Lecture – 15

Software Design

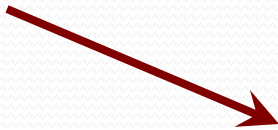
UNIT- 4

Software Design

- More creative than analysis
- Problem solving activity

WHAT IS DESIGN

‘HOW’



Software design document (SDD)

Software Design

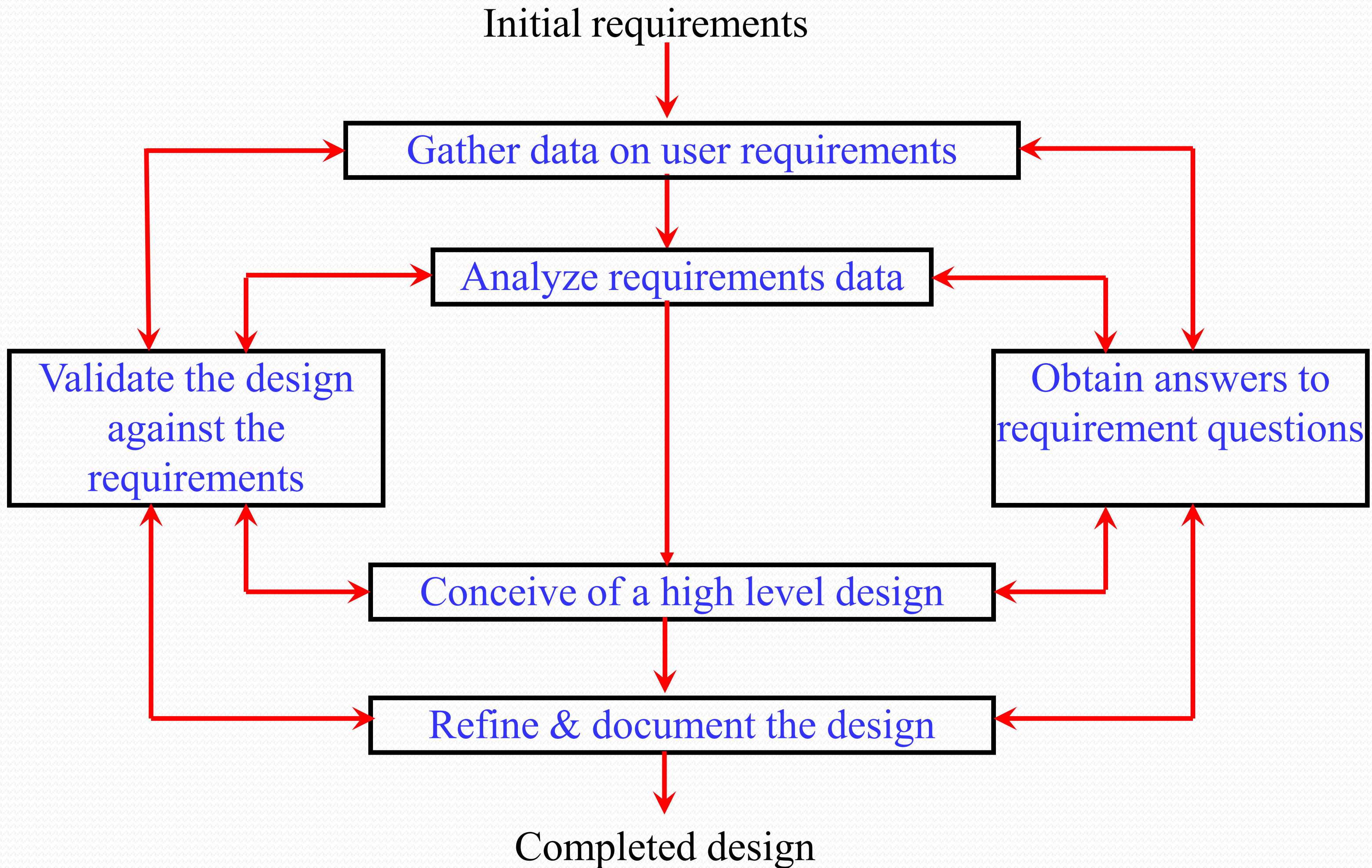
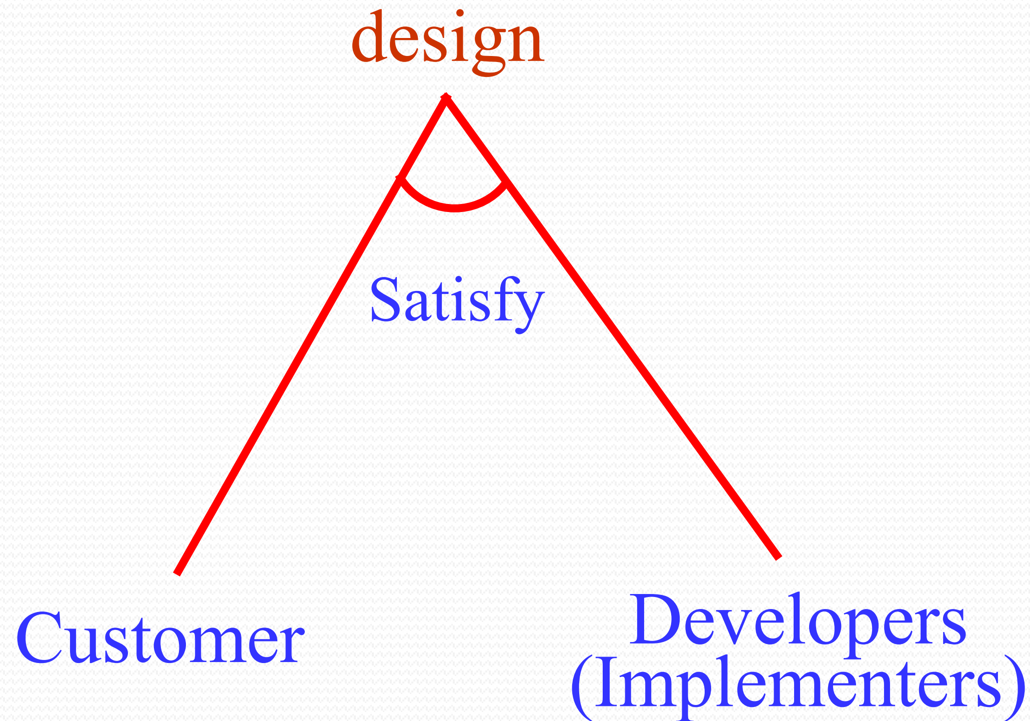


Fig. 1 : Design framework

Software Design



Conceptual Design and Technical Design

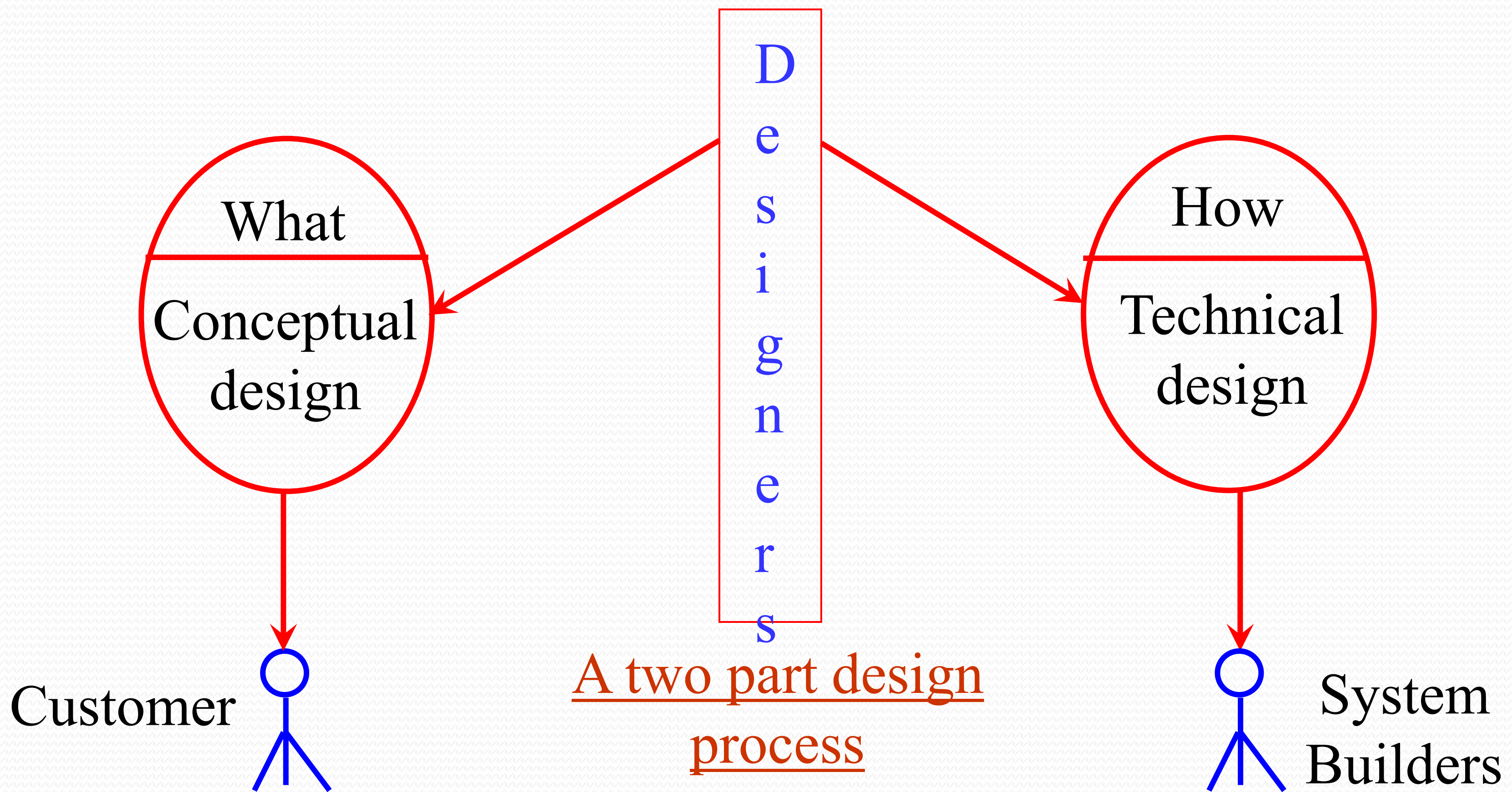


Fig. 2 : A two part design process

Software Design

Conceptual design answers :

- ✓ Where will the data come from ?
- ✓ What will happen to data in the system?
- ✓ How will the system look to users?
- ✓ What choices will be offered to users?
- ✓ What is the timings of events?
- ✓ How will the reports & screens look like?

Software Design

Technical design describes :

- Hardware configuration
- Software needs
- Communication interfaces
- I/O of the system
- Software architecture
- Network architecture
- Any other thing that translates the requirements in to a solution to the customer's problem.

Software Design

The design needs to be

- Correct & complete
- Understandable
- At the right level
- Maintainable

Software Design

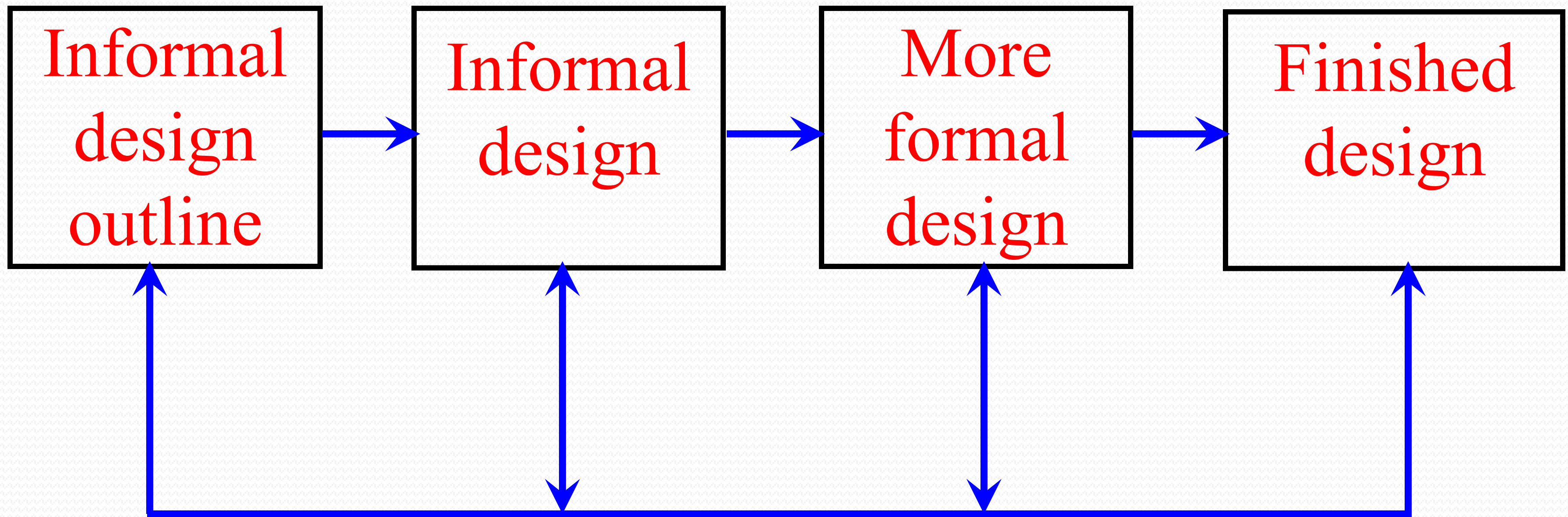


Fig. 3 : The transformation of an informal design to a detailed design.

MODULARITY

There are many definitions of the term module. Range is from :

i. Fortran subroutine
ii. Ada package
iii. Procedures & functions of PASCAL & C
iv. C++ / Java classes
v. Java packages
vi. Work assignment for an individual programmer

Software Design

All these definitions are correct. A modular system consist of well defined manageable units with well defined interfaces among the units.

Software Design

Properties :

i. Well defined subsystem
ii. Well defined purpose
iii. Can be separately compiled and stored in a library.
iv. Module can use other modules
v. Module should be easier to use than to build
vi. Simpler from outside than from the inside.

Software Design

Modularity is the single attribute of software that allows a program to be intellectually manageable. It enhances design clarity, which in turn eases implementation, debugging, testing, documenting, and maintenance of software product.

Lecture – 16

Software Design

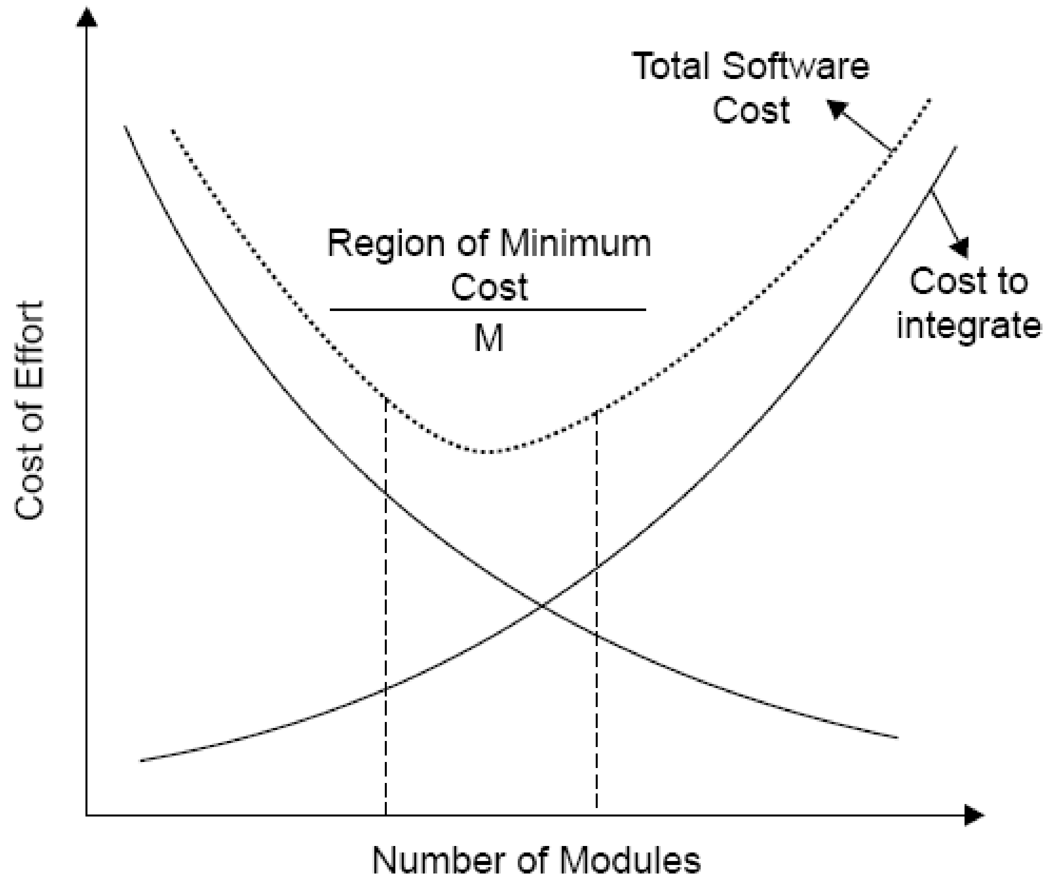
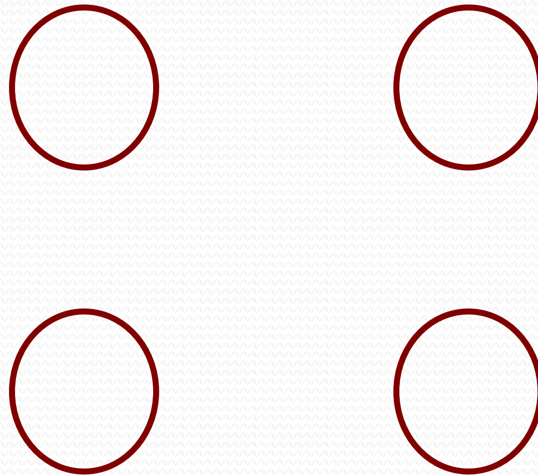


Fig. 4 : Modularity and software cost

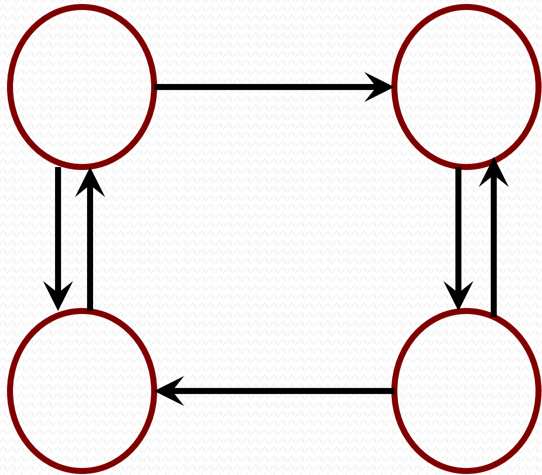
Module Coupling

Coupling is the measure of the degree of interdependence between modules.

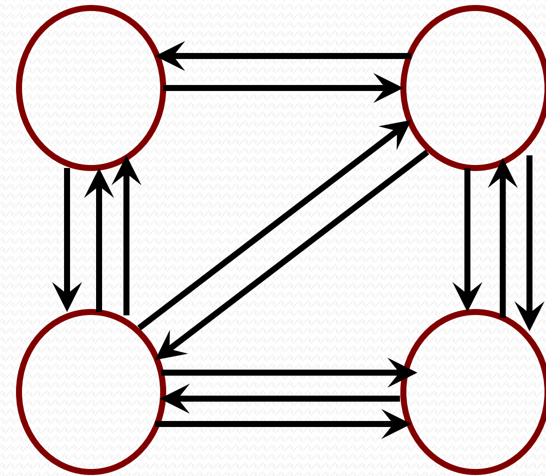


(Uncoupled : no dependencies)
(a)

Software Design



Loosely coupled:
some dependencies
(B)



Highly coupled:
many dependencies
(C)

Fig. 5 : Module coupling

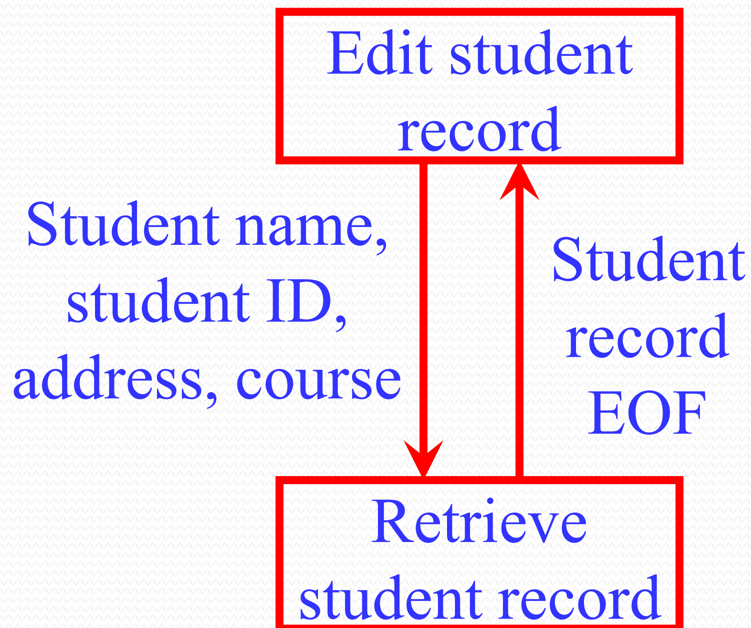
Software Design

This can be achieved as:

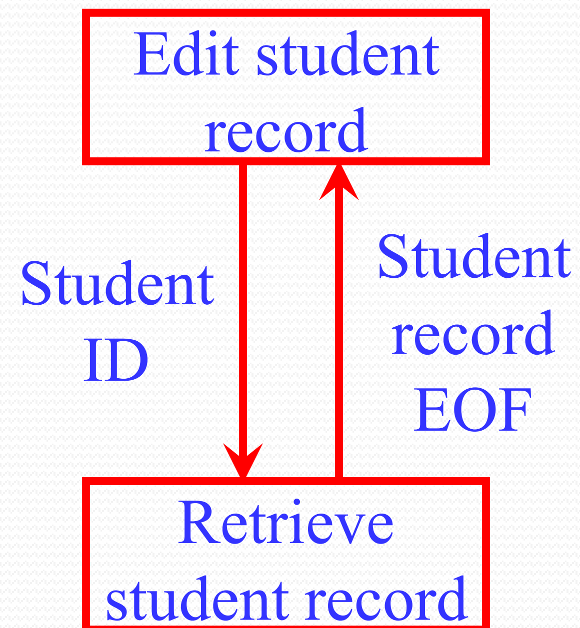
- Controlling the number of parameters passed amongst modules.
- Avoid passing undesired data to calling module.
- Maintain parent / child relationship between calling & called modules.
- Pass data, not the control information.

Software Design

Consider the example of editing a student record in a 'student information system'.



Poor design: Tight Coupling



Good design: Loose Coupling

Fig. 6 : Example of coupling

Data coupling	Best
Stamp coupling	↑
Control coupling	
External coupling	
Common coupling	
Content coupling	Worst

Fig. 7 : The types of module coupling

Given two procedures A & B, we can identify number of ways in which they can be coupled.

Data coupling

The dependency between module A and B is said to be data coupled if their dependency is based on the fact they communicate by only passing of data. Other than communicating through data, the two modules are independent.

Stamp coupling

Stamp coupling occurs between module A and B when complete data structure is passed from one module to another.

Control coupling

Module A and B are said to be control coupled if they communicate by passing of control information. This is usually accomplished by means of flags that are set by one module and reacted upon by the dependent module.

Common coupling

With common coupling, module A and module B have shared data. Global data areas are commonly found in programming languages. Making a change to the common data means tracing back to all the modules which access that data to evaluate the effect of changes.

Software Design

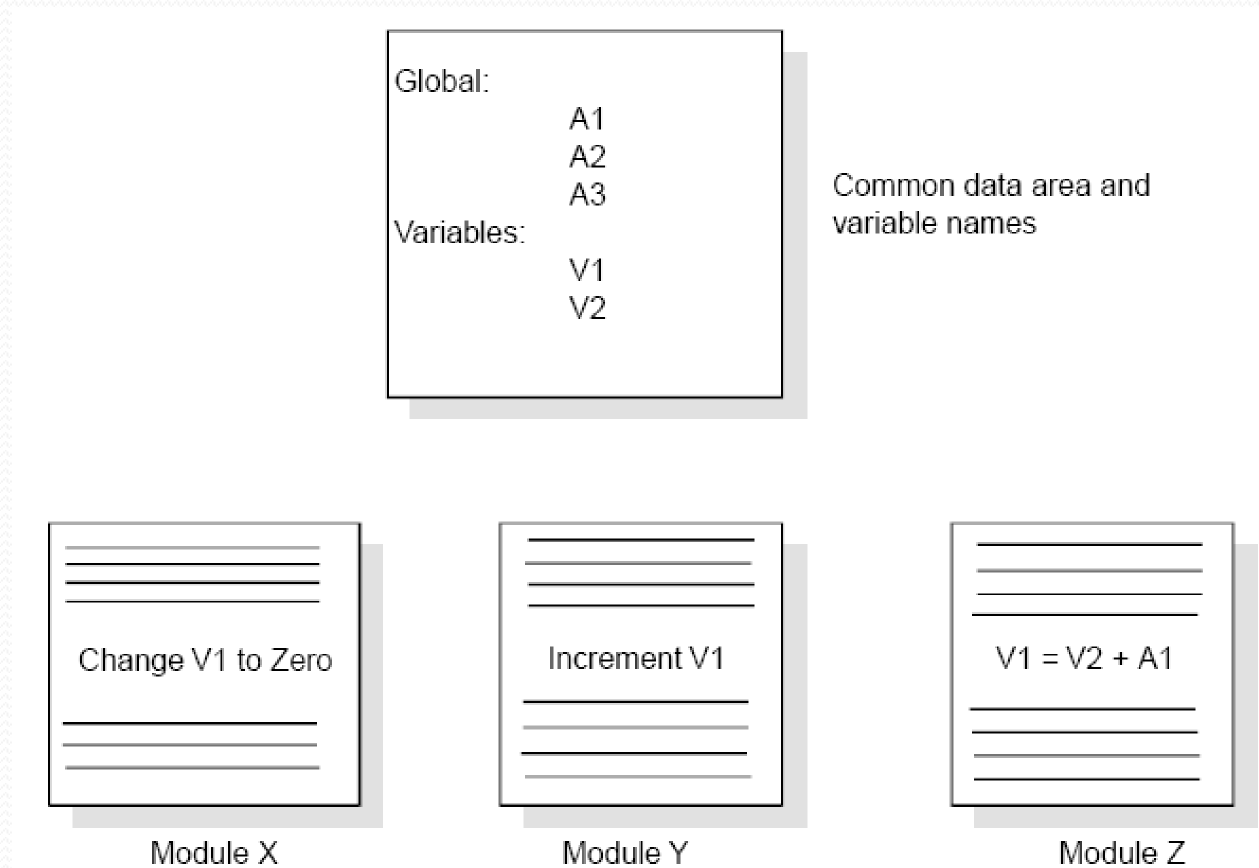


Fig. 8 : Example of common coupling

Content coupling

Content coupling occurs when module A changes data of module B or when control is passed from one module to the middle of another. In Fig. 9, module B branches into D, even though D is supposed to be under the control of C.

Software Design

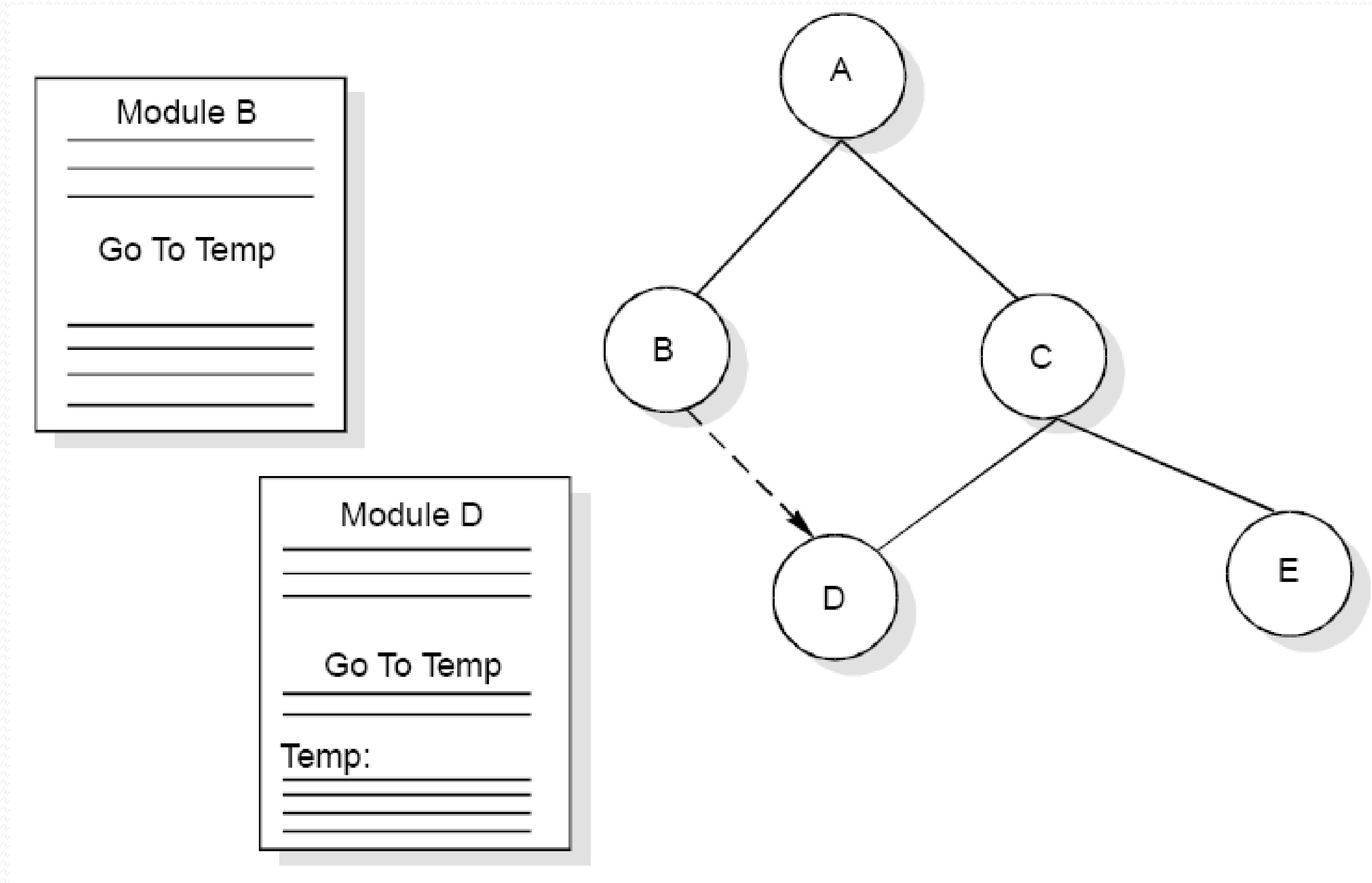


Fig. 9 : Example of content coupling

Module Cohesion

Cohesion is a measure of the degree to which the elements of a module are functionally related.

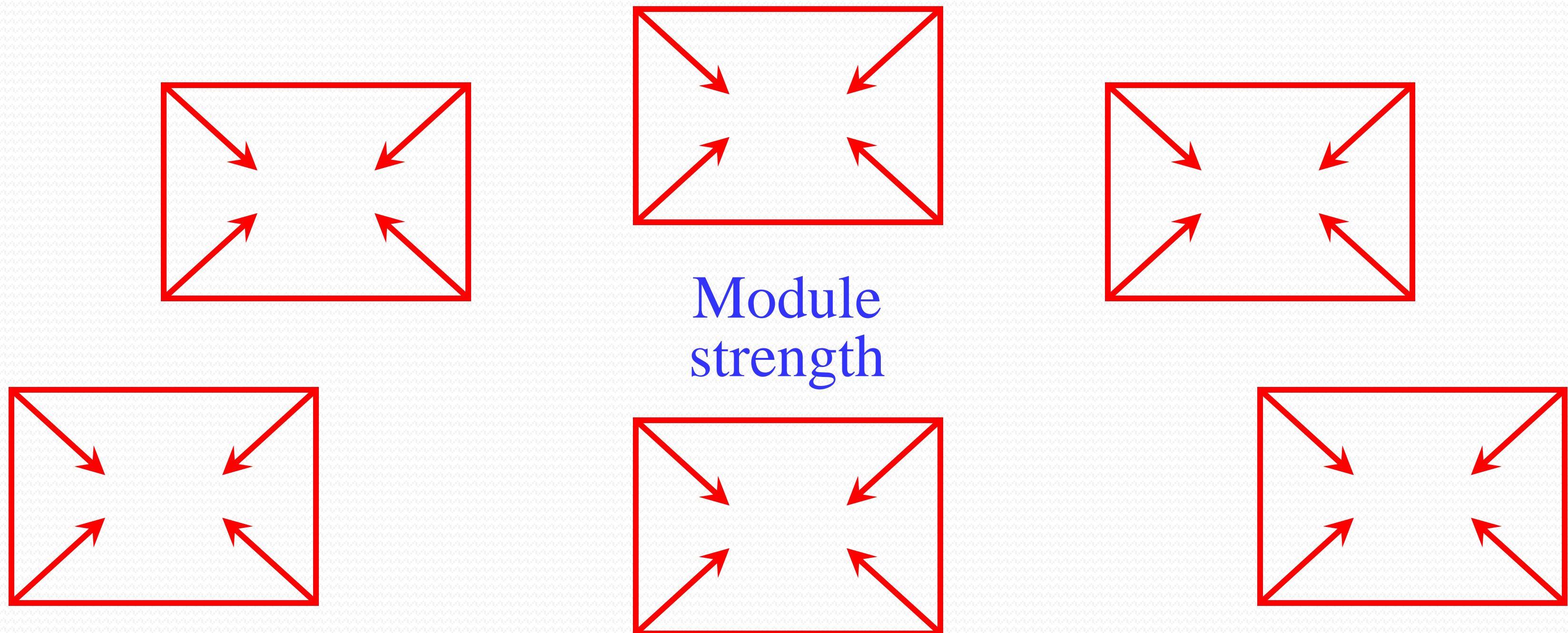


Fig. 10 : Cohesion=Strength of relations within modules

Types of cohesion

Functional cohesion

Sequential cohesion

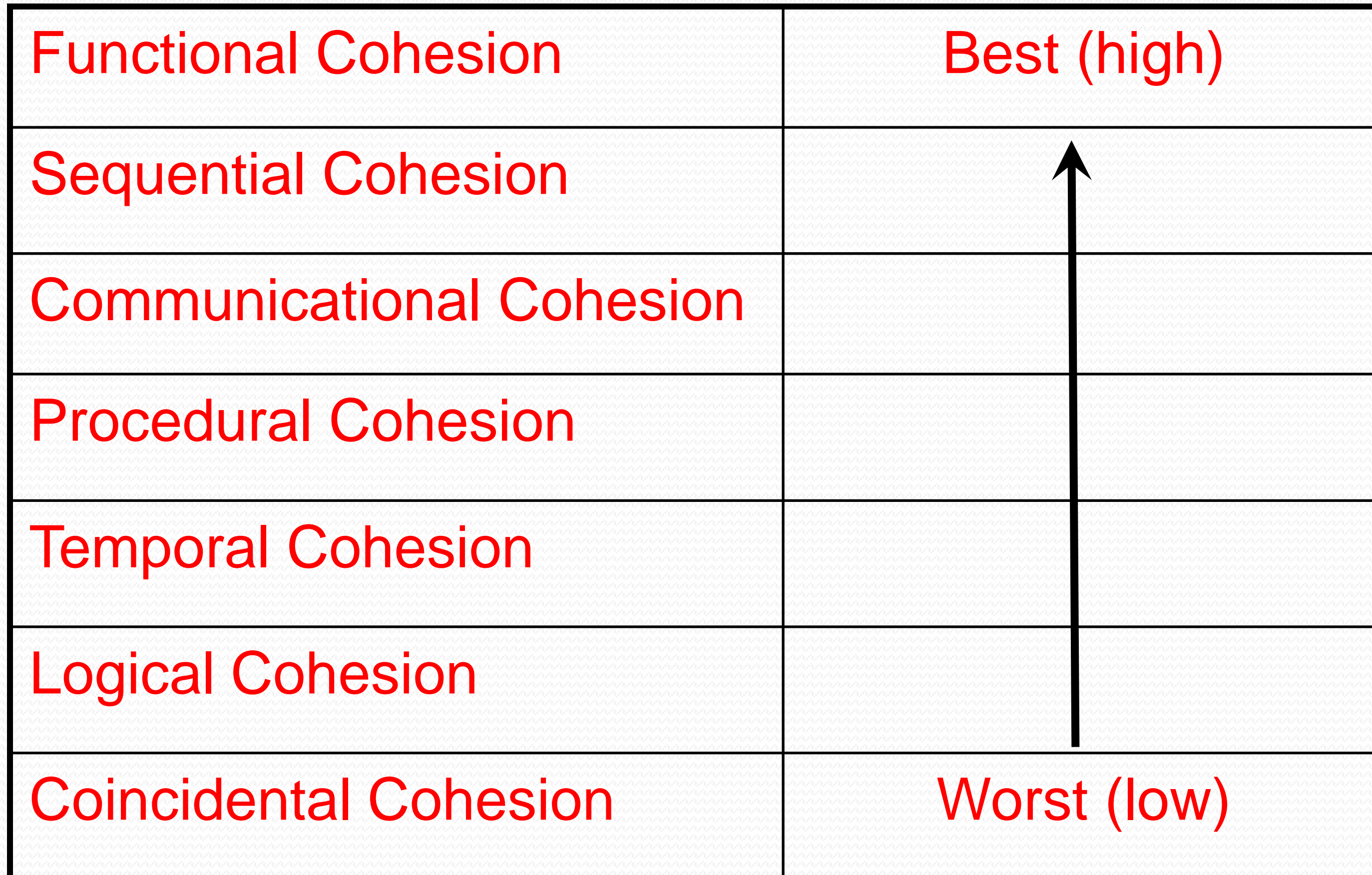
Procedural cohesion

Temporal cohesion

Logical cohesion

Coincident cohesion

Software Design



Functional Cohesion	Best (high)
Sequential Cohesion	
Communicational Cohesion	
Procedural Cohesion	
Temporal Cohesion	
Logical Cohesion	
Coincidental Cohesion	Worst (low)

Fig. 11 : Types of module cohesion

Functional Cohesion

A and B are part of a single functional task. This is very good reason for them to be contained in the same procedure.

Sequential Cohesion

Module A outputs some data which forms the input to B. This is the reason for them to be contained in the same procedure.

Procedural Cohesion

Procedural Cohesion occurs in modules whose instructions although accomplish different tasks yet have been combined because there is a specific order in which the tasks are to be completed.

Temporal Cohesion

Module exhibits temporal cohesion when it contains tasks that are related by the fact that all tasks must be executed in the same time-span.

Logical Cohesion

Logical cohesion occurs in modules that contain instructions that appear to be related because they fall into the same logical class of functions.

Coincidental Cohesion

Coincidental cohesion exists in modules that contain instructions that have little or no relationship to one another.

Relationship between Cohesion & Coupling

If the software is not properly modularized, a host of seemingly trivial enhancement or changes will result into death of the project. Therefore, a software engineer must design the modules with goal of high cohesion and low coupling.

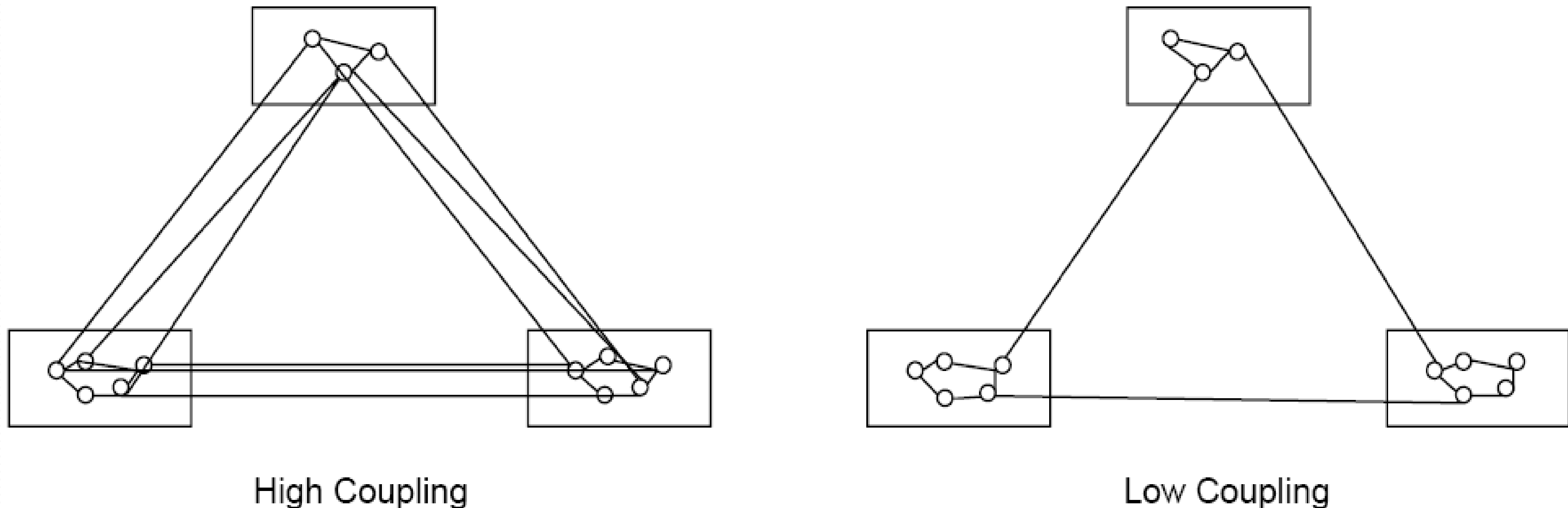


Fig. 12 : View of cohesion and coupling

STRATEGY OF DESIGN

A good system design strategy is to organize the program modules in such a way that are easy to develop and latter to, change. Structured design techniques help developers to deal with the size and complexity of programs. Analysts create instructions for the developers about how code should be written and how pieces of code should fit together to form a program. It is important for two reasons:

First, even pre-existing code, if any, needs to be understood, organized and pieced together.

Second, it is still common for the project team to have to write some code and produce original programs that support the application logic of the system.

Bottom-Up Design

These modules are collected together in the form of a “library”.

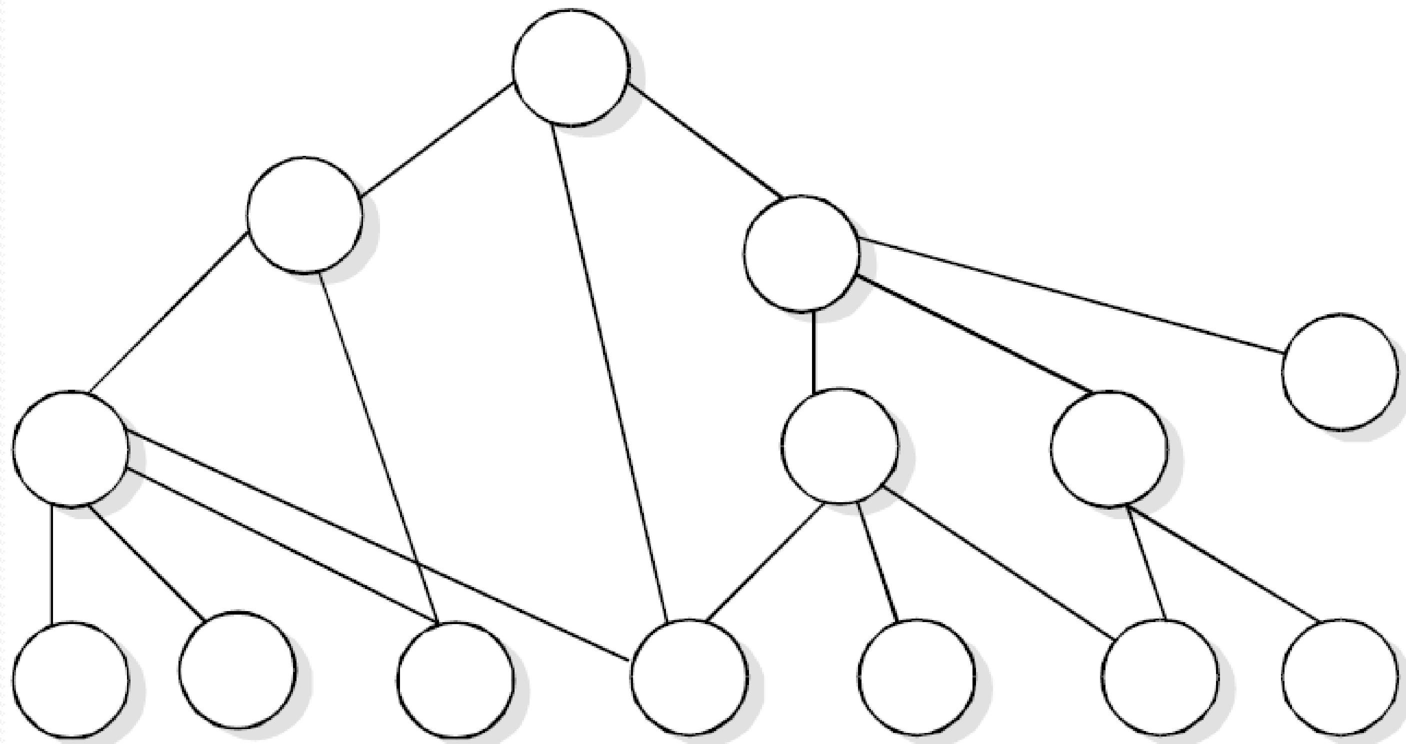


Fig. 13 : Bottom-up tree structure

Top-Down Design

A top down design approach starts by identifying the major modules of the system, decomposing them into their lower level modules and iterating until the desired level of detail is achieved. This is stepwise refinement; starting from an abstract design, in each step the design is refined to a more concrete level, until we reach a level where no more refinement is needed and the design can be implemented directly.

Hybrid Design

For top-down approach to be effective, some bottom-up approach is essential for the following reasons:

To permit common sub modules.

Near the bottom of the hierarchy, where the intuition is simpler, and the need for bottom-up testing is greater, because there are more number of modules at low levels than high levels.

In the use of pre-written library modules, in particular, reuse of modules.

FUNCTION ORIENTED DESIGN

Function Oriented design is an approach to software design where the design is decomposed into a set of interacting units where each unit has a clearly defined function. Thus, system is designed from a functional viewpoint.

Assignment

- Explain various types of software designs
- Difference b/t Cohesion & Coupling

Research

- **A Coupling and Cohesion Metrics Suite for Object-Oriented Software**

Lecture – 17

Software Design

Consider the example of scheme interpreter. Top-level function may look like:

```
While (not finished)
{
        Read an expression from the terminal;
        Evaluate the expression;
        Print the value;
}
```

We thus get a fairly natural division of our interpreter into a “read” module, an “evaluate” module and a “print” module. Now we consider the “print” module and is given below:

```
        Print (expression exp)
{
        Switch (exp → type)
        Case integer: /*print an integer*/
        Case real:    /*print a real*/
        Case list:    /*print a list*/
        :::
}
```

Software Design

We continue the refinement of each module until we reach the statement level of our programming language. At that point, we can describe the structure of our program as a tree of refinement as in design top-down structure as shown in fig. 14.

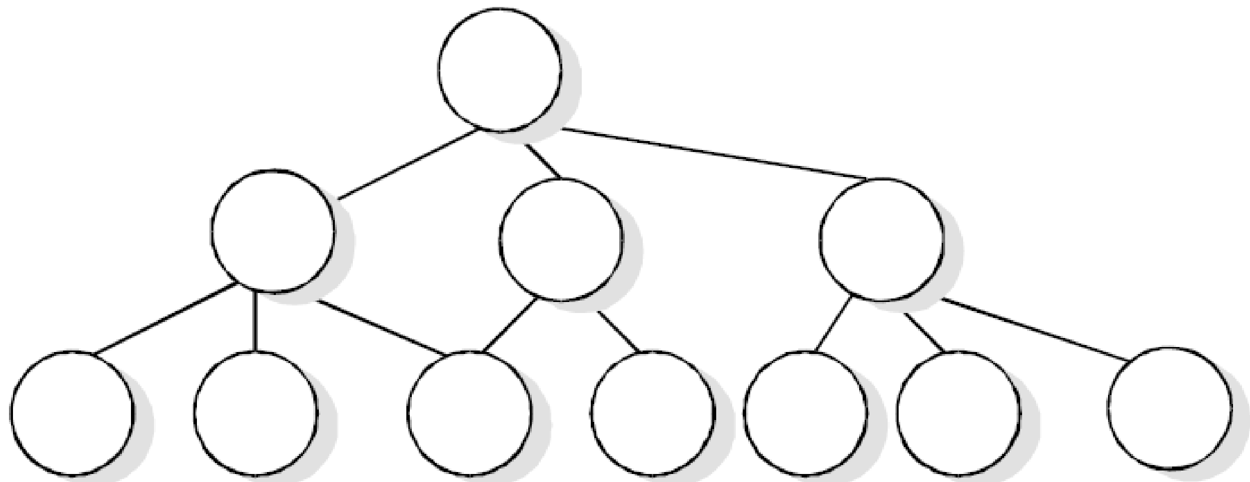


Fig. 14 : Top-down structure

Software Design

If a program is created top-down, the modules become very specialized. As one can easily see in top down design structure, each module is used by at most one other module, its parent. For a module, however, we must require that several other modules as in design reusable structure as shown in fig. 15.

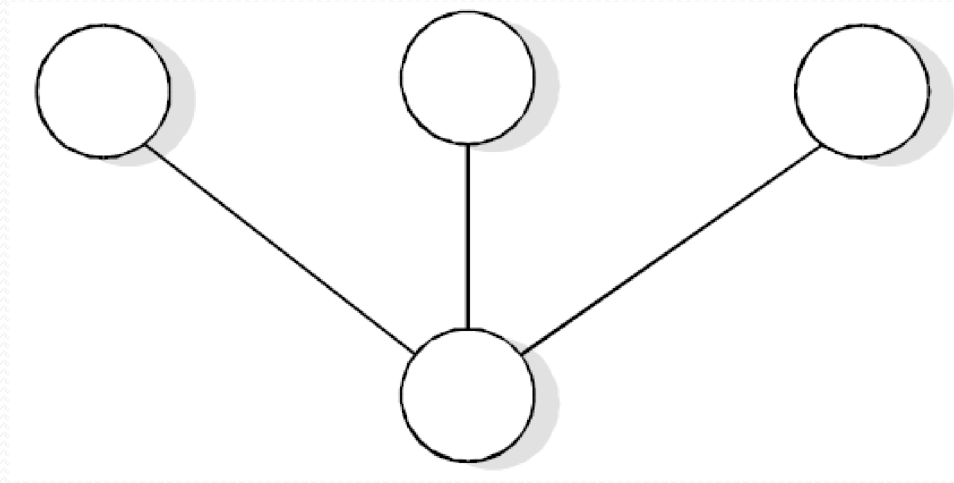


Fig. 15 : Design reusable structure

Design Notations

Design notations are largely meant to be used during the process of design and are used to represent design or design decisions. For a function oriented design, the design can be represented graphically or mathematically by the following:

Data flow diagrams

Data Dictionaries

Structure Charts

Pseudocode

Structure Chart

It partition a system into block boxes. A black box means that functionality is known to the user without the knowledge of internal design.

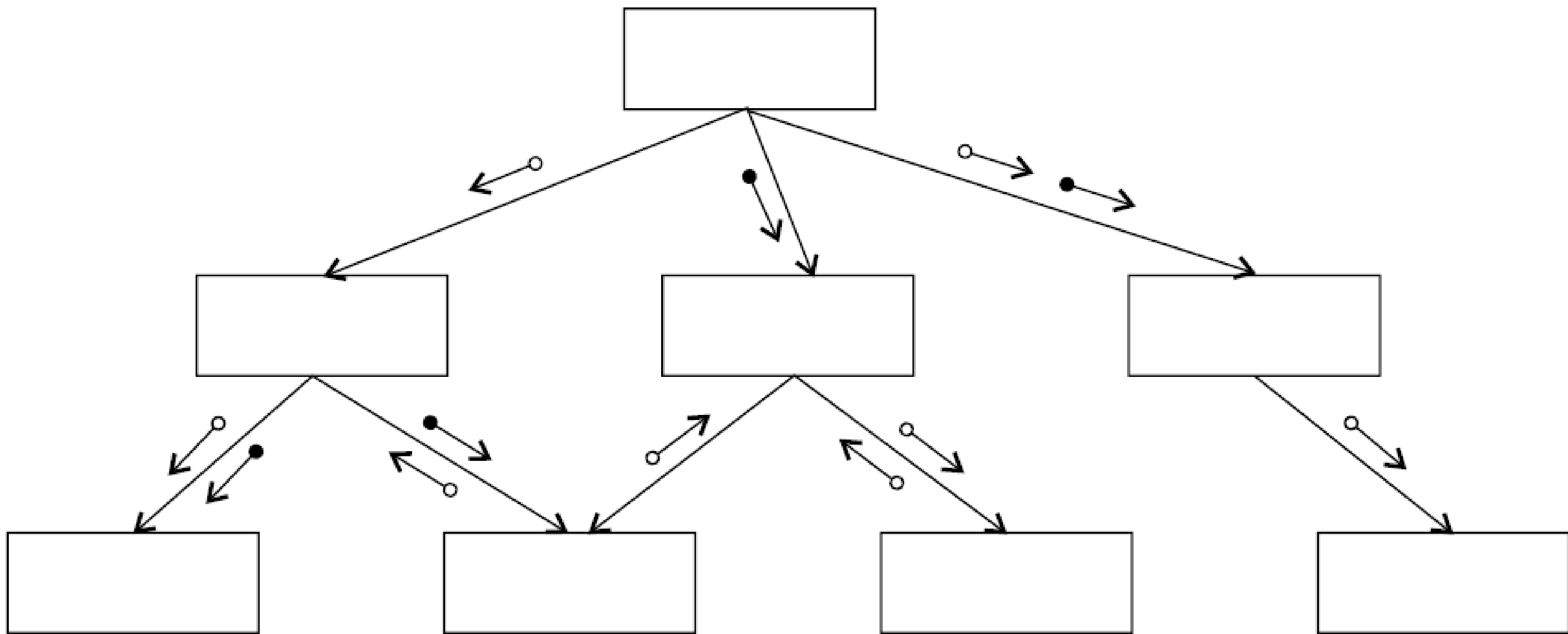


Fig. 16 : Hierarchical format of a structure chart

Software Design

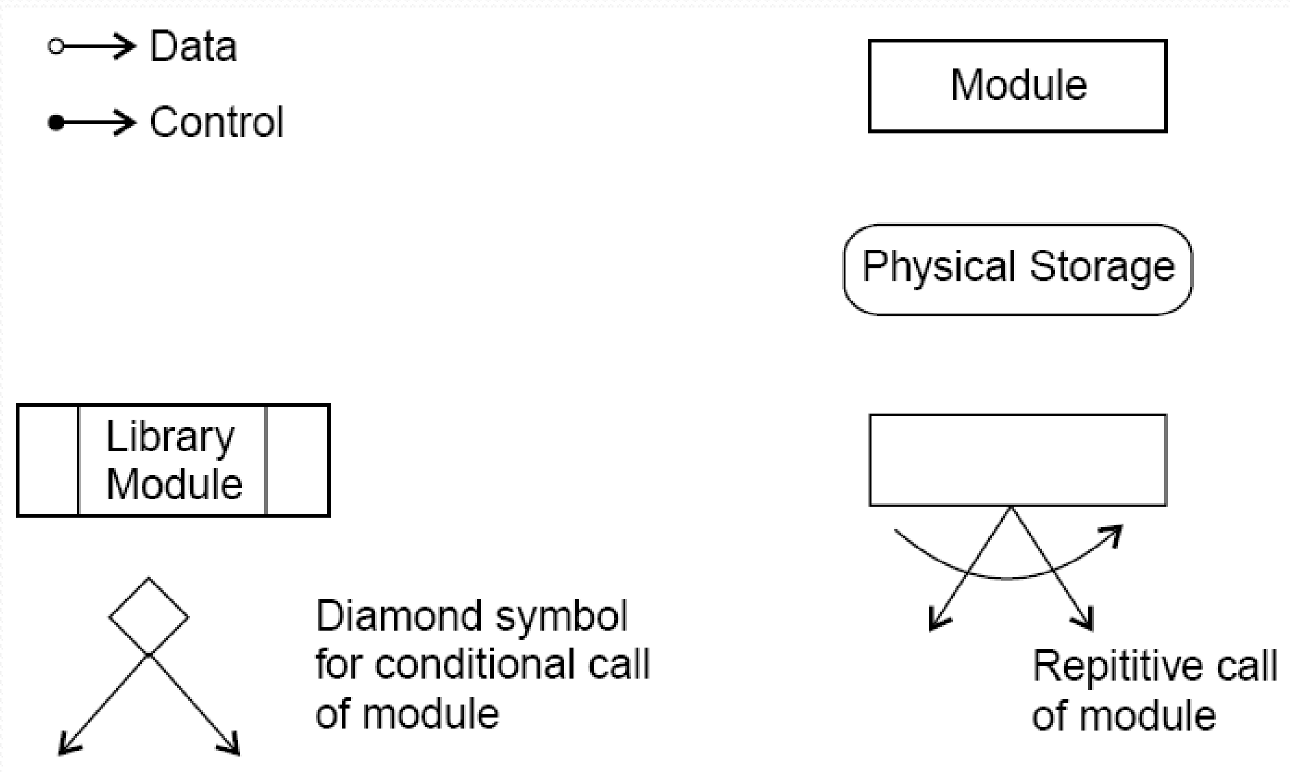


Fig. 17 : Structure chart notations

Software Design

A structure chart for "update file" is given in fig. 18.

Fig. 18 : Update file

Software Design

A transaction centered structure describes a system that processes a number of different types of transactions. It is illustrated in Fig.19.

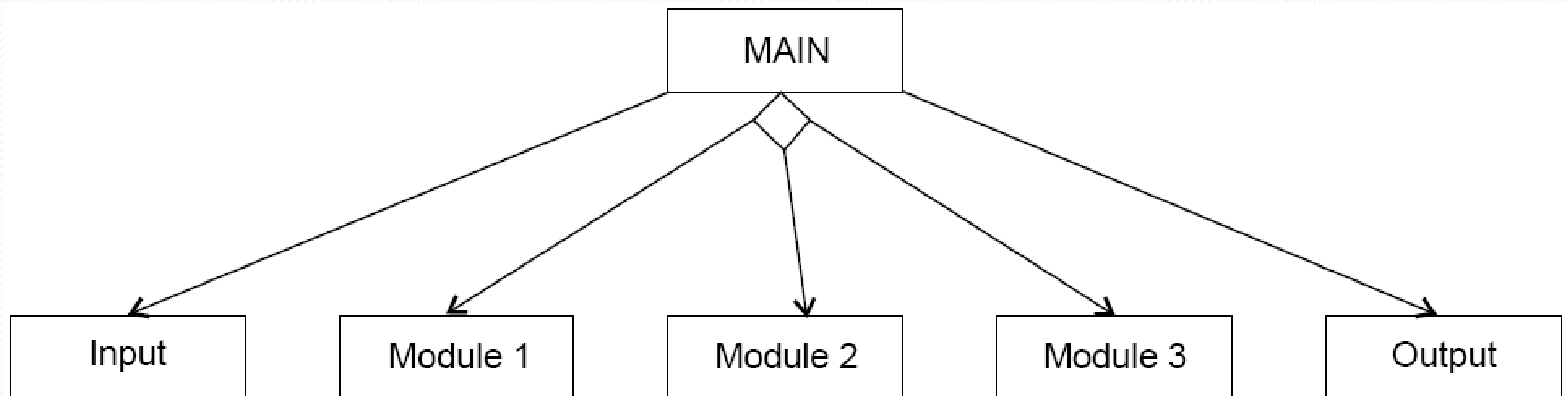


Fig. 19 : Transaction-centered structure

Software Design

In the above figure the MAIN module controls the system operation its functions is to:

invoke the INPUT module to read a transaction;

determine the kind of transaction and select one of a number of transaction modules to process that transaction, and

output the results of the processing by calling OUTPUT module.

Pseudocode

Pseudocode notation can be used in both the preliminary and detailed design phases.

Using pseudocode, the designer describes system characteristics using short, concise, English language phrases that are structured by key words such as It-Then-Else, While-Do, and End.

Functional Procedure Layers

Function are built in layers, Additional notation is used to specify details.

Level 0

- Function or procedure name
- Relationship to other system components (e.g., part of which system, called by which routines, etc.)
- Brief description of the function purpose.
- Author, date

Software Design

Level 1

- Function Parameters (problem variables, types, purpose, etc.)
- Global variables (problem variable, type, purpose, sharing information)
- Routines called by the function
- Side effects
- Input/Output Assertions

Software Design

Level 2

- Local data structures (variable etc.)
- Timing constraints
- Exception handling (conditions, responses, events)
- Any other limitations

Level 3

- Body (structured chart, English pseudo code, decision tables, flow charts, etc.)

Software Design

IEEE Recommended practice for software design descriptions (IEEE STD 1016-1998)

Scope

An SDD is a representation of a software system that is used as a medium for communicating software design information.

References

i. IEEE std 830-1998, IEEE recommended practice for software requirements specifications.

ii. IEEE std 610.12-1990, IEEE glossary of software engineering terminology.

Software Design

Definitions

i. **Design entity.** An element (Component) of a design that is structurally and functionally distinct from other elements and that is separately named and referenced.

ii. **Design View.** A subset of design entity attribute information that is specifically suited to the needs of a software project activity.

iii. **Entity attributes.** A named property or characteristics of a design entity. It provides a statement of fact about the entity.

iv. **Software design description (SDD).** A representation of a software system created to facilitate analysis, planning, implementation and decision making.

Software Design

Purpose of an SDD

The SDD shows how the software system will be structured to satisfy the requirements identified in the SRS. It is basically the translation of requirements into a description of the software structure, software components, interfaces, and data necessary for the implementation phase. Hence, SDD becomes the blue print for the implementation activity.

Design Description Information Content

- Introduction
- Design entities
- Design entity attributes

Software Design

The attributes and associated information items are defined in the following subsections:

a) Identification
b) Type
c) Purpose
d) Function
e) Subordinates
f) Dependencies
g) Interface
h) Resources
i) Processing
j) Data

Software Design

Design Description Organization

Each design description writer may have a different view of what are considered the essential aspects of a software design. The organization of SDD is given in table 1. This is one of the possible ways to organize and format the SDD.

A recommended organization of the SDD into separate design views to facilitate information access and assimilation is given in table 2.

Software Design

1. Introduction
   1.1 Purpose
   1.2 Scope
   1.3 Definitions and acronyms
2. References
3. Decomposition description
   3.1 Module decomposition
      3.1.1 Module 1 description
      3.1.2 Module 2 description
   3.2 Concurrent Process decompostion
      3.2.1 Process 1 description
      3.2.2 Process 2 description
   3.3 Data decomposition
      3.3.1 Data entity 1 description
      3.3.2 Data entity 2 description

Cont…

Software Design

4. Dependency description
   - 4.1 Intermodule dependencies
   - 4.2 Interprocess dependencies
   - 4.3 Data dependencies
5. Interface description
   - 5.1 Module Interface
     - 5.1.1 Module 1 description
     - 5.1.2 Module 2 description
   - 5.2 Process interface
     - 5.2.1 Process 1 description
     - 5.2.2 Process 2 description
6. Detailed design
   - 6.1 Module detailed design
     - 6.1.1 Module 1 detail
     - 6.1.2 Module 2 detail
   - 6.2 Data detailed design
     - 6.2.1 Data entry 1 detail
     - 6.2.2 Data entry 2 detail

Table 1: Organization of SDD

Software Design

Design View	Scope	Entity attribute	Example representation
Decomposition description	Partition of the system into design entities	Identification, type purpose, function, subordinate	Hierarchical decomposition diagram, natural language
Dependency description	Description of relationships among entities of system resources	Identification, type, purpose, dependencies, resources	Structure chart, data flow diagrams, transaction diagrams
Interface description	List of everything a designer, developer, tester needs to know to use design entities that make up the system	Identification, function, interfaces	Interface files, parameter tables
Detail description	Description of the internal design details of an entity	Identification, processing, data	Flow charts, PDL etc.

Table 2: Design views

Object Oriented Design

Object oriented design is the result of focusing attention not on the function performed by the program, but instead on the data that are to do manipulated by the program. Thus, it is orthogonal to function oriented design.

Object Oriented Design begins with an examination of the real world "things" that are part of the problem to be solved. These things (which we will call objects) are characterized individually in terms of their attributes and behavior.

Software Design

Basic Concepts

Object Oriented Design is not dependent on any specific implementation language. Problems are modeled using objects. Objects have:

- Behavior (they do things)
- State (which changes when they do things)

Software Design

The various terms related to object design are:

i. Objects

The word "Object" is used very frequently and conveys different meaning in different circumstances. Here, meaning is an entity able to save a state (information) and which offers a number of operations (behavior) to either examine or affect this state. An object is characterized by number of operations and a state which remembers the effect of these operations.

Software Design

ii. Messages

Objects communicate by message passing. Messages consist of the identity of the target object, the name of the requested operation and any other operation needed to perform the function. Message are often implemented as procedure or function calls.

iii. Abstraction

In object oriented design, complexity is managed using abstraction. Abstraction is the elimination of the irrelevant and the amplification of the essentials.

iv. Class

In any system, there shall be number of objects. Some of the objects may have common characteristics and we can group the objects according to these characteristics. This type of grouping is known as a class. Hence, a class is a set of objects that share a common structure and a common behavior.

We may define a class “car” and each object that represent a car becomes an instance of this class. In this class “car”, Indica, Santro, Maruti, Indigo are instances of this class as shown in fig. 20.

Classes are useful because they act as a blueprint for objects. If we want a new square we may use the square class and simply fill in the particular details (i.e. colour and position) fig. 21 shows how can we represent the square class.

Software Design

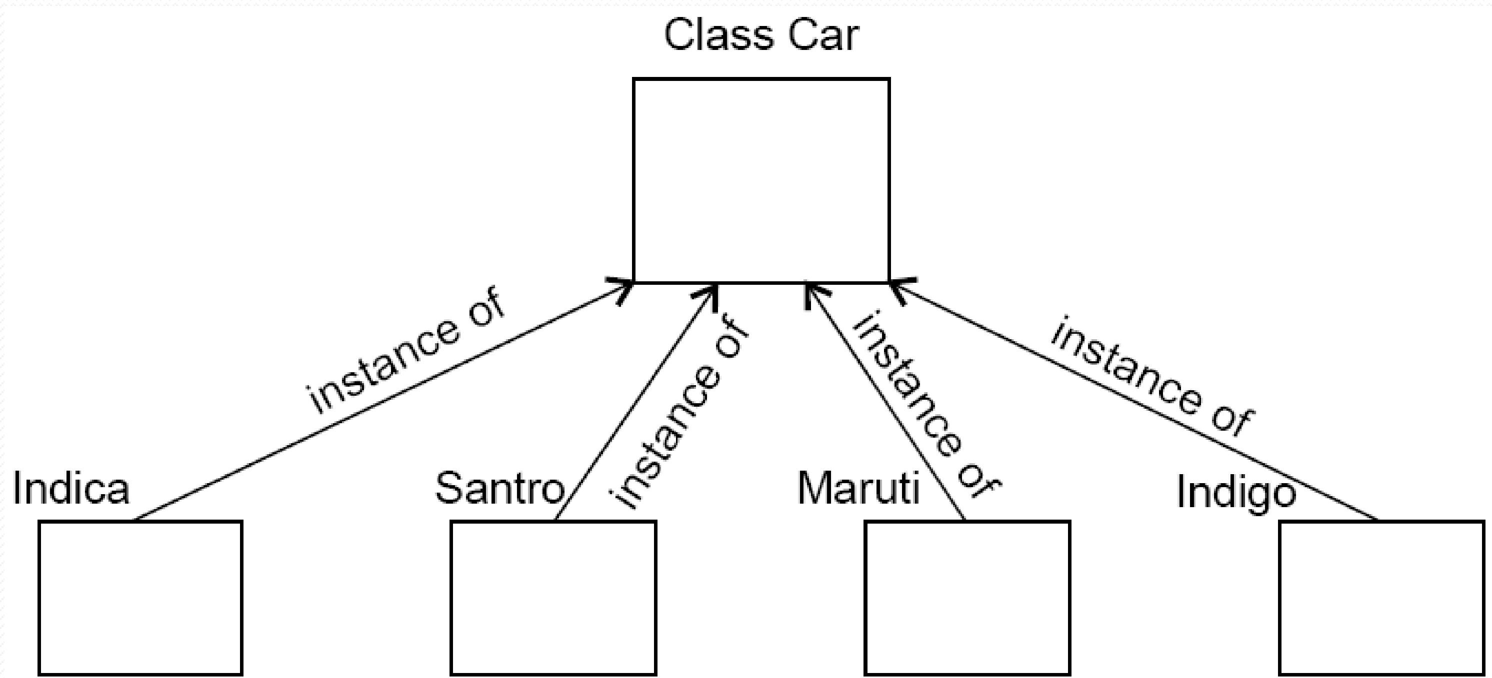


Fig.20: Indica, Santro, Maruti, Indigo are all instances of the class "car"

Software Design

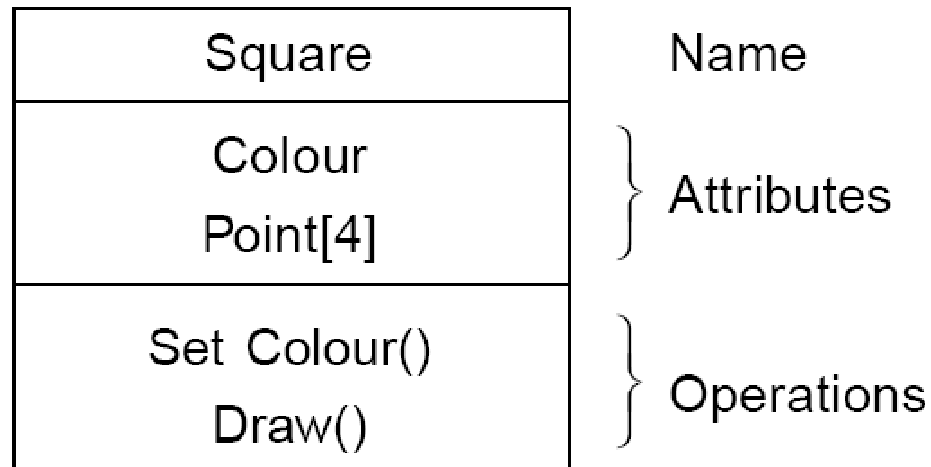


Fig. 21: The square class

v. Attributes

An attributes is a data value held by the objects in a class. The square class has two attributes: a colour and array of points. Each attributes has a value for each object instance. The attributes are shown as second part of the class as shown in fig. 21.

vi. Operations

An operation is a function or transformation that may be applied to or by objects in a class. In the square class, we have two operations: set colour() and draw(). All objects in a class share the same operations. An object “knows” its class, and hence the right implementation of the operation. Operation are shown in the third part of the class as indicated in fig. 21.

vii. Inheritance

Imagine that, as well as squares, we have triangle class. Fig. 22 shows the class for a triangle.

Class Triangle

Triangle
Colour Point[3]
Set Colour() Draw()

Fig. 22: The triangle class

Now, comparing fig. 21 and 22, we can see that there is some difference between triangle and squares classes.

For example, at a high level of abstraction, we might want to think of a picture as made up of shapes and to draw the picture, we draw each shape in turn. We want to eliminate the irrelevant details: we do not care that one shape is a square and the other is a triangle as long as both can draw themselves.

To do this, we consider the important parts out of these classes in to a new class called Shape. Fig. 23 shows the results.

Software Design

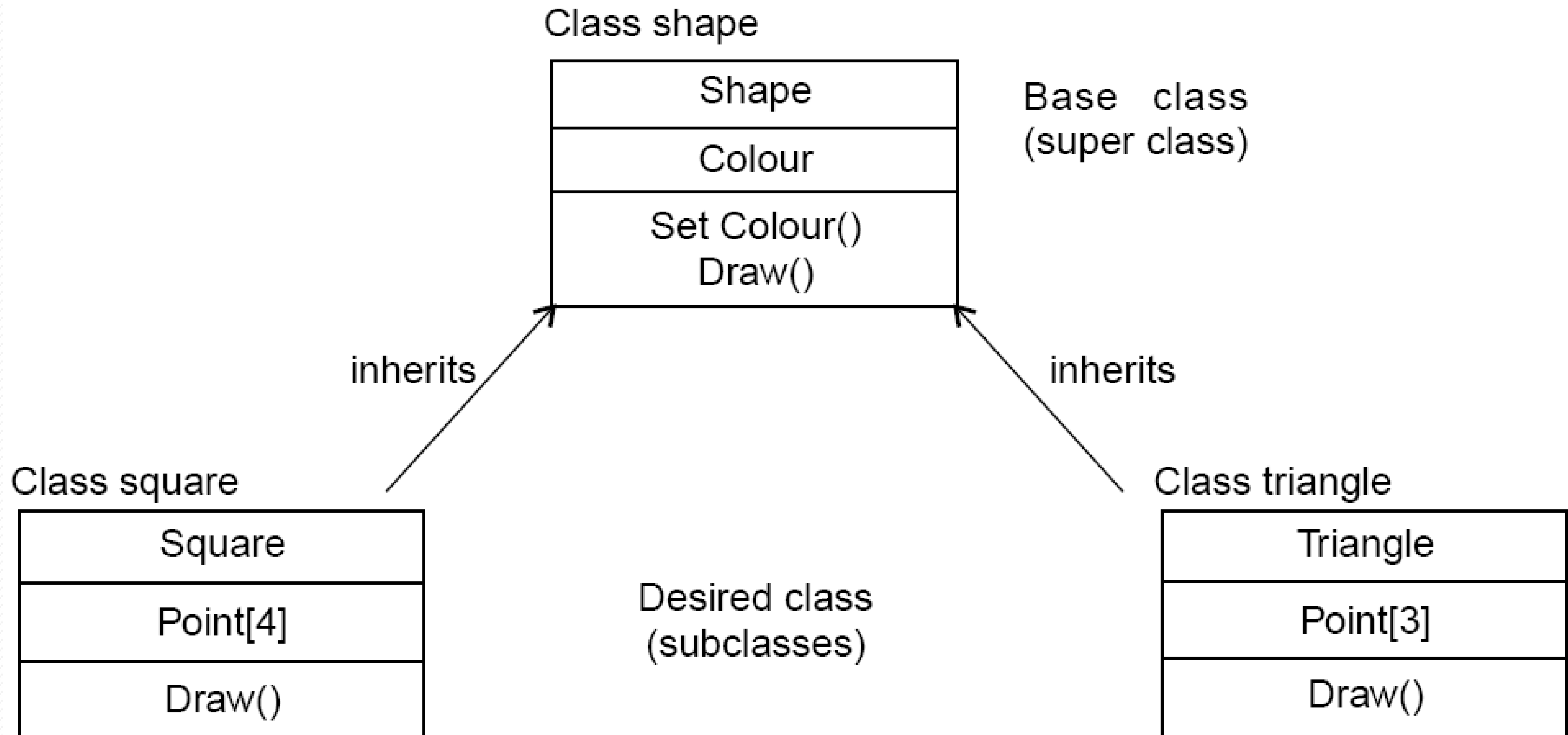


Fig. 23: Abstracting common features in a new class

This sort of abstraction is called inheritance. The low level classes (known as subclasses or derived classes) inherit state and behavior from this high level class (known as a super class or base class).

Software Design

viii. Polymorphism

When we abstract just the interface of an operation and leave the implementation to subclasses it is called a polymorphic operation and process is called polymorphism.

ix. Encapsulation (Information Hiding)

Encapsulation is also commonly referred to as “Information Hiding”. It consists of the separation of the external aspects of an object from the internal implementation details of the object.

x. Hierarchy

Hierarchy involves organizing something according to some particular order or rank. It is another mechanism for reducing the complexity of software by being able to treat and express sub-types in a generic way.

Lecture – 18

Software Design

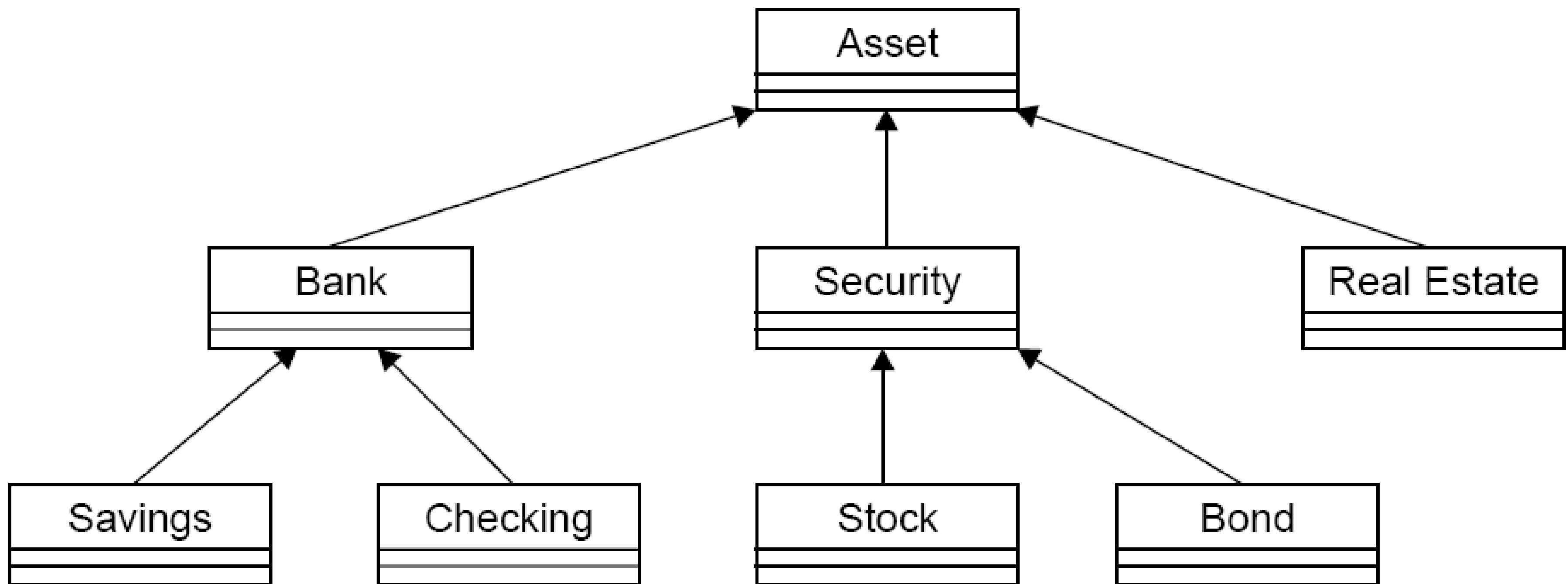


Fig. 24: Hierarchy

Steps to Analyze and Design Object Oriented System

There are various steps in the analysis and design of an object oriented system and are given in fig. 25

Software Design

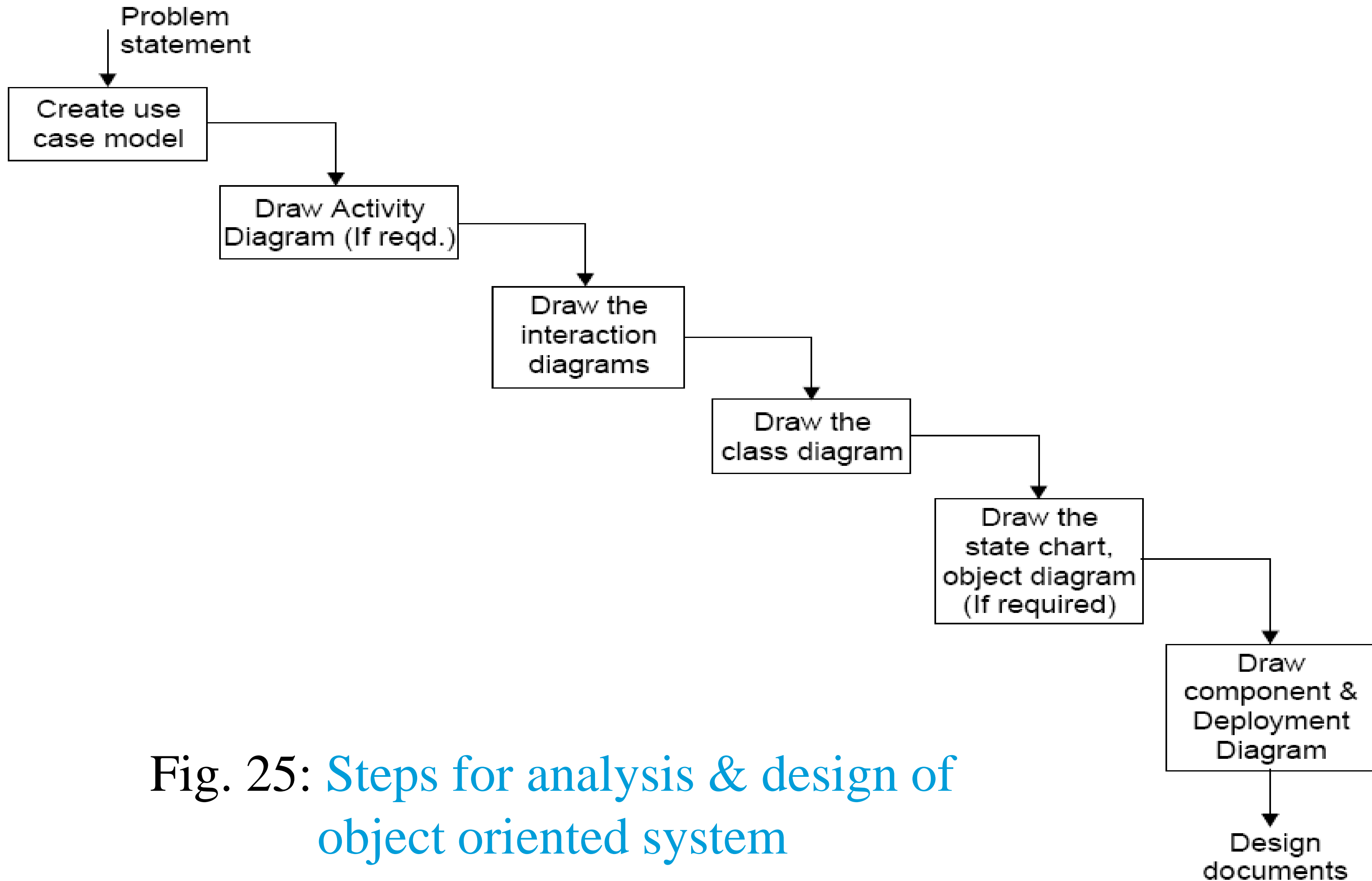


Fig. 25: Steps for analysis & design of object oriented system

Software Design

i. Create use case model

First step is to identify the actors interacting with the system. We should then write the use case and draw the use case diagram.

ii. Draw activity diagram (If required)

Activity Diagram illustrate the dynamic nature of a system by modeling the flow of control form activity to activity. An activity represents an operation on some class in the system that results in a change in the state of the system. Fig. 26 shows the activity diagram processing an order to deliver some goods.

iii. Draw the interaction diagram

An interaction diagram shows an interaction, consisting of a set of objects and their relationship, including the messages that may be dispatched among them. Interaction diagrams address the dynamic view of a system.

Steps to draws interaction diagrams are as under:

a) Firstly, we should identify that the objects with respects to every use case.

b) We draw the sequence diagrams for every use case.

d) We draw the collaboration diagrams for every use case.

The object types used in this analysis model are entity objects, interface objects and control objects as given in fig. 27.

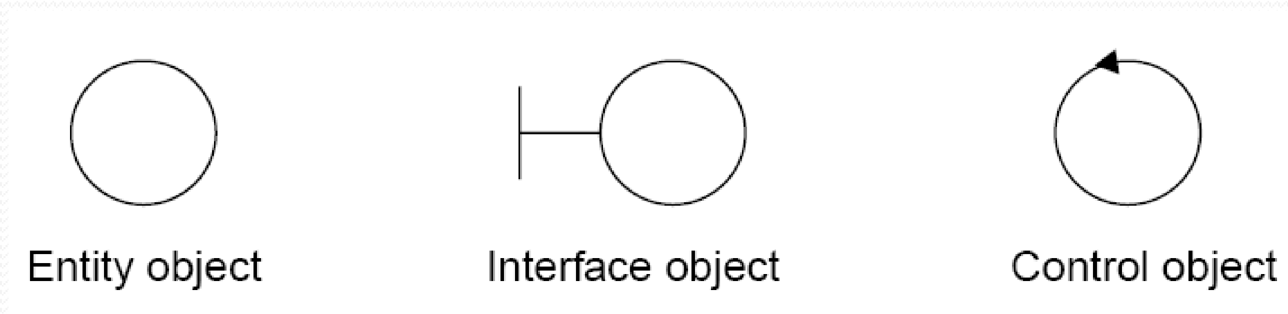


Fig. 27: Object types

iv. Draw the class diagram

The class diagram shows the relationship amongst classes. There are four types of relationships in class diagrams.

a) **Association** are semantic connection between classes. When an association connects two classes, each class can send messages to the other in a sequence or a collaboration diagram. Associations can be bi-directional or unidirectional.

b) **Dependencies** connect two classes. Dependencies are always unidirectional and show that one class, depends on the definitions in another class.

c) **Aggregations** are stronger form of association. An aggregation is a relationship between a whole and its parts.

d) **Generalizations** are used to show an inheritance relationship between two classes.

v. Design of state chart diagrams

A state chart diagram is used to show the state space of a given class, the event that cause a transition from one state to another, and the action that result from a state change. A state transition diagram for a "book" in the library system is given in fig. 28.

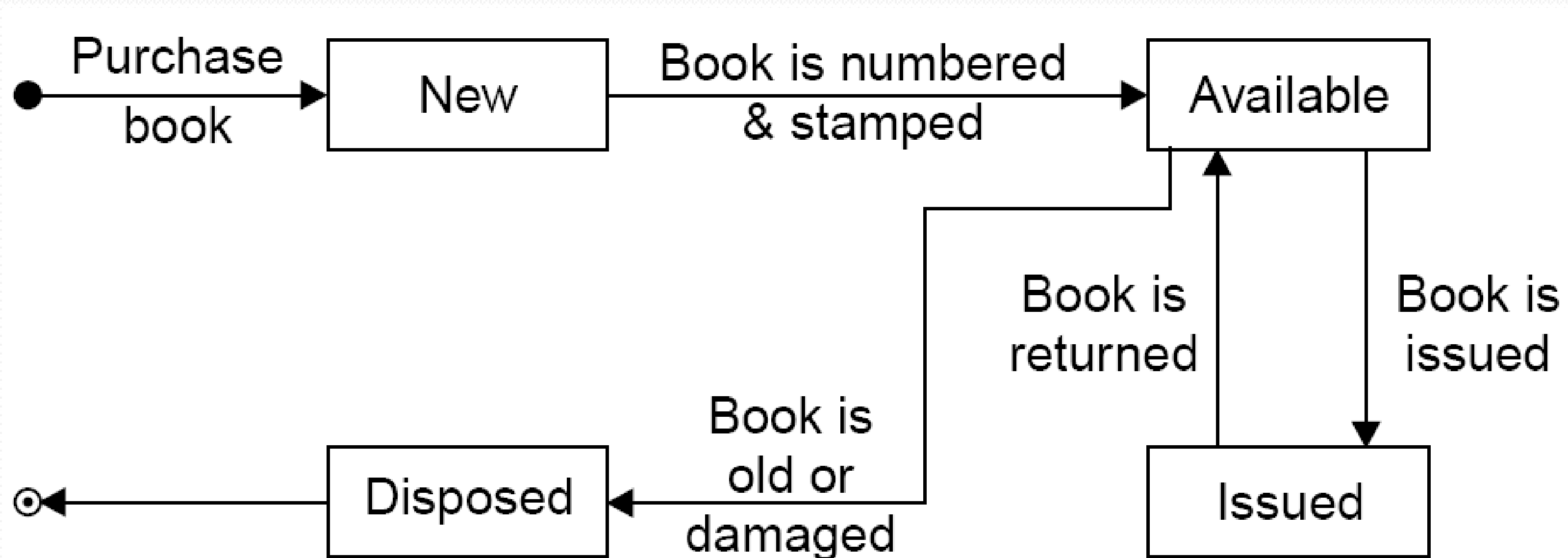


Fig. 28: Transition chart for "book" in a library system.

vi. Draw component and development diagram

Component diagrams address the static implementation view of a system they are related to class diagrams in that a component typically maps to one or more classes, interfaces or collaboration.

Deployment Diagram Captures relationship between physical components and the hardware.

Software Design

A software has to be developed for automating the manual library of a University. The system should be stand alone in nature. It should be designed to provide functionality's as explained below:

Issue of Books:

- A student of any course should be able to get books issued.
- Books from General Section are issued to all but Book bank books are issued only for their respective courses.
- A limitation is imposed on the number of books a student can issue.
- A maximum of 4 books from Book bank and 3 books from General section is issued for 15 days only.The software takes the current system date as the date of issue and calculates date of return.

Software Design

- A bar code detector is used to save the student as well as book information.
- The due date for return of the book is stamped on the book.

Return of Books:

- Any person can return the issued books.
- The student information is displayed using the bar code detector.
- The system displays the student details on whose name the books were issued as well as the date of issue and return of the book.
- The system operator verifies the duration for the issue.
- The information is saved and the corresponding updating take place in the database.

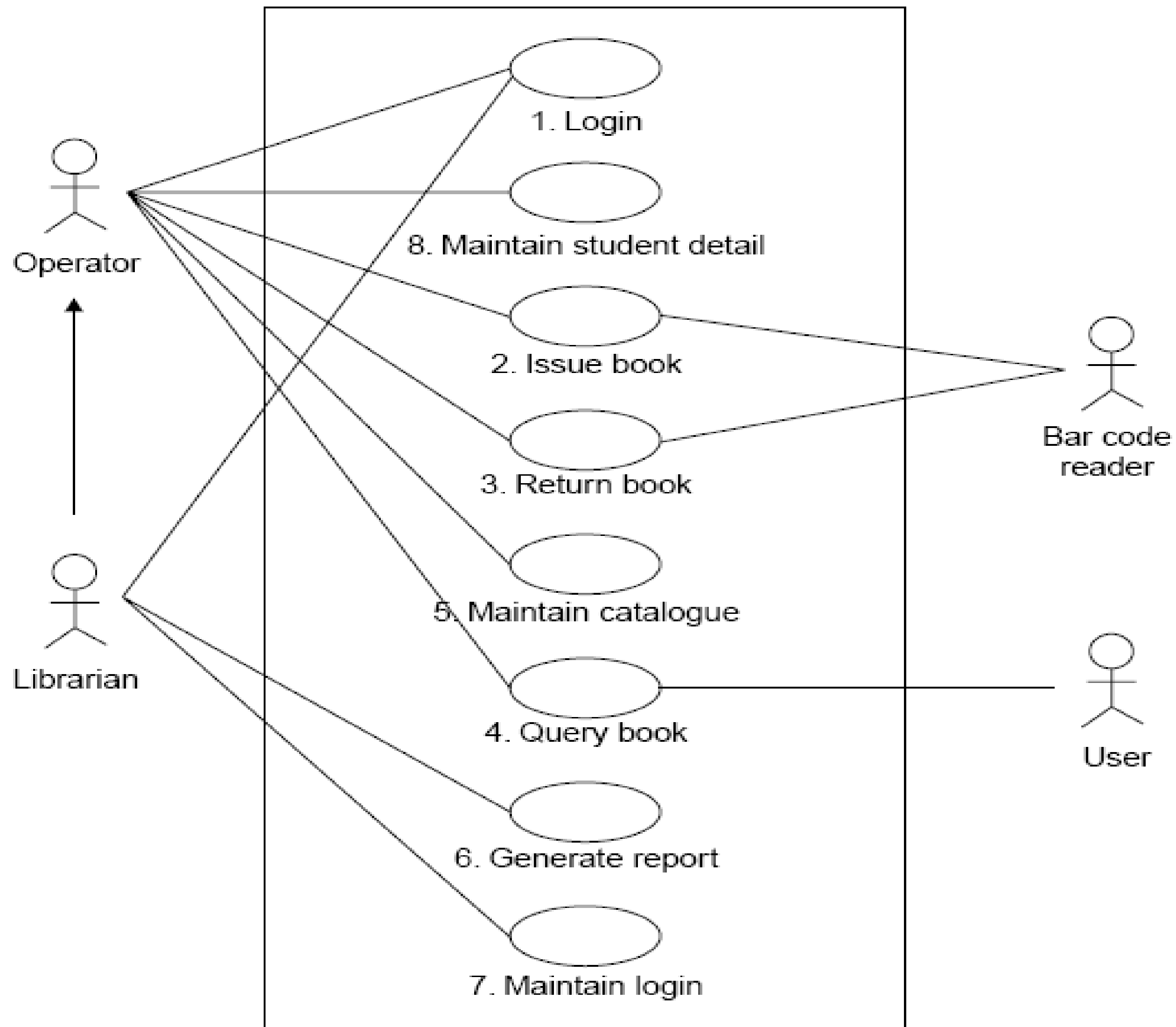
Software Design

Query Processing:

- The system should be able to provide information like:
- Availability of a particular book.
- Availability of book of any particular author.
- Number of copies available of the desired book.

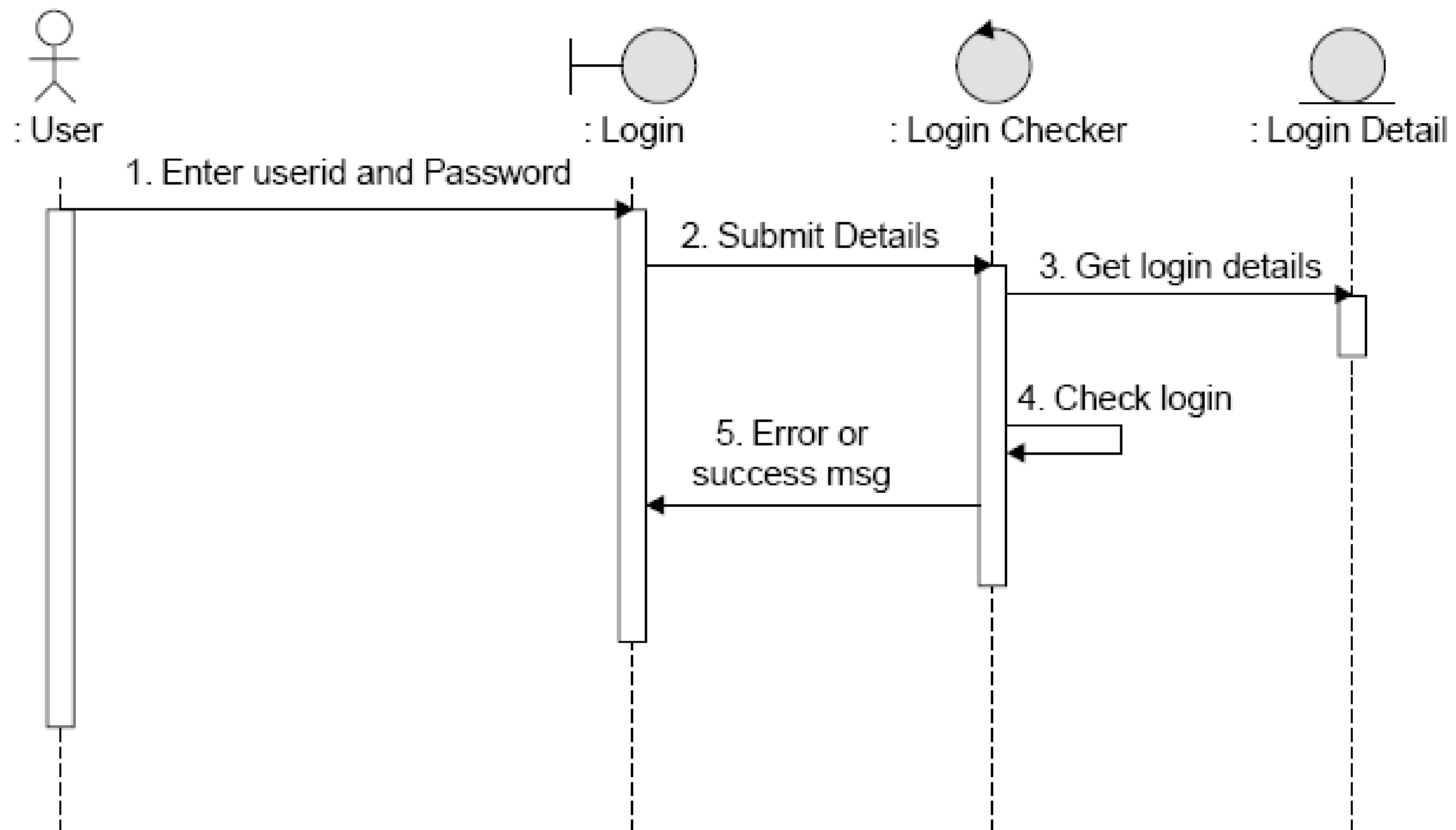
The system should also be able to generate reports regarding the details of the books available in the library at any given time. The corresponding printouts for each entry (issue/return) made in the system should be generated. Security provisions like the ‘login authenticity should be provided. Each user should have a user id and a password. Record of the users of the system should be kept in the log file. Provision should be made for full backup of the system.

Software Design



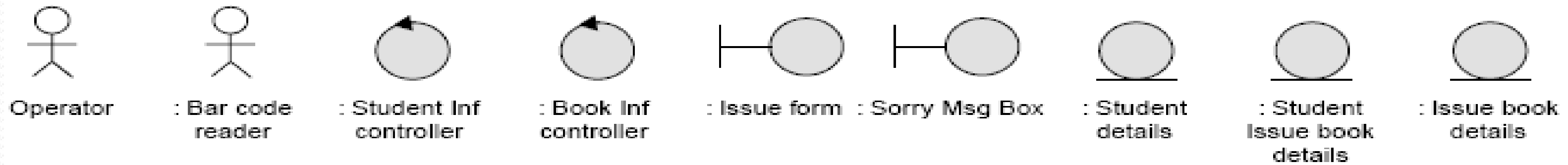
Use case diagram for library management system

Software Design

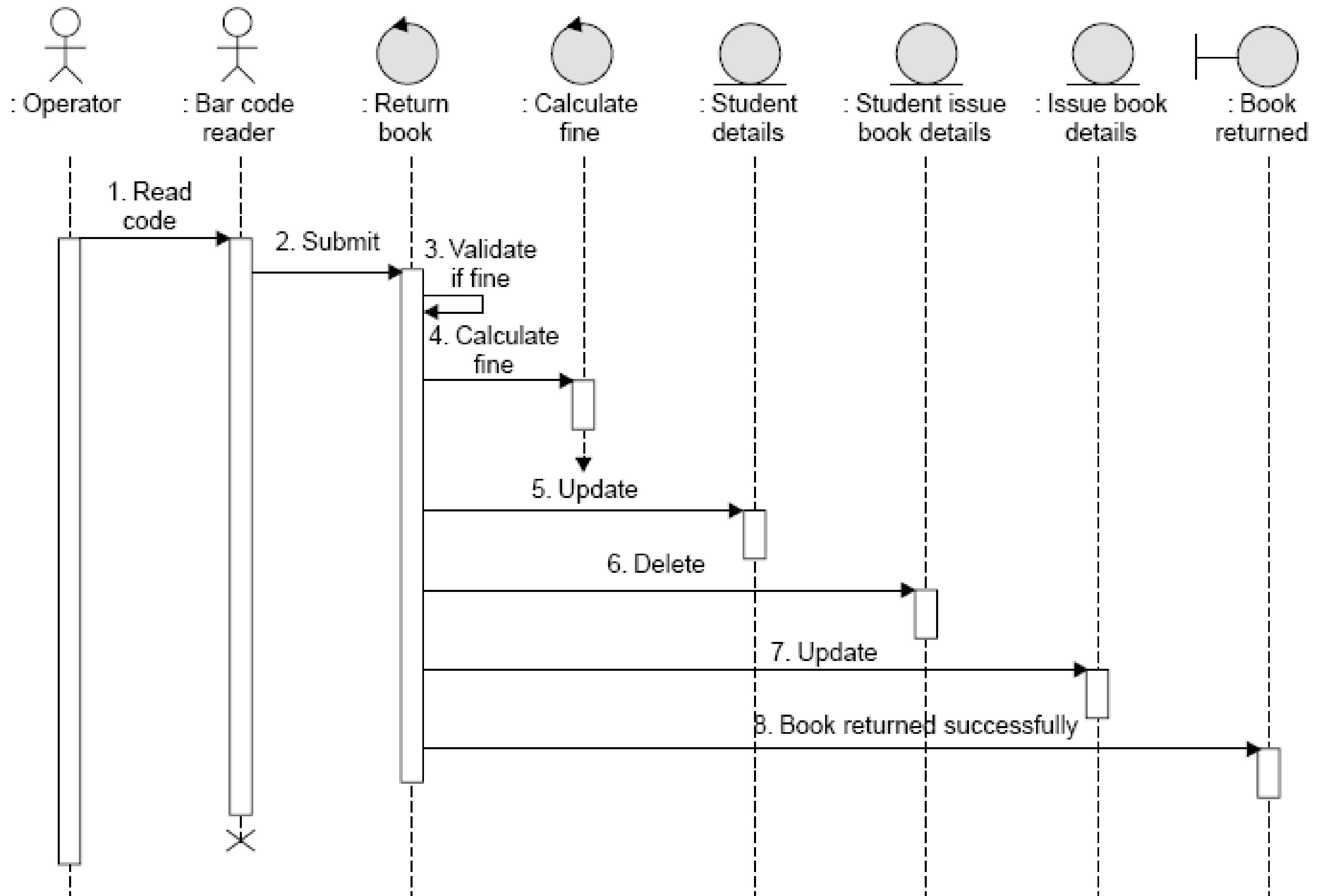


Sequence diagram—Login

Software Design

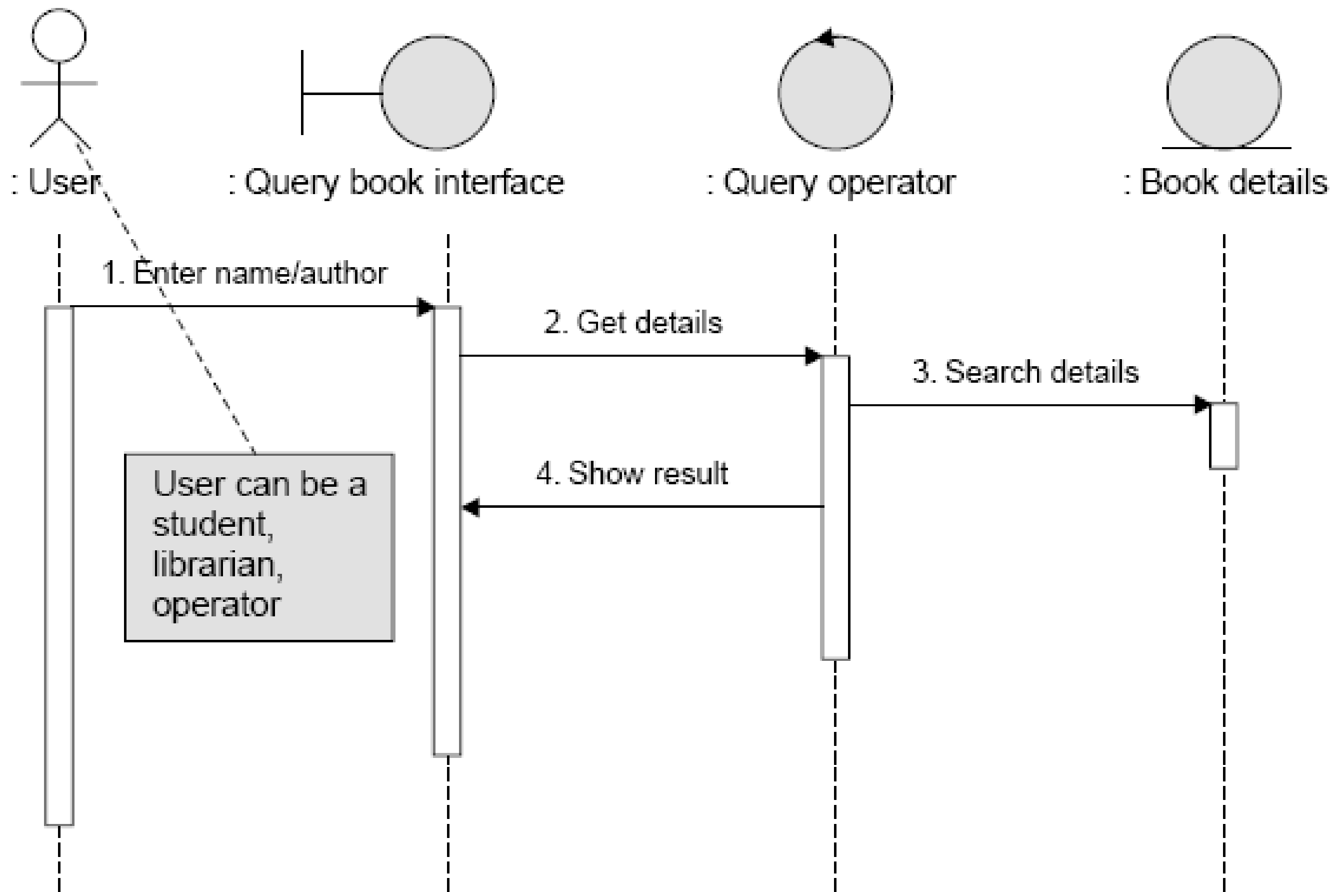


Sequence diagram—issue book

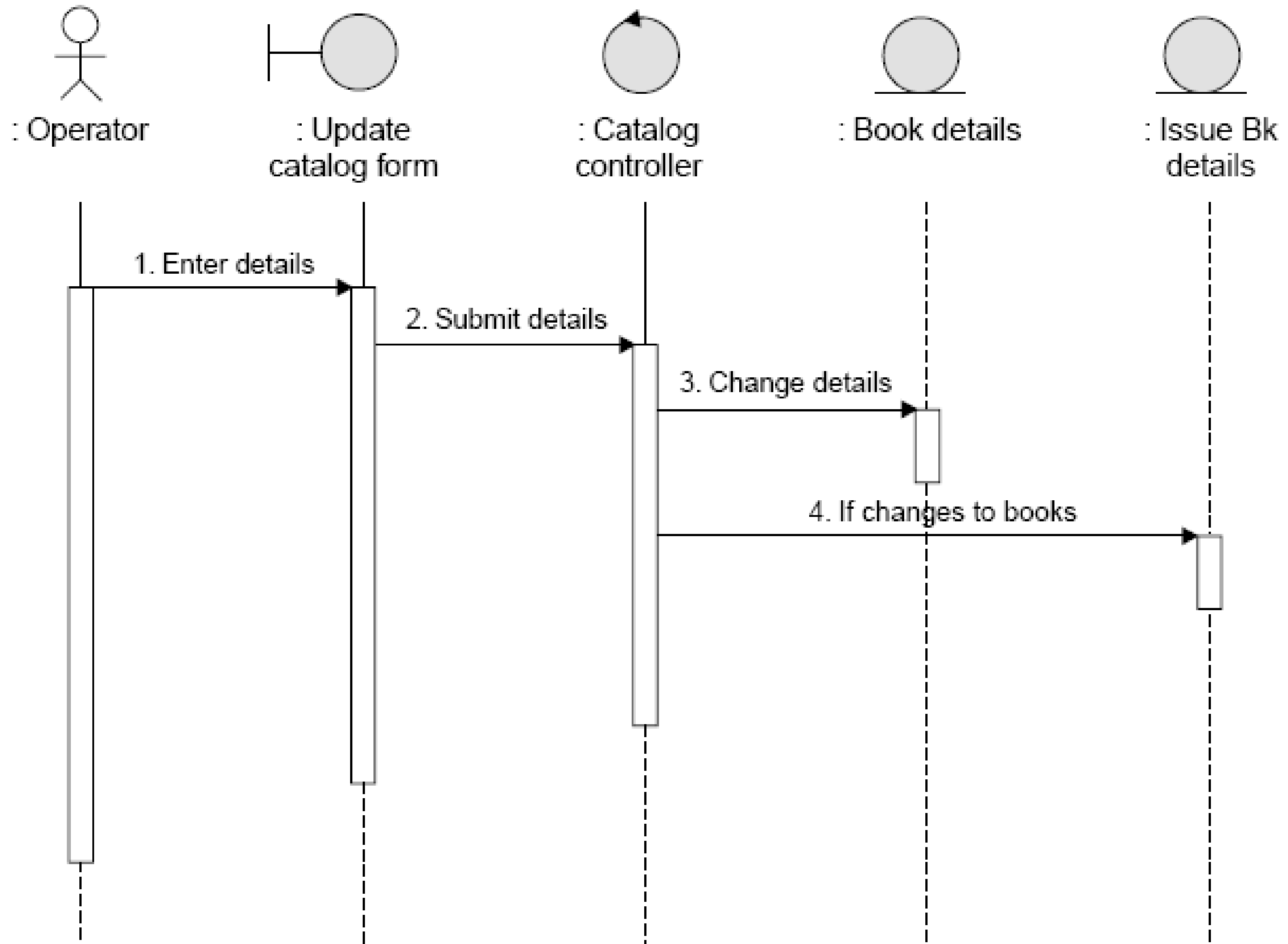


Sequence diagram—return book

Software Design

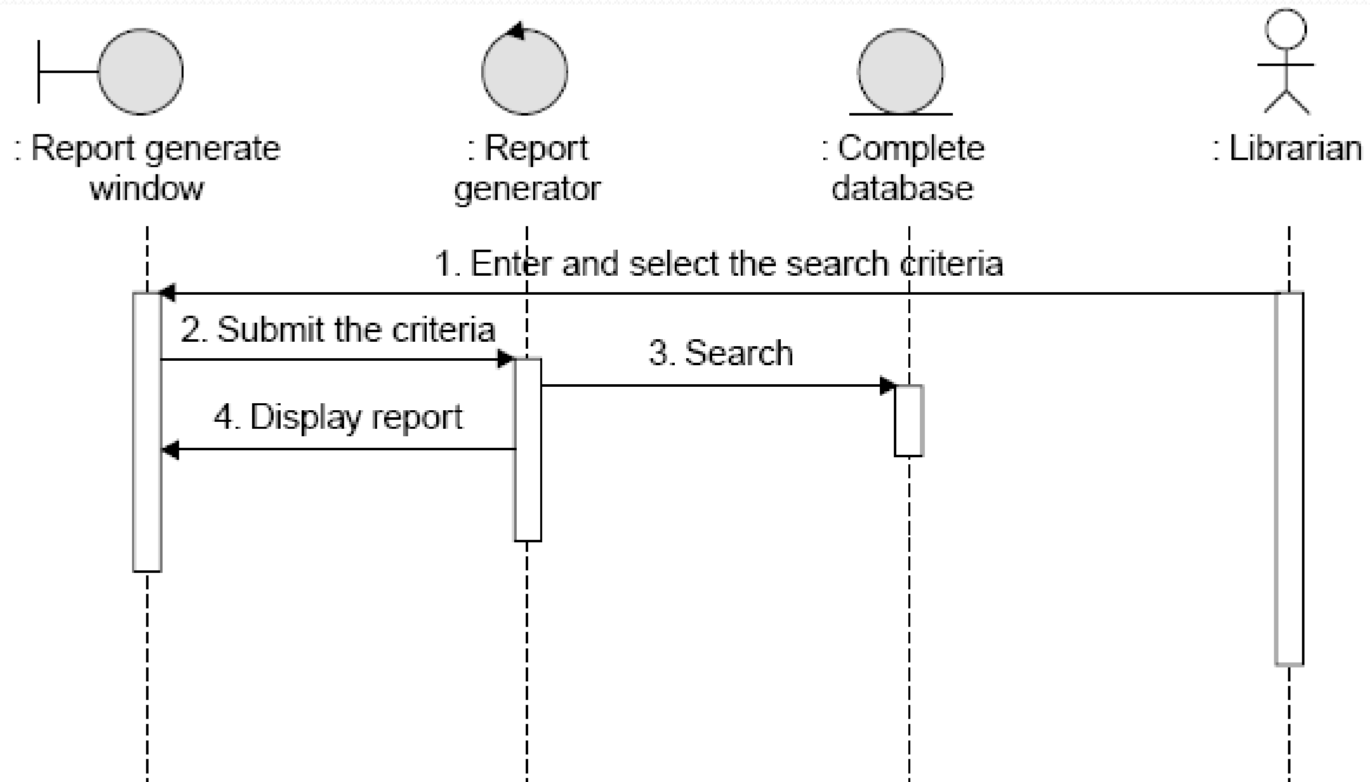


Sequence diagram—query book



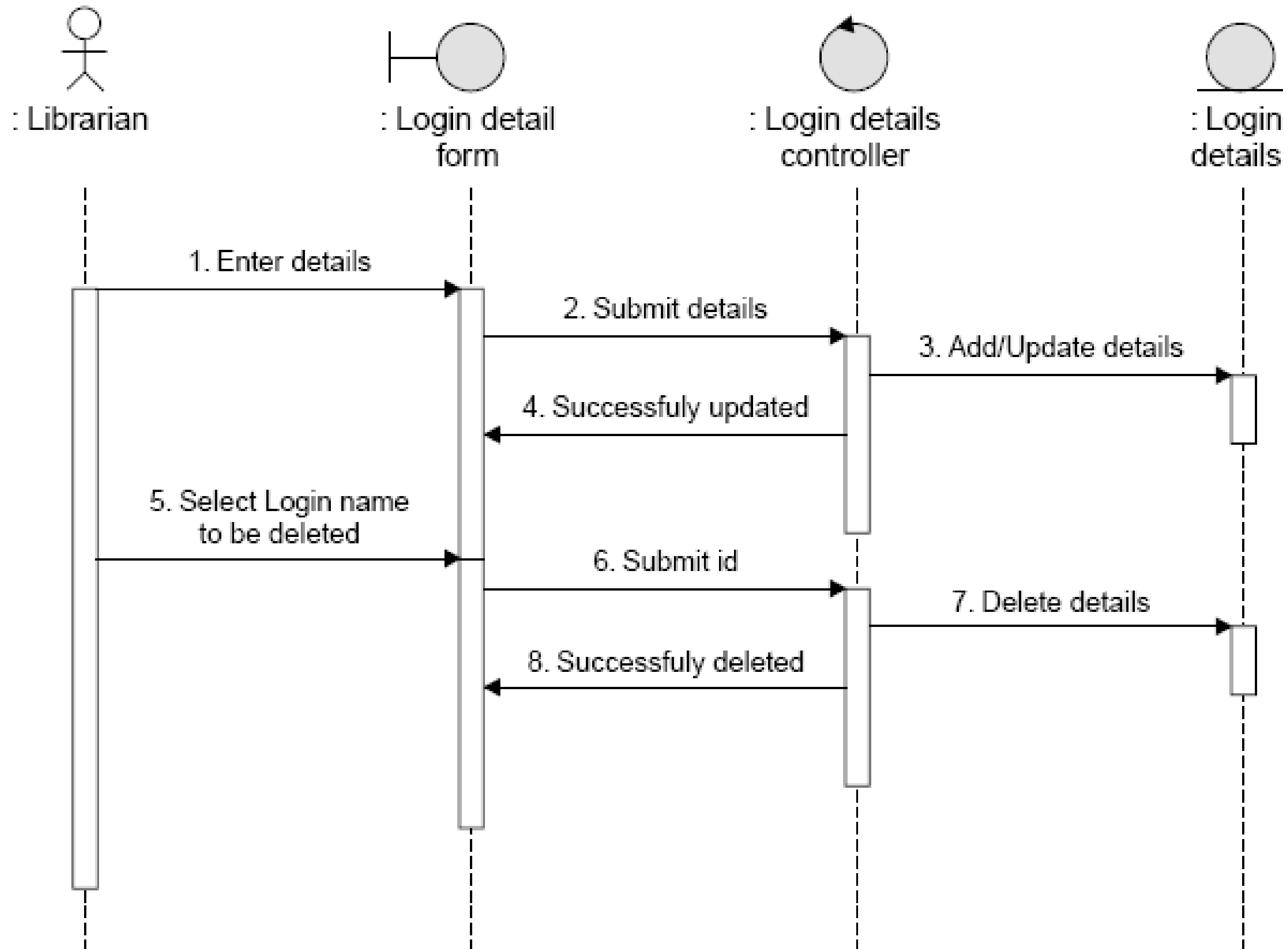
Sequence diagram—maintain catalog

Software Design



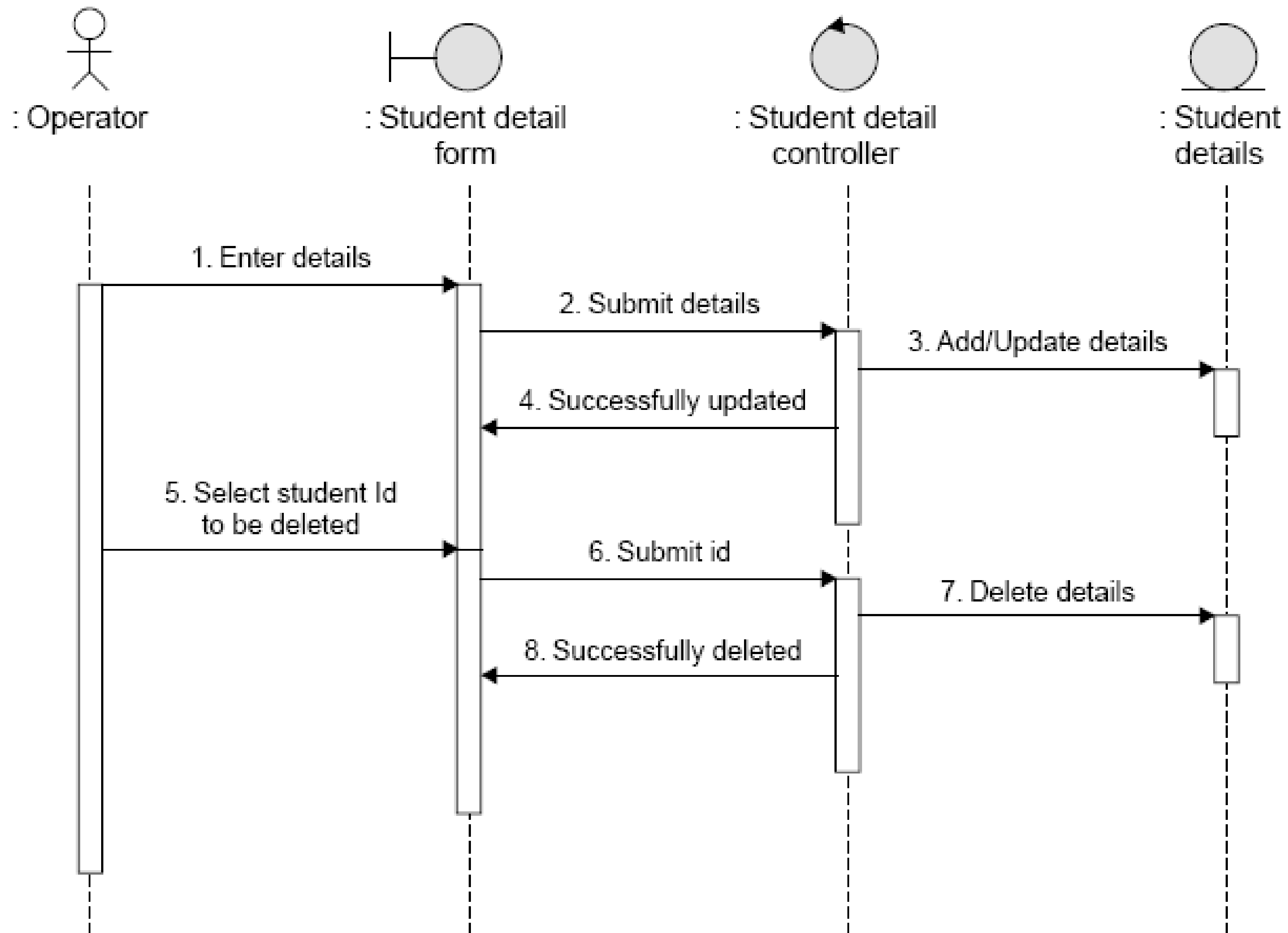
Sequence diagram—generate reports

Software Design



Sequence diagram—maintain login

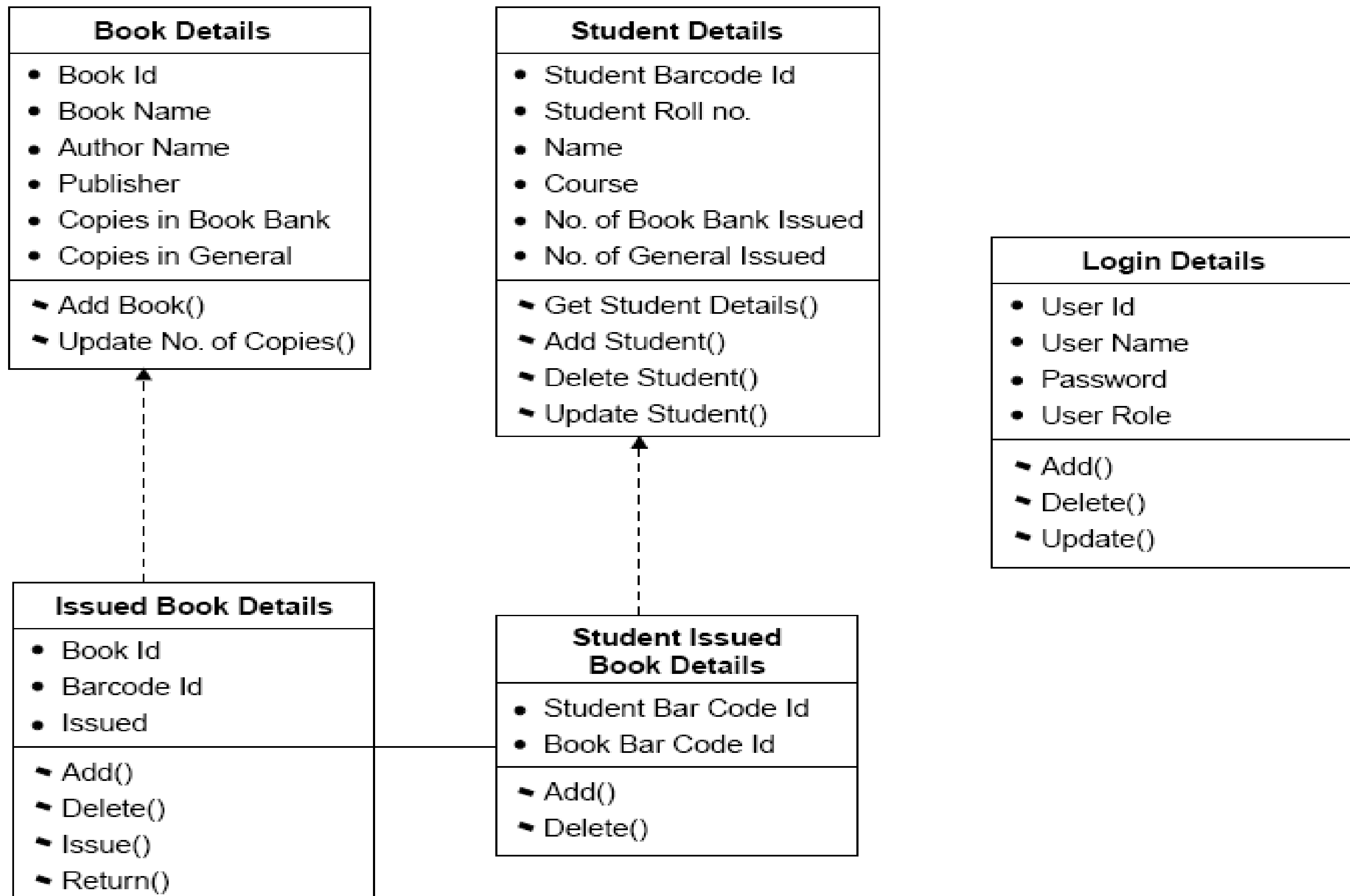
Software Design



Sequence diagram—maintain student details

Software Design

Class diagram of entity classes



Class diagram of entity classes

Architectural Design

Lecture – 19

Objectives

- To introduce architectural design and to discuss its importance
- To explain the architectural design decisions that have to be made
- To introduce three complementary architectural styles covering organisation, decomposition and control
- To discuss reference architectures are used to communicate and compare architectures

Topics covered

- Architectural design decisions
- System organisation
- Decomposition styles
- Control styles
- Reference architectures

Software architecture

- The design process for identifying the sub-systems making up a system and the framework for sub-system control and communication is architectural design.
- The output of this design process is a description of the software architecture.

Architectural design

- An early stage of the system design process.
- Represents the link between specification and design processes.
- Often carried out in parallel with some specification activities.
- It involves identifying major system components and their communications.

Advantages of explicit architecture

- Stakeholder communication
  - Architecture may be used as a focus of discussion by system stakeholders.
- System analysis
  - Means that analysis of whether the system can meet its non-functional requirements is possible.
- Large-scale reuse
  - The architecture may be reusable across a range of systems.

Architecture and system characteristics

- Performance
  - Localise critical operations and minimise communications. Use large rather than fine-grain components.
- Security
  - Use a layered architecture with critical assets in the inner layers.
- Safety
  - Localise safety-critical features in a small number of sub-systems.
- Availability
  - Include redundant components and mechanisms for fault tolerance.
- Maintainability
  - Use fine-grain, replaceable components.

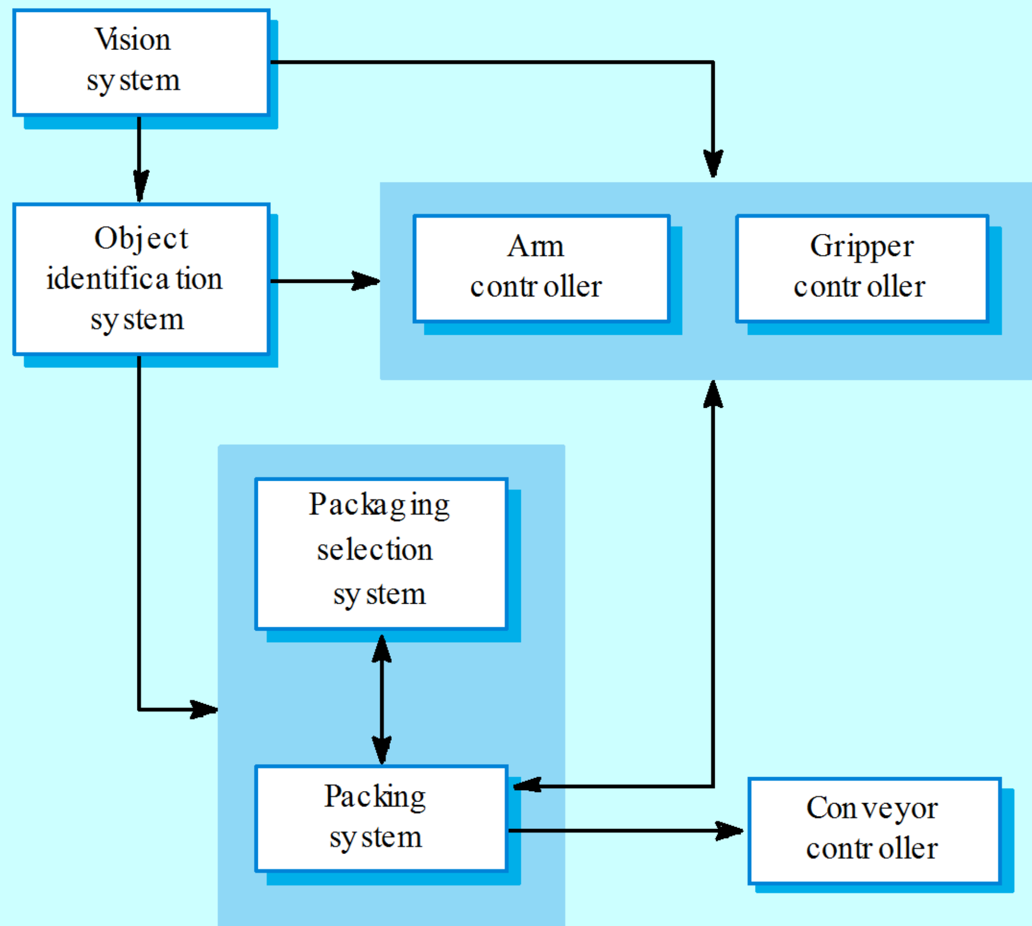
Architectural conflicts

- Using large-grain components improves performance but reduces maintainability.
- Introducing redundant data improves availability but makes security more difficult.
- Localising safety-related features usually means more communication so degraded performance.

System structuring

- Concerned with decomposing the system into interacting sub-systems.
- The architectural design is normally expressed as a block diagram presenting an overview of the system structure.
- More specific models showing how sub-systems share data, are distributed and interface with each other may also be developed.

Packing robot control system



Box and line diagrams

- Very abstract - they do not show the nature of component relationships nor the externally visible properties of the sub-systems.
- However, useful for communication with stakeholders and for project planning.

Architectural design decisions

- Architectural design is a creative process so the process differs depending on the type of system being developed.
- However, a number of common decisions span all design processes.

Architectural design decisions

- Is there a generic application architecture that can be used?
- How will the system be distributed?
- What architectural styles are appropriate?
- What approach will be used to structure the system?
- How will the system be decomposed into modules?
- What control strategy should be used?
- How will the architectural design be evaluated?
- How should the architecture be documented?

Architecture reuse

- Systems in the same domain often have similar architectures that reflect domain concepts.
- Application product lines are built around a core architecture with variants that satisfy particular customer requirements.
- Application architectures are covered in Chapter 13 and product lines in Chapter 18.

Architectural styles

- The architectural model of a system may conform to a generic architectural model or style.
- An awareness of these styles can simplify the problem of defining system architectures.
- However, most large systems are heterogeneous and do not follow a single architectural style.

Architectural models

- Used to document an architectural design.
- Static structural model that shows the major system components.
- Dynamic process model that shows the process structure of the system.
- Interface model that defines sub-system interfaces.
- Relationships model such as a data-flow model that shows sub-system relationships.
- Distribution model that shows how sub-systems are distributed across computers.

System organisation

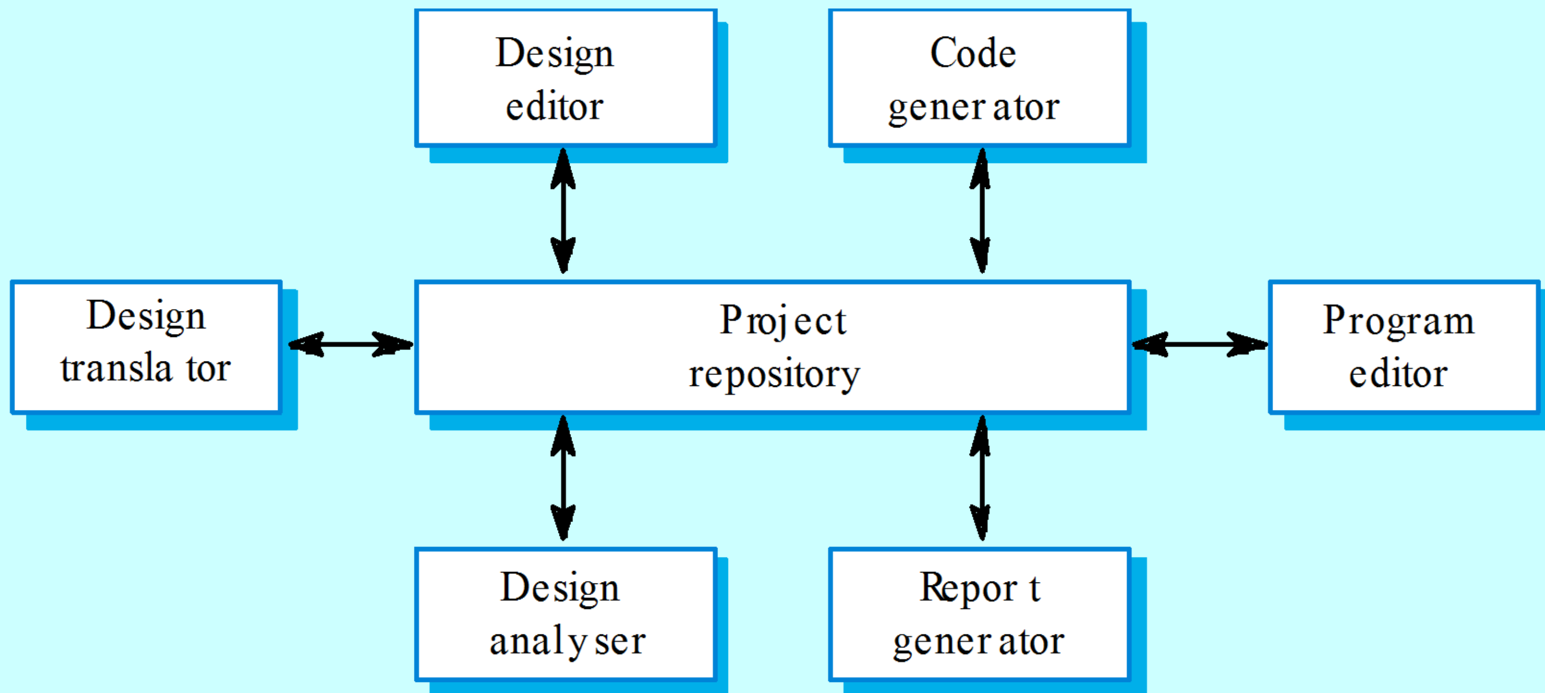
- Reflects the basic strategy that is used to structure a system.
- Three organisational styles are widely used:
  - A shared data repository style;
  - A shared services and servers style;
  - An abstract machine or layered style.

Lecture – 19

The repository model

- Sub-systems must exchange data. This may be done in two ways:
  - Shared data is held in a central database or repository and may be accessed by all sub-systems;
  - Each sub-system maintains its own database and passes data explicitly to other sub-systems.
- When large amounts of data are to be shared, the repository model of sharing is most commonly used.

CASE toolset architecture



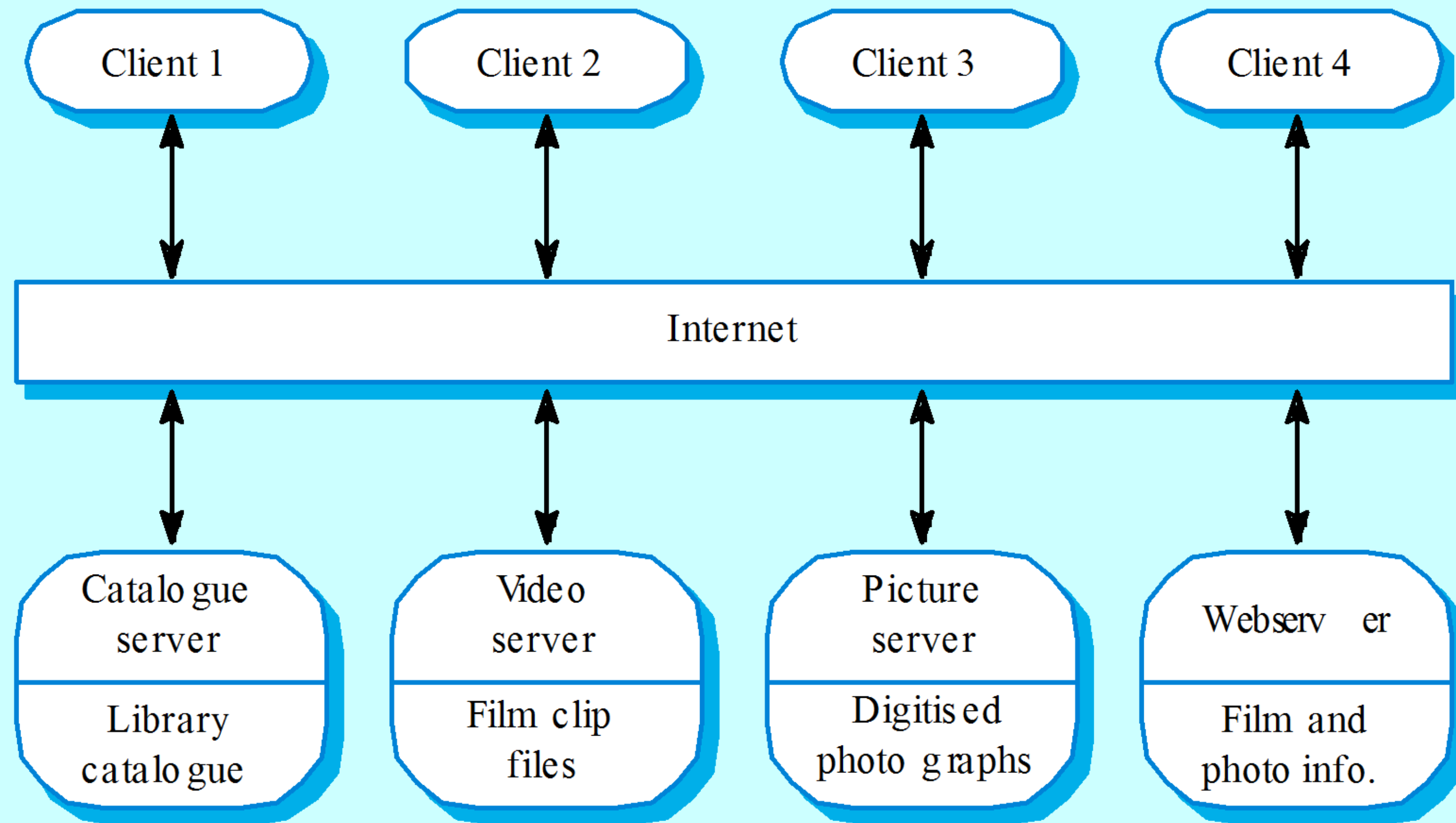
Repository model characteristics

- Advantages
  - Efficient way to share large amounts of data;
  - Sub-systems need not be concerned with how data is produced Centralised management e.g. backup, security, etc.
  - Sharing model is published as the repository schema.
- Disadvantages
  - Sub-systems must agree on a repository data model. Inevitably a compromise;
  - Data evolution is difficult and expensive;
  - No scope for specific management policies;
  - Difficult to distribute efficiently.

Client-server model

- Distributed system model which shows how data and processing is distributed across a range of components.
- Set of stand-alone servers which provide specific services such as printing, data management, etc.
- Set of clients which call on these services.
- Network which allows clients to access servers.

Film and picture library



Client-server characteristics

- Advantages
  - Distribution of data is straightforward;
  - Makes effective use of networked systems. May require cheaper hardware;
  - Easy to add new servers or upgrade existing servers.
- Disadvantages
  - No shared data model so sub-systems use different data organisation. Data interchange may be inefficient;
  - Redundant management in each server;
  - No central register of names and services - it may be hard to find out what servers and services are available.

Abstract machine (layered) model

- Used to model the interfacing of sub-systems.
- Organises the system into a set of layers (or abstract machines) each of which provide a set of services.
- Supports the incremental development of sub-systems in different layers. When a layer interface changes, only the adjacent layer is affected.
- However, often artificial to structure systems in this way.

Version management system

Configuration management system layer

Object management system layer

Database system layer

Operating system layer

Modular decomposition styles

- Styles of decomposing sub-systems into modules.
- No rigid distinction between system organisation and modular decomposition.

Sub-systems and modules

- A sub-system is a system in its own right whose operation is independent of the services provided by other sub-systems.
- A module is a system component that provides services to other components but would not normally be considered as a separate system.

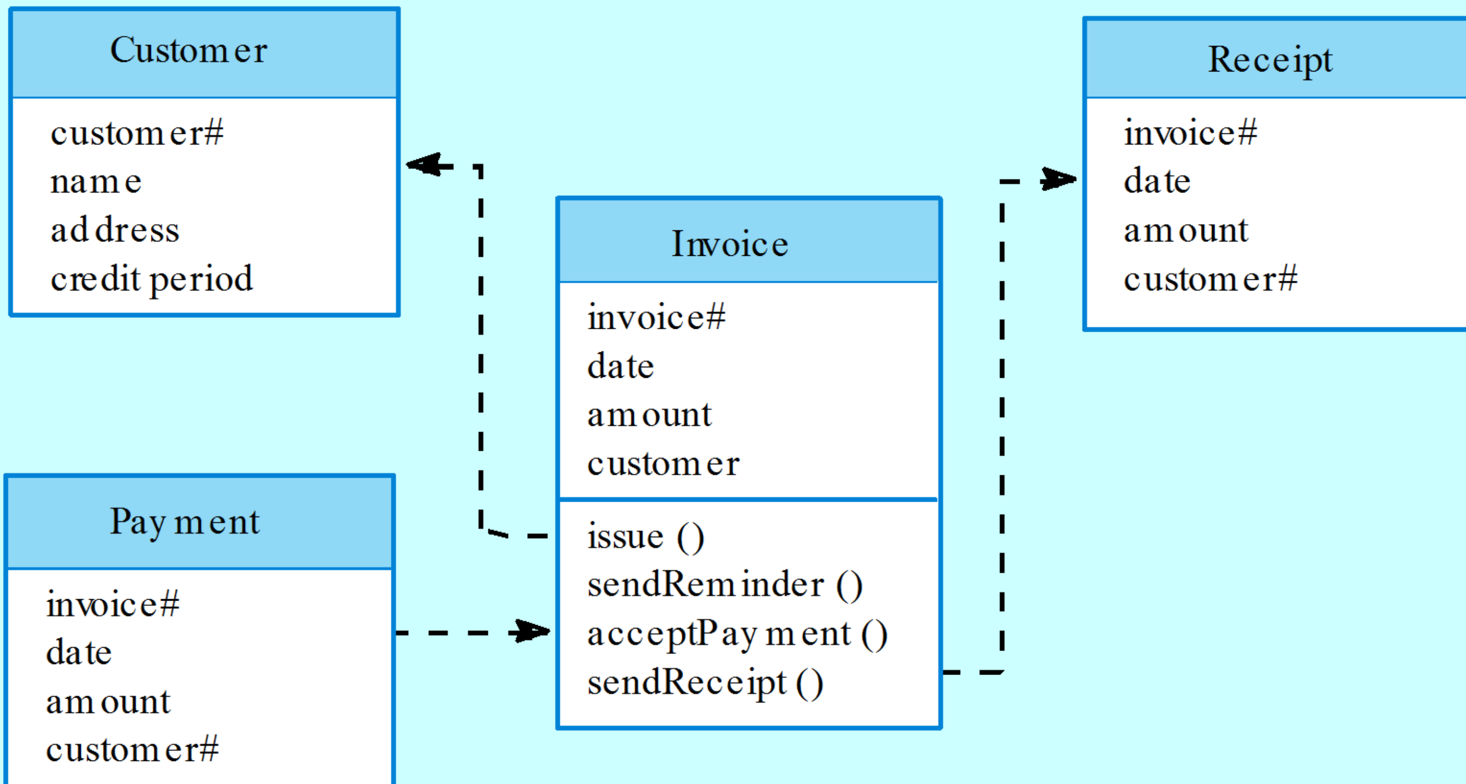
Modular decomposition

- Another structural level where sub-systems are decomposed into modules.
- Two modular decomposition models covered
  - An object model where the system is decomposed into interacting object;
  - A pipeline or data-flow model where the system is decomposed into functional modules which transform inputs to outputs.
- If possible, decisions about concurrency should be delayed until modules are implemented.

Object models

- Structure the system into a set of loosely coupled objects with well-defined interfaces.
- Object-oriented decomposition is concerned with identifying object classes, their attributes and operations.
- When implemented, objects are created from these classes and some control model used to coordinate object operations.

Invoice processing system



Object model advantages

- Objects are loosely coupled so their implementation can be modified without affecting other objects.
- The objects may reflect real-world entities.
- OO implementation languages are widely used.
- However, object interface changes may cause problems and complex entities may be hard to represent as objects.

Architectural models

- Different architectural models may be produced during the design process
- Each model presents different perspectives on the architecture

Architecture attributes

- Performance
  - Localise operations to minimise sub-system communication
- Security
  - Use a layered architecture with critical assets in inner layers
- Safety
  - Isolate safety-critical components
- Availability
  - Include redundant components in the architecture
- Maintainability
  - Use fine-grain, self-contained components

Lecture – 20

Objectives

- To explain how a software design may be represented as a set of interacting objects that manage their own state and operations
- To describe the activities in the object-oriented design process
- To introduce various models that can be used to describe an object-oriented design
- To show how the UML may be used to represent these models

Topics covered

- Objects and object classes
- An object-oriented design process
- Design evolution

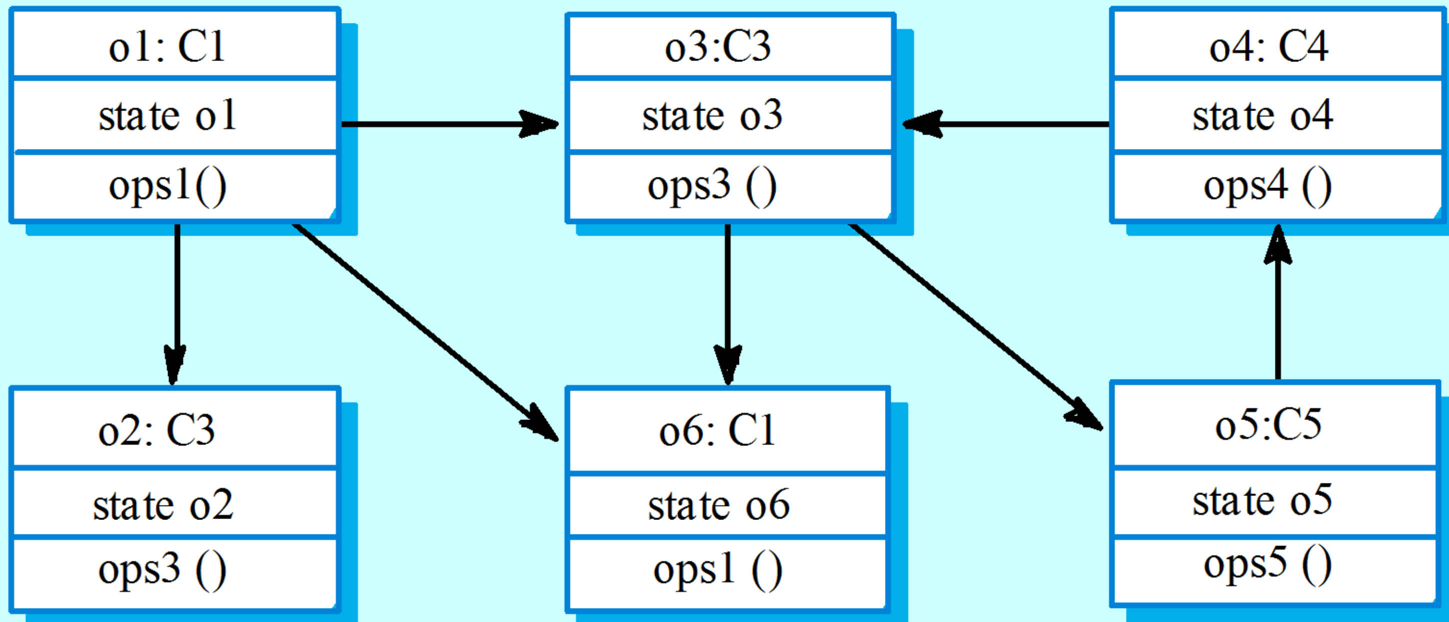
Object-oriented development

- Object-oriented analysis, design and programming are related but distinct.
- OOA is concerned with developing an object model of the application domain.
- OOD is concerned with developing an object-oriented system model to implement requirements.
- OOP is concerned with realising an OOD using an OO programming language such as Java or C++.

Characteristics of OOD

- Objects are abstractions of real-world or system entities and manage themselves.
- Objects are independent and encapsulate state and representation information.
- System functionality is expressed in terms of object services.
- Shared data areas are eliminated. Objects communicate by message passing.
- Objects may be distributed and may execute sequentially or in parallel.

Interacting objects



Advantages of OOD

- Easier maintenance. Objects may be understood as stand-alone entities.
- Objects are potentially reusable components.
- For some systems, there may be an obvious mapping from real world entities to system objects.

Objects and object classes

- Objects are entities in a software system which represent instances of real-world and system entities.
- Object classes are templates for objects. They may be used to create objects.
- Object classes may inherit attributes and services from other object classes.

Objects and object classes

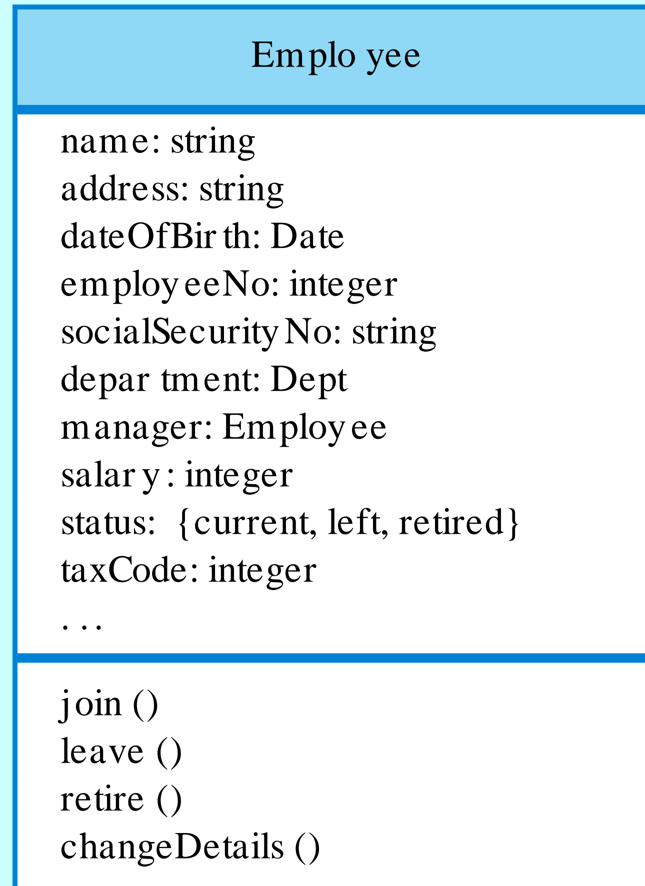
An ***object*** *is an entity that has a state and a defined set of operations which operate on that state. The state is represented as a set of object attributes. The operations associated with the object provide services to other objects (clients) which request these services when some computation is required.*

Objects are created according to some ***object class*** *definition. An object class definition serves as a template for objects. It includes declarations of all the attributes and services which should be associated with an object of that class.*

The Unified Modeling Language

- Several different notations for describing object-oriented designs were proposed in the 1980s and 1990s.
- The Unified Modeling Language is an integration of these notations.
- It describes notations for a number of different models that may be produced during OO analysis and design.
- It is now a *de facto* standard for OO modelling.

Employee object class (UML)



Object communication

- Conceptually, objects communicate by message passing.
- Messages
  - The name of the service requested by the calling object;
  - Copies of the information required to execute the service and the name of a holder for the result of the service.
- In practice, messages are often implemented by procedure calls
  - Name = procedure name;
  - Information = parameter list.

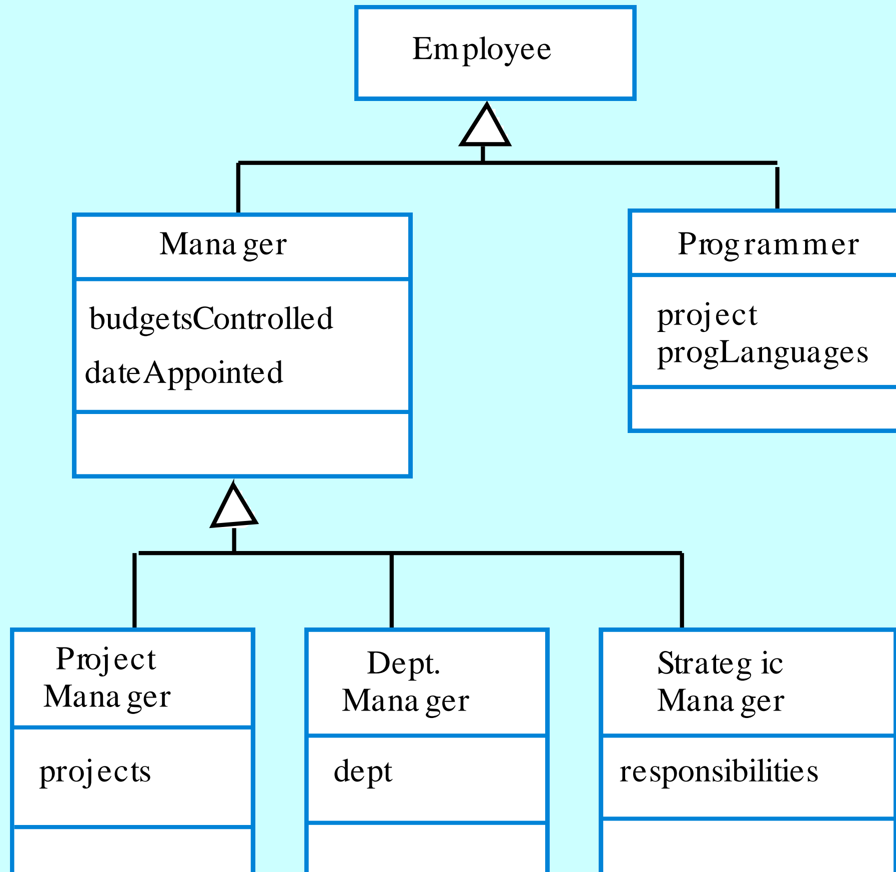
Message examples

```
// Call a method associated with a buffer
// object that returns the next value
// in the buffer

        v = circularBuffer.Get () ;

// Call the method associated with a
// thermostat object that sets the
// temperature to be maintained

        thermostat.setTemp (20) ;
```

Generalisation and inheritance

- Objects are members of classes that define attribute types and operations.
- Classes may be arranged in a class hierarchy where one class (a super-class) is a generalisation of one or more other classes (sub-classes).
- A sub-class inherits the attributes and operations from its super class and may add new methods or attributes of its own.
- Generalisation in the UML is implemented as inheritance in OO programming languages.

A generalisation hierarchy



Advantages of inheritance

- It is an abstraction mechanism which may be used to classify entities.
- It is a reuse mechanism at both the design and the programming level.
- The inheritance graph is a source of organisational knowledge about domains and systems.

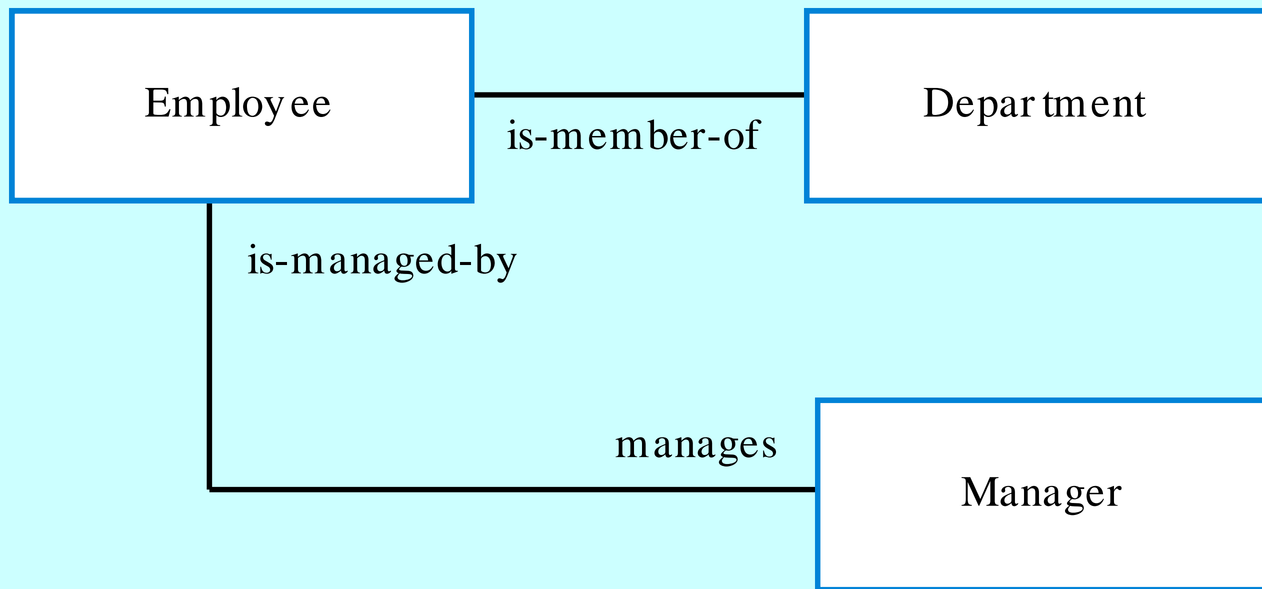
Problems with inheritance

- Object classes are not self-contained. they cannot be understood without reference to their super-classes.
- Designers have a tendency to reuse the inheritance graph created during analysis. Can lead to significant inefficiency.
- The inheritance graphs of analysis, design and implementation have different functions and should be separately maintained.

UML associations

- Objects and object classes participate in relationships with other objects and object classes.
- In the UML, a generalised relationship is indicated by an association.
- Associations may be annotated with information that describes the association.
- Associations are general but may indicate that an attribute of an object is an associated object or that a method relies on an associated object.

An association model



Concurrent objects

- The nature of objects as self-contained entities make them suitable for concurrent implementation.
- The message-passing model of object communication can be implemented directly if objects are running on separate processors in a distributed system.

Servers and active objects

- Servers.
  - The object is implemented as a parallel process (server) with entry points corresponding to object operations. If no calls are made to it, the object suspends itself and waits for further requests for service.
- Active objects
  - Objects are implemented as parallel processes and the internal object state may be changed by the object itself and not simply by external calls.

Active transponder object

- Active objects may have their attributes modified by operations but may also update them autonomously using internal operations.
- A Transponder object broadcasts an aircraft's position. The position may be updated using a satellite positioning system. The object periodically update the position by triangulation from satellites.

An object-oriented design process

- Structured design processes involve developing a number of different system models.
- They require a lot of effort for development and maintenance of these models and, for small systems, this may not be cost-effective.
- However, for large systems developed by different groups design models are an essential communication mechanism.

Process stages

- Highlights key activities without being tied to any proprietary process such as the RUP.
  - Define the context and modes of use of the system;
  - Design the system architecture;
  - Identify the principal system objects;
  - Develop design models;
  - Specify object interfaces.

Weather system description

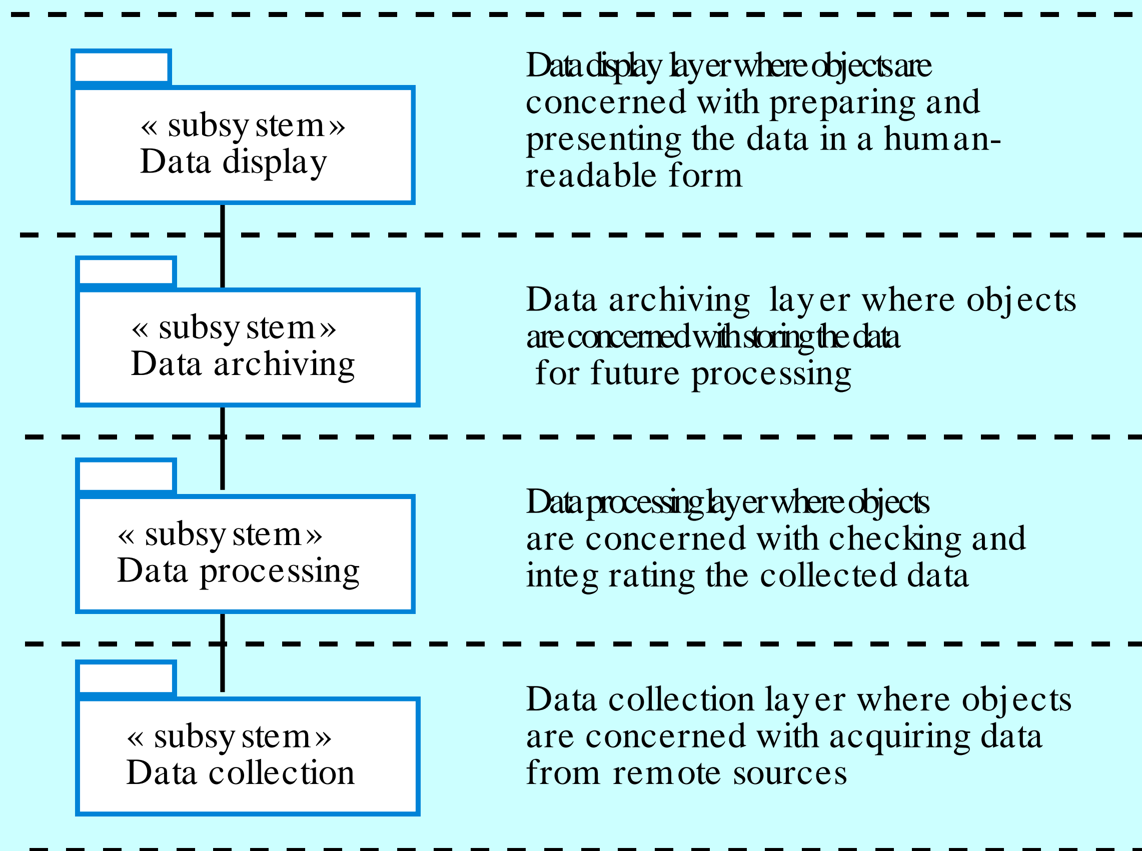
A weather mapping system is required to generate weather maps on a regular basis using data collected from remote, unattended weather stations and other data sources such as weather observers, balloons and satellites. Weather stations transmit their data to the area computer in response to a request from that machine.

The area computer system validates the collected data and integrates it with the data from different sources. The integrated data is archived and, using data from this archive and a digitised map database a set of local weather maps is created. Maps may be printed for distribution on a special-purpose map printer or may be displayed in a number of different formats.

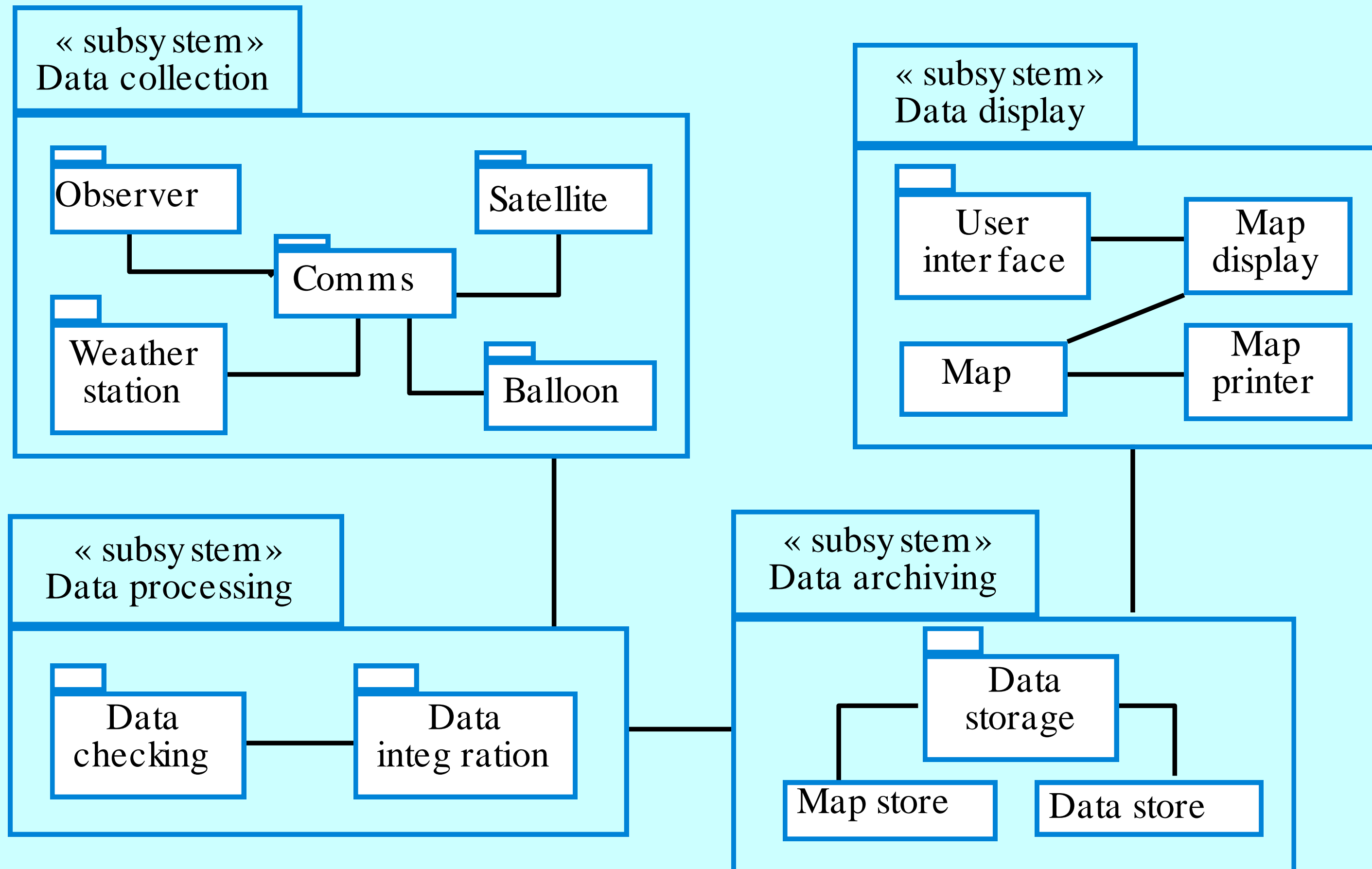
System context and models of use

- Develop an understanding of the relationships between the software being designed and its external environment
- System context
  - A static model that describes other systems in the environment. Use a subsystem model to show other systems. Following slide shows the systems around the weather station system.
- Model of system use
  - A dynamic model that describes how the system interacts with its environment. Use use-cases to show interactions

Layered architecture



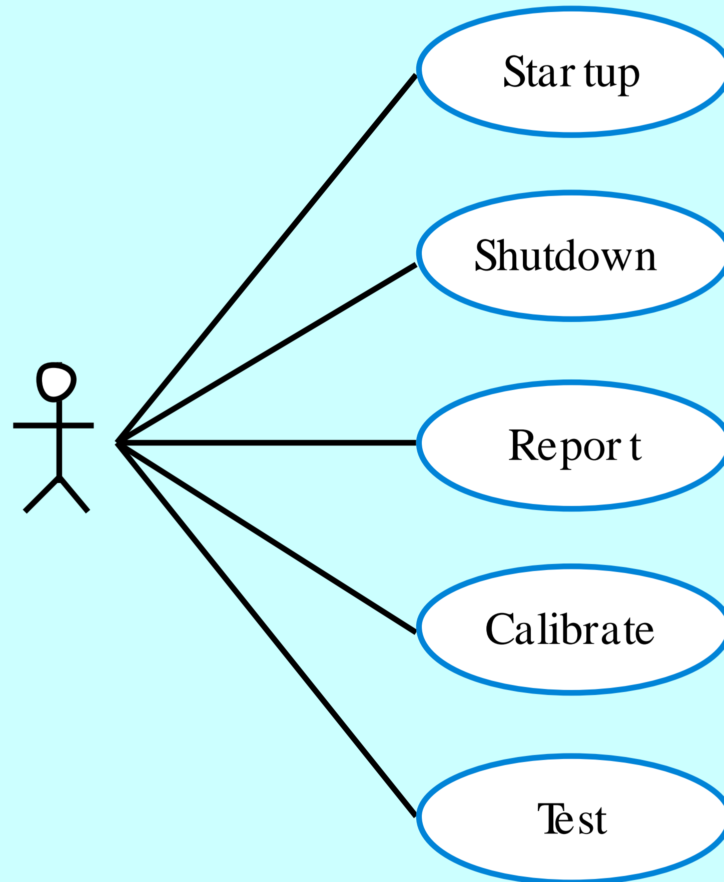
Subsystems in the weather mapping system



Use-case models

- Use-case models are used to represent each interaction with the system.
- A use-case model shows the system features as ellipses and the interacting entity as a stick figure.

Use-cases for the weather station



Use-case description

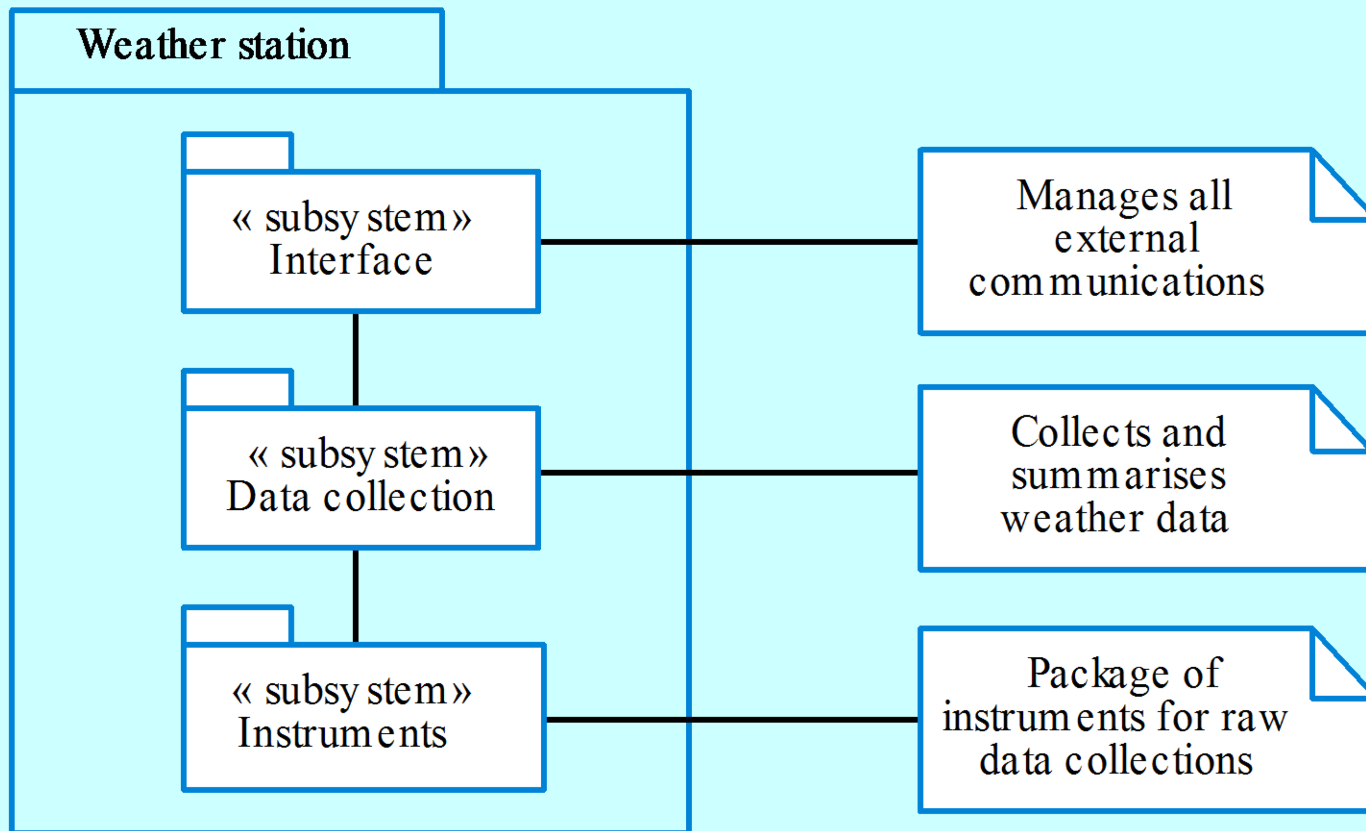
System	Weather station
Use-case	Report
Actors	Weather data collection system, Weather station
Data	The weather station sends a summary of the weather data that has been collected from the instruments in the collection period to the weather data collection system. The data sent are the maximum minimum and average ground and air temperatures, the maximum, minimum and average air pressures, the maximum, minimum and average wind speeds, the total rainfall and the wind direction as sampled at 5 minute intervals.
Stimulus	The weather data collection system establishes a modem link with the weather station and requests transmission of the data.
Response	The summarised data is sent to the weather data collection system
Comments	Weather stations are usually asked to report once per hour but this frequency may differ from one station to the other and may be modified in future.

Architectural design

- Once interactions between the system and its environment have been understood, you use this information for designing the system architecture.
- A layered architecture as discussed in Chapter 11 is appropriate for the weather station
  - Interface layer for handling communications;
  - Data collection layer for managing instruments;
  - Instruments layer for collecting data.
- There should normally be no more than 7 entities in an architectural model.

Lecture – 21

Weather station architecture



Object identification

- Identifying objects (or object classes) is the most difficult part of object oriented design.
- There is no 'magic formula' for object identification. It relies on the skill, experience
and domain knowledge of system designers.
- Object identification is an iterative process. You are unlikely to get it right first time.

Approaches to identification

- Use a grammatical approach based on a natural language description of the system (used in Hood OOD method).
- Base the identification on tangible things in the application domain.
- Use a behavioural approach and identify objects based on what participates in what behaviour.
- Use a scenario-based analysis. The objects, attributes and methods in each scenario are identified.

Weather station description

A weather station is a package of software controlled instruments which collects data, performs some data processing and transmits this data for further processing. The instruments include air and ground thermometers, an anemometer, a wind vane, a barometer and a rain gauge. Data is collected periodically.

When a command is issued to transmit the weather data, the weather station processes and summarises the collected data. The summarised data is transmitted to the mapping computer when a request is received.

Weather station object classes

- Ground thermometer, Anemometer, Barometer
  - Application domain objects that are 'hardware' objects related to the instruments in the system.
- Weather station
  - The basic interface of the weather station to its environment. It therefore reflects the interactions identified in the use-case model.
- Weather data
  - Encapsulates the summarised data from the instruments.

Weather station object classes

WeatherStation
- identifier
- reportWeather ()
- calibrate (instruments)
- test ()
- startup (instruments)
- shutdown (instruments)

WeatherData
- airTemperatures
- groundTemperatures
- windSpeeds
- windDirections
- pressures
- rainfall
- collect ()
- summarise ()

Ground thermometer
- temperature
- test ()
- calibrate ()

Anemometer
- windSpeed
- windDirection
- test ()

Barometer
- pressure
- height
- test ()
- calibrate ()

Further objects and object refinement

- Use domain knowledge to identify more objects and operations
  - Weather stations should have a unique identifier;
  - Weather stations are remotely situated so instrument failures have to be reported automatically. Therefore attributes and operations for self-checking are required.
- Active or passive objects
  - In this case, objects are passive and collect data on request rather than autonomously. This introduces flexibility at the expense of controller processing time.

Design models

- Design models show the objects and object classes and relationships between these entities.
- Static models describe the static structure of the system in terms of object classes and relationships.
- Dynamic models describe the dynamic interactions between objects.

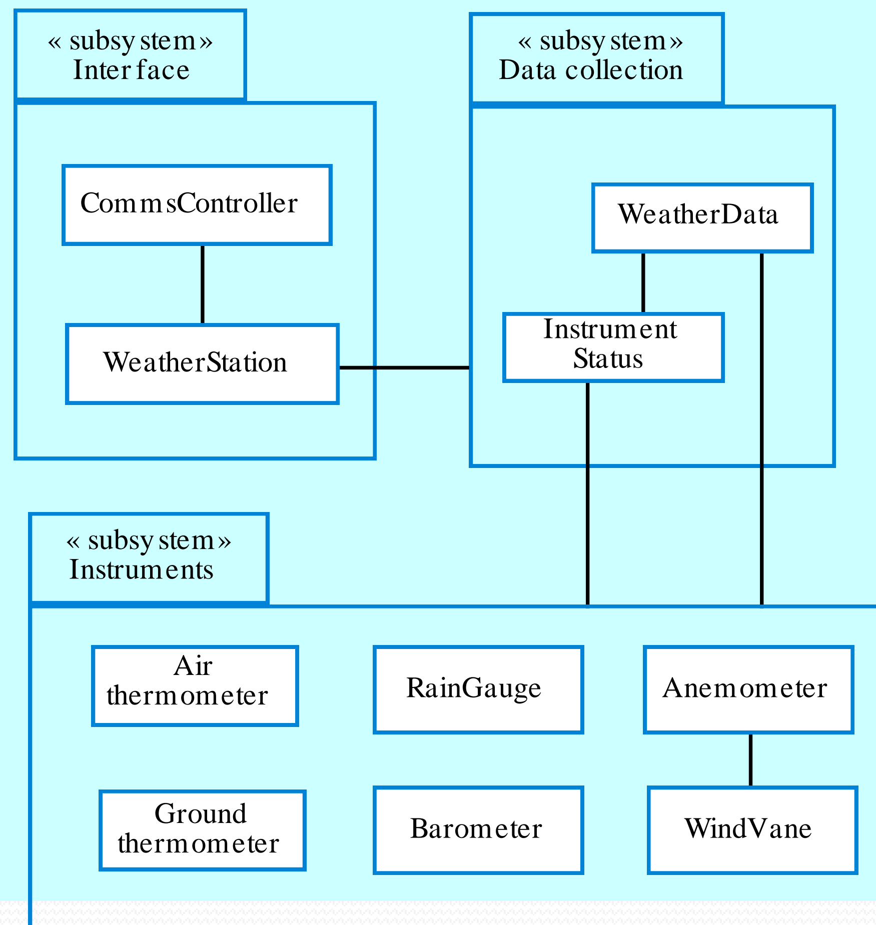
Examples of design models

- Sub-system models that show logical groupings of objects into coherent subsystems.
- Sequence models that show the sequence of object interactions.
- State machine models that show how individual objects change their state in response to events.
- Other models include use-case models, aggregation models, generalisation models, etc.

Subsystem models

- Shows how the design is organised into logically related groups of objects.
- In the UML, these are shown using packages - an encapsulation construct. This is a logical model. The actual organisation of objects in the system may be different.

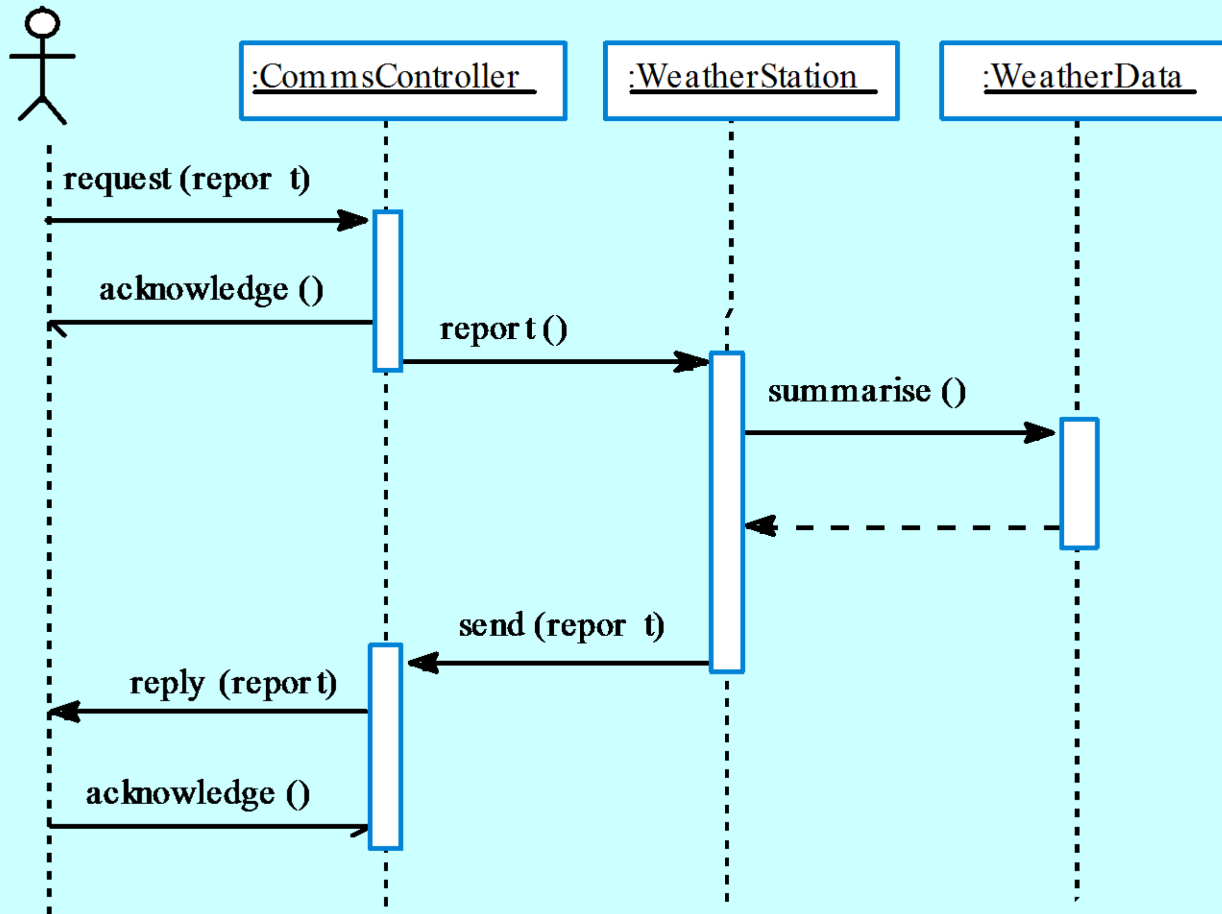
Weather station subsystems



Sequence models

- Sequence models show the sequence of object interactions that take place
  - Objects are arranged horizontally across the top;
  - Time is represented vertically so models are read top to bottom;
  - Interactions are represented by labelled arrows, Different styles of arrow represent different types of interaction;
  - A thin rectangle in an object lifeline represents the time when the object is the controlling object in the system.

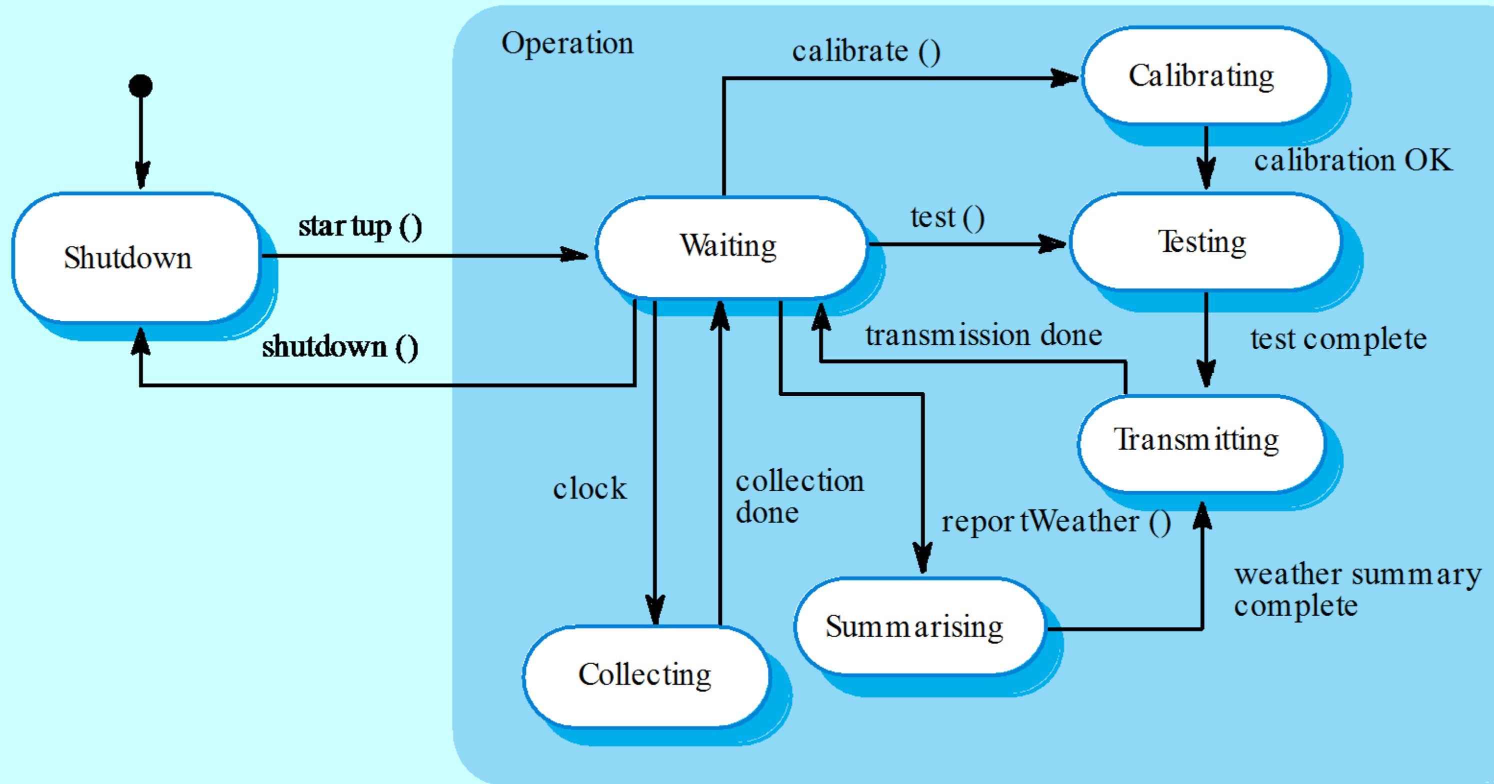
Data collection sequence



Statecharts

- Show how objects respond to different service requests and the state transitions triggered by these requests
  - If object state is Shutdown then it responds to a Startup() message;
  - In the waiting state the object is waiting for further messages;
  - If reportWeather () then system moves to summarising state;
  - If calibrate () the system moves to a calibrating state;
  - A collecting state is entered when a clock signal is received.

Weather station state diagram



Object interface specification

- Object interfaces have to be specified so that the objects and other components can be designed in parallel.
- Designers should avoid designing the interface representation but should hide this in the object itself.
- Objects may have several interfaces which are viewpoints on the methods provided.
- The UML uses class diagrams for interface specification but Java may also be used.

Weather station interface

```
interface WeatherStation {

        public void WeatherStation () ;

        public void startup () ;
        public void startup (Instrument i) ;

        public void shutdown () ;
        public void shutdown (Instrument i) ;

        public void reportWeather ( ) ;

        public void test () ;
        public void test ( Instrument i ) ;

        public void calibrate ( Instrument i) ;

        public int getID () ;

} //WeatherStation
```

Design evolution

- Hiding information inside objects means that changes made to an object do not affect other objects in an unpredictable way.
- Assume pollution monitoring facilities are to be added to weather stations. These sample the air and compute the amount of different pollutants in the atmosphere.
- Pollution readings are transmitted with weather data.

Changes required

- Add an object class called Air quality as part of WeatherStation.
- Add an operation reportAirQuality to WeatherStation. Modify the control software to collect pollution readings.
- Add objects representing pollution monitoring instruments.

Pollution monitoring

WeatherStation

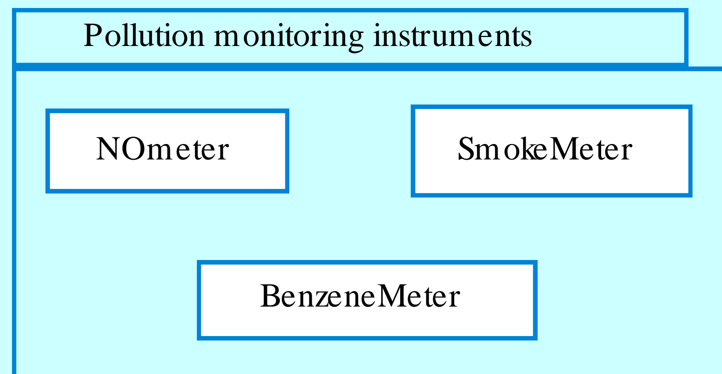
identifier

reportWeather ()
reportAirQuality ()
calibrate (instruments)
test ()
startup (instruments)
shutdown (instruments)

Air quality

NOData
smokeData
benzeneData

collect ()
summarise ()



Key points

- OOD is an approach to design so that design components have their own private state and operations.
- Objects should have constructor and inspection operations. They provide services to other objects.
- Objects may be implemented sequentially or concurrently.
- The Unified Modeling Language provides different notations for defining different object models.

Key points

- A range of different models may be produced during an object-oriented design process. These include static and dynamic system models.
- Object interfaces should be defined precisely using e.g. a programming language like Java.
- Object-oriented design potentially simplifies system evolution.

Real-time Software Design

Objectives

- To explain the concept of a real-time system and why these systems are usually implemented as concurrent processes
- To describe a design process for real-time systems
- To explain the role of a real-time operating system
- To introduce generic process architectures for monitoring and control and data acquisition systems

Topics covered

- System design
- Real-time operating systems
- Monitoring and control systems
- Data acquisition systems

Real-time systems

- Systems which monitor and control their environment.
- Inevitably associated with hardware devices
  - Sensors: Collect data from the system environment;
  - Actuators: Change (in some way) the system's environment;
- Time is critical. Real-time systems MUST respond within specified times.

Definition

- A real-time system is a software system where the correct functioning of the system depends on the results produced by the system and the time at which these results are produced.
- A soft real-time system is a system whose operation is degraded if results are not produced according to the specified timing requirements.
- A hard real-time system is a system whose operation is incorrect if results are not produced according to the timing specification.

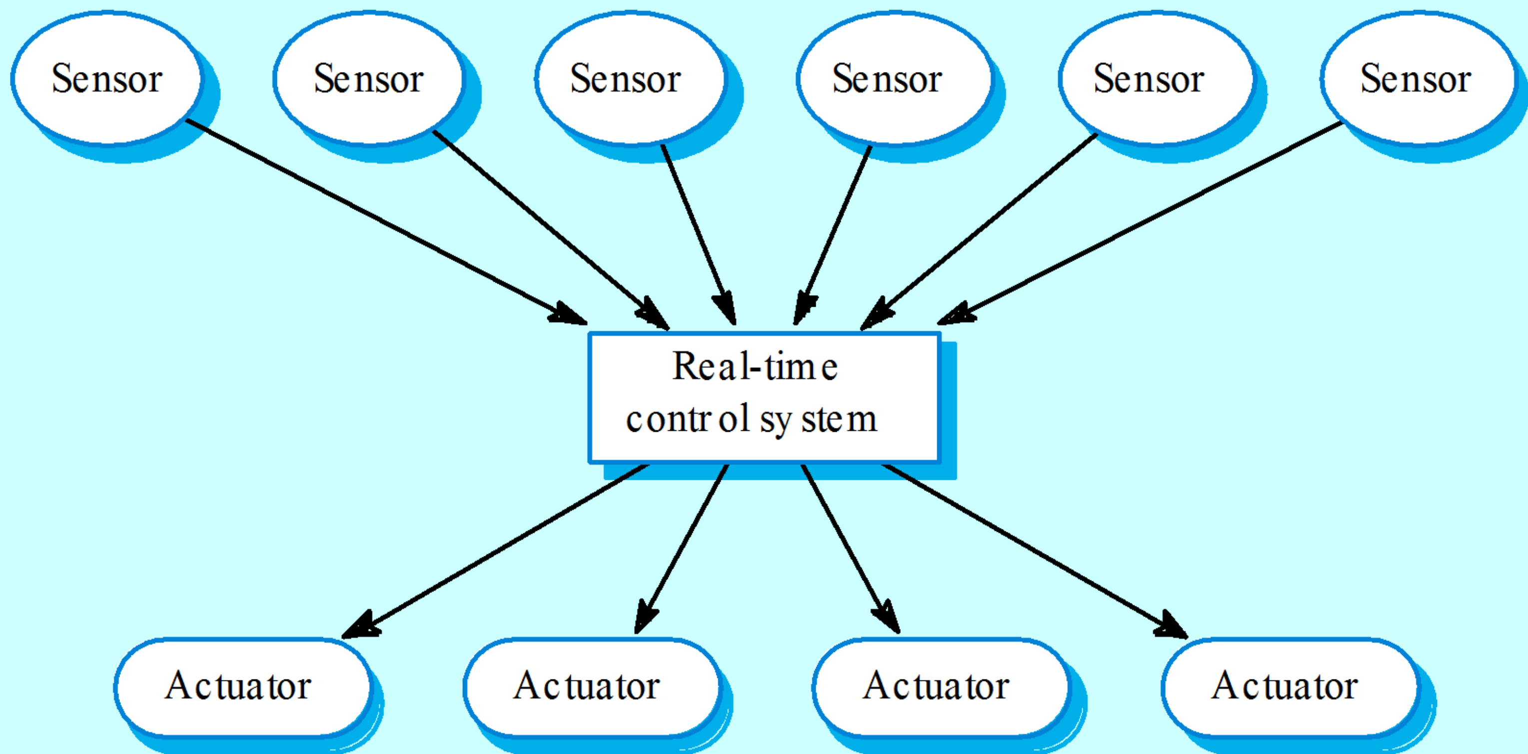
Stimulus/Response Systems

- Given a stimulus, the system must produce a response within a specified time.
- Periodic stimuli. Stimuli which occur at predictable time intervals
  - For example, a temperature sensor may be polled 10 times per second.
- Aperiodic stimuli. Stimuli which occur at unpredictable times
  - For example, a system power failure may trigger an interrupt which must be processed by the system.

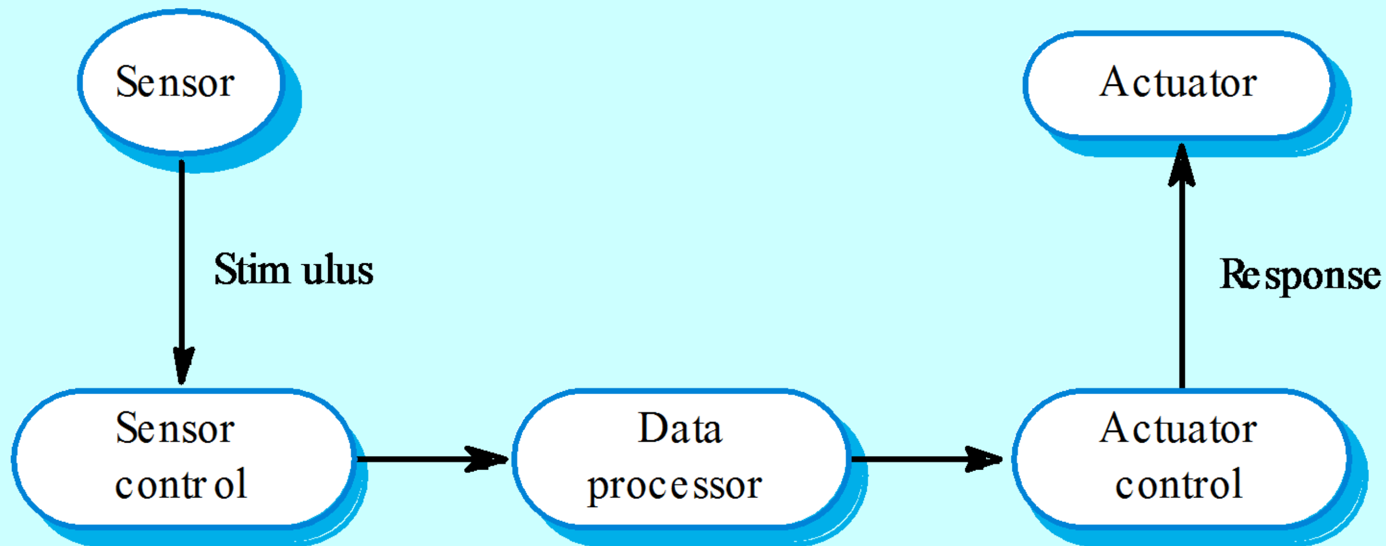
Architectural considerations

- Because of the need to respond to timing demands made by different stimuli/responses, the system architecture must allow for fast switching between stimulus handlers.
- Timing demands of different stimuli are different so a simple sequential loop is not usually adequate.
- Real-time systems are therefore usually designed as cooperating processes with a real-time executive controlling these processes.

A real-time system model



Sensor/actuator processes



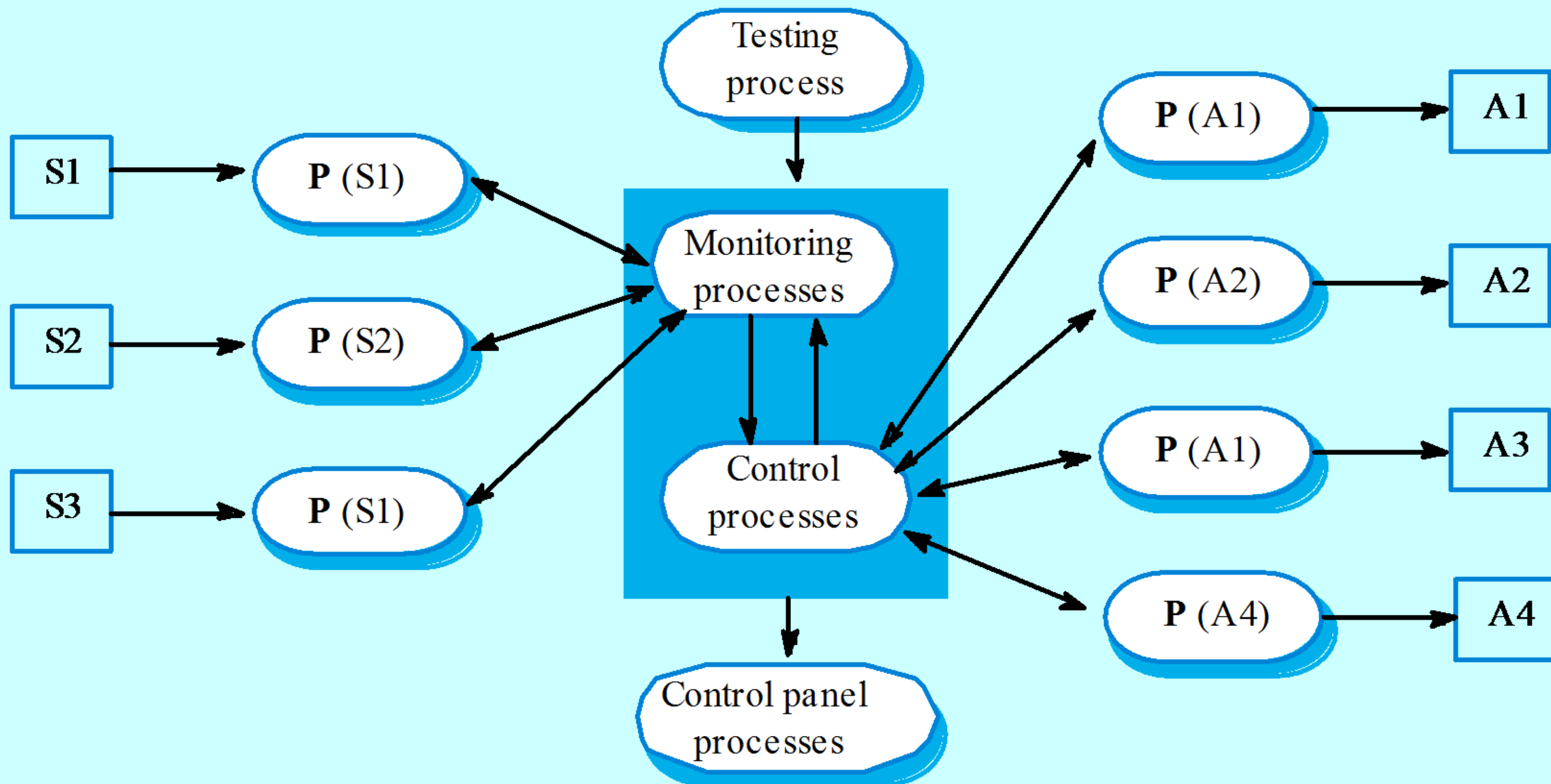
System elements

- Sensor control processes
  - Collect information from sensors. May buffer information collected in response to a sensor stimulus.
- Data processor
  - Carries out processing of collected information and computes the system response.
- Actuator control processes
  - Generates control signals for the actuators.

Monitoring and control systems

- Important class of real-time systems.
- Continuously check sensors and take actions depending on sensor values.
- Monitoring systems examine sensors and report their results.
- Control systems take sensor values and control hardware actuators.

Generic architecture



Assignment

- Explain Monitoring & Control systems

Research

- ***Monitoring*** **Greenhouse using Wireless Sensor Network - Accent**