored with the use cases because this information needs to be shared by several use cases.

This additional information can be documented in a Supplementary Specification Document, which often contains:

- NFRs
- Project Risks
- Project Constraints
- Glossary of Terms

Non-Functional Requirements (NFRs)

- Non-functional requirements (NFRs) define the qualitative characteristics of the system. As in an animal, the NFRs describe strength, speed, and agility of the internal features of the animal. How fast can the animal move? How much weight can the animal carry?
- Any adverbial phrase can be an NFR.

NFRs: Examples

- NFR1: The system must support 200 simultaneous users in the Web application.
- NFR2: The process for completing any reservation activity must take the average user no more than 10 minutes to finish.
- NFR3: The capacity of reservation records could grow to 2,600 per month.
- NFR4: The Web access should use the HTTPS transport layer when critical customer information is being communicated.
- NFR5: The numerical accuracy of all financial calculations (for example, reports and customer receipts) should follow a 2-significant-digit precision with standard rounding of intermediate results.

NFRs: Examples

- NFR6: The System must be available “7 by 24 by 365”. However, the applications can be shut down for maintenance once a week for one hour. This maintenance activity should be scheduled between 3 a.m. and 6 a.m.
- NFR7: Based on historical evidence, there are approximately 600 reservations per month per property.
- NFR8: The search for available rooms must take no longer than 30 seconds.

Glossary of Terms

The Glossary of Terms defines business or IT terms that will be used in the project.

This is a living document, which should be appended with new terms, or amended if a term is found to be incorrect or needs redefinition.

Glossary of Terms: Examples

Term	**Definition**
Reservation	An allocation of a specific number of rooms, each of a specified *room type*, for a specified period of days.
Date Range	Specifies a start date and an end date.
Room	A resource that can be allocated to a reservation, and is occupied by that reservation *customer* and their *guests* for the *date range* of the *reservation.* A room is identified by either a *room name* or a *room number*. Each room is assigned a *room type*.
Payment Guarantee	Debit/Credit card pre-authorization or purchase order from either corporate companies or travel agents.
Basic Rate	The per day price for a room type without any additional *in-line charges* or *promotions*.
Room Type	A room type indicates the number of beds, *basic rate,* and configuration of the room.

Description of a Use Case Form

A Use Case form provides a tool to record the detailed analysis of a single use case and its scenarios.

Form Element	Description
Use Case Name	The name of the use case from the Use Case diagram.
Description	A one-line or two-line description of the purpose of the use case.
Actors	This element should list all relevant actors that are permitted to use this use case.
Priority	This is used to describe the relative priority of this use case. Priority is often in the form of MuSCoW prioritization, which is Must have, Should have, Could have, or Won't have.
Risk	A High, Medium, or Low ranking of this use case's risk factors.

Description of a Use Case Form

Form Element	Description
Pre-conditions and assumptions	The conditions that must be true. If these conditions are not true, the outcome of the use case cannot be predicted.
Extension Points	A list of any extension points used by this use case.
Extends	A list of any use cases that this use case extends.
Trigger	The condition that "informs" the actor that the use case should be invoked.
Flow of Events	The primary trace of user actions and events that constitute this use case.
Alternate Flows	Any and all secondary traces of user actions and events that are possible in this use case.
Post-conditions	The conditions that shall exist after the use case has been completed.

Description of a Use Case Form

Form Element	Description
Business Rules	A list of business rules that must be complied with and that are related to this use case. These rules might be referred to during the execution of the use case in the main flow and the alternate flow, but this is not always necessary. You can describe these rules in this form. Alternatively, you can refer to the list in the Supplementary Specification Document.
Non-Functional Requirements	A list of the NFRs that are related to this use case. You can either summarize the NFRs or list their codes from the Supplementary Specification Document.
Notes	Any other information that can be of value regarding this use case.

Description of a Use Case Form

Some methodologies recommend more or less analysis of the use cases. The Analysis workflow presented in this module tends to be more detailed.

Use Case forms are not standard. There are different styles that can be used to create a Use Case form.

Creating a Use Case Form

Steps to determine the information for the Use Case form:

1. Determine a brief description from the primary scenarios.
2. Determine the actors who initiate and participate in this use case from the Use Case diagrams.
3. Determine the priority of this use case from discussions with the stakeholders.
4. Determine the risk from scenarios and from discussions with the stakeholders.
5. Determine the extension points from the Use Case diagrams.
6. Determine the pre-conditions from the scenarios.
7. Determine the trigger from the scenarios.

Creating a Use Case Form

8. Determine the flow of events from the primary (happy) scenarios.
9. Determine the alternate flows from the secondary (sad) scenarios.
10. Determine the business rules from scenarios and from discussions with stakeholders.
11. Determine the post-conditions.
12. Determine the new NFRs from discussions with stakeholders.
13. Add notes for information—gathered from discussions with stakeholders—that does not fit into the standard sections of the form.

Fill in Values for the Use Case Form

Fill in elements derived from stakeholders and previous artifacts

Form Element	Description
Use Case Name	Create Reservation
Description	The Customer requests a reservation for hotel rooms for a date range. If all the requested rooms are available, the price is calculated and offered to the Customer. If details of the customer and a payment guarantee are provided, the reservation will be confirmed to the Customer.
Actor(s)	Primary: Booking Agent, Online Booker, Travel Agent System Secondary: None Note: Primary actors are proxies for the Customer.
Priority	Must have: Essential to this system

Fill in Values for the Use Case Form

Risk	High: Primarily because of the complexity of identifying if rooms are available and the number of different actor roles that can use this use case.
Trigger	A Customer wishes to make a reservation in the hotel.
Pre-conditions	At least one room exists in the hotel. Primary Actor can be identified.
Post-conditions	One reservation is added. Payment guarantee details are recorded.
Non-Functional Requirements	*NFR1 (Simultaneous Users)* *NFR2 (Duration of Use Case)* *NFR4 (Web Security)* *NFR6 (System Availability)* *NFR8 (Max Time for Room Availability Search)*
Notes	A fast method of checking room availability is still under investigation.

Fill in Values for the Main Flow of Events

Flow of Events	1: Use case starts when Customer requests to create a reservation 2: Customer enters types of rooms, arrival date, and departure date [A1] [A2] 2.1: System creates a reservation and reserves rooms applying BR3 [A3] 2.3: System calculates quoted price applying BR4 2.3.1 System records quoted price 2.4: System notifies Customer of reservation details (including rooms and price) 3: Customer accepts rooms offered [A5] 3.1: Extension Point (new customer) [A6] 3.2: Extension Point (payment guarantee) [A7] 3.3: System changes reservation status to “confirmed” 3.4: System notifies Customer of confirmed reservation details 4: Use case ends

Fill in Values for the Alternate Flow of Events

Determine the alternate flows from the secondary scenarios and remaining primary scenarios:

- Perform a *difference analysis* between the scenario used for the main flow and each of the other scenarios (in turn).
- The alternate flows are the steps that are different between the scenario used for the main flow and each of the other scenarios.

Fill in Values for the Alternate Flow of Events

Alternate Flows	A1: Customer can enter duration instead of departure date, go to step 2.1 [A2] A2: Failed date check BR1. Notify error to Customer, go to step 2 A3: Complying with BR2, System determines that required rooms are not available, System upgrades one or more room types, go to step 2.1[A4] A4: No further upgrades available. Notify message to Customer, go to step 2 A5: Rooms offered are declined, go to step A9 A6: Customer already exists, Customer enters customer name and zip code, System searches for matching customers, notifies Customer of matching customers, Customer selects correct customer details, go to step 3.2 [A8]

Fill in Values for the Alternate Flow of Events

Alternate Flows (continued)	A7: Payment guarantee fails. Notify message to Customer, go to step 3.2 A8: Existing customer not found, go to step 3.1 A9: Reservation not confirmed, reservation deleted, use case ends *At any time*: Customer may cancel the use case, use case ends [A9] *After use case inactivity of 10 minutes*: use case ends [A9]

Fill in Values for the Business Rules

Business Rules (BR)	*BR1*: The arrival date must not be before today's date, and the departure date must be after the arrival date *BR2:* Overbooking is not allowed *BR3:* Reservations with assigned rooms but no payment guarantee have a status of “held” *BR4:* The quoted price is the sum of the base price of the room types after applying BR5 and BR6 *BR5:* Seasonal Adjustment can be applied if reservation dates are applicable BR6: Offer adjustments can be applied if reservation qualifies *BR7:* Reservations with “held” status can be deleted *BR8:* Reservations with a status of “confirmed” must be linked to a payment guarantee and a customer *BR9:* Reservation must not exist without being linked to at least one room

Summary

- A Use Case scenario is written to provide a detailed description of the activities involved in one instance of the use case.
- Use Case scenarios should provide as many different situations as possible so that the whole range of activities for that use case are documented.
- Use Case scenarios provide much detail about a use case. An analysis of this detail is recorded in the Use Case form.
- The activities of a use case are distilled into Flow of Events portion of the Use Case form. Alternate flows are identified from unusual situations in one or more scenarios.

Module 5

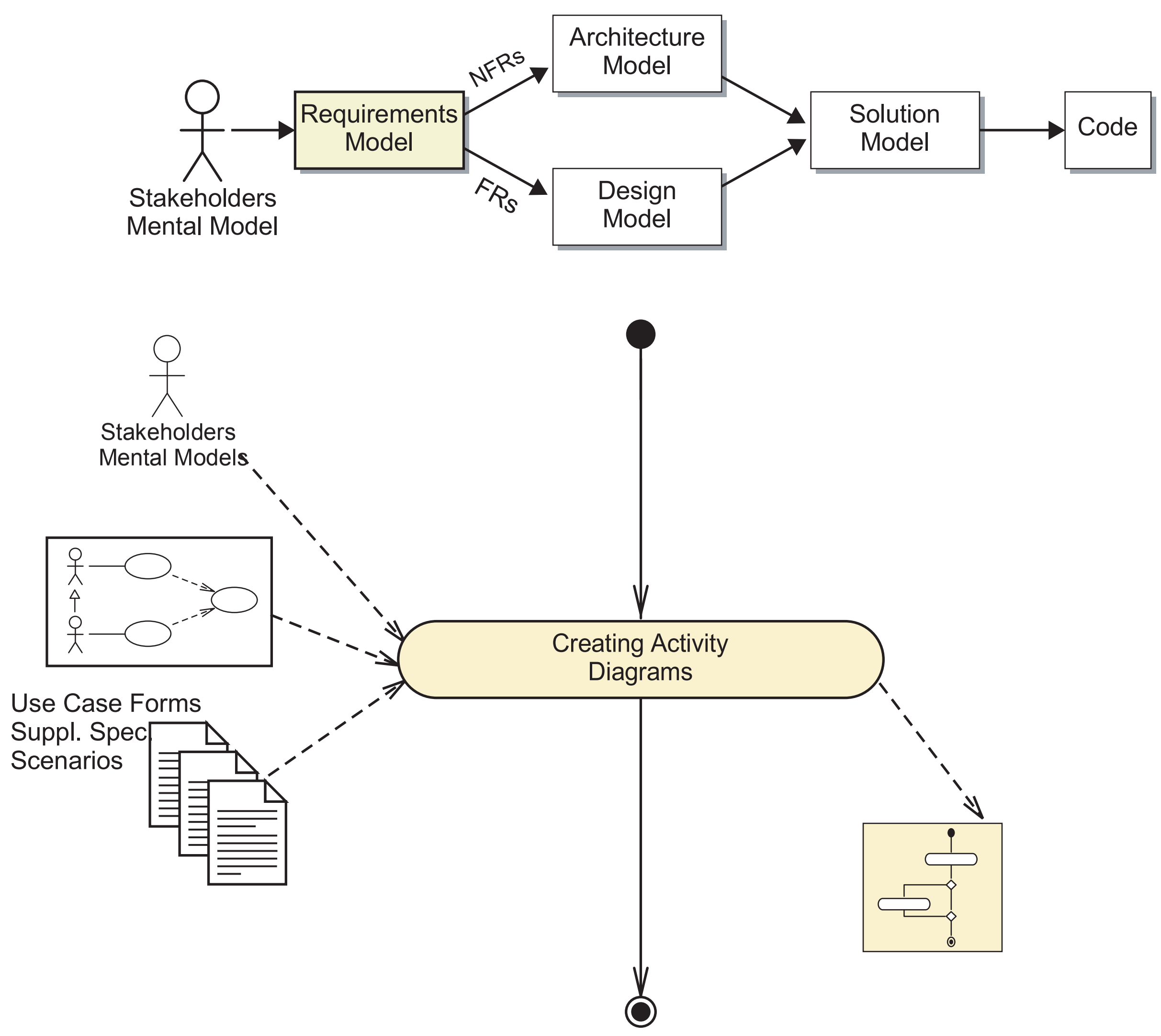
Creating Activity Diagrams

Objectives

Upon completion of this module, you should be able to:

- Identify the essential elements of an Activity diagram
- Model a Use Case flow of events using an Activity diagram

Process Map


Stakeholders
Mental Model
Requirements Model
NFRs
FRs
Architecture Model
Design Model
Solution Model
Code
Stakeholders
Mental Models
Use Case Forms
Suppl. Spec
Scenarios
Creating Activity Diagrams

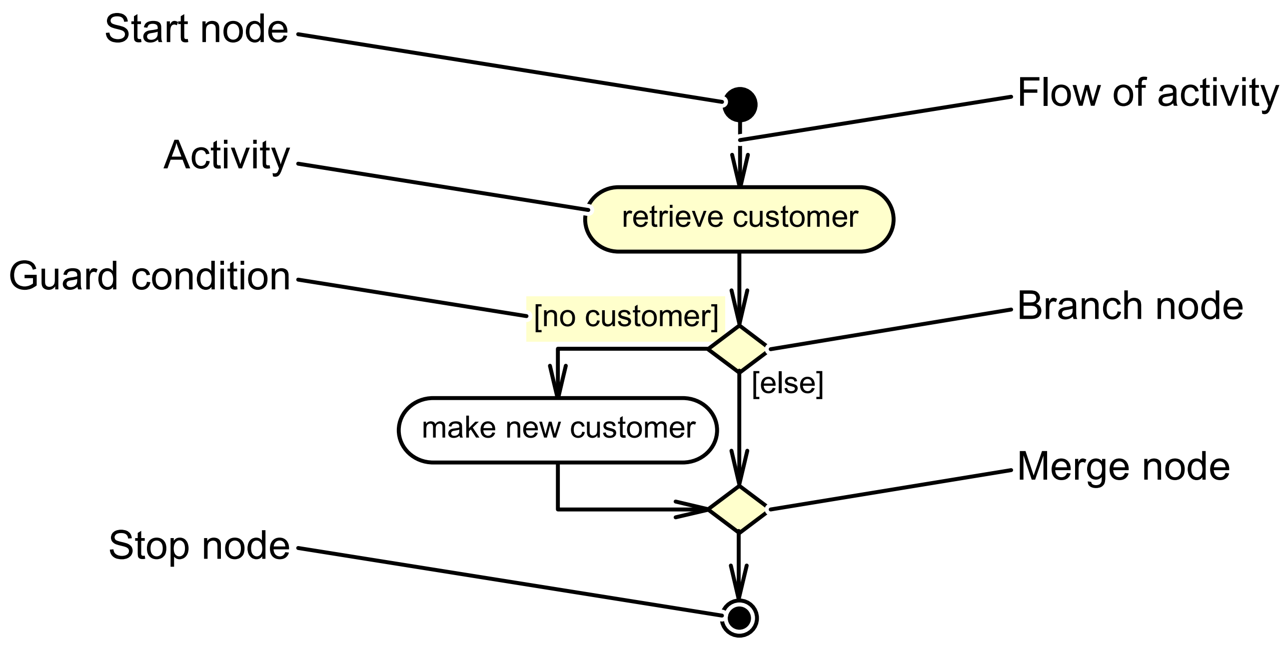
Describing a Use Case With an Activity Diagram

To verify a mental model of a Use Case you can:

- Model the flow of events of an Use Case in an Activity diagram
- Validate the Use Case by reviewing the Activity diagram with the stakeholders

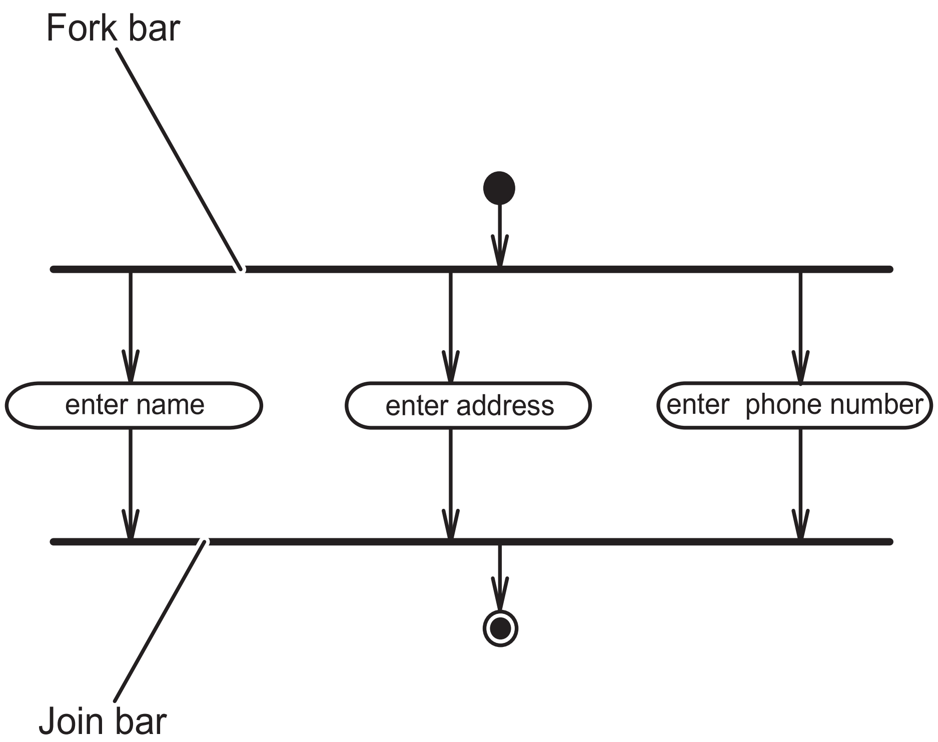
Identifying the Elements of an Activity Diagram

An Activity diagram is composed of the following elements:



Identifying Elements of an Activity Diagram

An example of concurrent activities:



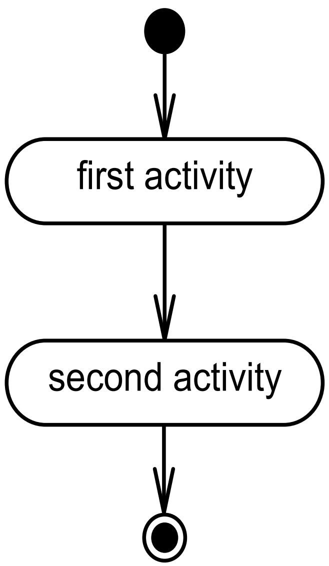
Activities And Actions

Activities and actions are processes taken by the system or an actor.

- Activity nodes and action nodes use the same notation in UML
- An activity can be divided into other activities or actions
- An action is an activity node which cannot be divided within the context of the current view.
- A primitive form of action results in a change in the state of the system or the return of a value.

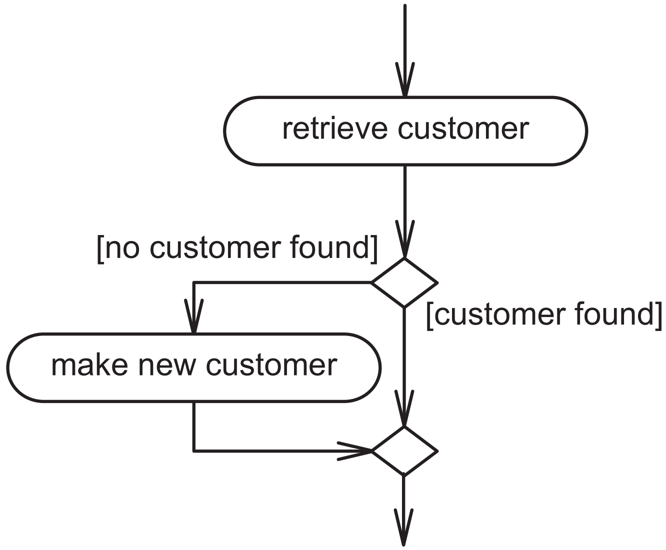
Flow of Control

An Activity diagram must start with a Start node and end with a Stop node. Flow of control is indicated by the arrows that link the activities together.



Branching

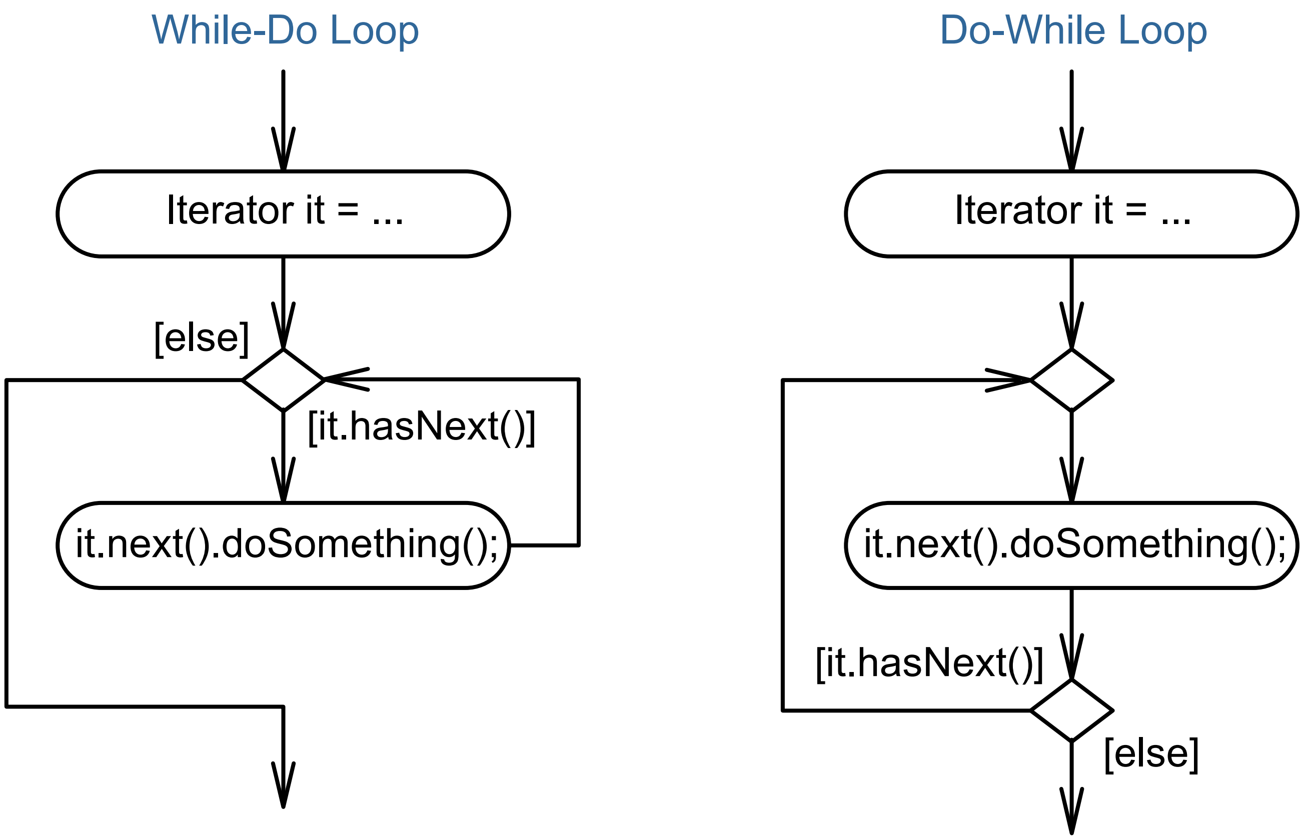
The branch and merge nodes represent conditional flows of activity.



- A branch node has two or more outflows, with Boolean predicates to indicate the selection condition.
- A merge node collapses conditional branches.

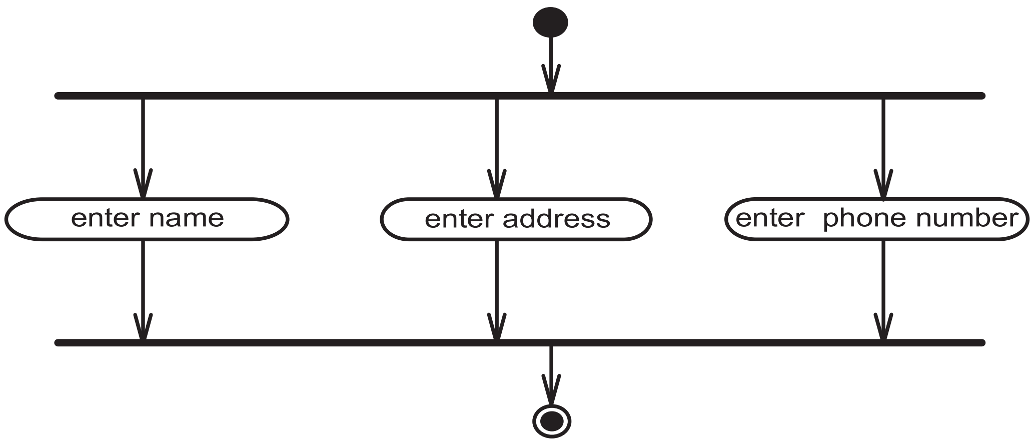
Iteration

Iteration can be achieved using branch nodes.



Concurrent Flow of Control

The fork and join bars indicate concurrent flow of control.

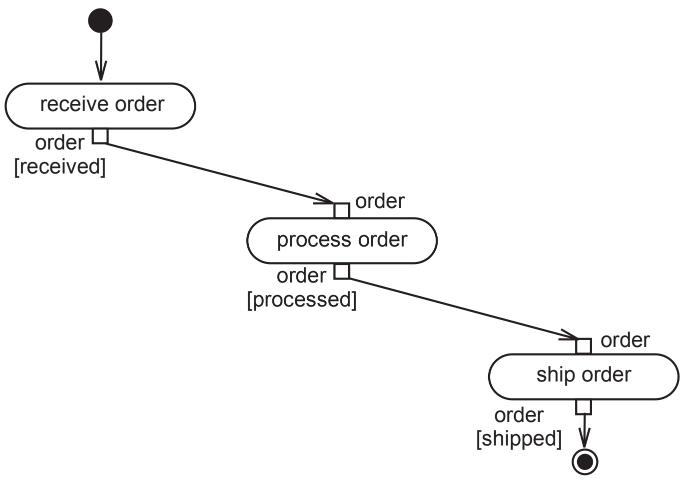


- Fork and join bars can represent either threaded activities or parallel user activities.
- The multiplicity indicator specifies how many of the parallel activities must have been processed.

Passing an Object between Actions

An Activity diagram can show objects being passed between actions

- A pin is a connection point of an action for object input or output

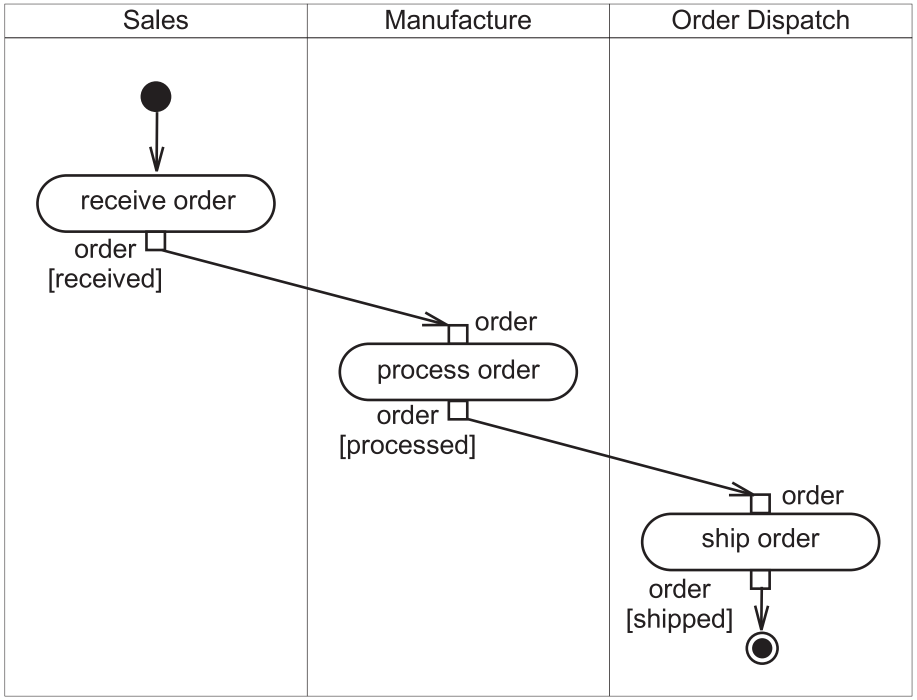


- The name of the pin denotes the object being passed

Partitions in Activity Diagrams

An Activity diagram can show objects grouped into partitions (formerly called swimlanes)

Partitions can be vertical, horizontal or both

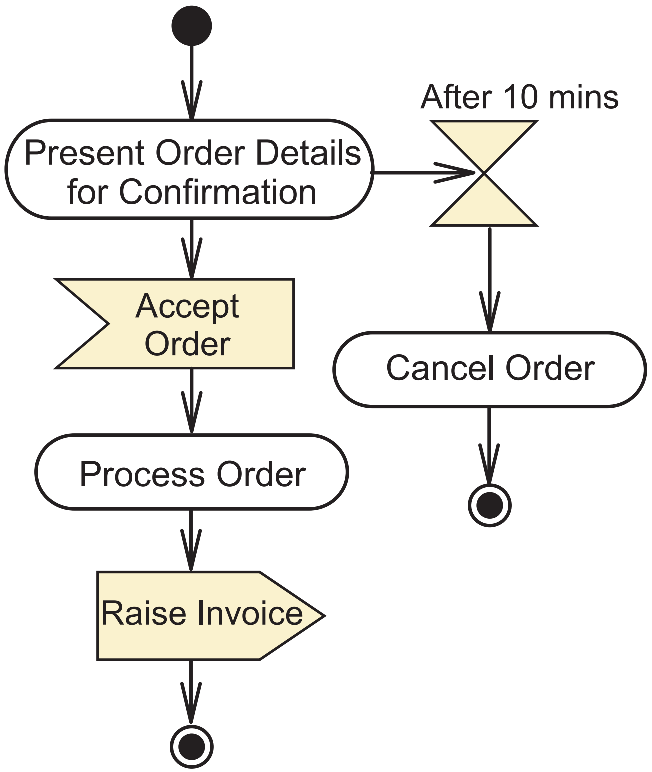


Signals in Activity Diagrams

An Activity diagram can show the receiving and sending of signals.

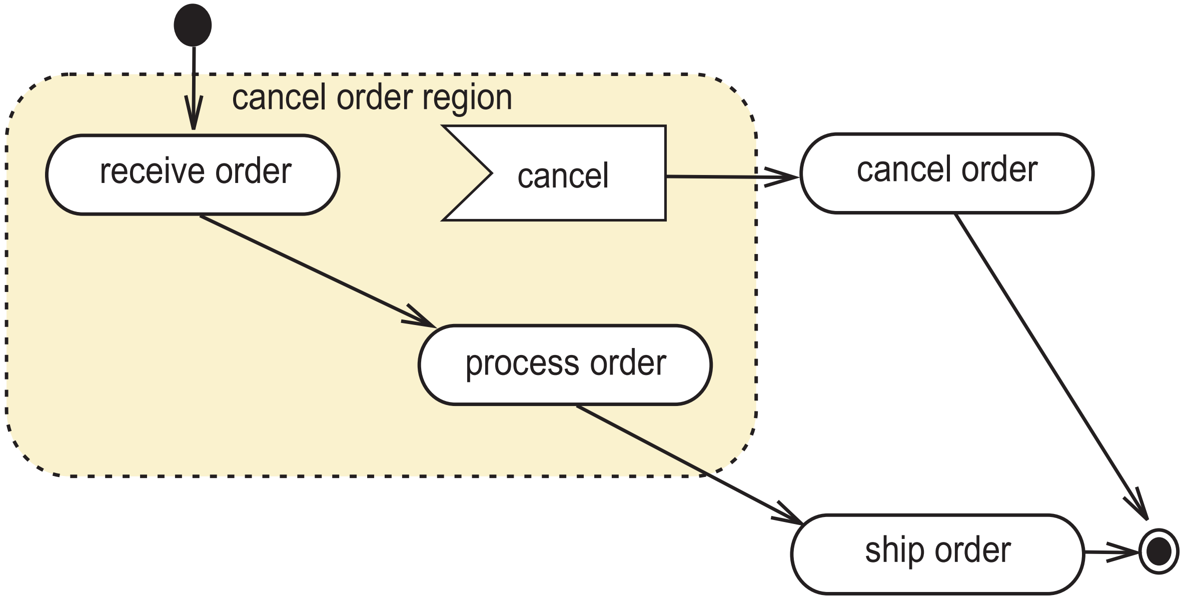
- An Accept Event Action element or an Accept Time Event element is used to show the receiving of a signal
- A Send Event Action element is used to show the sending of a signal

Displaying Signals in Activity Diagrams



Interruptible Activity Regions

An Activity diagram can show a sub set of activities that can be interrupted by an event.



Creating an Activity Diagram for a Use Case

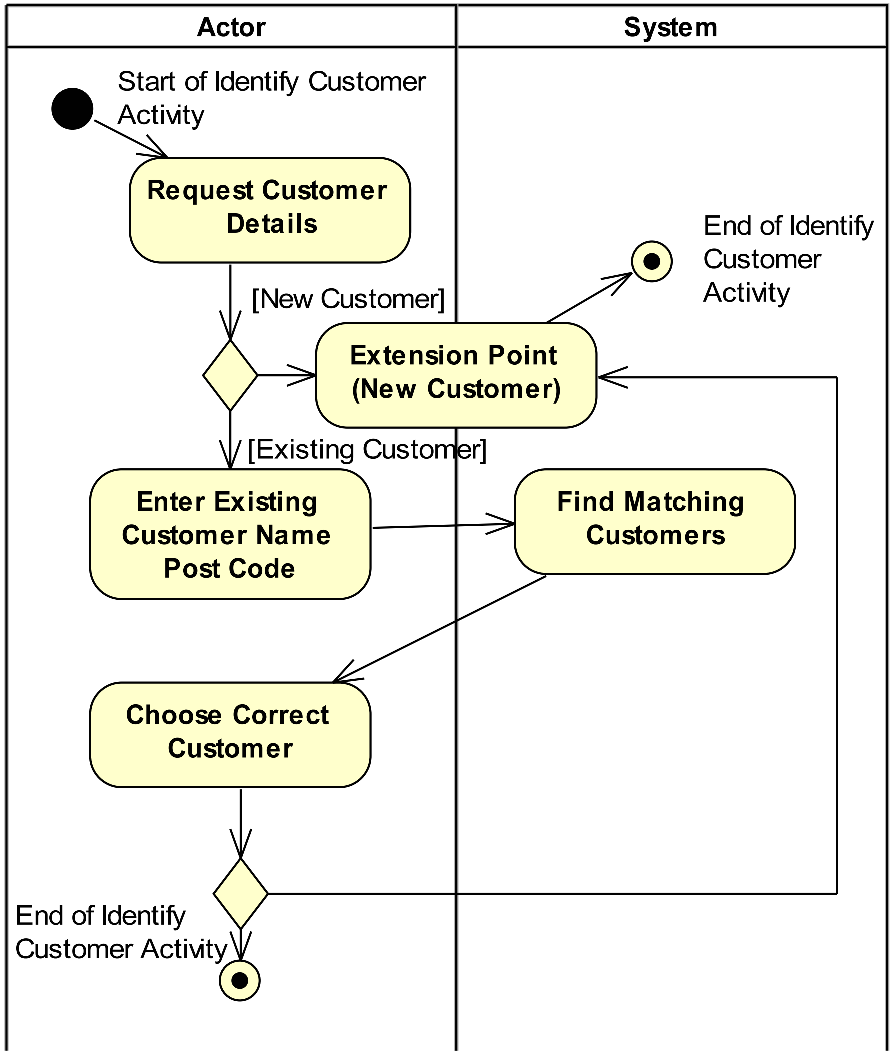
Analyze the flow of events field in the Use Case form:

- Identify activities
- Identify branching and looping
- Identify concurrent activities

Creating Activity Diagrams – Example 1

- The following slide illustrates a simple sequence of activities for a part of the Create Reservation Use Case.
- The diagram shows the activities involved in identifying the customer:
  - by either delegating the entry of the new customer details to the extension point (New Customer)
  - or by the actor entering a subset of customer information in order to find the existing customer
- If no existing customer is found then the extension point (New Customer) is used.

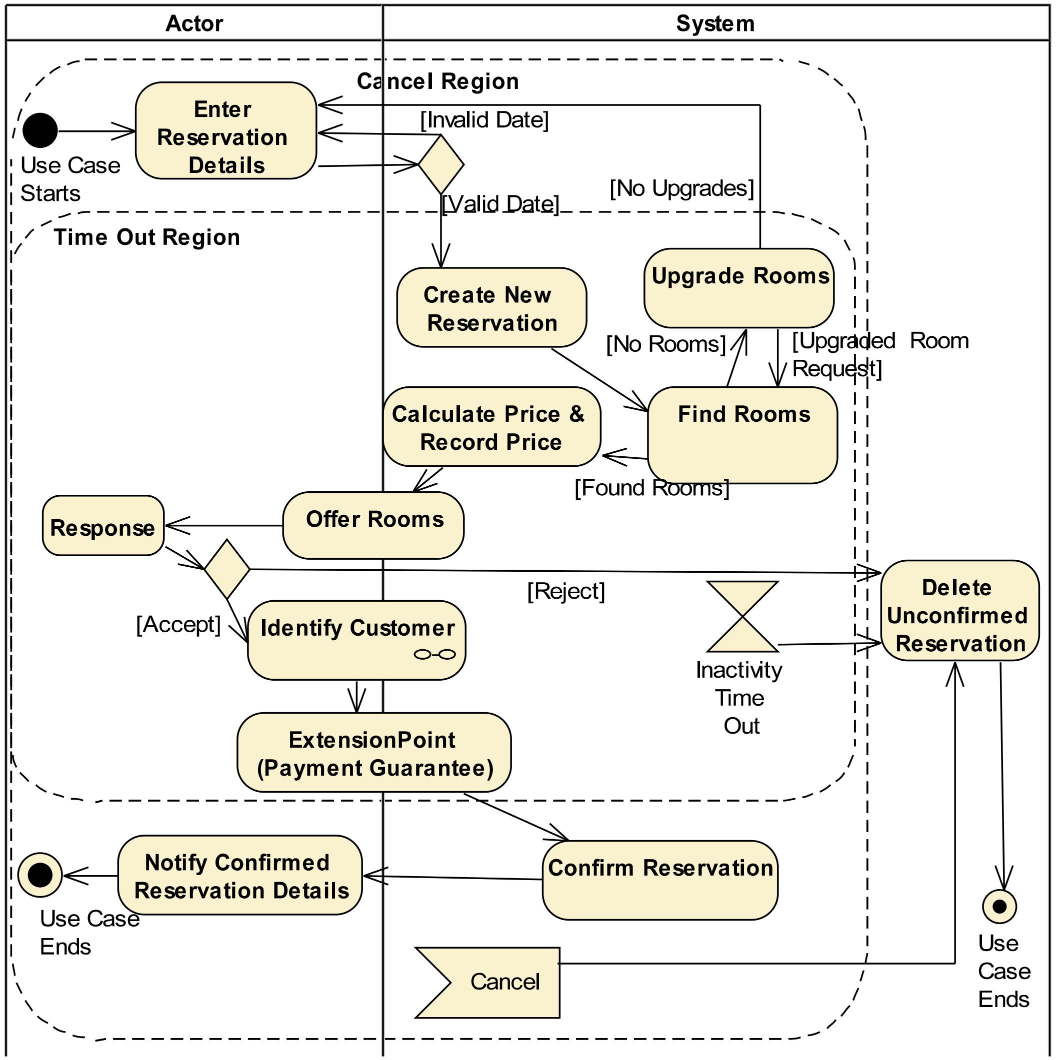
Creating Activity Diagrams – Example 1



Creating Activity Diagrams – Example 2

The following slide shows an Activity diagram that represents the main flow path and the alternate flow path of the Create Reservation Use Case Form.

Creating Activity Diagrams – Example 2



Summary

In this module you identified:

- The essential elements of an Activity diagram
- How to visually represent the flow of events of a Use Case with an Activity diagram

Module 6

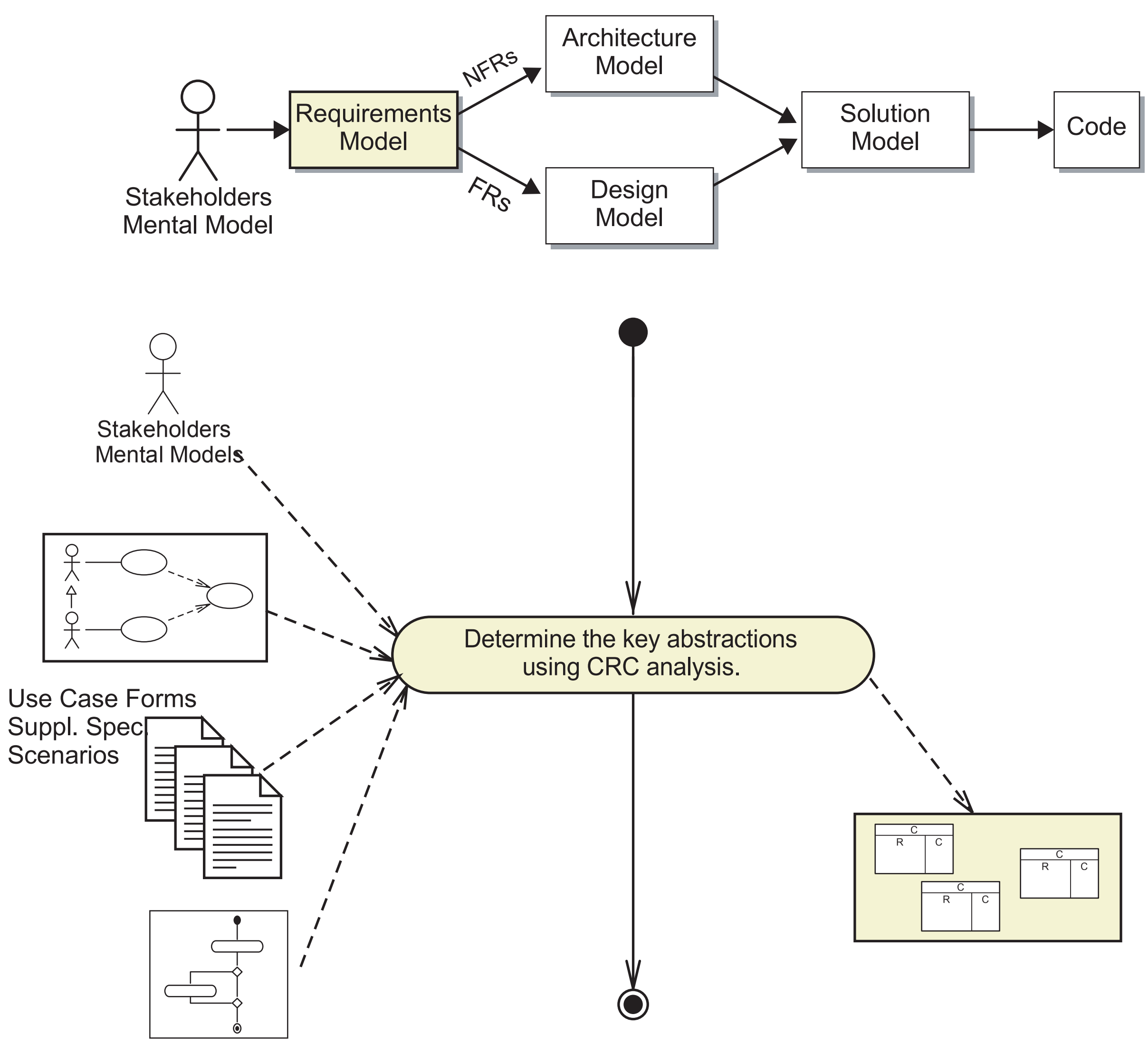
Determining the Key Abstractions

Objectives

Upon completion of this module, you should be able to:

- Identify a set of candidate key abstractions
- Identify the key abstractions using CRC analysis

Process Map



Stakeholders
Mental Model
Requirements Model
NFRs
FRs
Architecture Model
Design Model
Solution Model
Code
Stakeholders
Mental Models
Use Case Forms
Suppl. Spec
Scenarios
Determine the key abstractions using CRC analysis.

Introducing Key Abstractions

"A key abstraction is a class or object that forms part of the vocabulary of the problem domain." (Booch OOAD page 162)

Represents the primary objects within the system. Finding key abstractions is a process of discovery.

1. Identify all candidate key abstractions by listing all nouns from the project artifacts in a "Candidate Key Abstractions Form."
2. Use CRC analysis to determine the essential set of key abstractions.

   Key abstractions are recognized as objects that have responsibilities and are used by other objects (the collaborators).

Identifying Candidate Key Abstractions

Begin the process of identifying all of the unique nouns in the project artifacts by focusing on the following areas in these documents:

- The Main Flow and Alternate Flow sections of the use case forms
- The other sections of the use case forms
- The use case scenarios
- The Glossary of terms
- The Supplementary Specification document.

Tip: With practice you will be able to skip some of the nouns that are obviously not part of the domain.

Identifying the Candidate Abstractions

Here are a few excerpts from the Hotel System artifacts with the nouns marked in bold:

- From the Create Reservation Use Case Form Description Section:

  The **Customer** requests a **reservation** for **hotel rooms** for a **date range**. If all the requested **rooms** are available, the **price** is calculated and offered to the **Customer**. If **details of the customer** and a **payment guarantee** are provided, the **reservation** will be confirmed to the **Customer**.

Identifying the Candidate Abstractions

- From the Create Reservation Use Case Form Main Flow Section:

  Customer enters **types of rooms**, **arrival date**, and **departure date**
  Systems creates a **reservation** and reserves **rooms**
  System calculates **quoted price**
  System records **quoted price**
  System notifies **Customer** of **reservation details** (including **rooms** and **price**)
  Customer accepts **rooms** offered
  Extension Point (new **customer**)
  Extension Point (**payment guarantee**)
  System changes **reservation status** to “confirmed”
  System notifies **Customer** of **confirmed reservation** details

Identifying the Candidate Abstractions

- From the Create Reservation Use Case Form Alternate Flow Section:

  Customer can enter **duration** instead of **departure date**
  Failed date check BR1. Notify **error** to **Customer**
  Complying with BR2, **System** determines that required **rooms** are not available
  System upgrades one or more **room types**
  No further upgrades available. Notify **message** to **Customer**
  Rooms offered are declined
  Customer already exists, **Customer** enters **customer name** & **zip code**
  System searches for matching **customers**, notifies **Customer** of matching **customers**, **Customer** selects correct **customer details**
  Payment guarantee fails. Notify **message** to **Customer**
  Existing **customer** not found
  Reservation not confirmed, **reservation** deleted

Identifying the Candidate Abstractions

- From the Create Reservation Use Case Form Business Rules Section:

  The **arrival date** must not be before **today's date**, and the **departure date** must be after the **arrival date**
  Reservations with assigned **rooms** but no **payment guarantee** have a **status** of “held”
  Reservations with a **status** of “confirmed” must be linked to a **payment guarantee** and a **customer**
  Reservation must not exist without being linked to at least one **room**

Identifying the Candidate Abstractions

- From the Create Reservation Use Case Form Remaining Sections:

  …

- From the Supplementary Specification Documents. For example the Project Glossary:

  Reservation: An allocation of a specific **number of rooms**, each of a specified **room type**, for a specified **period of days**

  Date Range: Specifies a **start date** and an **end date**

Candidate Key Abstractions Form

The form for recording candidate key abstractions uses three fields:

- Candidate Key Abstraction – This field contains a noun discovered from the project artifacts.
- Reason For Elimination – This field is left blank if the candidate becomes a key abstraction. Otherwise, this field contains the reason why the candidate was rejected.
- Selected Name – This field contains the name of the class if this entry is selected as a key abstraction.

Candidate Key Abstractions Form (Example)

Candidate Key Abstraction	Reason for Elimination	Selected Component Name
Reservation		
Customer actor		
System		
Customer		
Room		
Date Range		
Price		
Customer Details		
...		

Project Glossary

The process of identifying candidate key abstractions is also a good opportunity to verify that your project glossary is up-to-date.

- Verify that all domain-specific terms have been listed and defined.
- Identify synonyms in the project glossary and select a primary term to use throughout the documentation and source code.

Discovering Key Abstractions Using CRC Analysis

After you have a complete list of candidate key abstractions, you need to filter this list. One technique is CRC analysis:

1. Select one candidate key abstraction.
2. Identify a use case in which this candidate is prominent.
3. Scan the use case forms, use case scenarios to determine responsibilities and collaborators.
4. Scan the Glossary for all references to the noun.
5. Document this key abstraction with a CRC card.
6. Update Candidate Key Abstractions Form based on findings.

Selecting a Key Abstraction Candidate

Selecting a good key abstraction candidate is largely intuition, but here are a few tactics:

- Ask a domain expert.
- Choose a candidate key abstraction that is used in a use case name.
- Choose a candidate key abstraction that is used in a use case form.

Selecting a Key Abstraction Candidate

The noun “reservation” appears many times in the following areas:

- In the following use case names:
  - Create *Reservation*
  - Update *Reservation*
  - Delete *Reservation*
- In many places throughout the use case forms. For example, the Check In Customer Use Case Form will describe assigning a bill to a *Reservation*

Identifying a Relevant Use Case

To determine whether the candidate key abstraction is a real key abstraction, you must determine if the candidate has any responsibilities and collaborators.

To identify a use case that might declare a candidate's responsibilities and collaborators:

1. Scan the use case names for the candidate key abstraction.
2. Scan the use case forms for the candidate key abstraction.
3. Scan the use case scenarios for the candidate key abstraction.

Identifying a Relevant Use Case - Contd.

4. Scan the text of the use case scenarios to see if the candidate key abstraction is mentioned.

Identifying a Relevant Use Case

As mentioned previously, there are three use cases that focus on the reservation key abstraction:

- Create *Reservation*
- Update *Reservation*
- Delete *Reservation*

Determining Responsibilities and Collaborators

Scan the scenarios and use case forms of the identified use cases for responsibilities (operations and attributes) of the candidate key abstraction and the objects with which it must collaborate.

If you cannot find any responsibilities, then you can reject this candidate.

Determining Responsibilities and Collaborators

Following are a few relevant artifacts:

- Glossary Term, Reservation: An allocation of a specific number of rooms, each of a specified room type, for a specified period of days
- Business Rule BR9: Reservation must not exist without being linked to at least one room
- Business Rule BR8: Reservations with a status of “confirmed” must be linked to a payment guarantee and a customer
- Main Flow 3.3: System changes reservation status to “confirmed”

Documenting a Key Abstraction Using a CRC Card

Class Name	
Responsibilities	Collaborators

Documenting a Key Abstraction Using a CRC Card

Reservation	
Responsibilities	**Collaborators**

`Reserves a Room`	`Room`
	`Customer`
	`Payment Guarantee`

`status`
`(New, Held, Confirmed)`
`arrival date`
`departure date`	

Updating the Candidate Key Abstractions Form

- If the candidate you selected has responsibilities, then enter the name of the key abstraction (from the CRC card) into the “Selected Name” field.
- Otherwise, enter an explanation why the candidate was not selected as a key abstraction.

Updating the Candidate Key Abstractions Form

Candidate Key Abstraction	Eliminated for the Following Reason	Selected Component Name
Reservation		Reservation
Customer actor	External to the system	
System	The whole system	
Customer		Customer
Rooms		Room
Date Range	A synonym for Arr. and Dept. Date	
Price	A synonym for Quoted Price	
Customer Details	Same as Customer	

Updating the Candidate Key Abstractions Form

Candidate Key Abstraction	Eliminated for the Following Reason	Selected Component Name
Payment Guarantee		Payment Guarantee
Room Type		RoomType
Arrival Date	Attribute of Reservation	
Departure Date	Attribute of Reservation	
Quoted Price	Attribute of Reservation	
Reservation Details	Same as Reservation	
Customer Name	Attribute of Customer	
Customer Zip Code	Attribute of Customer	
Today Date	External to the system	
Period of Days	A synonym for Duration	

Summary

- Key abstractions are the essential nouns in the language of the problem domain.
- To identify the key abstractions:
  a. List all (problem domain) nouns from the project analysis artifacts, in a Candidate Key Abstractions Form.
  b. Use CRC analysis to identify the key abstractions (a class with responsibilities and collaborators) from the candidate list.

Module 7

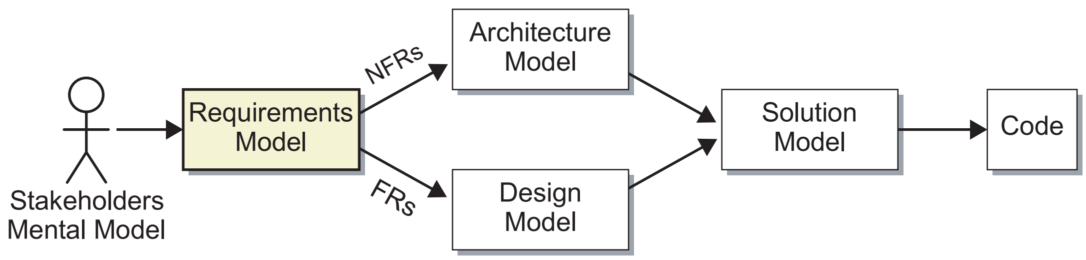
Constructing the Problem Domain Model

Objectives

Upon completion of this module, you should be able to:

- Identify the essential elements in a UML Class diagram
- Construct a Domain model using a Class diagram
- Identify the essential elements in a UML Object diagram
- Validate the Domain model with one or more Object diagrams

Process Map



Stakeholders Mental Model
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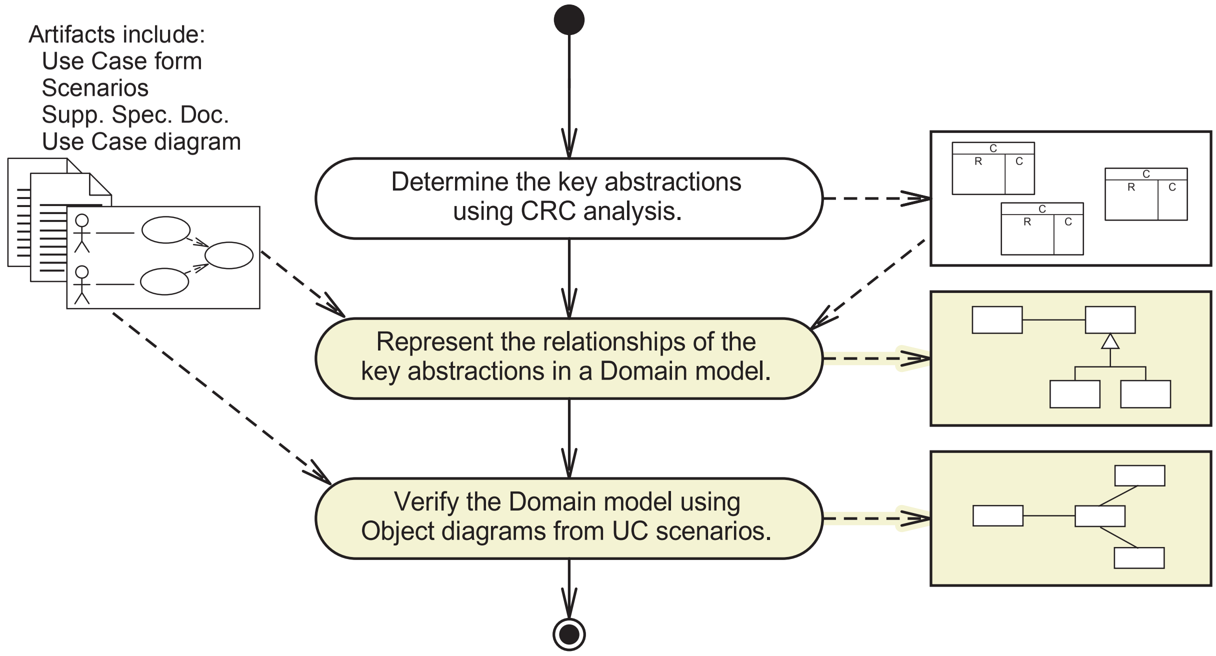


Artifacts include:
Use Case form
Scenarios
Supp. Spec. Doc.
Use Case diagram
Determine the key abstractions using CRC analysis.
Represent the relationships of the key abstractions in a Domain model.
Verify the Domain model using Object diagrams from UC scenarios.

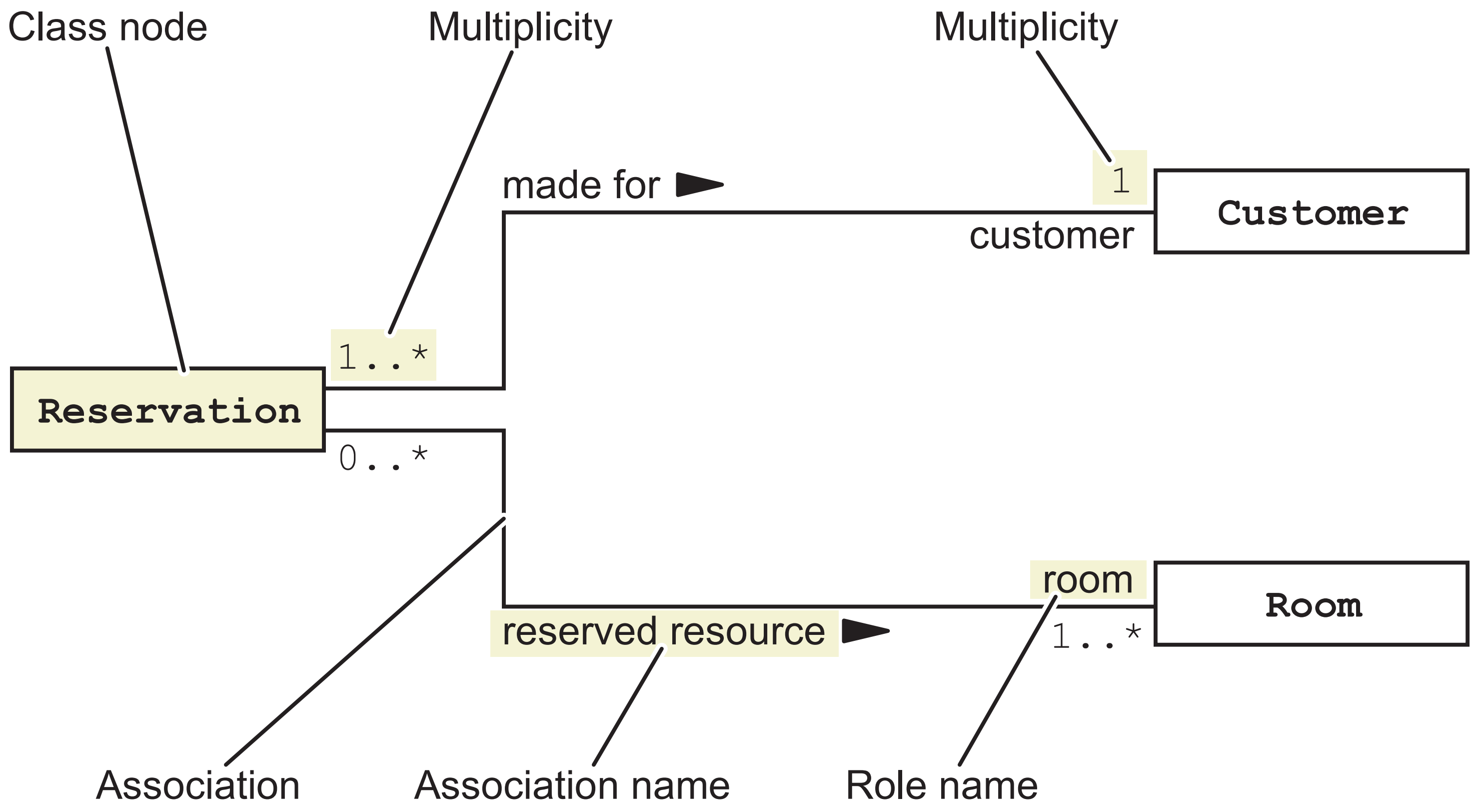
Introducing the Domain Model

Domain model – "The sea of classes in a system that serves to capture the vocabulary of the problem space; also known as a conceptual model." (Booch Object Solutions page 304)

- The classes in the Domain model are the system's key abstractions.
- The Domain model shows relationships (collaborators) between the key abstractions.

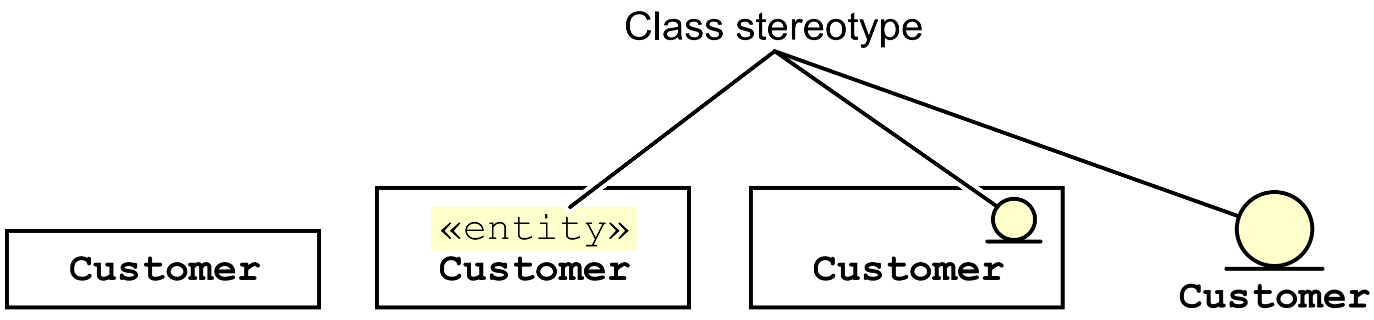
Identifying the Elements of a Class Diagram

A UML Class diagram is composed of the following elements:



Class Nodes

Class nodes represent classes of objects within the model.

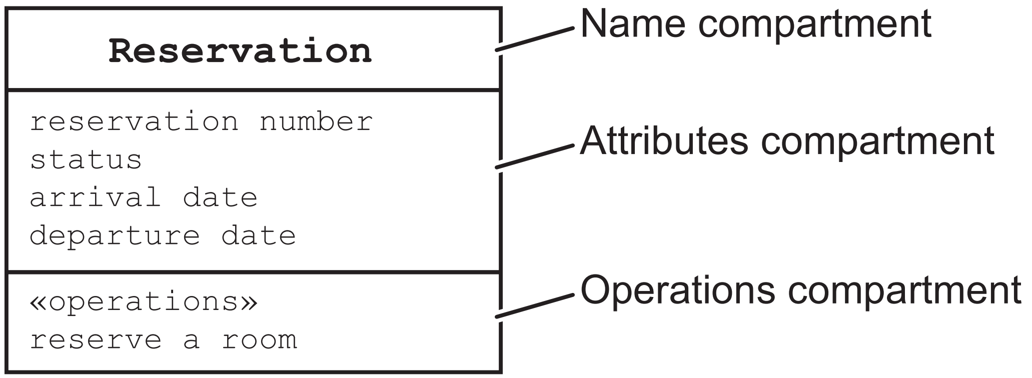


These can represent:

- Conceptual entities, such as key abstractions
- Real software components

A stereotype can help identify the type of the class node.

Class Node Compartments

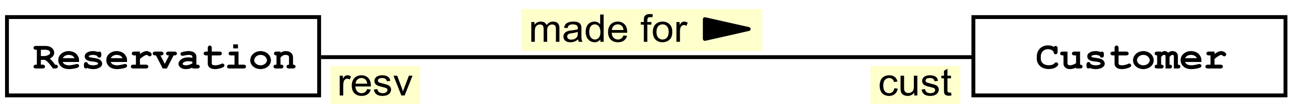


- The name compartment records the name of the class.
- The attributes compartment records attributes (or instance variables) of the class.
- The operations compartment records operations (or methods) of the class.
- Additional compartments may be added.

Associations

Associations represent relationships between classes. Associations are manifested at runtime, but these models represent all possible runtime arrangements between objects.

Relationship and Roles



This association would be read as "A reservation is made for a customer."

Multiplicity

Multiplicity determines how many objects might participate in the relationship.

For example:

This association would be read as "A reservation is made for one and only one customer." Reading it in the other direction is "A customer can make one or more reservations."

Navigation

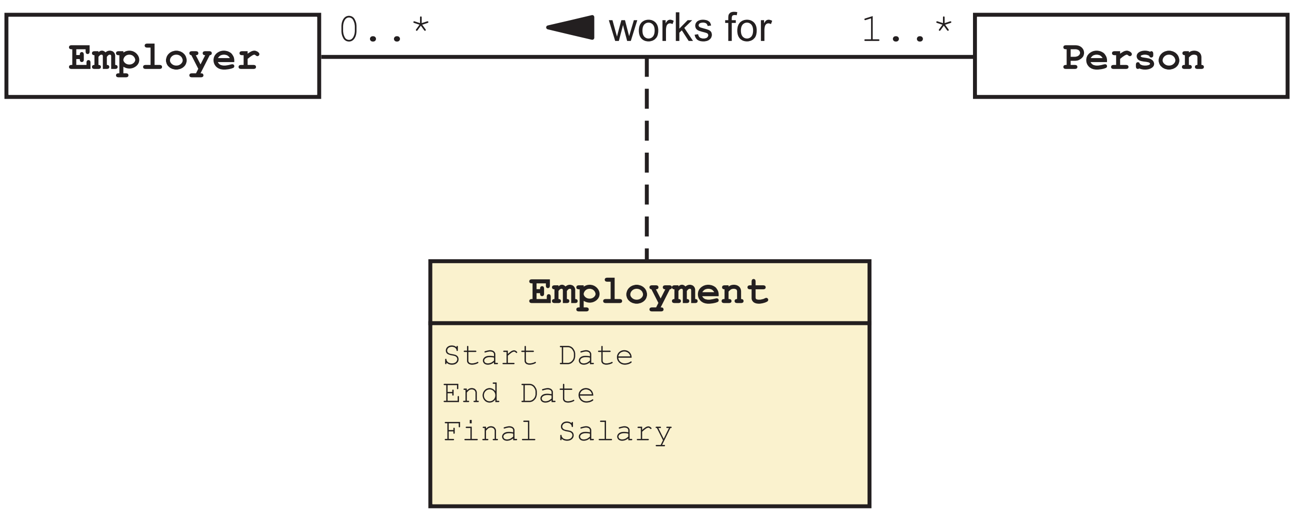
Navigation arrows on the association determine what direction an association can be traversed at runtime.

For example:

This association would be read as "From a reservation the system *can directly* retrieve the room, and from a room the system *cannot directly* retrieve the reservation for that room."

Association Classes

Sometimes information is included in the association between two classes. For example:



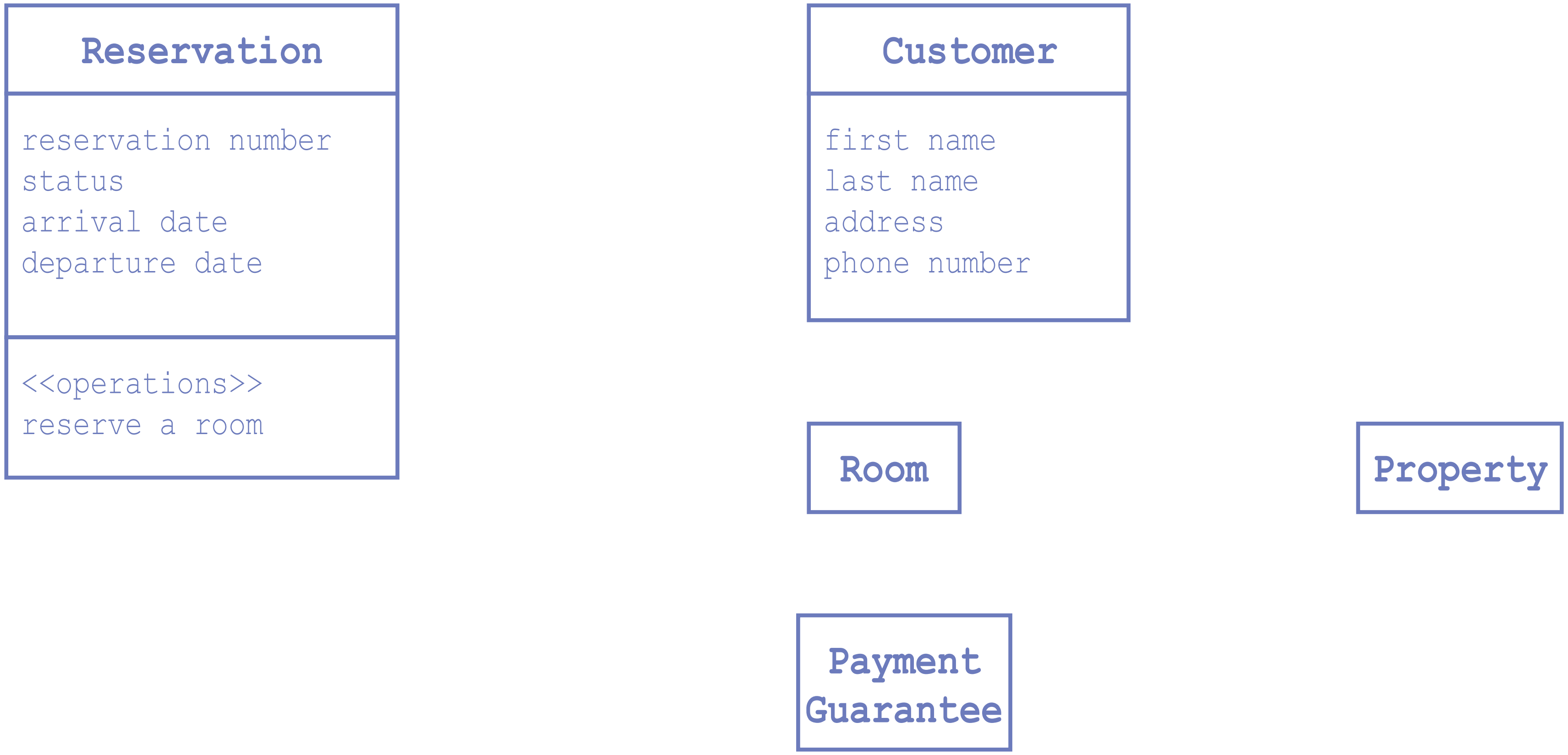
`Employment` is an association class that records the employment details for each term of employment between a person and an employer.

Creating a Domain Model

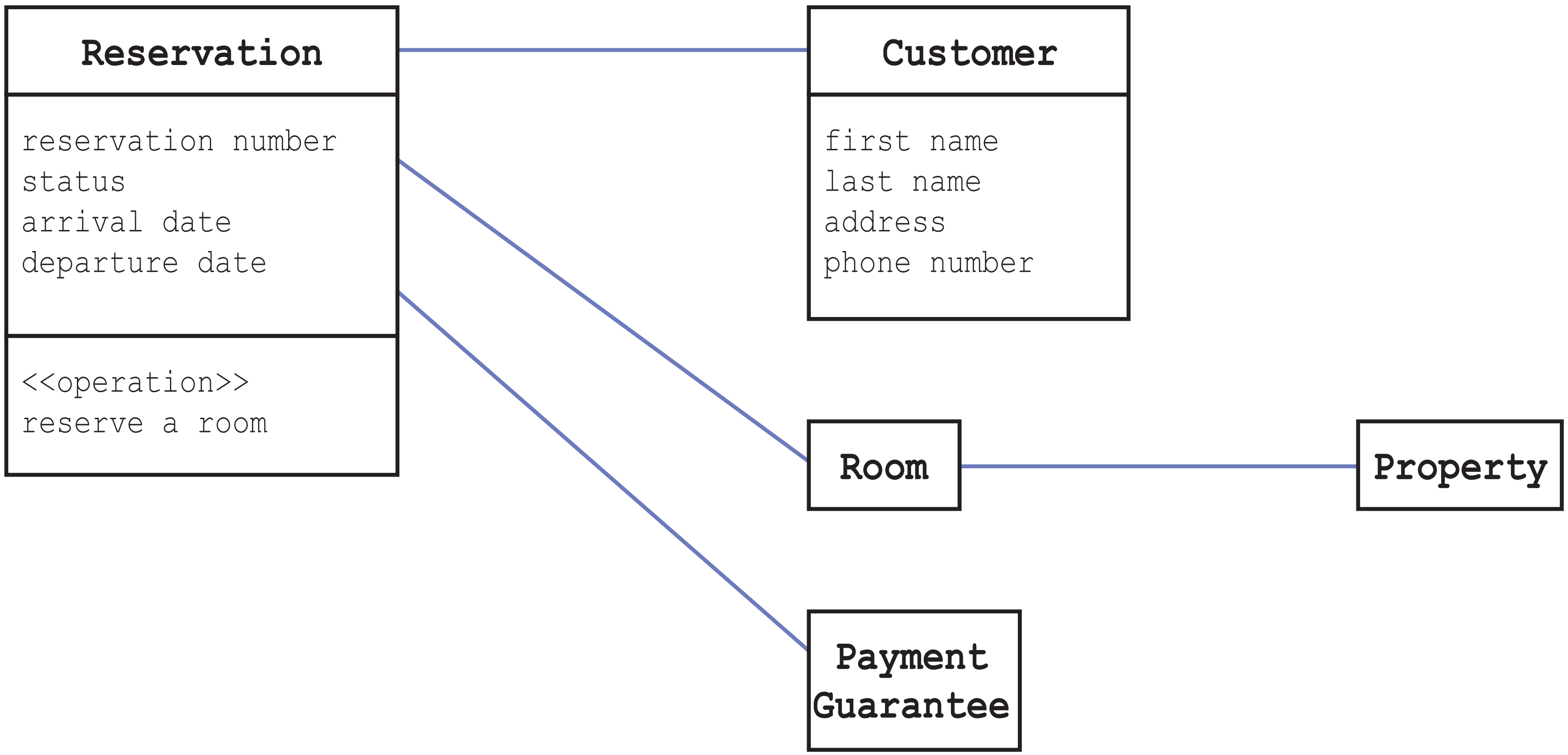
Starting with the key abstractions, you can create a Domain model using these steps:

1. Draw a class node for each key abstraction, and:
   a. List known attributes.
   b. List known operations.
2. Draw associations between collaborating classes.
3. Identify and document relationship and role names.
4. Identify and document association multiplicity.
5. Optionally, identify and document association navigation.

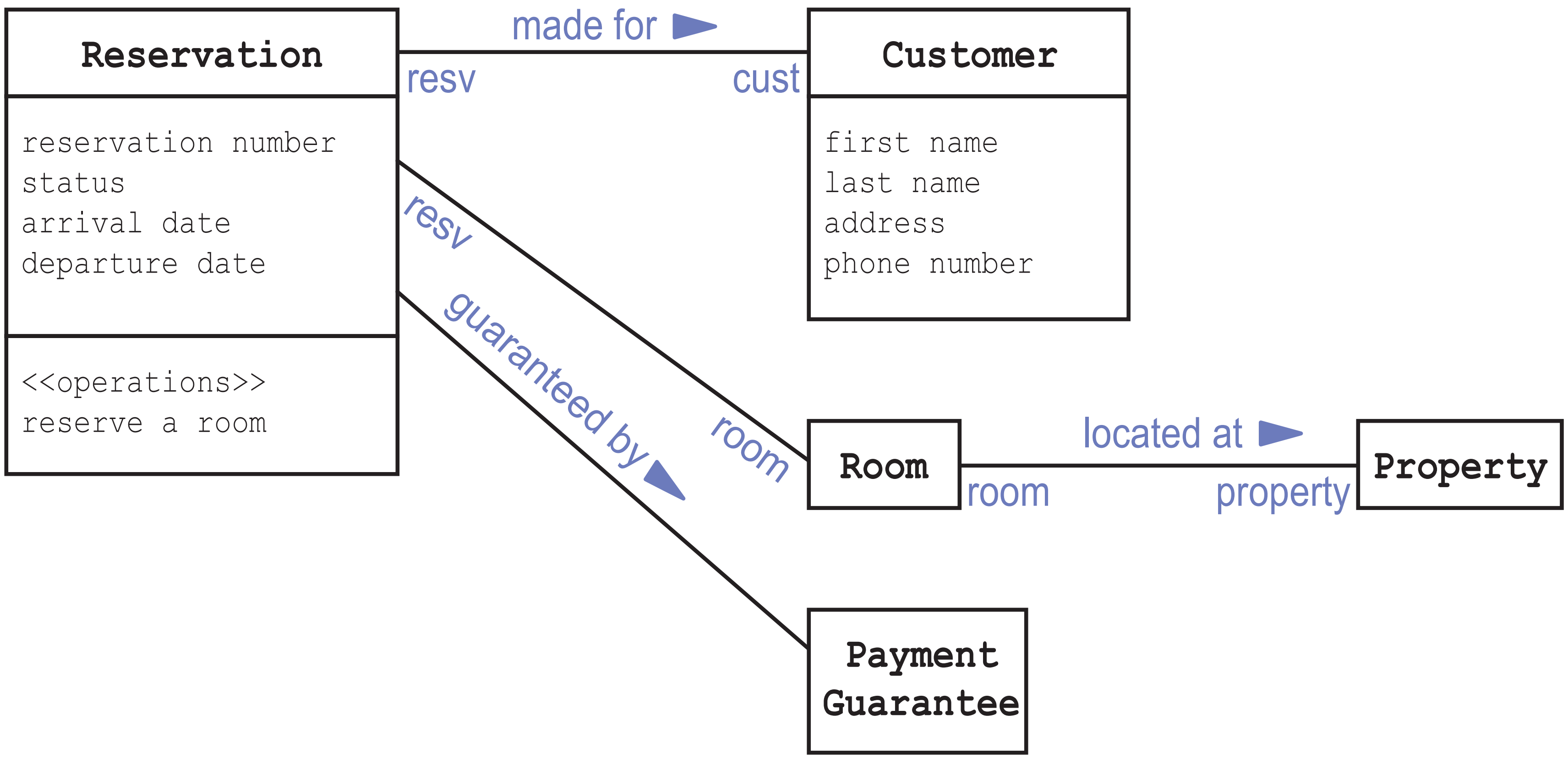
Step 1 – Draw the Class Nodes



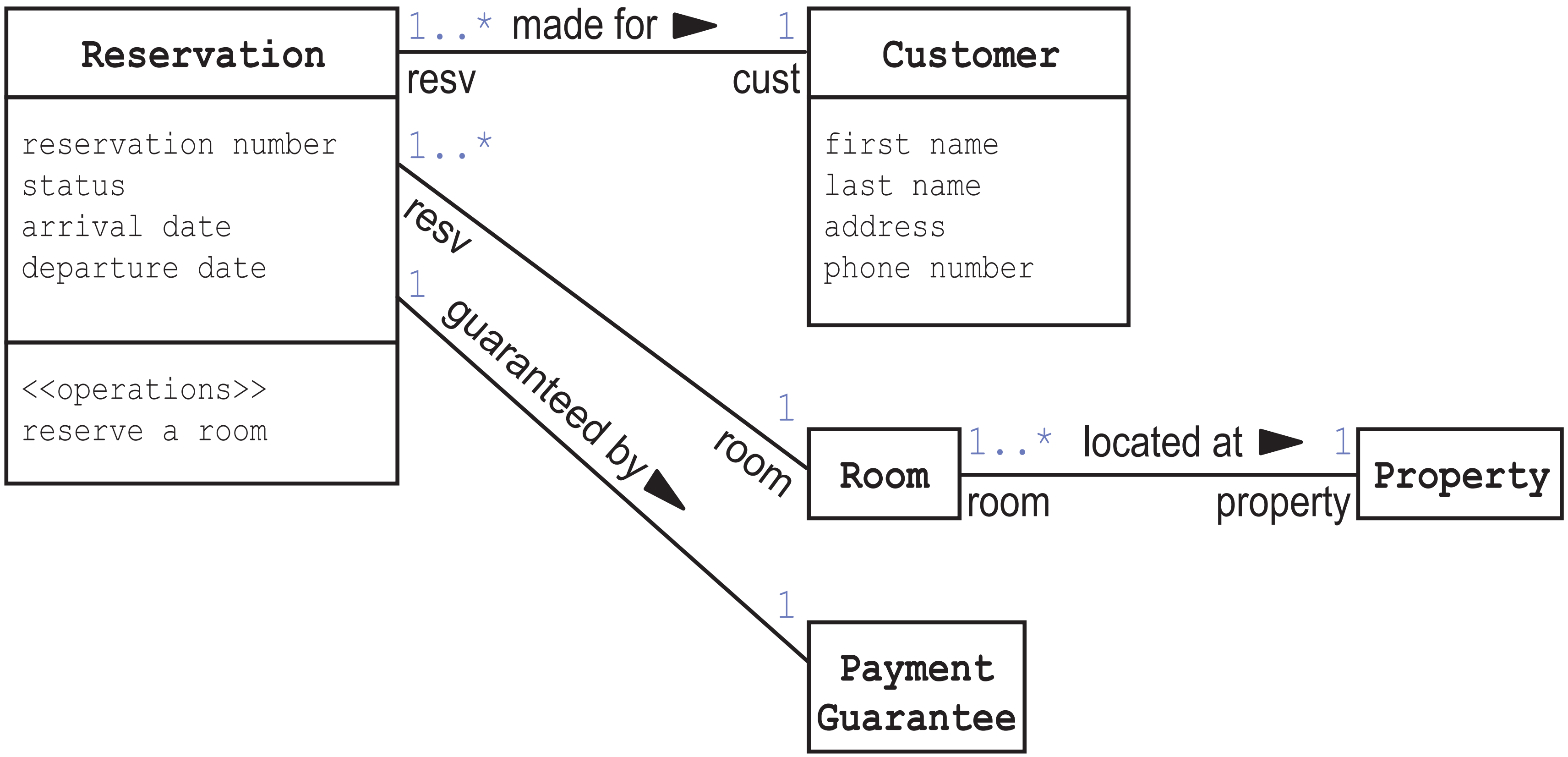
Step 2 – Draw the Associations



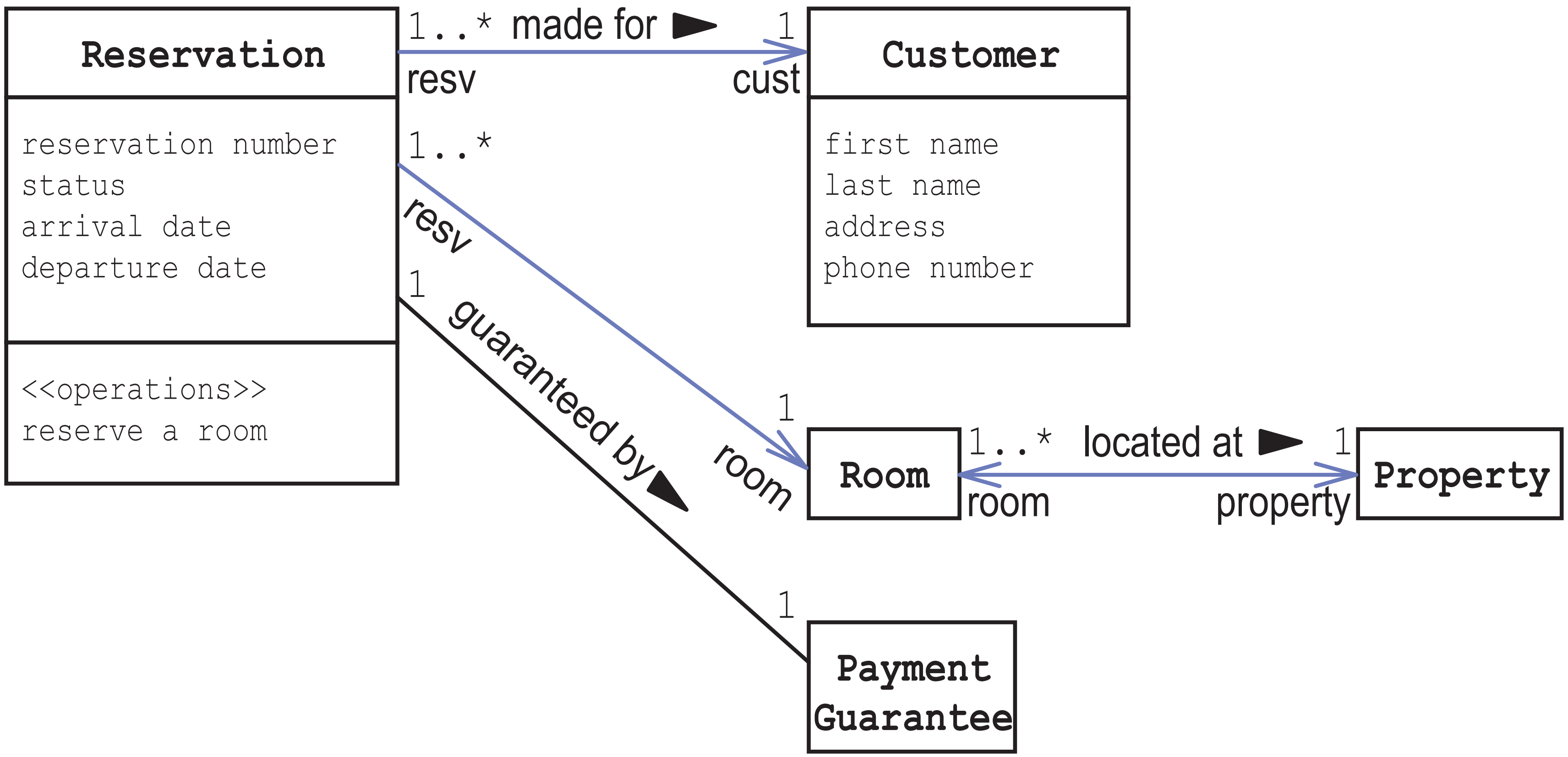
Step 3 – Label the Associations and Role Names



Step 4 – Label the Association Multiplicity



Step 5 – Draw the Navigation Arrows



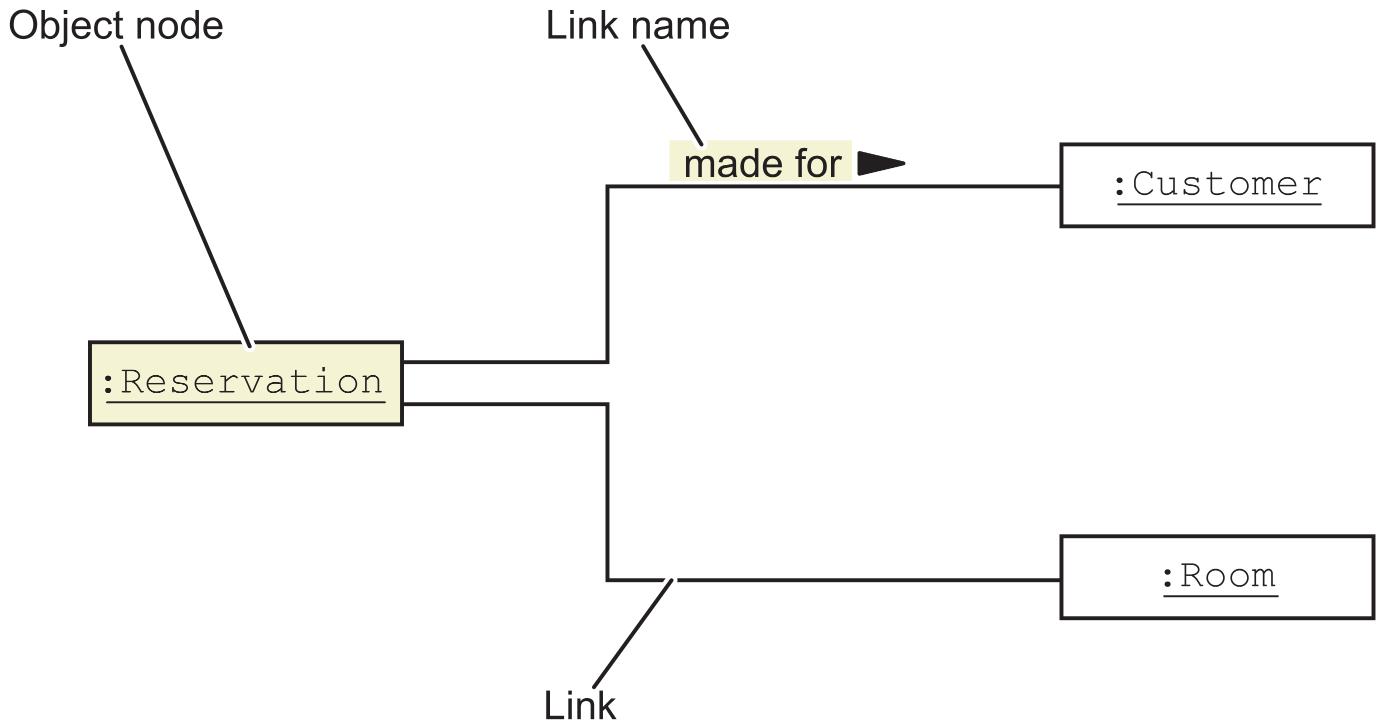
Validating the Domain Model (Intro)

You can validate the Domain model by analyzing multiple Object diagrams based on use case scenarios.

First, the essential elements of Object diagrams are presented.

Identifying the Elements of an Object Diagram

A static object diagram is an instance of a class diagram; it shows a snapshot of the detailed state of a system at a point in time. [UML specv1.4, page 3-35]



Object Nodes

An object node includes some form of name and data type:

Object name without type	Type without a name	Type with a name
Victoria	:Room	Blue:Room

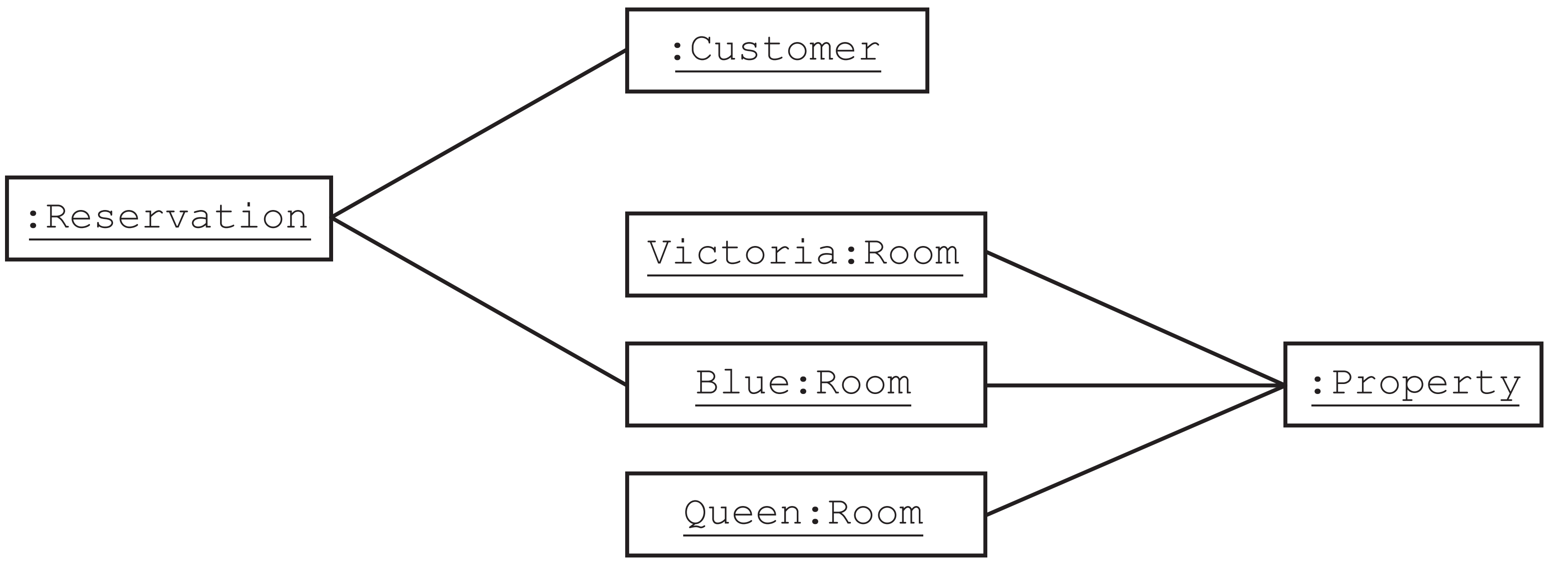
An object node might also include attributes:

```
:Customer
---------------------------------
first name = "Jane"
last name = "Googol"
address = "2 Main St, ..."
phone number = "999-555-4747"
```

Links

In Object diagrams each link is unique and is one-to-one with respect to the participants.

For example:



Validating the Domain Model Using Object Diagrams

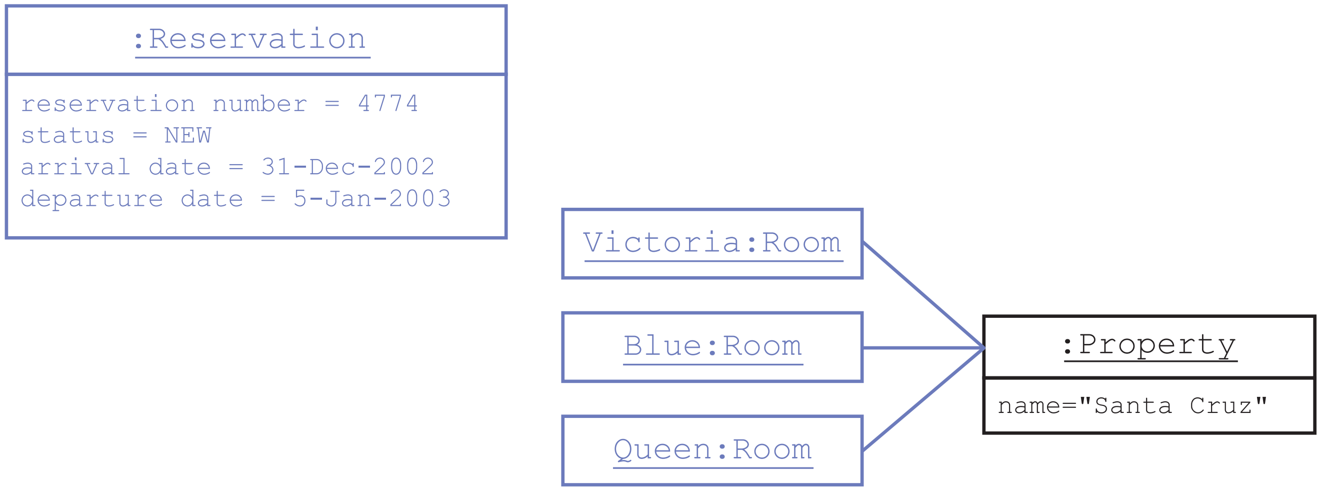
1. Pick one or more use cases that exercise the Domain model.
2. Pick one or more use case scenarios for the selected use cases.
3. Walk through each scenario (separately), and construct the objects (with data) mentioned in the scenario.
4. Compare each Object diagram against the Domain model to see if any association constraints are violated.

Step 1 – Create Reservation Scenario 1

The use case begins when the booking agent receives a request to make a reservation for rooms in the hotel. The booking agent enters the arrival date, the departure date, and the quantity of each type of room that is required.

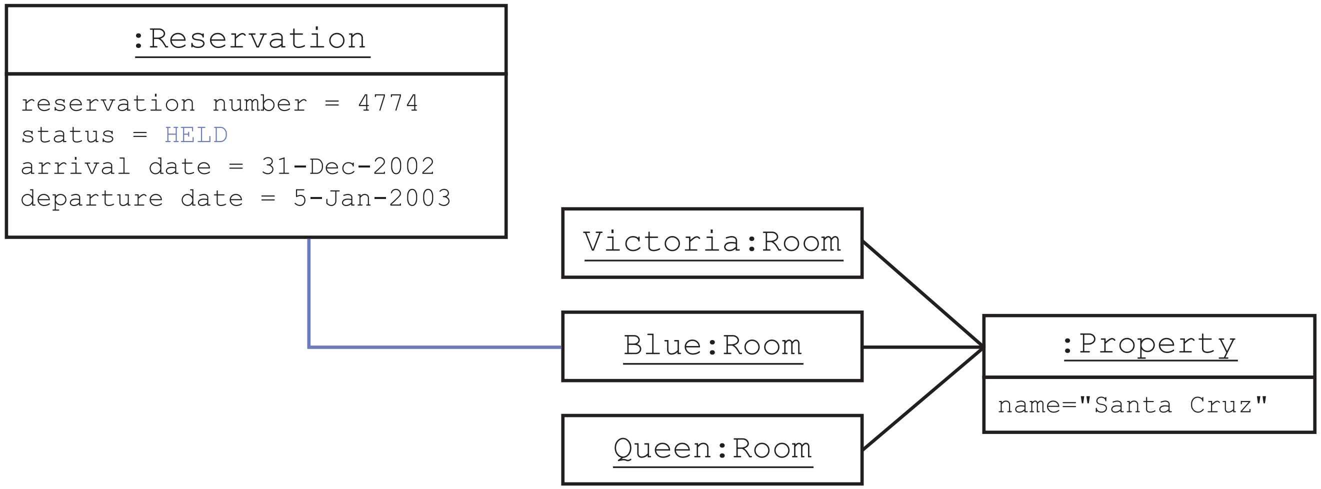
Step 2 – Create Reservation Scenario 1

The booking agent then submits the entered details. The system finds rooms thatwill be available during the period ofthe reservation.



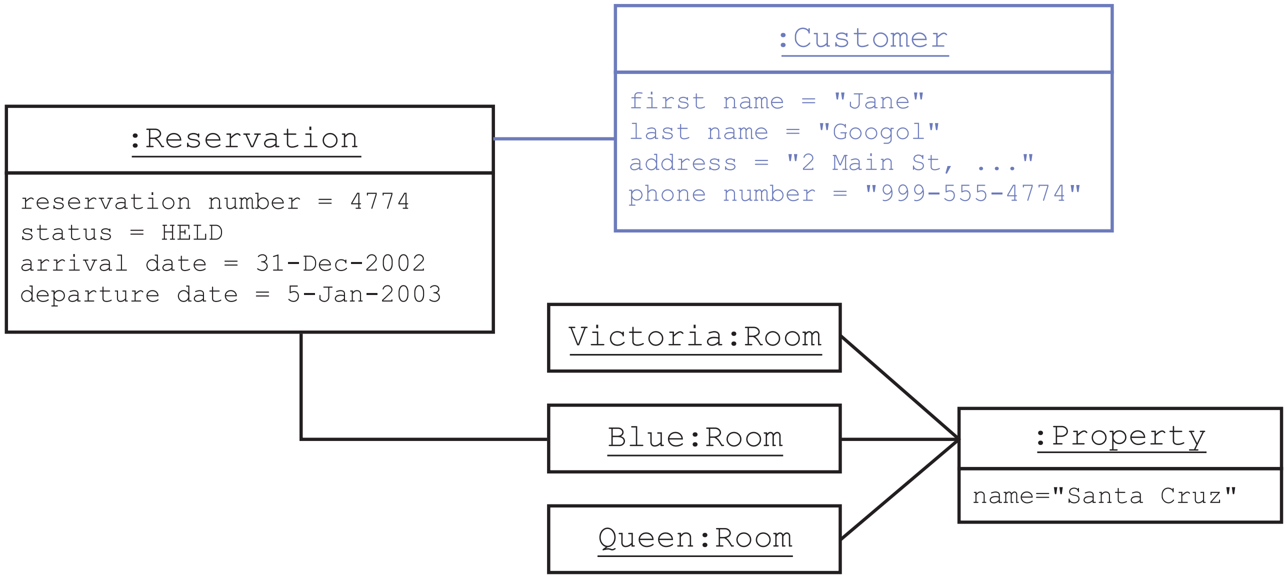
Step 3 – Create Reservation Scenario 1

The system allocates the required number and type of rooms from the available rooms. The system responds that the specified rooms are available, returns the provisional reservation number, and marks the reservation as "held"



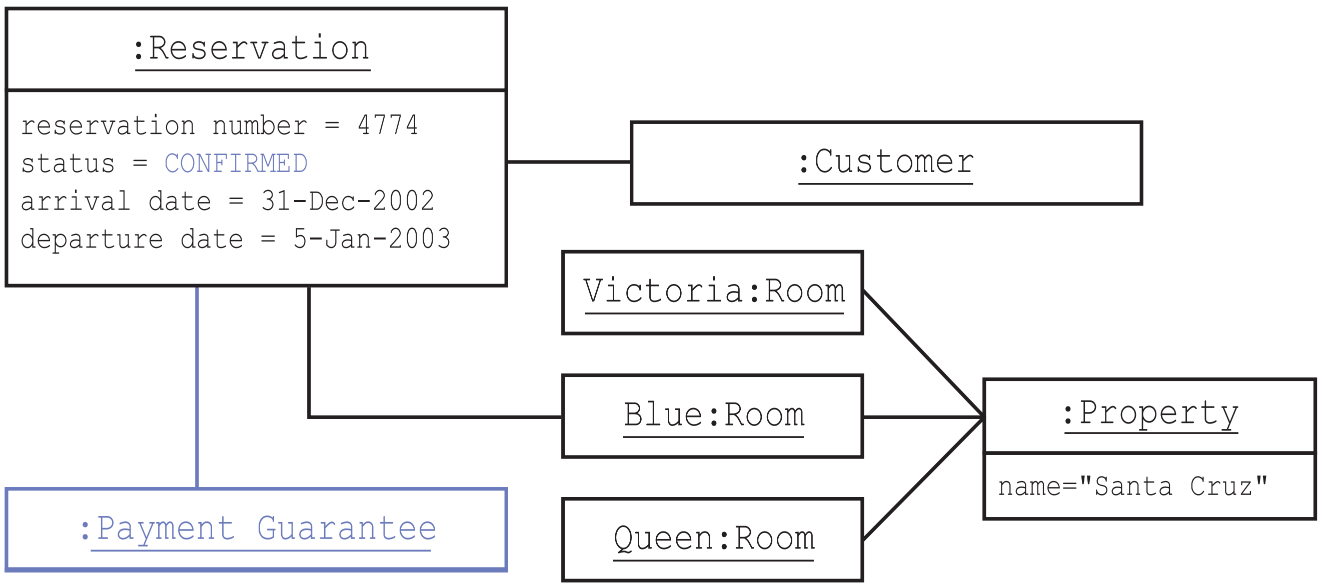
Step 4 – Create Reservation Scenario 1

The booking agent accepts the rooms offered. The booking agent selects that the customer has visited one of the hotels in this group before, and enters the zip code and customer name. The system finds and returns a list of matching customers with full address details. The booking agent selects one of the customers as being the valid customer. The system assigns this customer to the reservation.



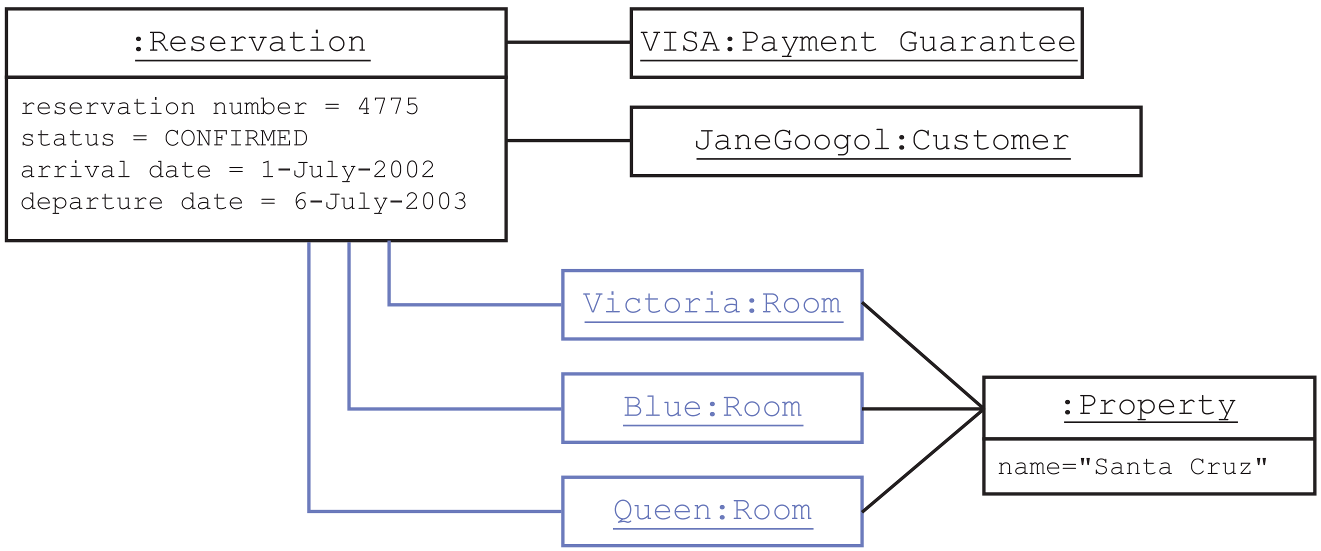
Step 5 – Create Reservation Scenario 1

The booking agent performs a payment guarantee check. This check is successful. The system assigns the payment guarantee to the reservation and changes the state of the reservation to “confirmed”. The system returns the reservation ID and booking details



Create Reservation Scenario No. 2

Another “Create a Reservation” scenario has the Actor making a reservation for a small family reunion in which three rooms are booked:

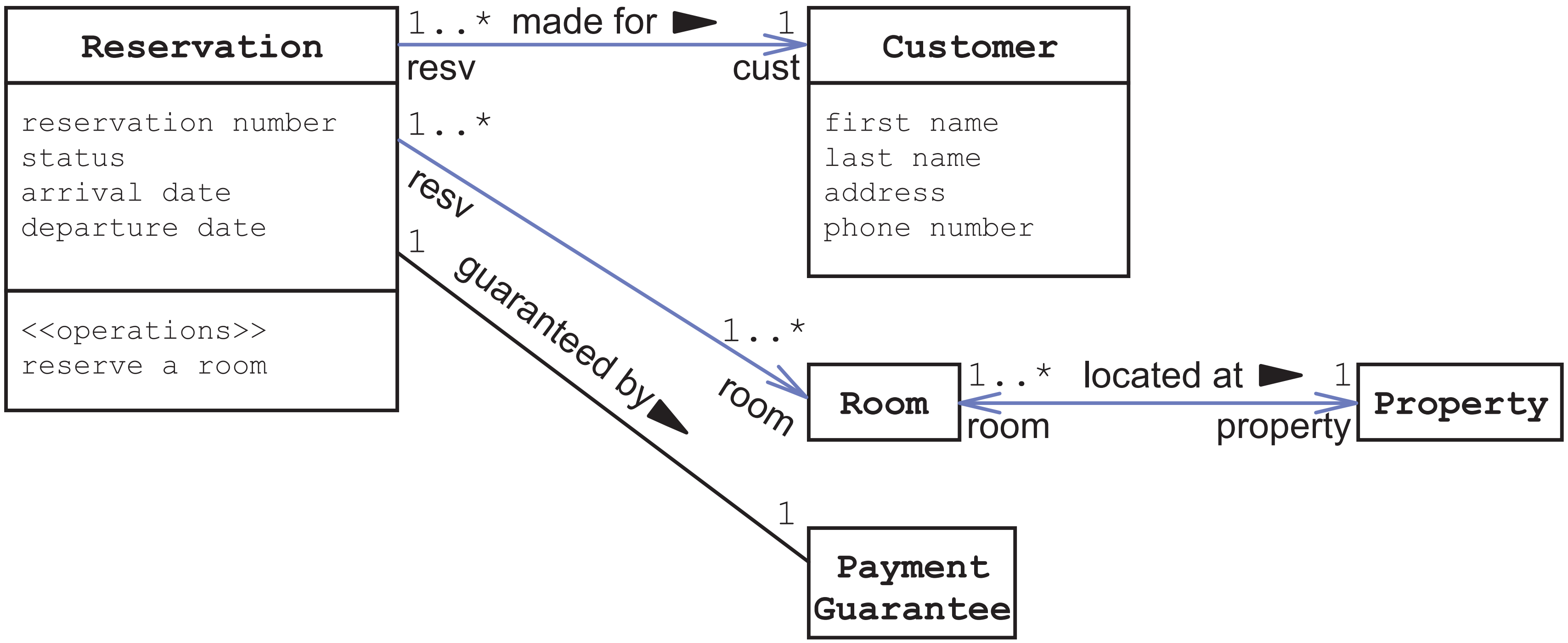


Comparing Object Diagrams to Validating the Domain Model

To validate the Domain model, compare the Class diagram with the scenario Object diagrams.

- Are there attributes or responsibilities mentioned in a scenario that are not listed in the Domain model?
- Are there associations in the Object diagrams that do not exist in the Domain model?
- Are there scenarios in which the multiplicity of a relationship is wrong?

Revised Domain Model for the Hotel Reservation System



Summary

- Use the Domain model to provide a static view of the key abstractions for the problem domain.
- Use the UML Class diagrams to represent the Domain model.
- Validate the Domain model by creating Object diagrams from use case scenarios to see if the network of objects fits the association constraints specified by the Domain model.

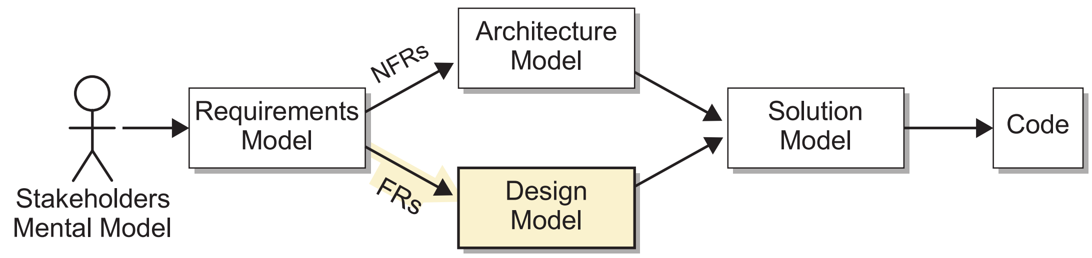
Module 8

Transitioning from Analysis to Design Using Interaction Diagrams

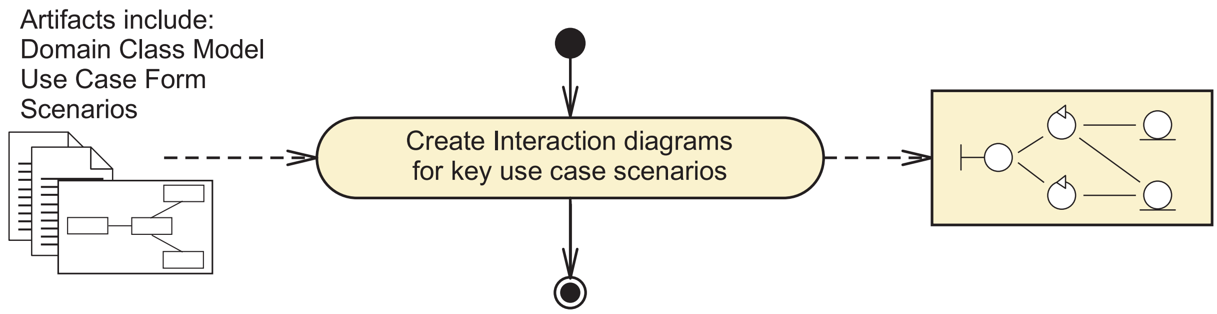
Objectives

- Explain the purpose and elements of the Design model
- Identify the essential elements of a UML Communication diagram
- Create a Communication diagram view of the Design model
- Identify the essential elements of a UML Sequence diagram
- Create a Sequence diagram view of the Design model

Process Map



Stakeholders
Mental Model
Requirements
Model
NFRs
FRs
Architecture
Model
Design
Model
Solution
Model
Code

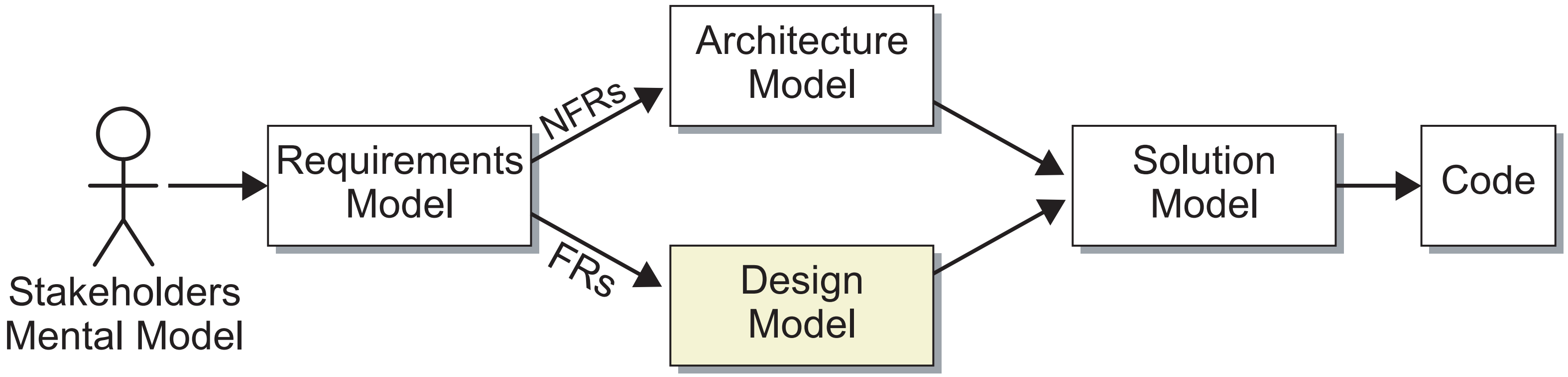


Artifacts include:
Domain Class Model
Use Case Form
Scenarios
Create Interaction diagrams
for key use case scenarios

Introducing the Design Model

The Design model is created from the Requirements model (use cases and Domain model).

The Design model is merged with the Architecture model to produce the Solution model.



Interaction Diagrams

UML Interaction diagrams are the collective name for the following diagrams:

- Sequence diagrams
- Communication diagrams

    Formerly known as Collaboration diagrams
- Interaction Overview diagrams

    A combination of Activity diagram and Sequence diagram fragments

Interaction Diagrams

Each UML Interaction diagram is used to show the sequence of interactions that occur between objects during:

- One or two use case scenarios
- A fragment of one use case scenario

UML Interaction diagrams may also be used to show the sequence of interactions that occur between:

- Systems
- Subsystems

Comparing Analysis and Design

Analysis helps you model *what* is known about a business process that the system must support:

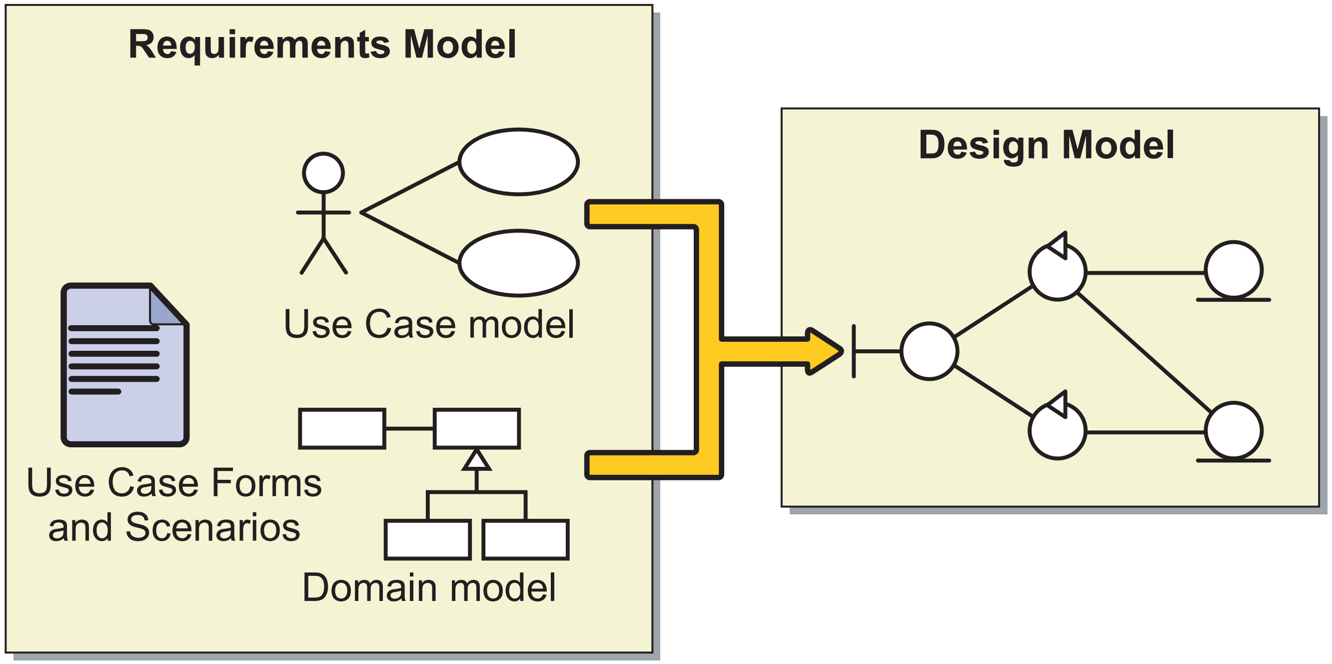
- Use cases
- Domain model

Design helps you model *how* the system will support the business processes. The Design model consists of:

- Boundary (UI) components
- Service components
- Entity components

Robustness Analysis

Robustness analysis is a process that assists in identifying design components that would be required in the Design model:



Robustness Analysis

Inputs to Robustness Analysis:

- A use case
- The use case scenarios for that use case
- The use case Activity diagram (if available) for that use case
- The Domain model

Output from Robustness Analysis:

The Design model is usually captured in UML Interaction diagrams with design components such as Boundary, Service, and Entity components.

Boundary Components

"A boundary class (component) is used to model interaction between the system and its actors (that is, users and external systems)." (Jacobson, Booch, and Rumbaugh page 183)

- Abstractions of UI screens, sensors, communication interfaces, and so on.
- High-level UI components.
- Every boundary component must be associated with at least one actor.

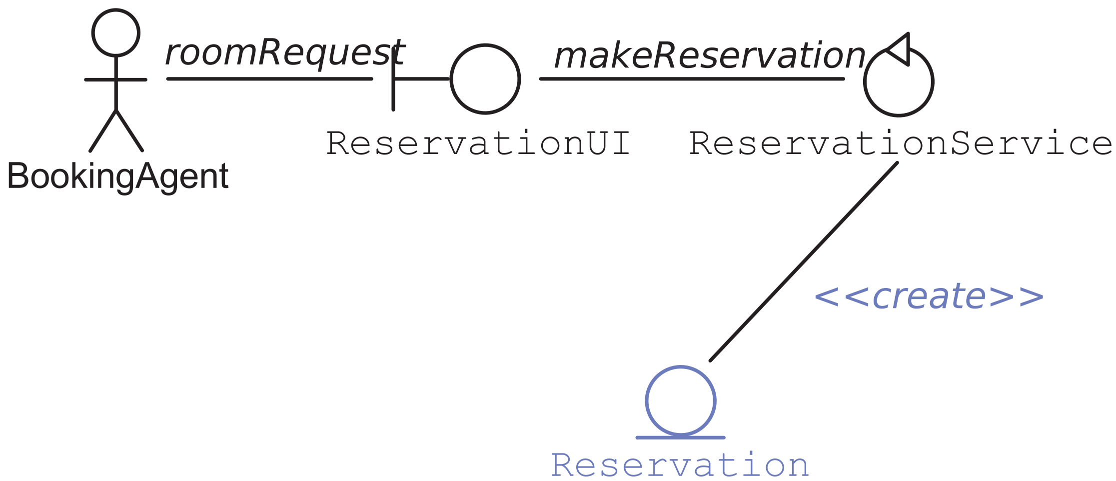
Service Components

"Control (Service) classes (components) represent coordination, sequencing, transactions, and control of other objects and are often used to encapsulate control related to a specific use case." (Jacobson, Booch, and Rumbaugh page 185)

- Coordinate control flow
- Isolate any changes in workflow from the boundary and entity components

Entity Components

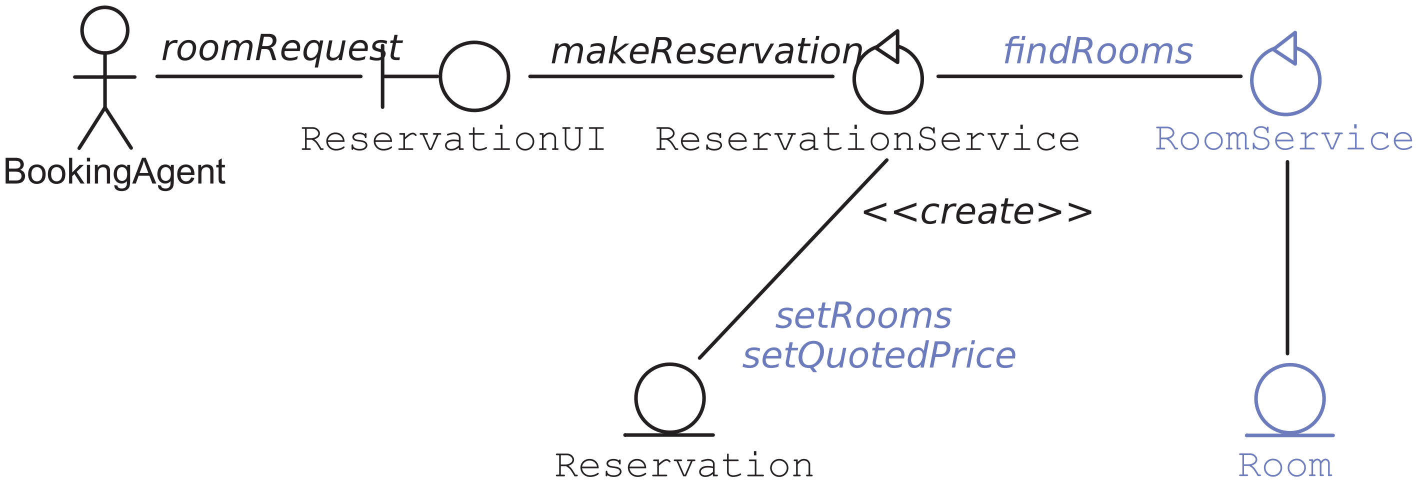
"An entity class (component) is used to model information that is long-lived and often persistent." (Jacobson, Booch, and Rumbaugh page 184)



- Entities usually correspond to domain objects.
- Most entities are persistent.
- Entities can have complex behavior.

Service and Entity Components

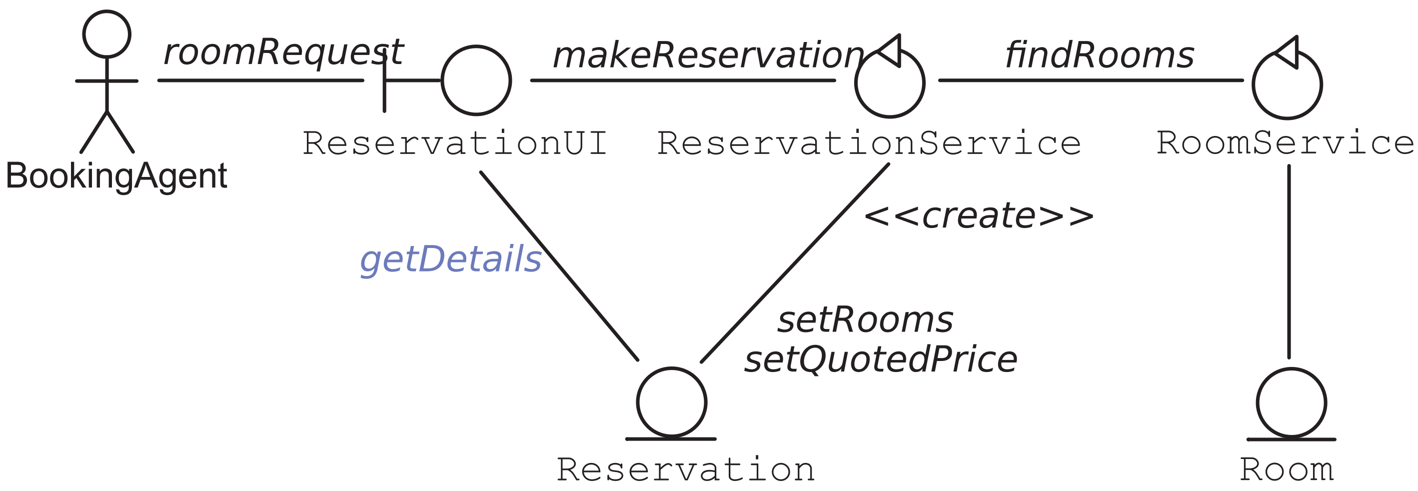
An Entity component will often have a corresponding Service component



- A service object will often control its corresponding entity object
- A service object can delegate to another service object

Boundary And Entity Components

A Boundary component can often retrieve the attributes of an Entity component

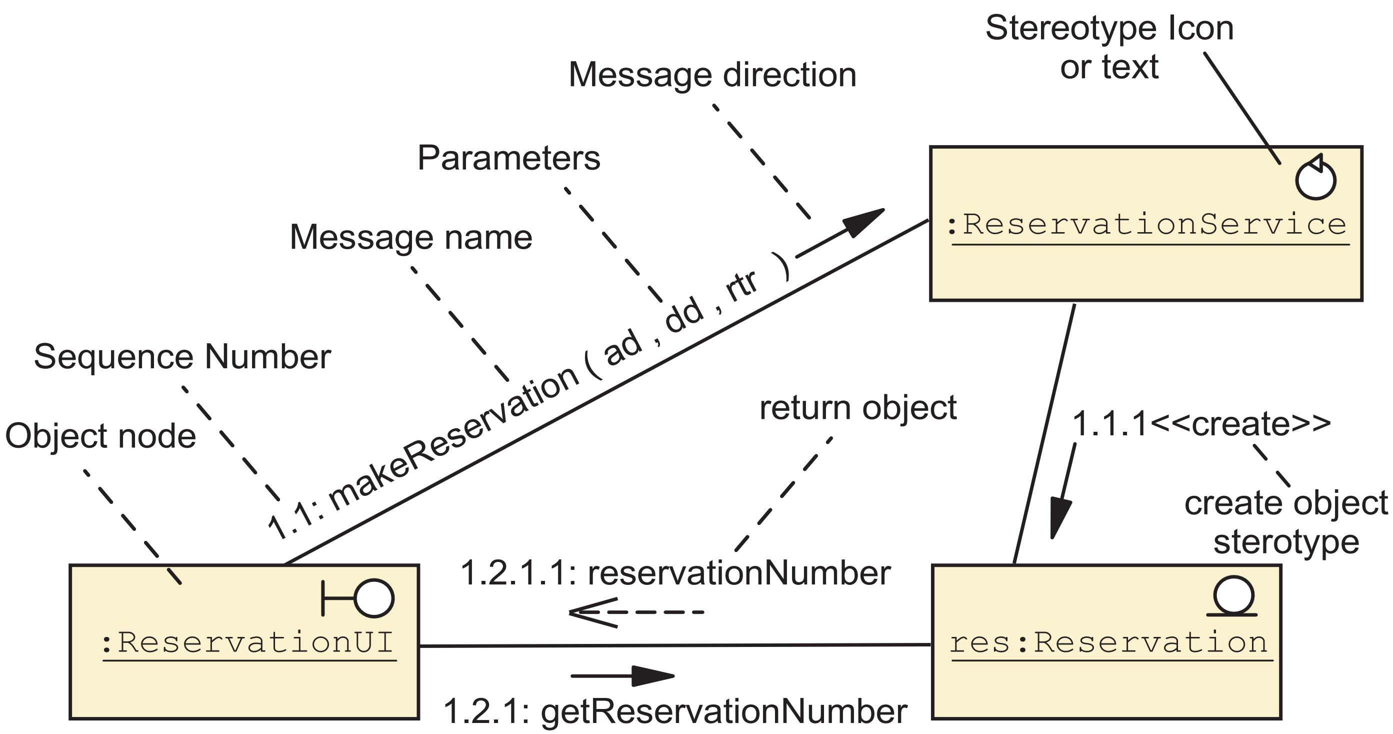


Describing the Robustness Analysis Process

1. Select a use case.
2. Construct a Communication diagram or a Sequence diagram that satisfies the activities of the use case.
   a. Identify Design components that support the activities of the use case.
   b. Draw the associations between these components.
   c. Label the associations with messages.
3. Convert the Communication diagram into a Sequence diagram, or vice versa, for an alternate view (optional).

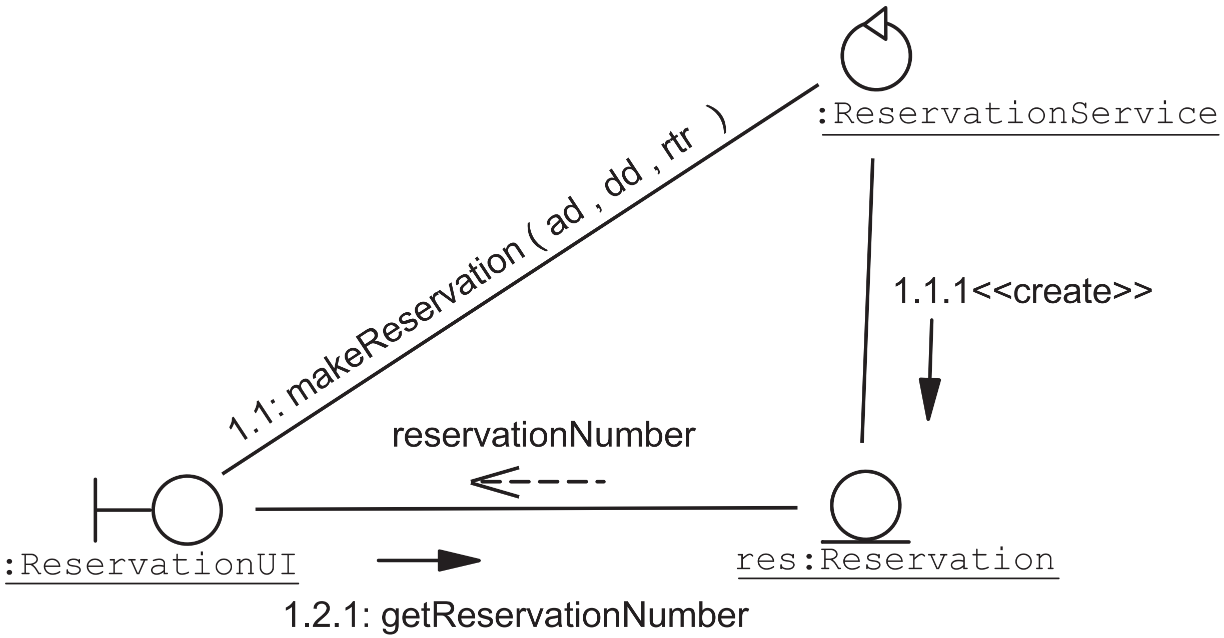
Identifying the Elements of a Communication Diagram

A UML Communication diagram is composed of the following elements:



Identifying the Elements of a Communication Diagram

A variation of the previous Communication diagram:



Identifying the Elements of a Communication Diagram

A message can indicate:

- A message name
- A direction arrow
  - An solid arrowhead is a synchronous message
  - An open arrowhead is an asynchronous message
- A sequence number describing the order of the message
- A list of parameters passed to the receiving object
- A guard condition indicating a conditional message
- A return parameter

Creating a Communication Diagram

Select an appropriate use case.

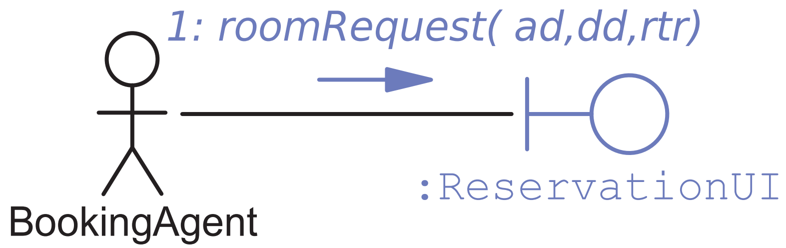
1. Place the actor in the Communication diagram.
2. Analyze the Use Case form or the Activity diagram for the use case.
   For every action in the use case:
   a. Identify and add a Boundary component.
   b. Identify and add a Service component.
   c. Identify and add an Entity component.
   d. Identify and add further Interactions, discovering new Methods, Boundary, Service and Entity components.

Step 1— Place the Actor in the Diagram

Place the actor in the Communication diagram:

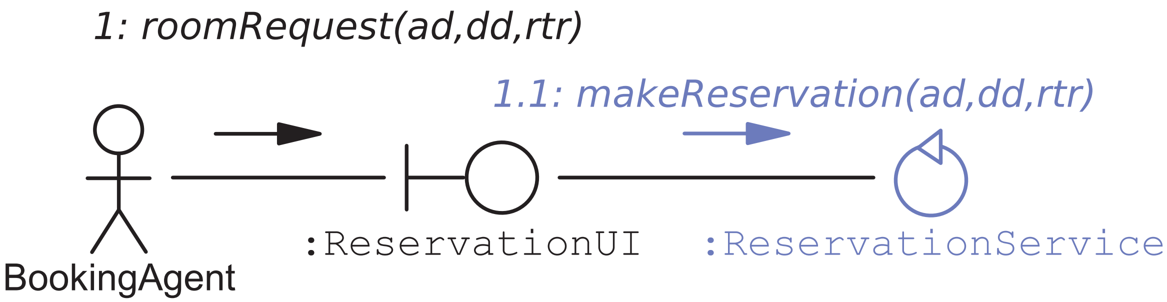
Step 2a — Identify Boundary Components

BookingAgent makes a room request passing the arrival date (ad), departure date (dd), requested types of room (rtr):



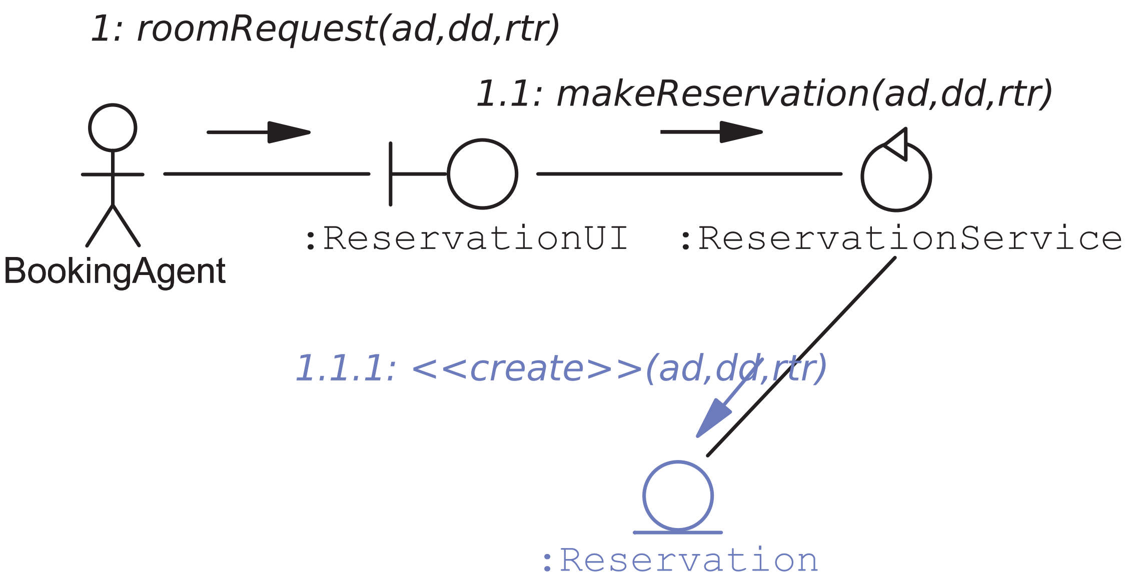
Step 2b — Identify Service Components

The ReservationUI boundary object uses ReservationService object to make the Reservation:



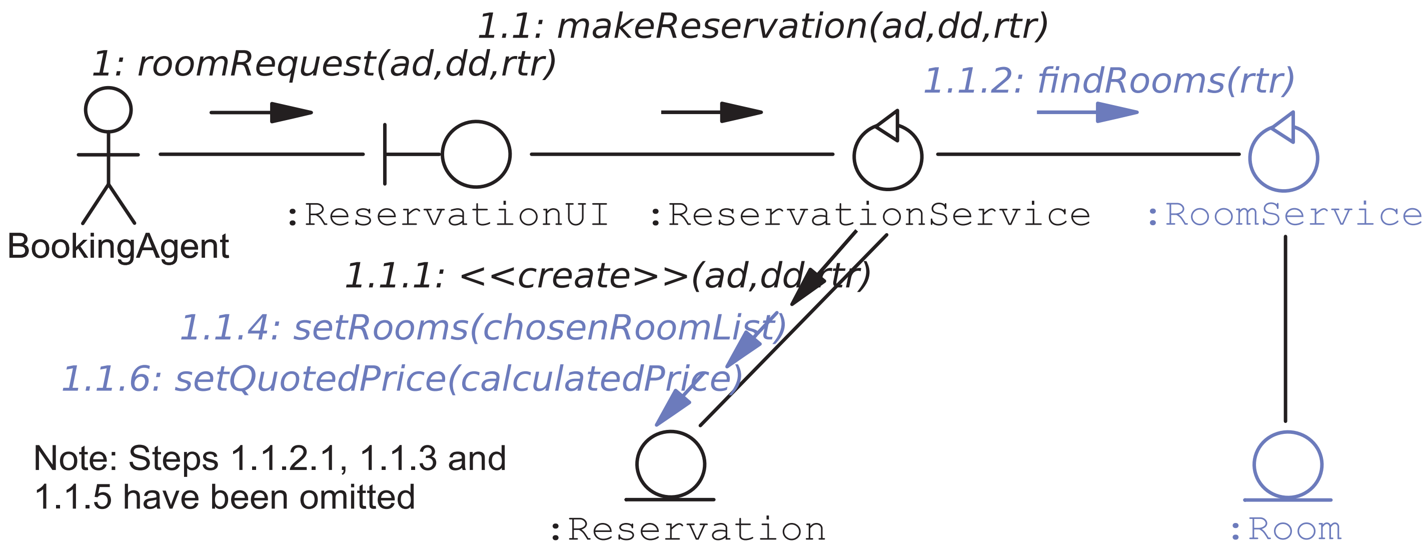
Step 2c — Identify Entity Components

The makeResevation method in the ReservationService object creates the Reservation entity object:



Step 2d — Identify Additional Interactions

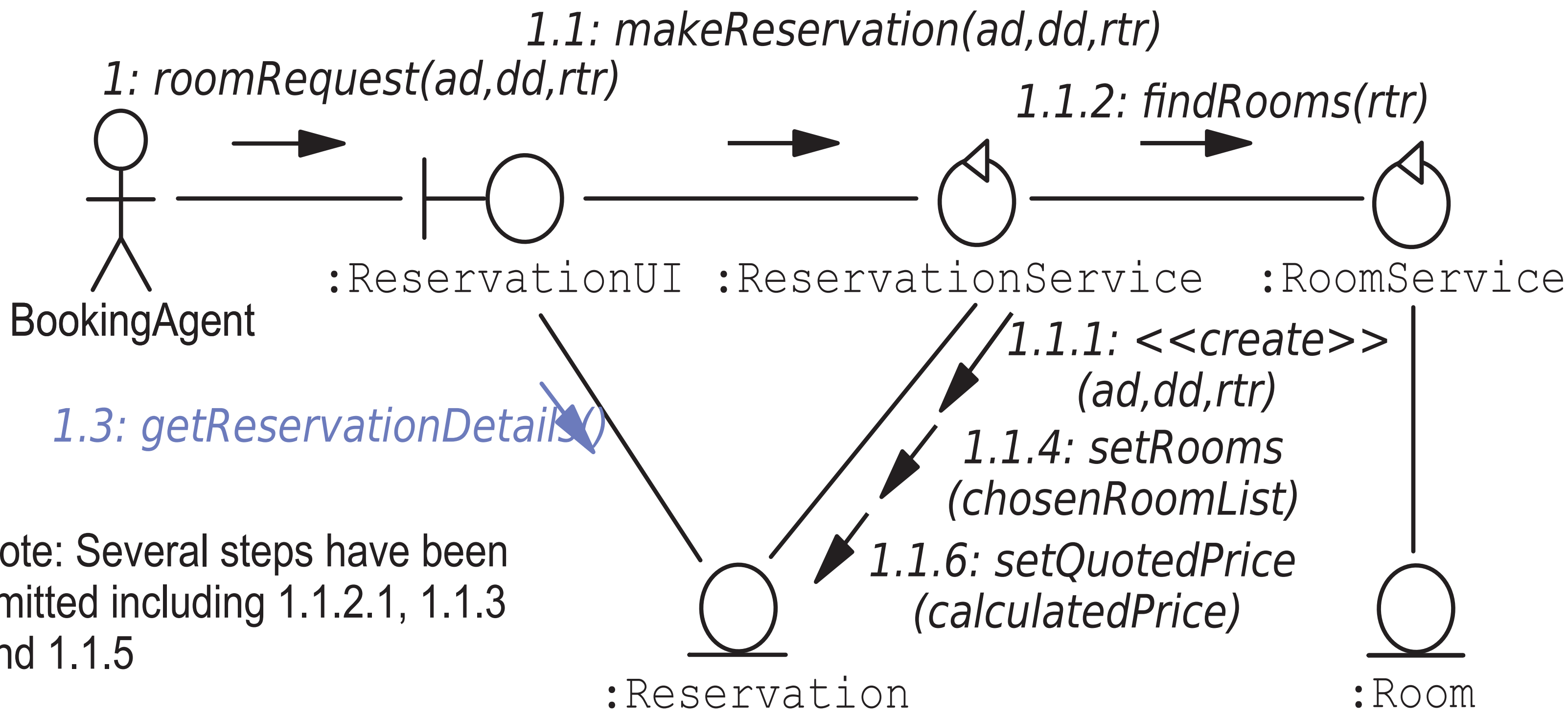
The makeReservation method uses the findRoom method to find rooms of the required type. After finding and choosing free rooms (not shown) the setRooms method assigns the rooms to the Reservation. The calculated price (not shown) is assigned to the Reservation:



Step 2d — Identify Additional Methods

The makeReservation method of the ReservationService object returns the Reservation object (not shown) to the ReservationUI. The roomRequest method of ReservationUI then calls the getReservationDetails method of the Reservation object, which returns the details of the reservation. These will then be notified to the booking agent (not shown):

Step 2d — Identify Additional Methods



Note: Several steps have been omitted including 1.1.2.1, 1.1.3 and 1.1.5

Communication Diagram Examples

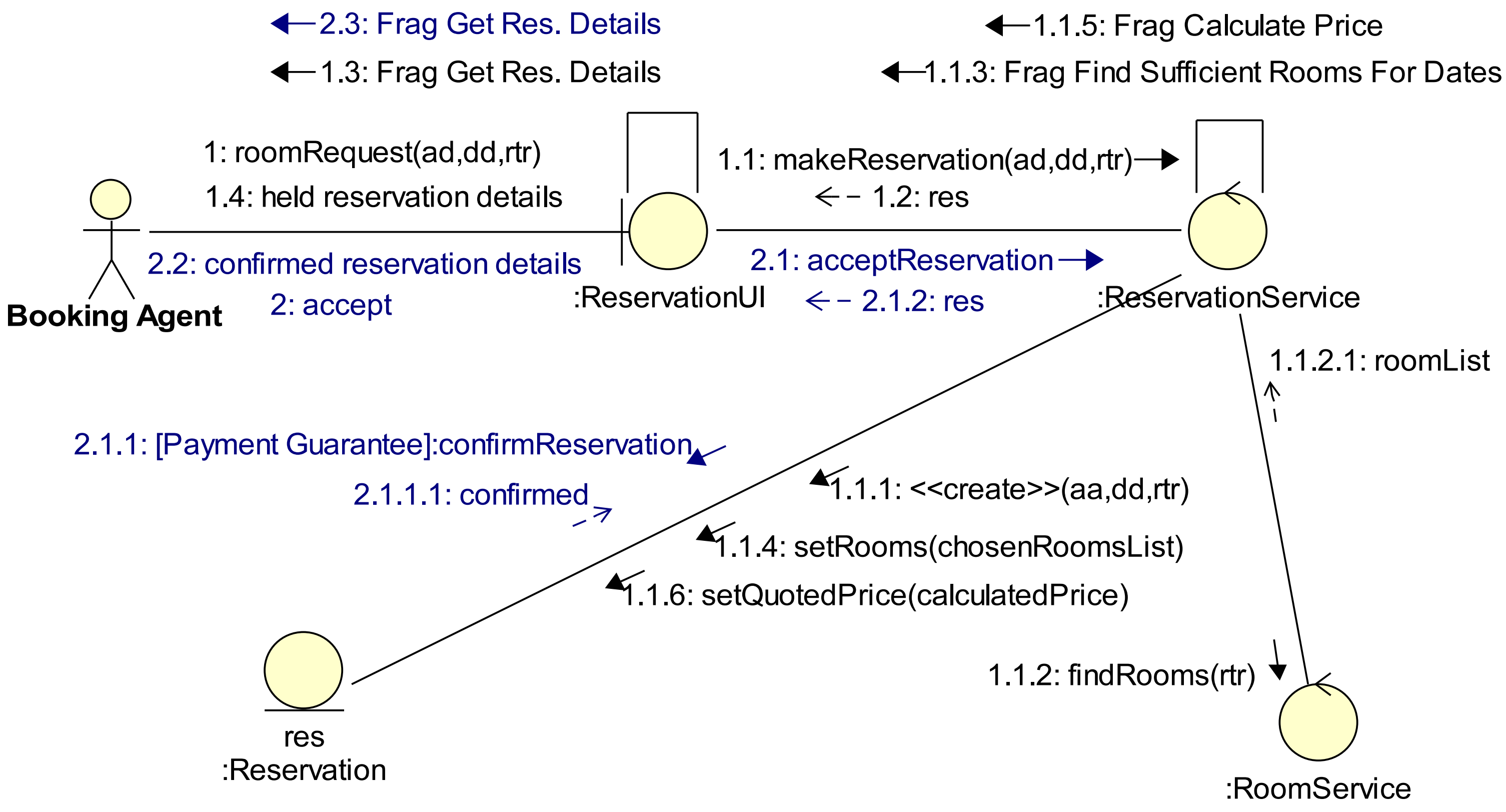
The following two Communication diagrams show a more detailed view of the CreateReservation:

1. Primary (successful) scenario
2. Secondary (unsuccessful) scenario

   Rooms offered are rejected by the booking agent

The finer details has been omitted, to reduce complexity.

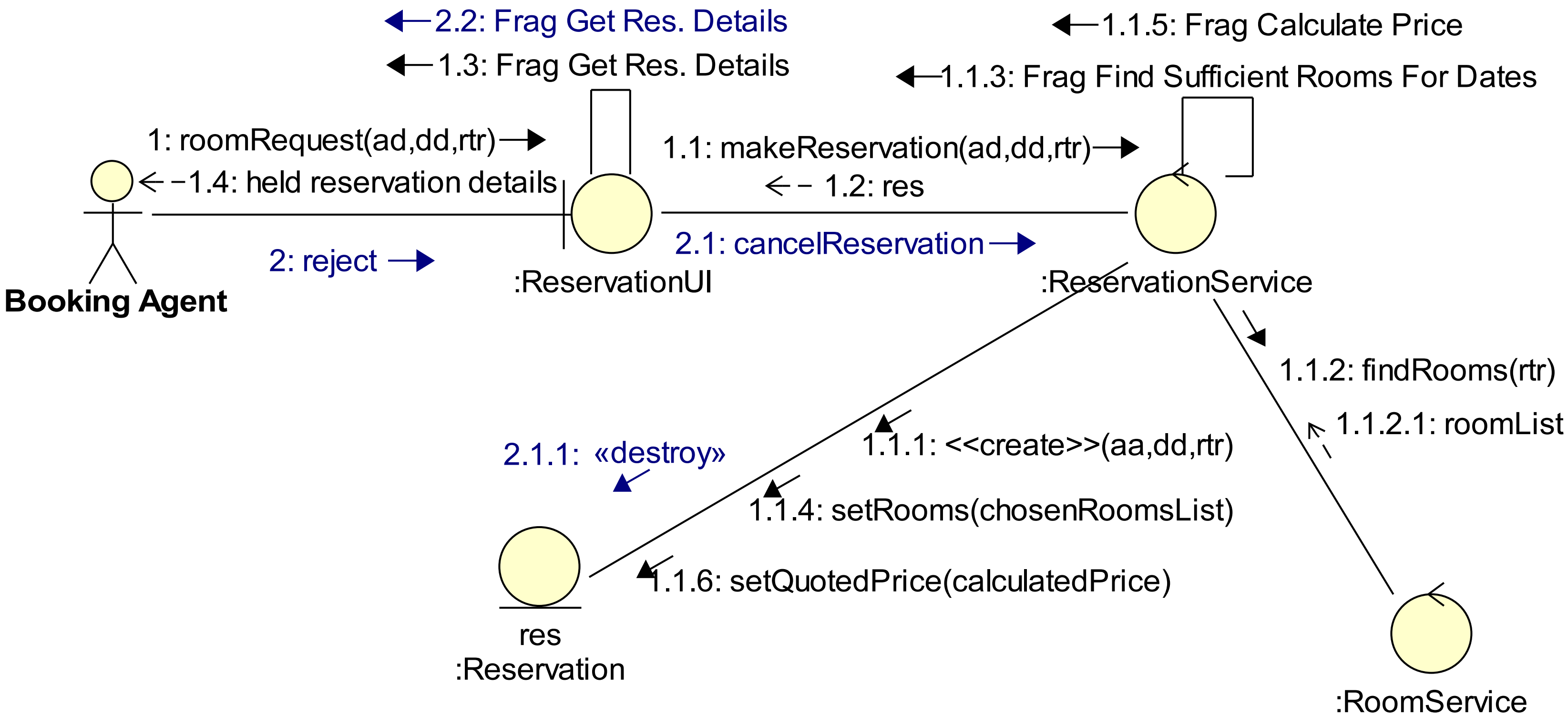
Communication Diagram Example 1



Key:
ad - arrivalDate
dd - departureDate
rtr - requestedTypeOfRoom

Note:
Frag: These are fragments where detail can be shown in another diagram
We have omitted two fragments that Identify Customer and Payment Guarantee

Communication Diagram Example 2



Key:
ad - arrivalDate
dd - departureDate
rtr - requestedTypeOfRoom

Note:
Frag: These are fragments where detail can be shown in another diagram
We have omited two fragments that Identify Customer and Payment Guarantee

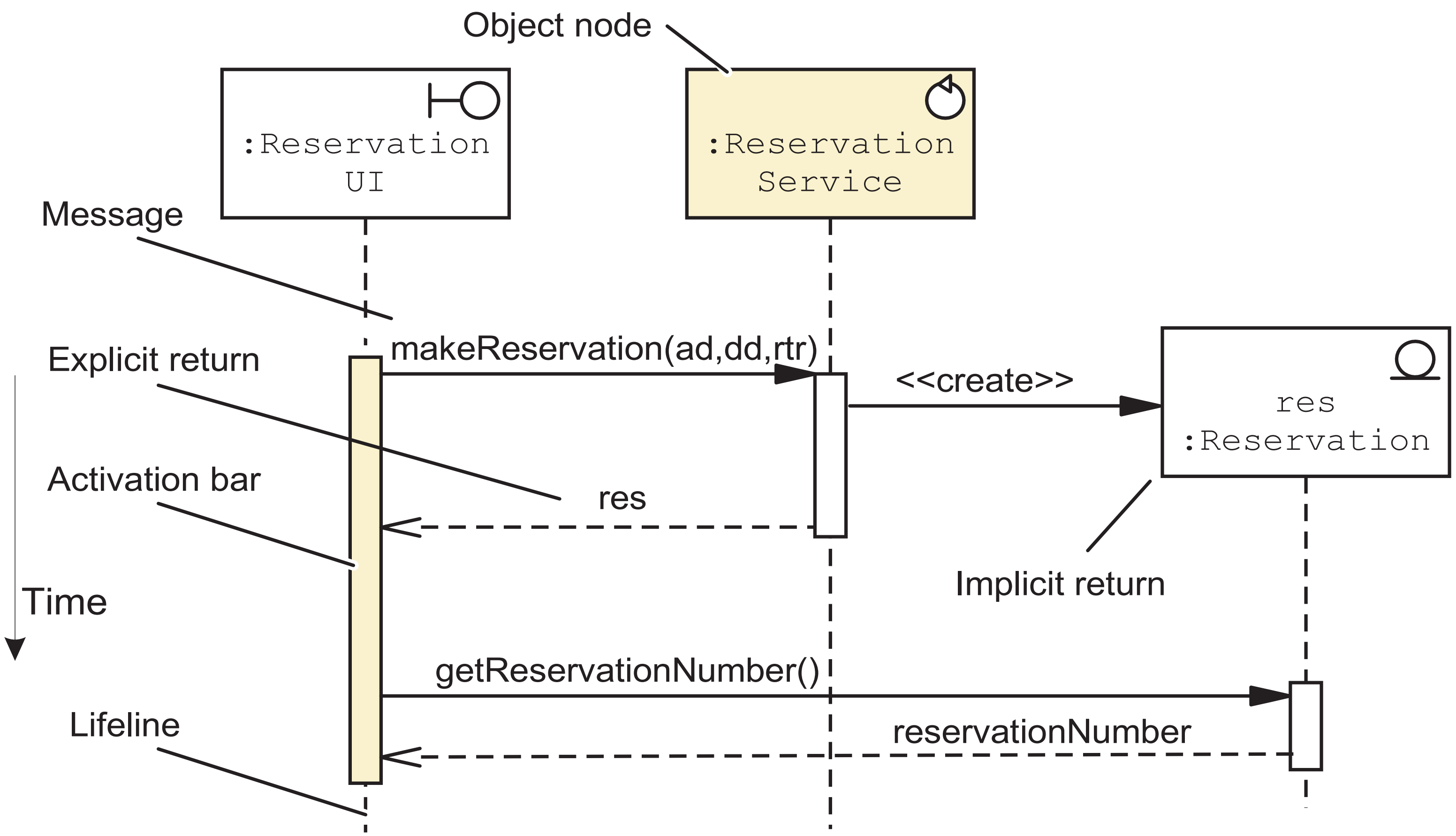
Sequence Diagrams

Sequence diagrams:

- Provide a different perspective of the interactions between objects
- Can be used instead of Communication diagrams
- Can be converted to or from Communication diagrams
- Prove to be more useful for developers.
- Highlight the time ordering of the interactions

The next section describes UML Sequence diagrams.

Identifying the Elements of a Sequence Diagram



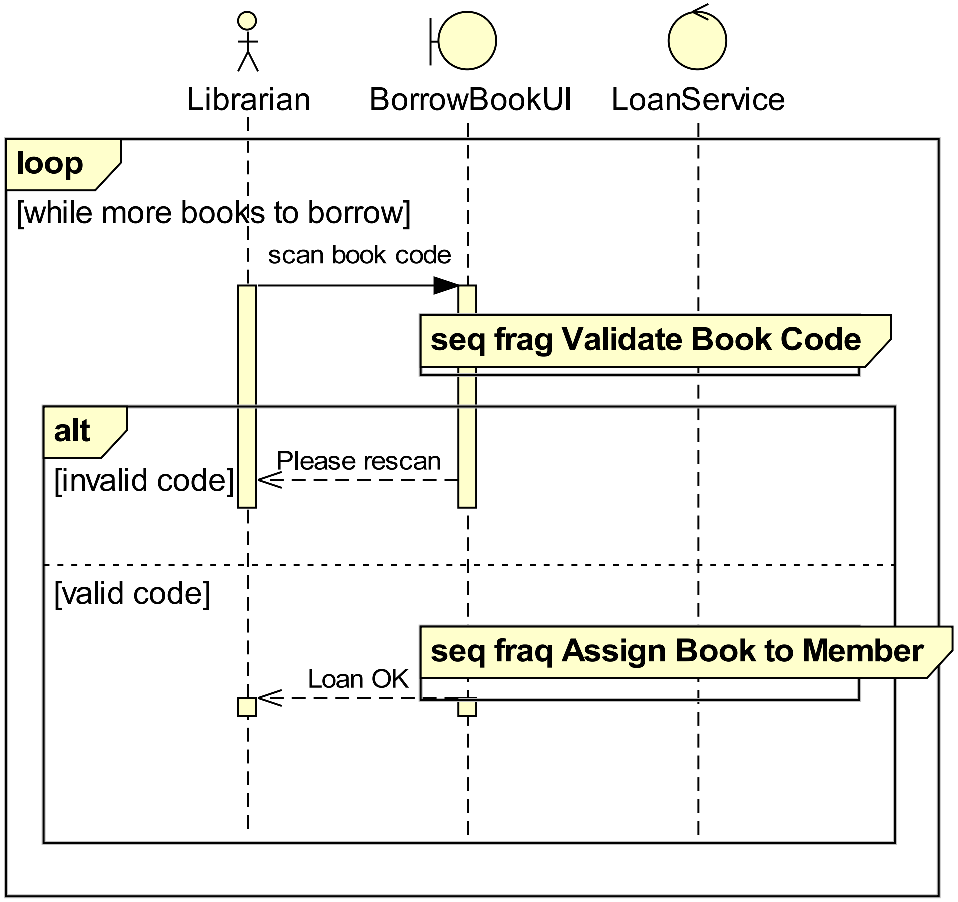
Fragments

Sequence diagrams support a Fragment notation. The uses of fragments include:

- Showing sequence loops
- Showing alternative paths
- Allowing two or more scenarios to be shown on one diagram
- Showing a reference to another detailed Sequence diagram fragment
- Allowing you to break up a large diagram into several smaller diagrams

The following slide shows examples of the Fragment notation

Fragment Examples



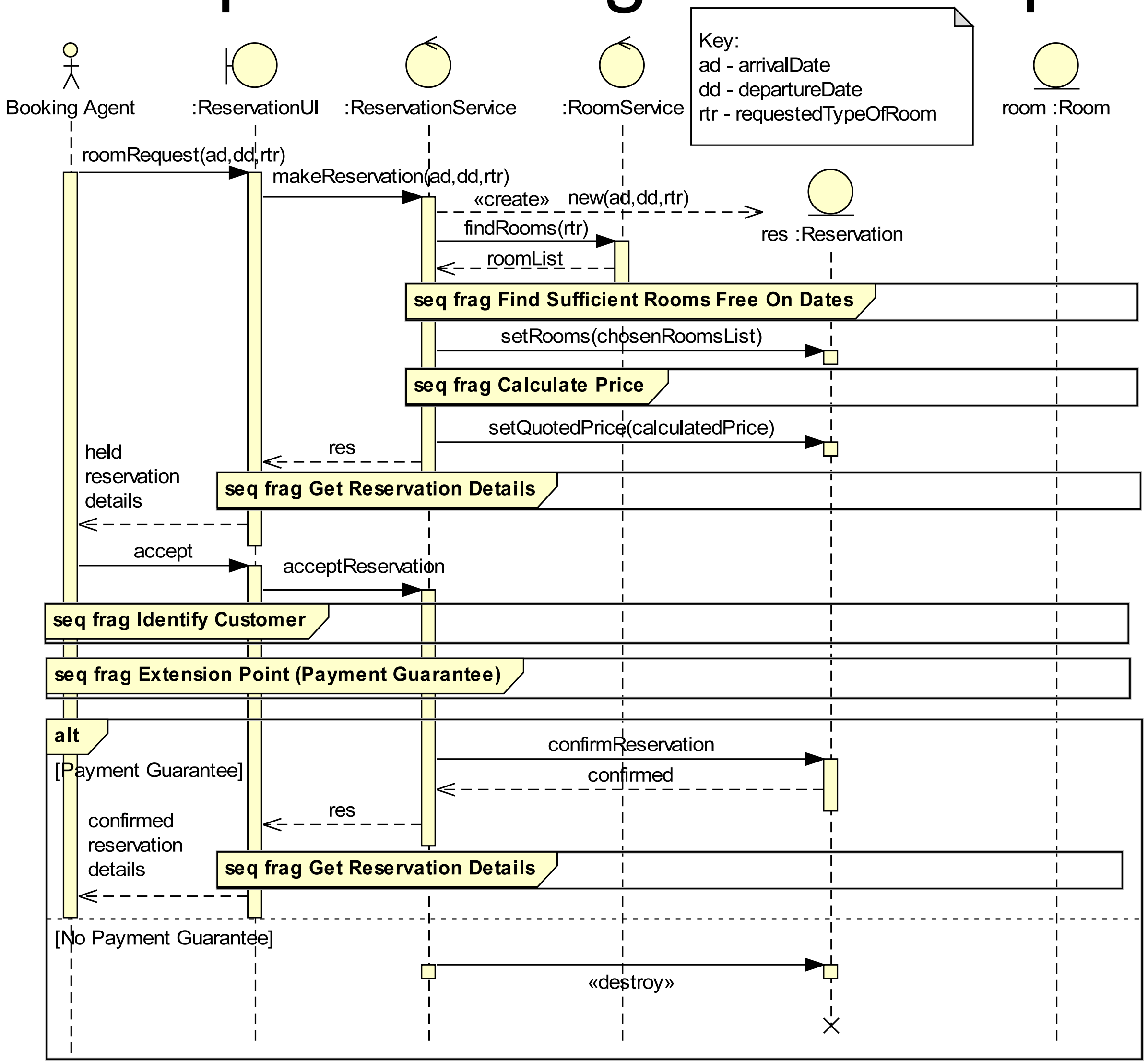
Sequence Diagram Examples

The following three Sequence diagrams show a more detailed view of CreateReservation:

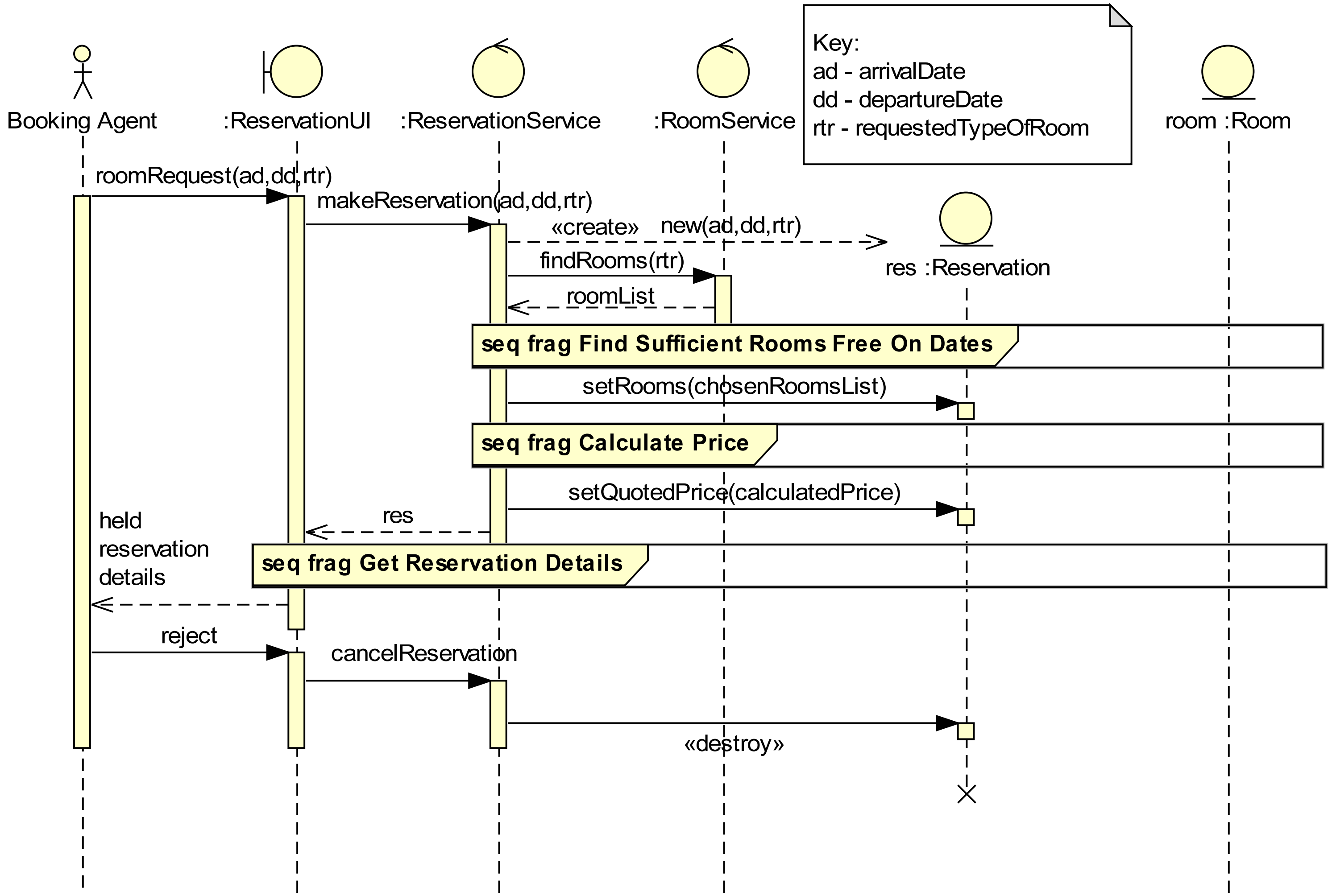
1. Primary (successful) scenario and a secondary (unsuccessful) scenario in one diagram using an *alt* fragment
2. Secondary (unsuccessful) scenario where rooms offered are rejected by the booking agent
3. A Fragment Sequence diagram showing the finer details for the GetReservationDetails fragment, and includes a *loop* fragment

The finer detail has been hidden in fragments.

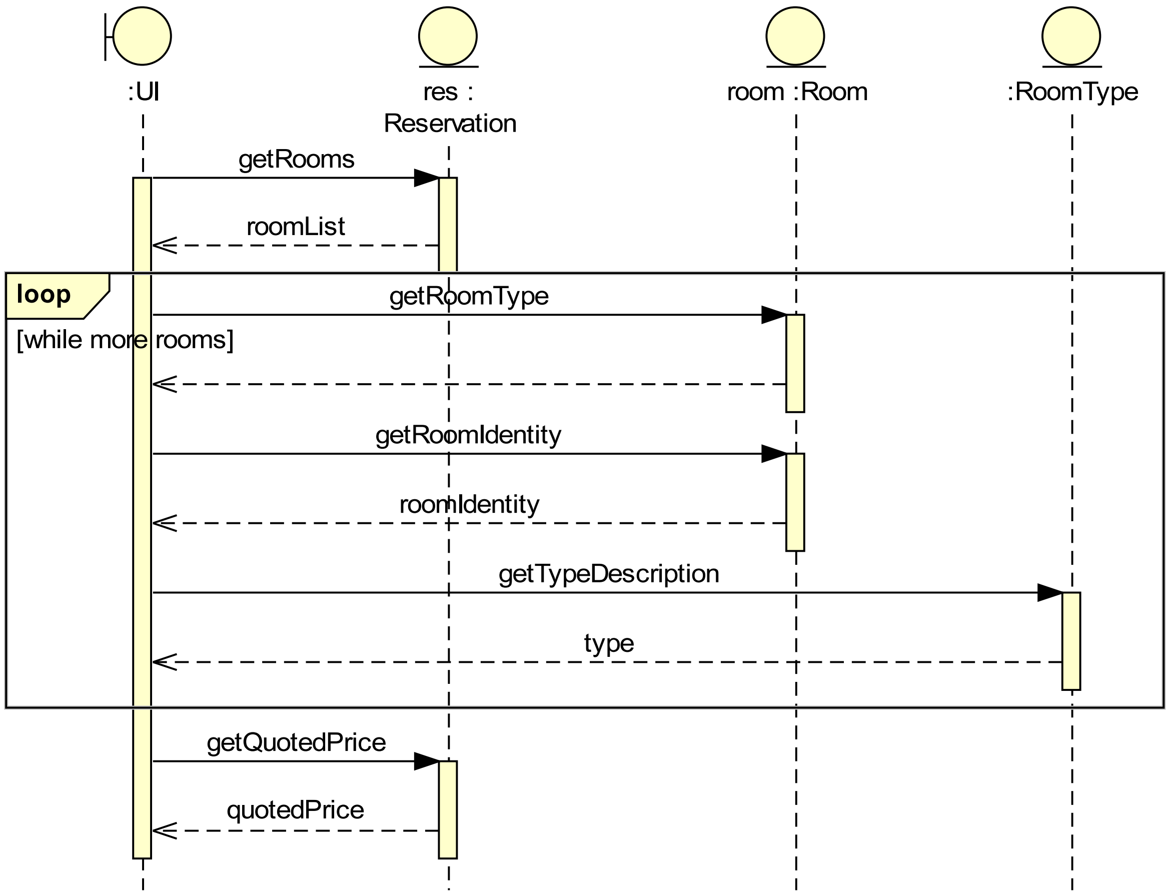
Sequence Diagram Example 1



Sequence Diagram Example 2



Sequence Diagram Fragment Example 3



Summary

- Interaction diagrams are used to identify design components that satisfy a use case.
- Object interactions can be visualized with a UML
  - Communication diagram
  - Sequence diagram