Lecture 4 - Object Oriented Analysis and Design with UML

COMP2013 (AUT1 23-24)

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Register your attendance

COMP2013: Developing Maintainable Software
Week 5 – 4:00pm Monday – 23 October 2023

valid for 65 minutes from 3:55pm
generated 2023-10-10 03:14

Overview

- Why UML?
- Introduction to 2 case studies
- Use case diagrams
- Use case specifications
- Activity diagrams
- Sequence diagrams
- State machine diagrams
- State machine
- Review class diagrams

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Topics for this Week

- Lecture 04A:
  - OO Analysis and Design (OOA/D) with UML

- Lecture 04B:
  - Build Tools (Maven and Gradle)
  - Introduction the Formative Group project
  - Preview of 2022/2023 coursework

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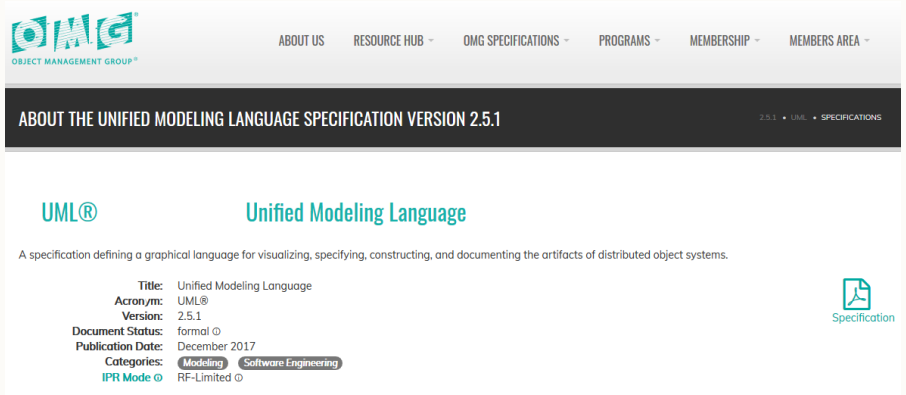
- Lab 04:
  - Virtual UML Speed Refactor/Extend Challenge for Group Project groups

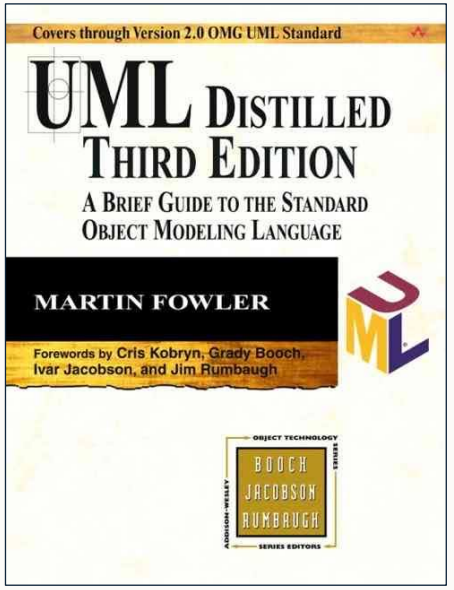
Unified Modelling Language

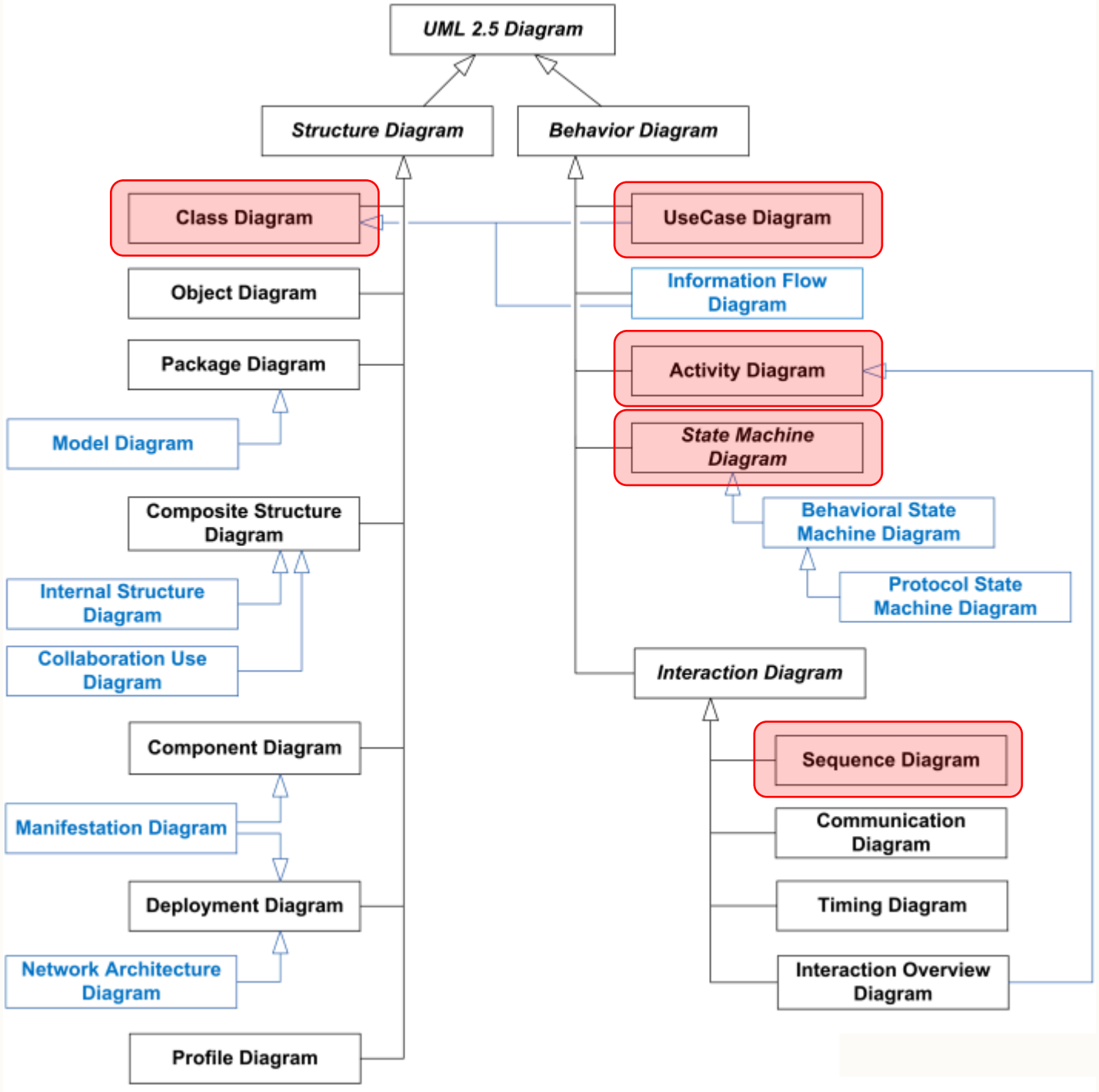
UML: An Overview

- UML: "A specification defining a graphical language for visualizing, specifying, constructing, and documenting the artifacts of distributed object systems." https://www.omg.org/spec/UML/About-UML/

- Latest Version: 2.5.1 (Dec 2017)






UML 2.5 Diagram
Structure Diagram
Behavior Diagram
Class Diagram
Object Diagram
Package Diagram
Model Diagram
Composite Structure Diagram
Internal Structure Diagram
Collaboration Use Diagram
Component Diagram
Manifestation Diagram
Deployment Diagram
Network Architecture Diagram
Profile Diagram
UseCase Diagram
Information Flow Diagram
Activity Diagram
State Machine Diagram
Behavioral State Machine Diagram
Protocol State Machine Diagram
Interaction Diagram
Sequence Diagram
Communication Diagram
Timing Diagram
Interaction Overview Diagram

1

2

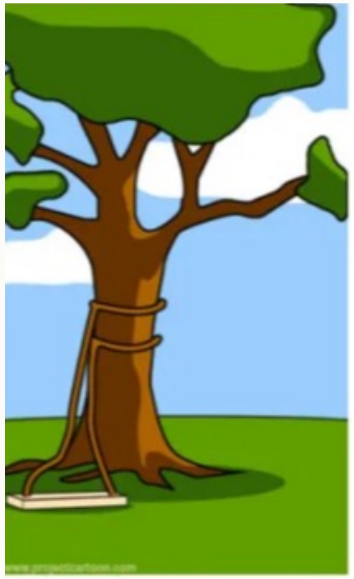
How the customer explained it

How the programmer wrote it.

How the customer really needed.

How the customer was billed.

3



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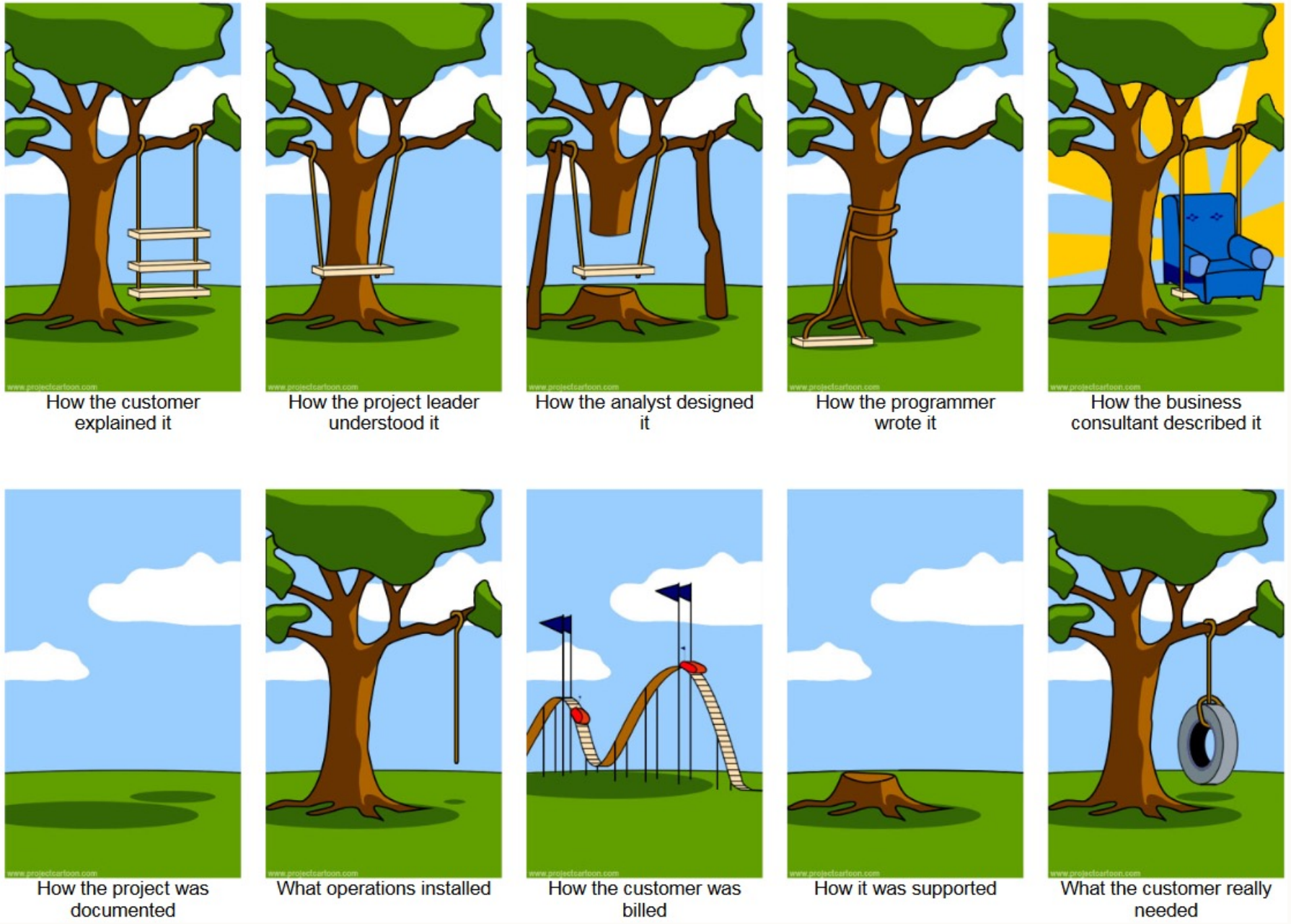
Source: https://medium.com/@thx2001r/the-project-cartoon-root-cause-5e82e404ec8a



Source: http://www.projectcartoon.com/

Why UML?

- Advantages of using UML:

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Why UML?

- Advantages of using UML:
  - Enhances communication and ensures the right communication
  - Captures the logical software architecture independent of the implementation language
  - Helps to manage the complexity
    - Abstraction
  - Enables reuse of design

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Object oriented analysis and design process

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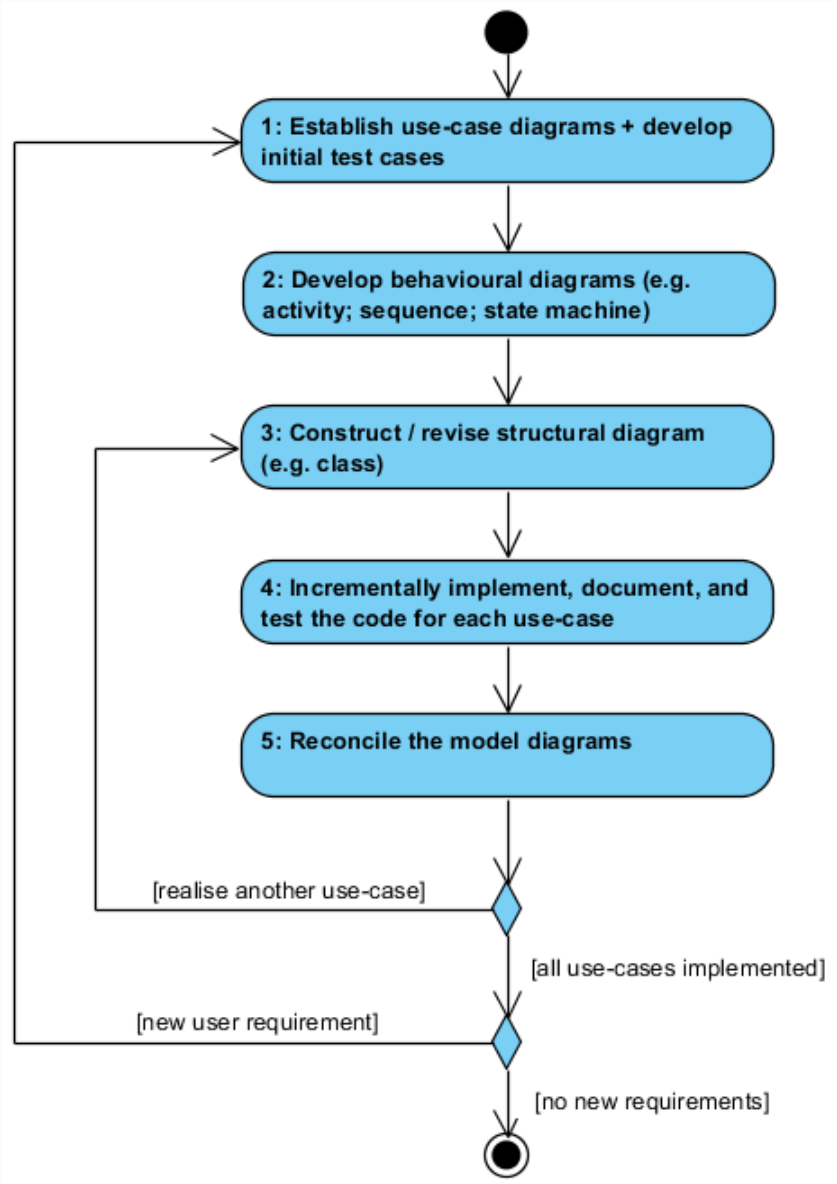
"Use Case Driven" OOA/D Process



[after Barclay and Savage 2004]

Case Study 1

Library Booking System

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Case Study 1: Library Booking System

Case Study 1: Library Booking System

- Library Rules
  - The library contains books and journals; it may have several copies of a given book; some are for short term loan only; the others can be borrowed by any library member for three weeks
  - Normal members can borrow up to 6 books at the same time, staff members up to 12
  - Only staff members can borrow journals

- System Requirement
  - The system must keep track of when books and journals are borrowed and returned, enforcing the rules described above

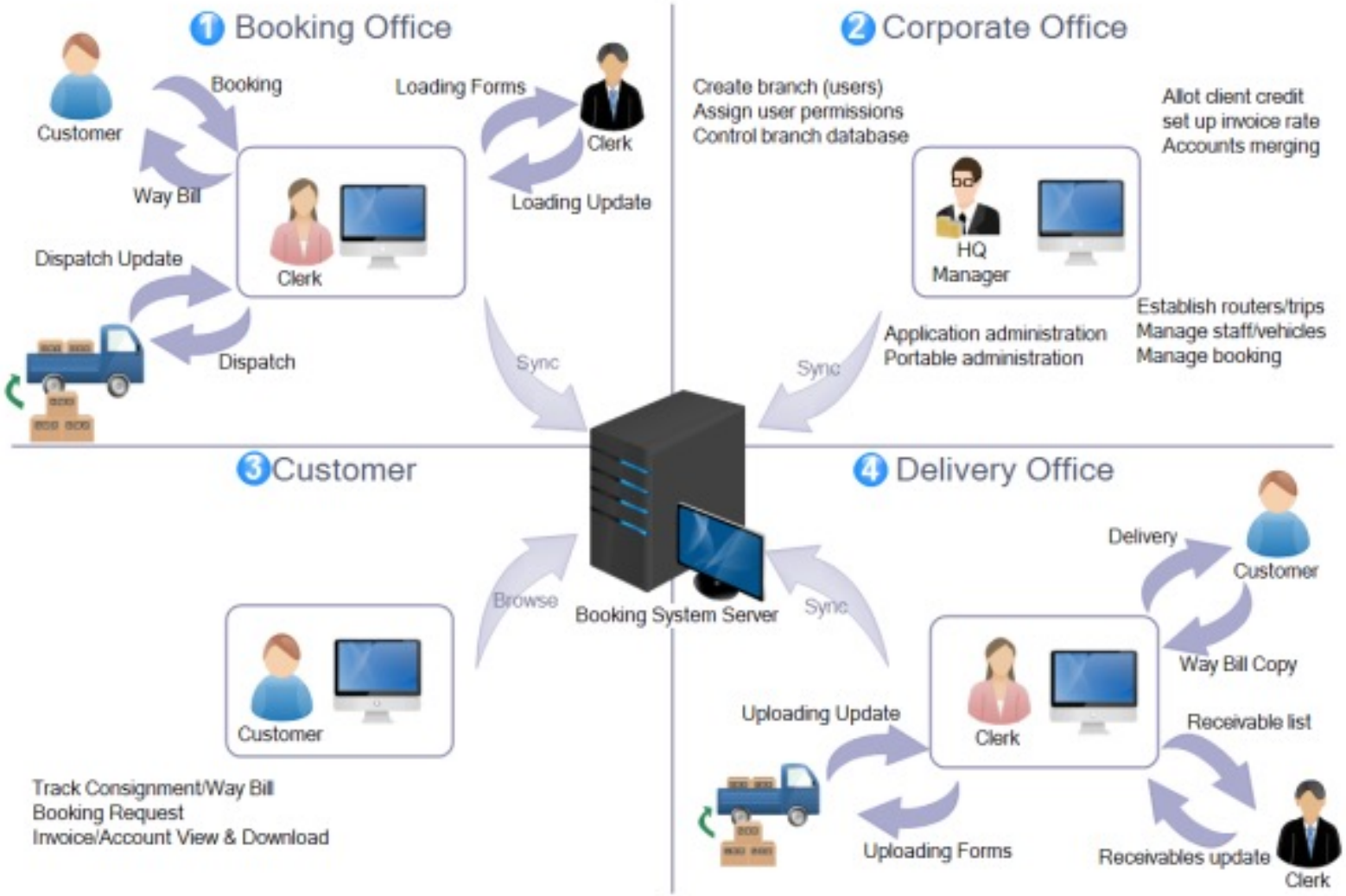
Case Study 1: Library Booking System

- Our Job: Development of a Library Booking System
  - After discussing priorities with the university we decided that the first iteration of the system should consider the following user stories:
    - As a university member I want to be able to borrow a copy of a book
    - As a university member I want to be able to return a copy of a book
    - As a university staff member I want to be able to borrow a journal
    - As a university staff member I want to be able to return a journal

Case Study 2

Fleet Logistics Management

Case Study 2: Fleet Logistics Management



Case Study 2: Fleet Logistics Management

- User stories
  - As a client I want to be able to check availability of lorries
  - As a client I want to be able to track cargo
  - As a manager I want to be able to see the finances
  - As an admin I want to be able to search for information
  - As an admin I want to be able to organise routes
  - As an admin I want to be able to track lorries and cargo

Object oriented analysis

Fleet Logistics Management

Components Covered

- We will be looking at:
  - Use case diagrams
  - Use case specifications

- Are use case diagrams structure or behaviour diagrams?

Use Case Diagrams

- What are use case diagrams used for?
  - They describe a set of actions that some system or systems should or can perform in collaboration with one or more external users of the system or systems
  - No attempt to represent an order or a number of executions

- Use case diagram components
  - Actors
  - Use cases
  - Subject (also referred to as "system boundary")
  - Relationships

Use Case Diagrams

- Actors
  - Entities that interface with the system
  - Can be people or other systems

- Use cases
  - Based on user stories
  - Represent what the actor wants your system to do for them
  - In the use case diagram only the use case name is represented
  - In a use case specification each use case is formally described

Use Case Diagrams

- Subject (also referred to as "system boundary")
  - Classifier representing a business, software system, physical system or device under analysis, design, or consideration

- Relationships
  - Relationship between use case and actor:
    - Association indicates which actor initiates which use case
  - Relationship between two use cases:
    - Specifying common functionality and simplifying use case flows
    - Using <<include>> or <<extend>>

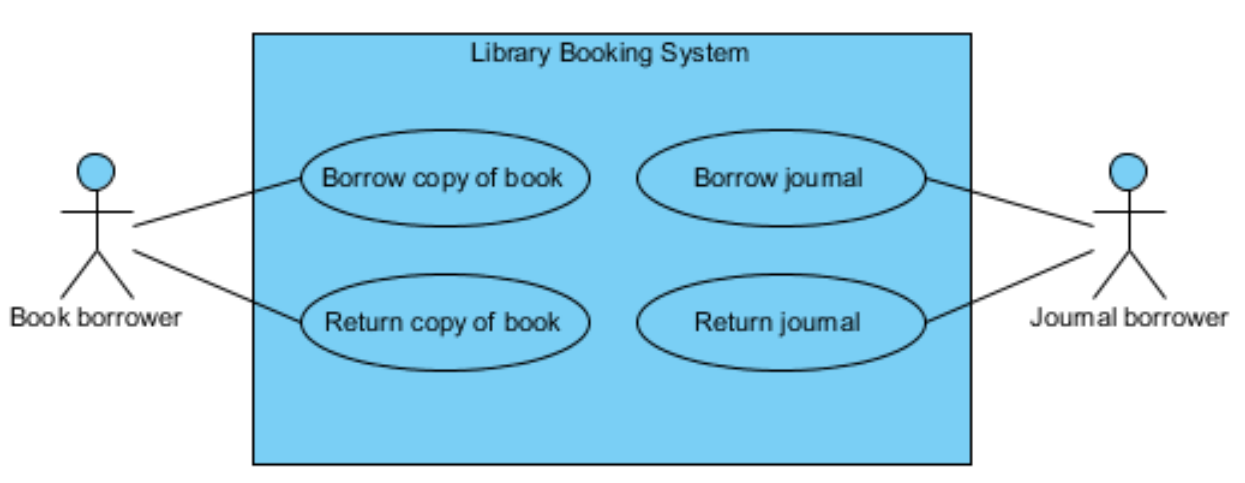
Use Case Diagrams

- <<include>>
  - Used when multiple use cases share a piece of same functionality which is placed in a separate use case
  - Arrow points to the more specific use case

- <<extends>>
  - Used when activities might be performed as part of another activity but are not mandatory for a use case to run successfully
  - Arrow points to the more general use case

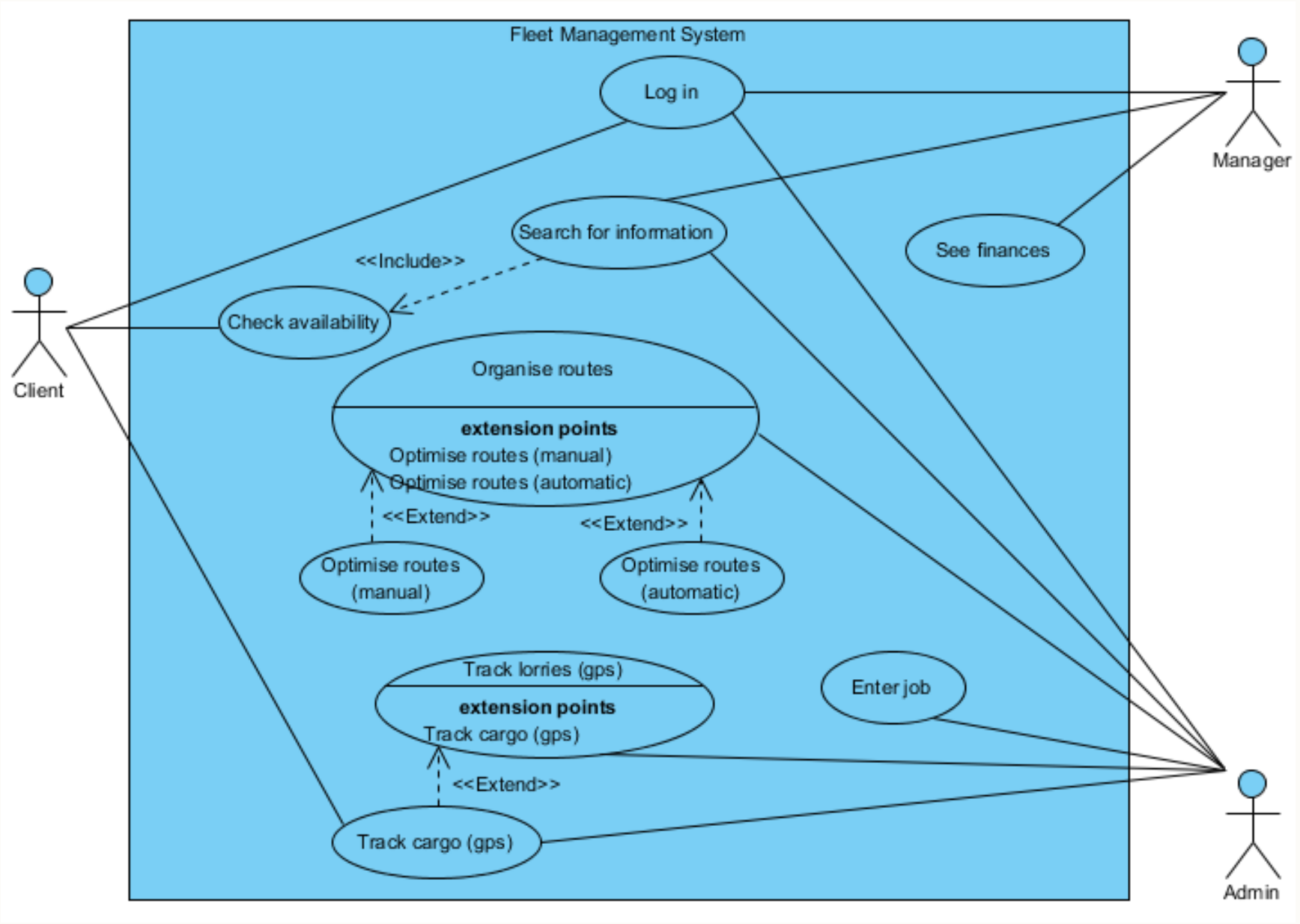
Example: Library Booking System

- Reminder
  - The library contains books and journals; it may have several copies of a given book; only staff members can borrow journals



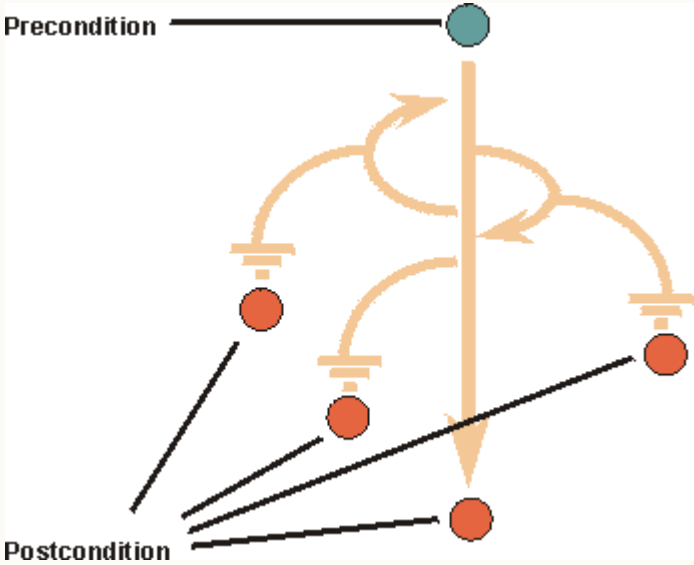
Activity: Fleet Logistics Management

- Use Case Diagram?
  - Reminder
    - Client wants to check availability of lorries and track cargo. Manager wants to see the finances. Admin wants to search for information, organise routes and track lorries and cargo


Fleet Management System
Log in
Search for information
<<Include>>
Check availability
Organise routes
extension points
Optimise routes (manual)
Optimise routes (automatic)
<<Extend>>
<<Extend>>
Optimise routes (manual)
Optimise routes (automatic)
Track lorries (gps)
extension points
Track cargo (gps)
<<Extend>>
Track cargo (gps)
Enter job
See finances
Client
Manager
Admin

Use Case Specification

- Use case specification elements
  - Use case name
  - Use case purpose
  - Pre-condition(s)
  - Base Path
  - Alternative Paths
  - Post-condition(s)



Use Case Specification

- Base and alternative path:
  - Base Path (optimistic flow)
    - "happy day" scenario
  - Alternative Paths (pragmatic flows)
    - Every other possible way the system can be (ob)used
    - Includes perfectly normal alternative use, but also errors and failures

Example: Library Booking System

- Use Case: Borrow copy of books
  - Purpose:
    - The Book Borrower borrows a book from the library using the Library Booking System
  - Pre-condition(s):
    - The book must exist
    - The book must be available

Example: Library Booking System

- Use Case: Borrow copy of books
  - Base Path (optimistic flow)
    1. LBS requests membership card
    2. BB provides membership card
    3. BB is logged in by LBS
    4. LBS checks permissions / debts
    5. LBS asks for presenting a book
    6. BB presents a book
    7. LBS scans RFID tag inside book
    8. LBS updates records accordingly
    9. LBS disables anti-theft device
    10. BB is logged out by LBS
    11. LBS confirms that process has been completed successfully

BB = Book Borrower
LBS = Library Booking System

Example: Library Booking System

- Use Case: Borrow copy of books
  - Alternative Paths (pragmatic flows)
    1. BB's card has expired: Step 3a: LBS must provide a message that card has expired; LBS must exit the use case
    2. ...
  - Post-condition(s) for base path:
    - Base Path
      - BB has successfully borrowed the book; the LBS is up to date
    - Alternative Path 1
      - BB was NOT able to borrow the book; the LBS is up to date
    - Alternative Path 2
      - ...

BB = Book Borrower
LBS = Library Booking System

Activity: Fleet Logistics Management

- Use Case Specification for use case "Search for Information"?
  - Reminder
    - Client wants to check availability of lorries and track cargo. Manager wants to see the finances. Admin wants to search for information, organise routes and track lorries and cargo

- Use case specification elements
  - Use case name
  - Use case purpose
  - Pre-condition(s)
  - Base Path
  - Alternative Paths
  - Post-condition(s)

Activity: Fleet Logistics Management

- Use Case: Search for Information
  - Purpose:
    - Admin can search the DB for any kind of information related to lorries and jobs
  - Pre-condition(s):
    - Admin is logged in

DB = Database

Activity: Fleet Logistics Management

- Use Case: Search for Information
  - Base Path (optimistic flow)
    1. Admin opens search window
    2. Admin defines query using query editor
    3. Admin sends query to DB
    4. DB deals with query: finding results
    5. DB deals with query: organising them by relevance
    6. DB sends results back
    7. DB requests confirmation that result is sufficient
    8. Admin confirms that result is sufficient
    9. DB closes search window

Activity: Fleet Logistics Management

- Use Case: Search for Information

  - Alternative Paths (pragmatic flows)
    1. Admin has not received the required information: Step 7a Admin denies that result is sufficient; Admin must go back to Step 2.
    2. DB is not accessible: Step 3a: DB returns warning message that DB is not accessible; use case needs to be left

  - Post-condition(s):
    - Base Path and Alternative Path 1
      - The admin has retrieved the required information
    - Alternative path 2
      - The admin has NOT retrieved the required information

Object oriented design

Fleet Logistics Management

Components Covered

- We will be looking at:
  - Activity diagrams
  - Sequence diagrams
  - State machine diagrams
  - Class diagrams

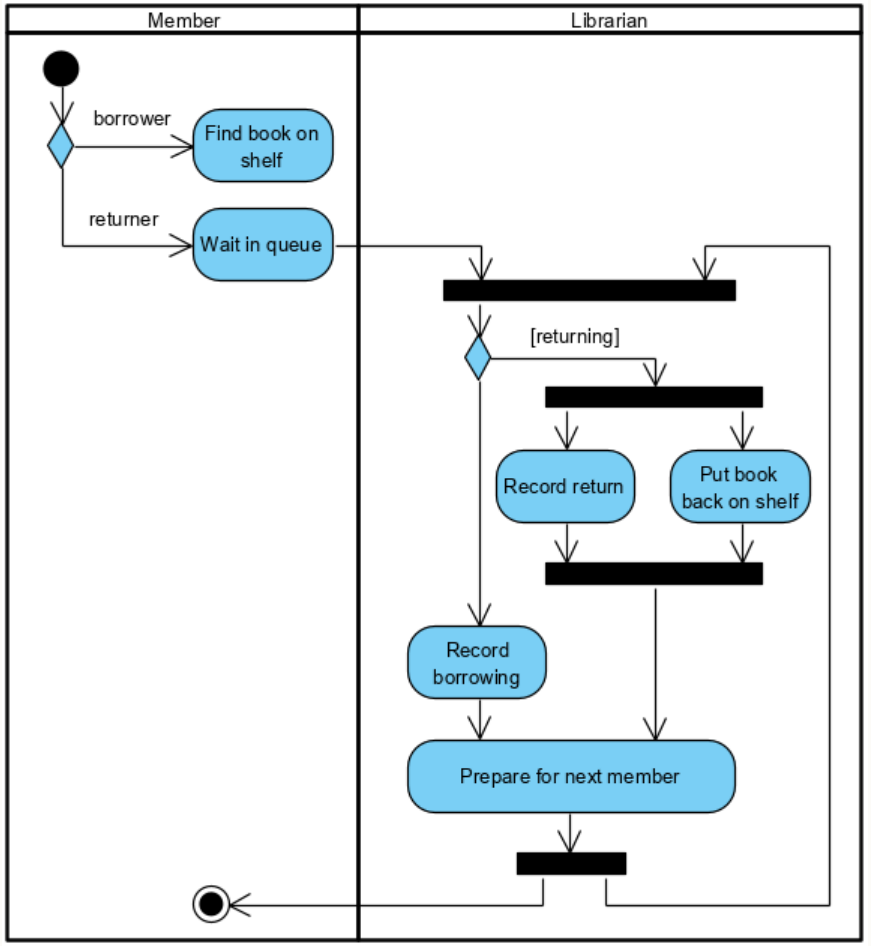
- Which of these are structure / behaviour diagrams?

Activity Diagrams

- What are activity diagrams used for?
  - Graphical representations of workflows of stepwise activities and actions related to an individual use case or across many use cases
  - Support representation of parallel behaviour

- Activity diagram components
  - Activity: A state that is left once the activity is finished
  - Activity edge: Transition that fires when previous activity completes
  - Synchronisation bar: Describes the co-ordination of activities
  - Decision diamond: Used to show decisions
  - Start and stop marker: Used to define entry and exit points
  - Swim lane: A way to group activities performed by the same actor on an activity diagram or to group activities in a single thread

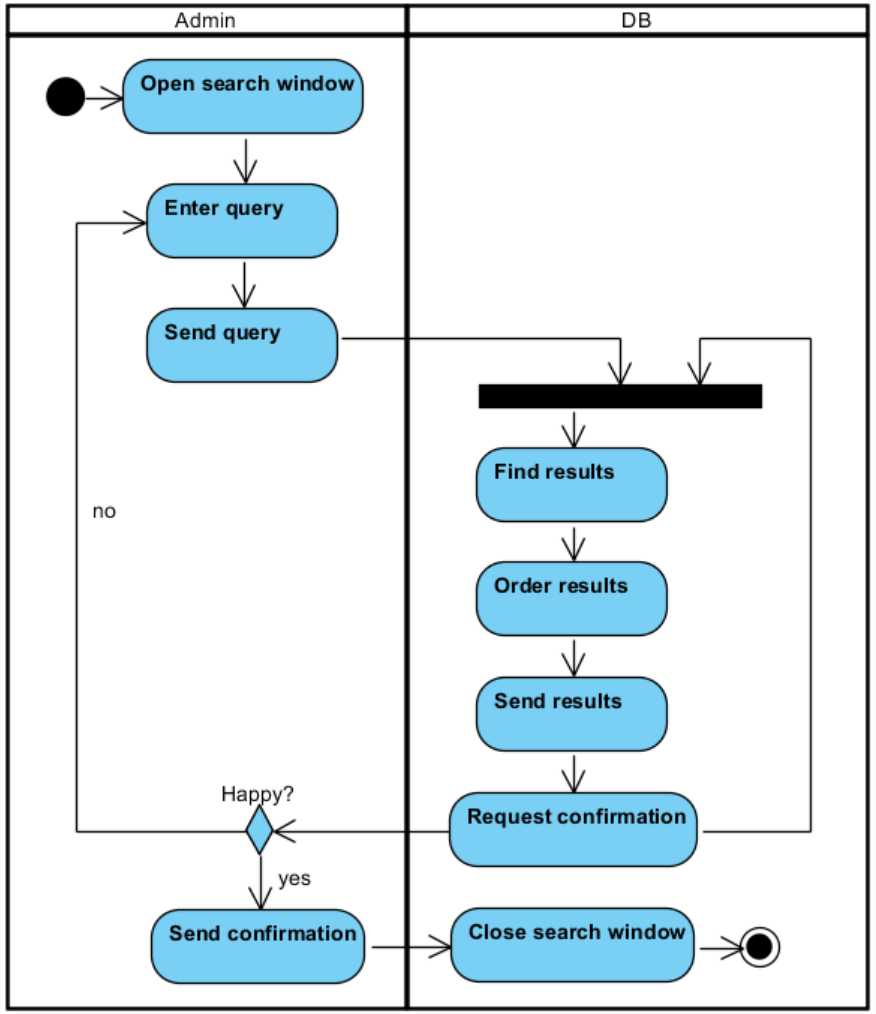
Example: Library Booking System



Activity: Fleet Logistics Management

- Activity Diagram for use case "Search for Information"?
  - Reminder: Base Path (optimistic flow) for this use case
    1. Admin opens search window
    2. Admin defines query using query editor
    3. Admin sends query to DB
    4. DB deals with query: finding results
    5. DB deals with query: organising them by relevance
    6. DB sends results back
    7. DB requests confirmation that result is sufficient
    8. Admin confirms that result is sufficient
    9. DB closes search window

Activity: Fleet Logistics Management



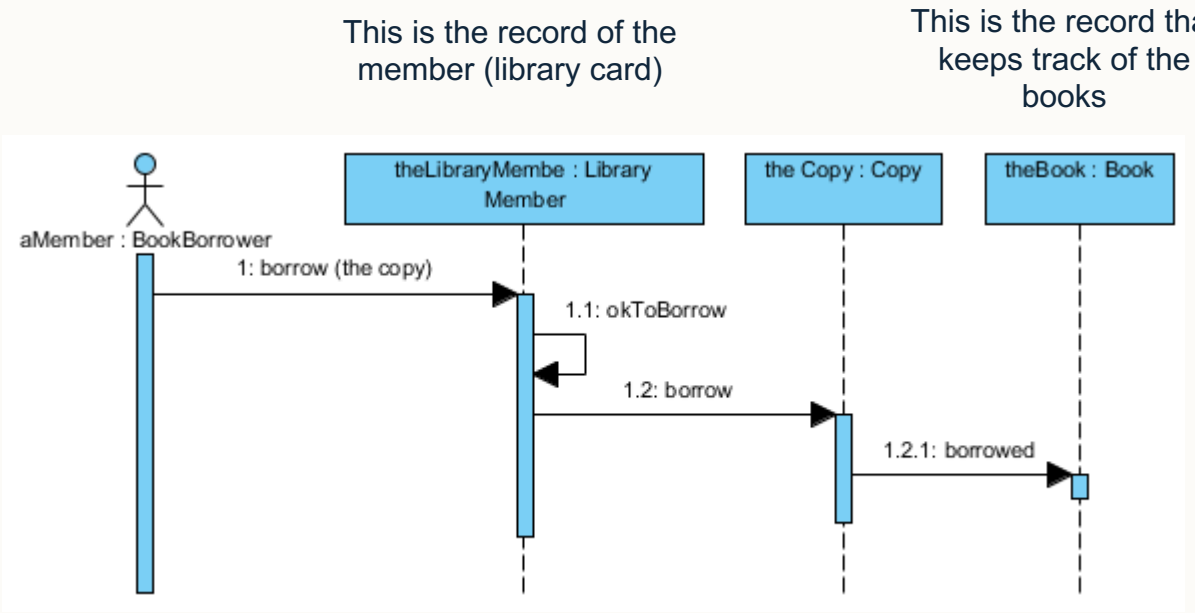
Sequence Diagrams

- What are sequence diagram used for?
  - Sequence diagrams are a temporal representation of objects and their interactions

- Sequence diagram components
  - Participant: Object or actors that act in the sequence diagram
  - Vertical line (called lifeline): Represent time as seen by the object
    - Narrow rectangle covering an object's life line shows a live activation of the object
  - Arrow from sender's lifeline to receiver's lifeline:
    - General: Message, denoting an event or the invocation of an operation
    - Object creation: Arrow with 'new' written above it
    - Object deletion: An X at bottom of lifeline (in some OOP languages this is handled automatically)
  - Sequence fragment: Let you show loops, branches, and other alternatives

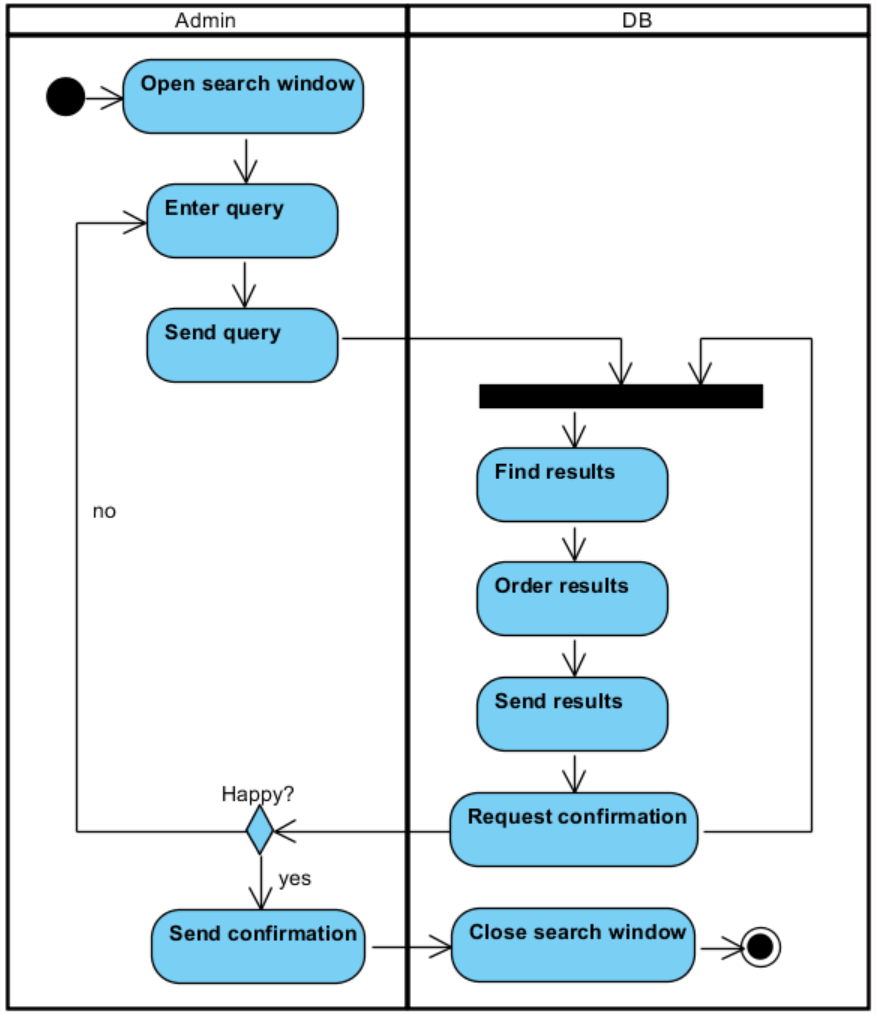
Example: Library Booking System

- Reminder
  - The library contains books and journals; it may have several copies of a given book; only staff members can borrow journals

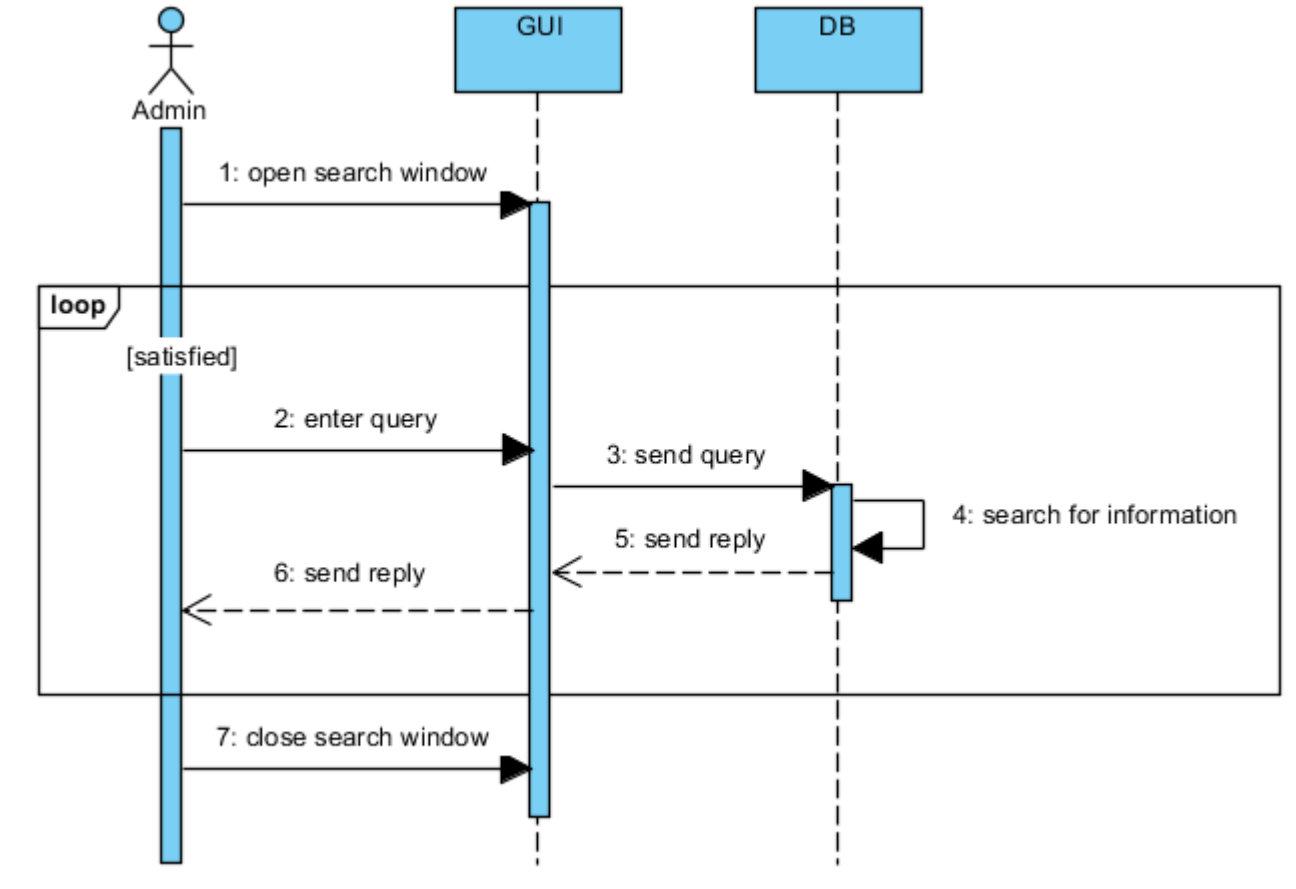


Activity: Fleet Logistics Management

- Sequence Diagram for use case "Search for Information"?
  - Reminder: Activity Diagram



Activity: Fleet Logistics Management



State Machine Diagrams

- What are state machine diagrams used for?
  - Show the possible states of a single object, the events or messages that cause a transition from one state to another, and the action that result from that state change
  - Only reactive objects require a state machine diagram!

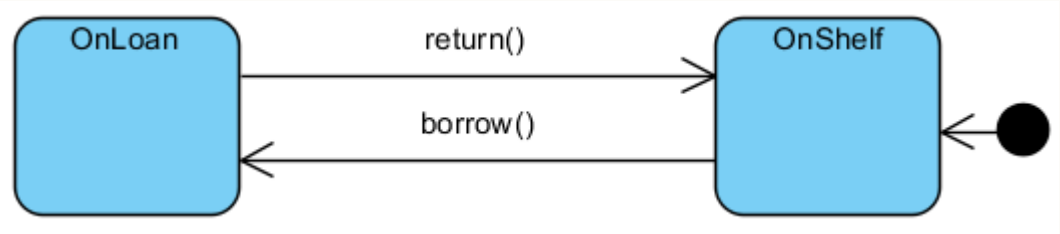
- State machine diagram components
  - State: A condition during the life of an object when it satisfies some condition, performs some action, or waits for an event. Special states:
    - Start state: Each state diagram must have one and only one start state
    - Stop state: An object can have multiple stop states

State Machine Diagrams

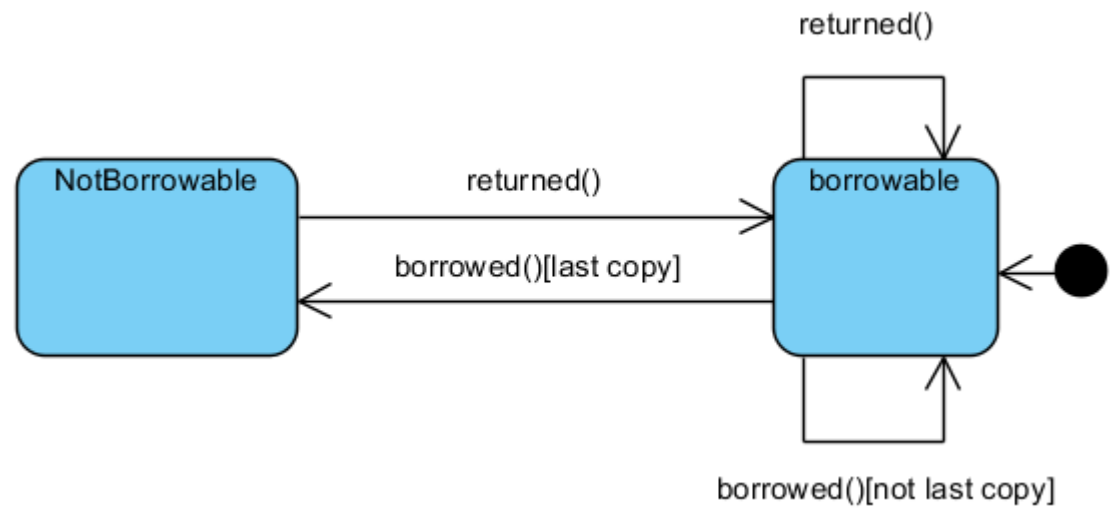
- State machine diagram components (continued)
  - Transition: Denotes the transition between states or to the same state (self-transition)
    - A transition may have a trigger, a guard and an effect (Trigger[Guard]/Effect):
      - Trigger: The cause of the transition (signal; event; change in some condition; passage of time)
      - Guard: Condition which must be true in order for the trigger to cause the transition
      - Effect: Action invoked directly on the object that owns the state machine as a result of the transition

Example: Library Booking System

- State machine diagram for the "Copy" class



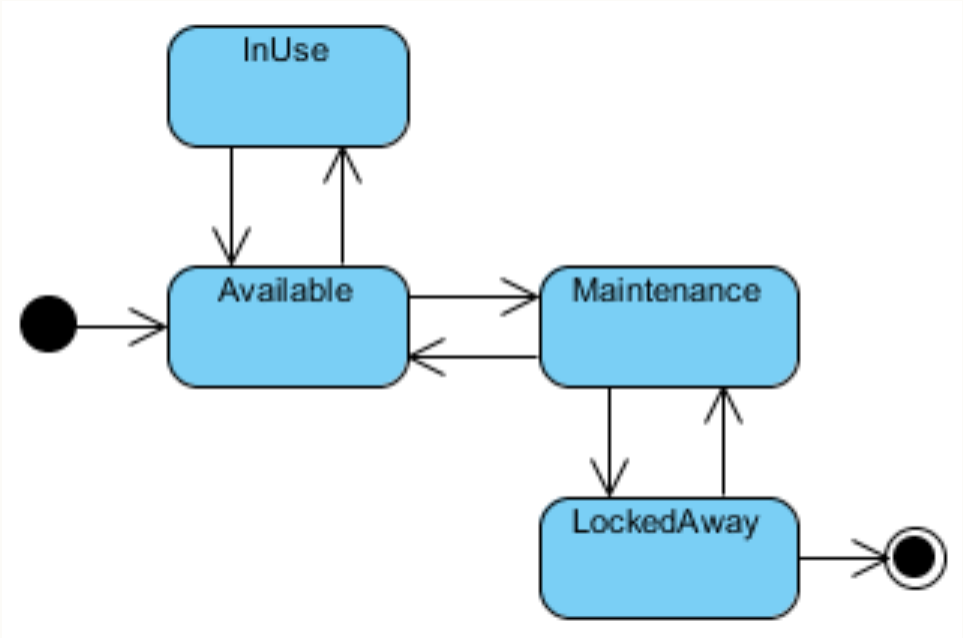
- State machine diagram for the "Book" class



Activity: Fleet Logistics Management

- State Machine Diagram for "Lorry" Class?

Activity: Fleet Logistics Management



Class Diagrams

- What is a class diagram used for?
  - A class diagrams shows the existence of classes and their structures and relationships in the logical view of a system

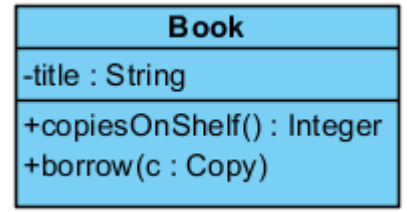
- Class diagram's main components:
  - Classes
  - Class relationships
    - Associations; dependencies; aggregations; compositions; realisations; generalisations
  - Multiplicity indicators

Class Diagrams

- Class representation
  - In UML classes are depicted as rectangles with three compartments
    - Class name
    - Attributes: Describe the data contained in an object of the class
    - Operations: Define the ways in which objects interact

  - Additional symbols

+	public
#	protected
-	private
/	derived
$	static



This is the record that keeps track of the books

Class Diagrams

Associations between classes

- Classes are associated if an instance of class A (the source class) has to know about an instance of class B (the target class) or vice versa

Multiplicity indicators

- Number of links between each instance of the source class and instances of the target class
  - 1 = exactly 1
  - * = unlimited number (zero or more)
  - 0..* = zero or more
  - 1..* = one or more
  - 0..1 = zero or 1
  - 3..7 = specified range (from 3 to 7)

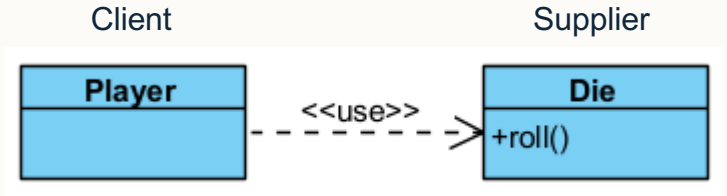
Class Diagrams

- Relationship: Association
  - Reference based relationship between two classes
  - Class A holds a class level reference to class B
  - Represented by a line between A and B with an arrow indicating the navigation direction
    - If no arrow or arrow on the both sides, association has bidirectional navigation


```
1  class Asset {
2      ...
3  }
4
5  class Player {
6      private Asset asset
7      ...
8      public Player(Asset purchasedAsset) {
9          this.asset = purchasedAsset;
10         ...
11     }
12 }
```

Class Diagrams

- Relationship: Dependency
  - Created when you receive a reference to a class as part of a particular method
  - Dependency indicates that you may invoke one of the APIs of the received class reference and any modification to that class may break your class as well
  - Multiplicity does not make sense on a Dependency



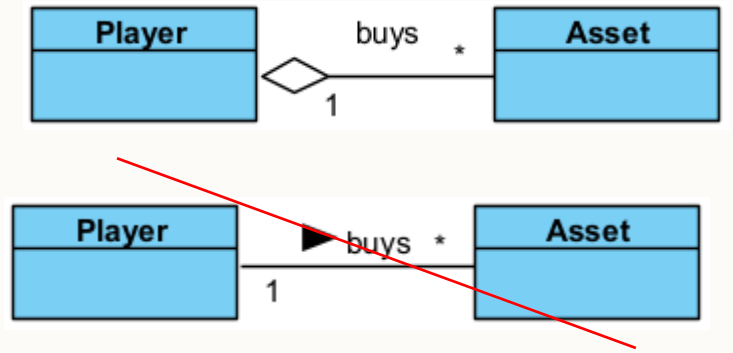
Supplier-client relationship, where the supplier provides something to the client, and thus the client is in some sense incomplete while semantically or structurally dependent on the supplier element(s). Modification of the supplier may impact the client elements.

<<use>> The source (Player) requires the target (Die) for the implementation

```
1  class Die {
2      ...
3      public void roll() {...}
4  }
5
6  class Player {
7      ...
8      public void takeTurn(Die die) {
9          die.roll();
10         ...
11     }
12 }
```

Class Diagrams

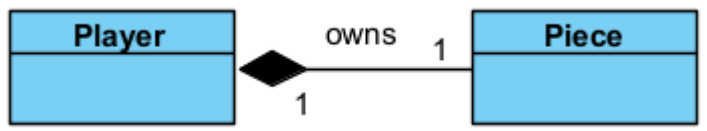
- Relationship: Aggregation ("is part of" relationship)
  - Often seen as redundant relationship as technically the same as an association; but semantically there is a difference
  - It is used when an object logically or physically contains another; the container is called "aggregate"; the components of the aggregate can be shared with others

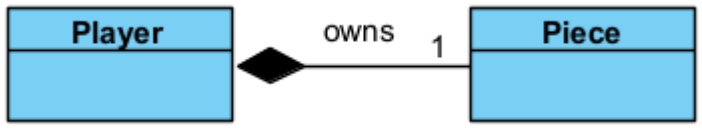



```
1  class Asset {
2      ...
3  }
4
5  class Player {
6      private List assets
7      ...
8      public void addAsset(Asset purchasedAsset) {
9          ..
10         assets.add(purchasedAsset);
11         ...
12     }
13 }
```

Class Diagrams

- Relationship: Composition
  - Relates to instance creational responsibility
  - When class B is composed by class A, class A instance owns the creation or controls lifetime of instance of class B
    - Composition binds lifetime of a specific instance for a given class, while class itself may be accessible by other parts of the system.
  - Multiplicity at the composition end is always 1 as parts have no meaning outside the whole

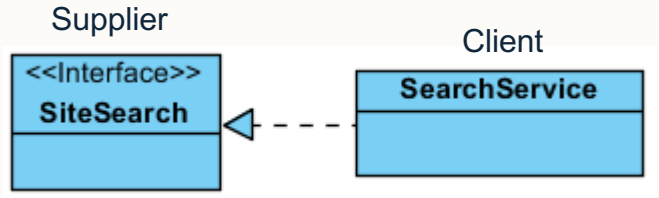





```
1  class Piece {
2      ...
3  }
4
5  class Player {
6      private Piece piece=new Piece();
7      ...
8  }
```

Class Diagrams

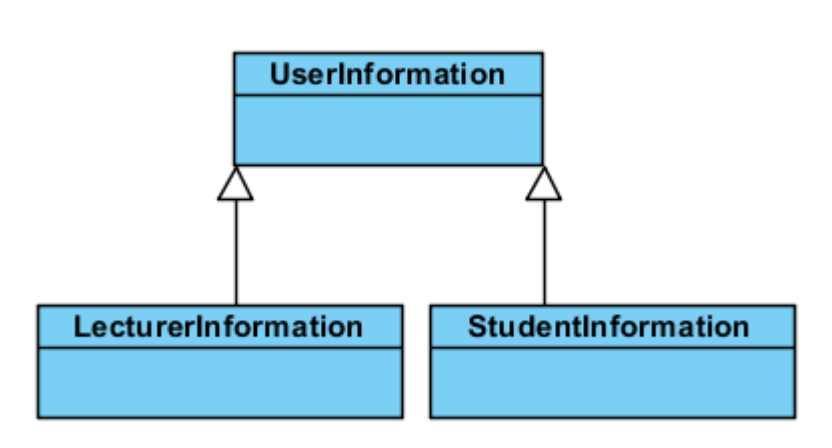
- Relationship: Realisation
  - A "Realisation" is a specialised abstraction relationship between two sets of model elements, one representing a specification (the supplier) and the other representing an implementation (the client) of the specification




```
1  class SearchService implements SiteSearch {
2      ...
3  }
```

Class Diagrams

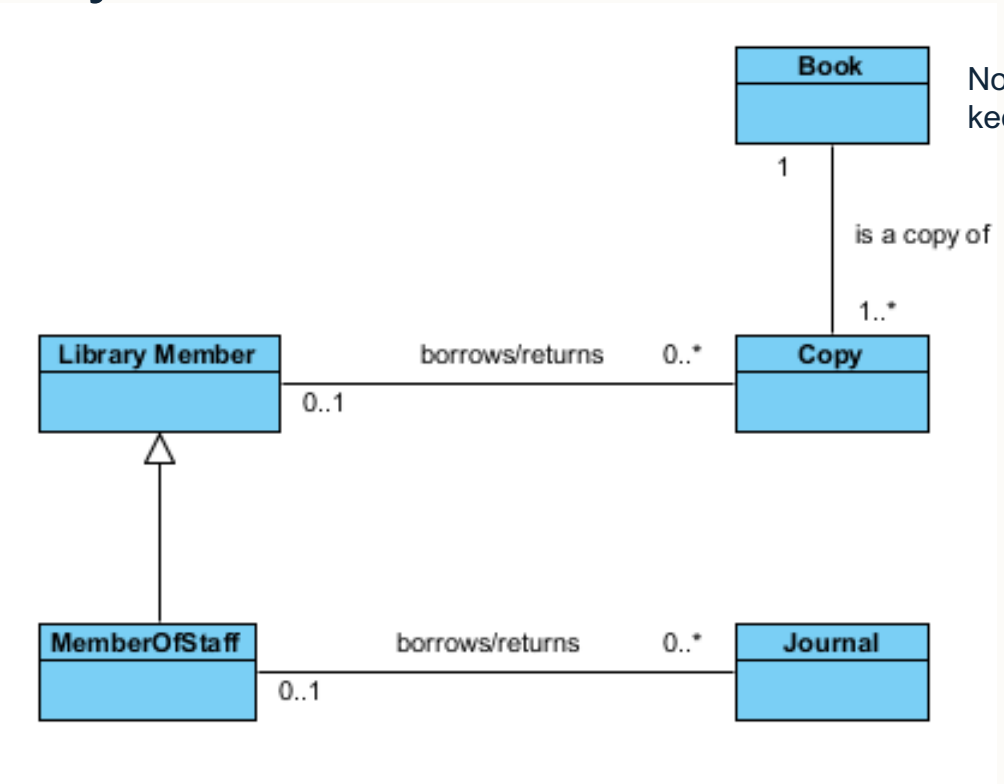
- Relationship: Generalisation ("is a" relationship)
  - A directed relationship between a more general classifier (superclass) and a more specific classifier (subclass)




```
1  class LecturerInformation extends UserInformation {
2      ...
3  }
4
5  class StudentInformation extends UserInformation {
6      ...
7  }
```

Example: Library Booking System

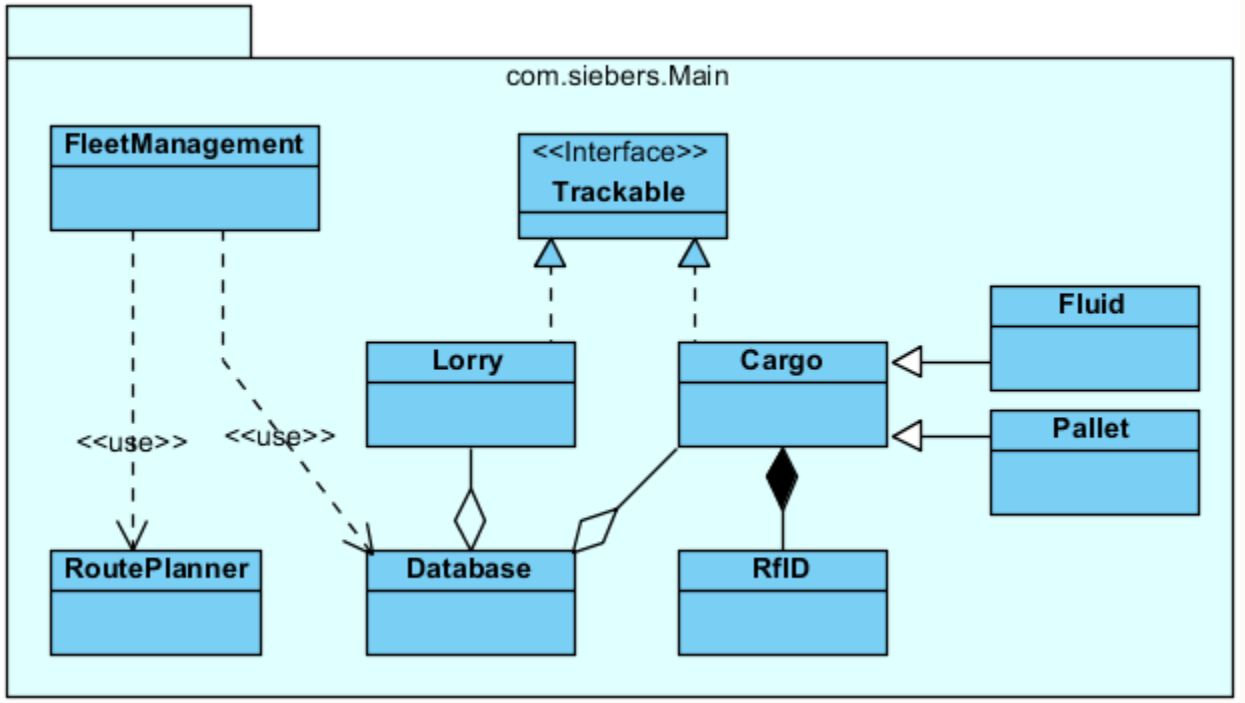
- Reminder
  - The library contains books and journals; it may have several copies of a given book; only staff members can borrow journals



Activity: Fleet Logistics Management

- Class Diagram?
  - Reminder
    - Client wants to check availability of lorries and track cargo. Manager wants to see the finances. Admin wants to search for information, organise routes and track lorries and cargo

Activity: Fleet Logistics Management



Acknowledgement

- Slides based on material from
  - Peer-Olaf Siebers's lecture slides 2022/2023

- Barclay and Savage (2004) Object-Oriented Design with UML and Java

- Some of the relationship descriptions taken from https://nirajrules.wordpress.com/2011/07/15/association-vs-dependency-vs-aggregation-vs-composition/

- A good read on interface and inheritance

  https://medium.com/@marcomvidal/oop-when-using-interfaces-751c74767b8c