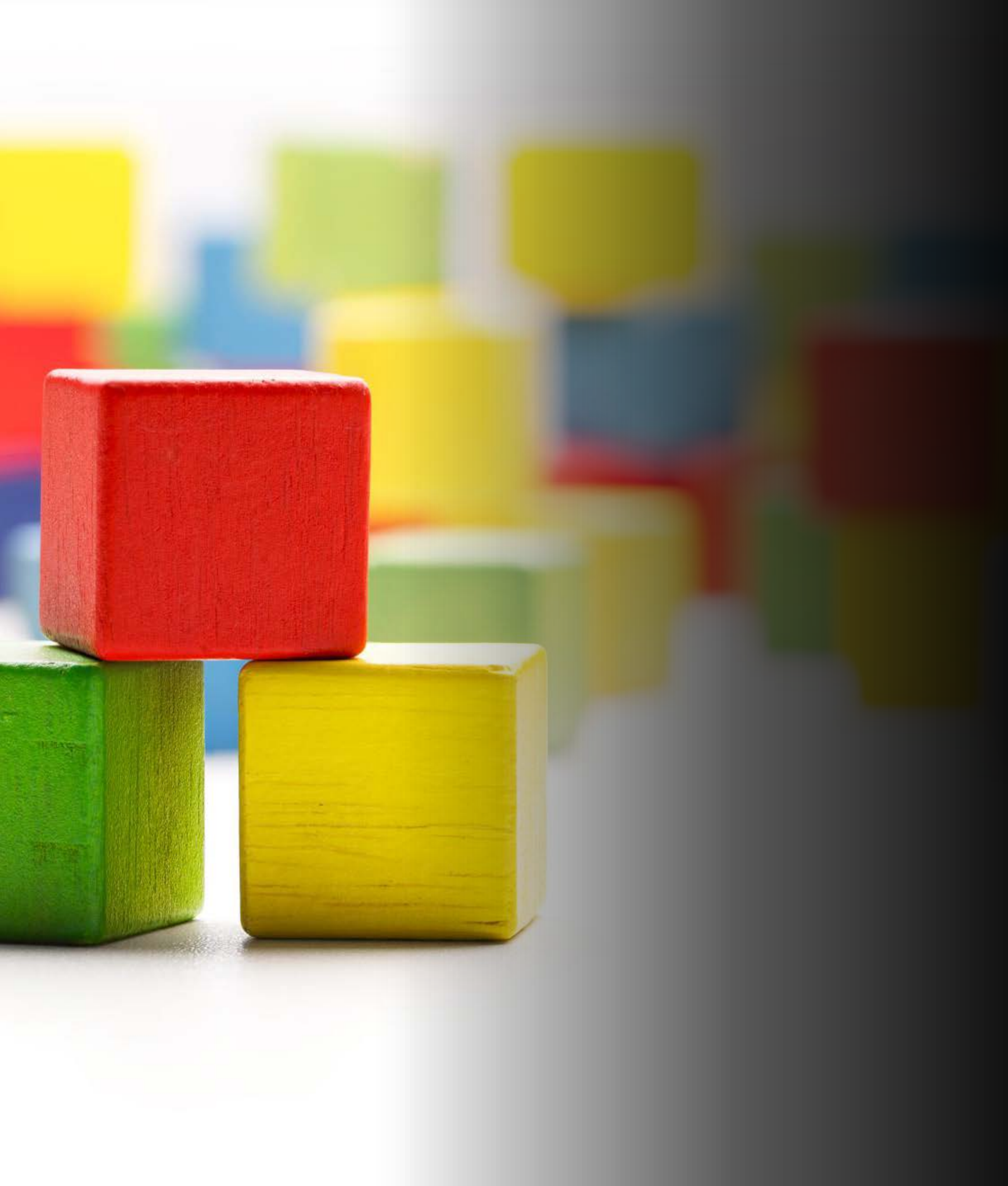

Software Engineering

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Contents of the slides are prepared based on the materials from web and textbooks. It is stated that this material will be used to make the students aware of the topics and practiced for non-profit purposes.

(slide can be found in this secure domain)

Software Design

Contents…

- Introduction to software design
- Goodness of a design
- Functional Independence
- Cohesion and Coupling
- Function-oriented design vs. Object-oriented design
- Summary

Introduction

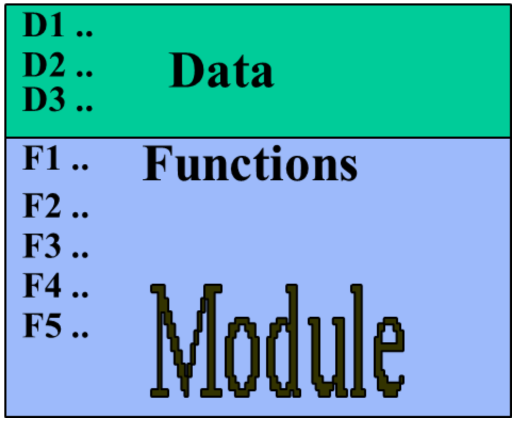
- Design phase transforms SRS document:
  - ✓ To a form easily implementable in some programming language.

Items Designed During Design Phase

- Module structure,
- Control relationship among the modules
  - ✓ call relationship or invocation relationship
- Interface among different modules,
  - ✓ Data items exchanged among different modules,
- Data structures of individual modules,
- Algorithms for individual modules.

Module Structure

- A module consists of:
  - ✓ Several functions
  - ✓ Associated data structures.



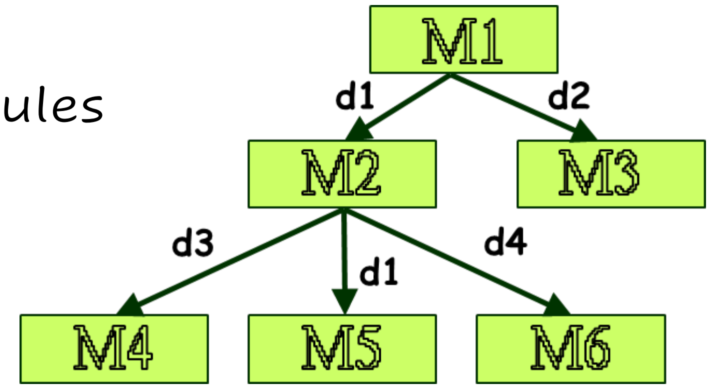
- Good software designs:
  - ✓ Seldom arrived through a single step procedure:
  - ✓ But through a series of steps and iterations.

Module Structure (CONT.)

- Design activities are usually classified into two stages:
  - ✓ Preliminary (or high-level) design.
  - ✓ Detailed design.
- Meaning and scope of the two stages:
  - ✓ Vary considerably from one methodology to another.

High-Level Design

- Identify:
  - ✓ Modules
  - ✓ Control relationships among modules
  - ✓ Interfaces among modules.



- The outcome of high-level design:
  - ✓ Program structure (or software architecture).

High-Level Design (CONT.)

- Several notations are available to represent high-level design:
  - ✓ Usually a tree-like diagram called structure chart is used.
  - ✓ Other notations:
    - ❑ Jackson diagram or Warnier-Orr diagram can also be used.

Detailed Design

- For each module, design:
  - ✓ Data structure
  - ✓ Algorithms
- Outcome of detailed design:
  - ✓ Module specification.

A Classification of Design Methodologies

- Procedural (aka Function-oriented)
- Object-oriented
- More recent:
  - ✓ Aspect-oriented
  - ✓ Component-based (Client-Server)

Does a Design Technique Lead to a Unique Solution?

- No:
  - ✓ Several subjective decisions need to be made to trade off among different parameters.
  - ✓ Even the same designer can come up with several alternate design solutions.

Analysis versus Design

- An analysis technique helps elaborate the customer requirements through careful thinking:
  - ✓ And at the same time consciously avoids making any decisions regarding implementation.
- The design model is obtained from the analysis model through transformations over a series of steps:
  - ✓ Decisions regarding implementation are consciously made.

A Fundamental Question

- How to distinguish between the superior of two alternate design solutions?
  - ✓ Unless we know what a good software design is:
    - ❑We can not possibly design one.

Good and Bad Designs

- There is no unique way to design a system.
- Even using the same design methodology:
  - ✓ Different designers can arrive at very different design solutions.
- We need to distinguish between good and bad designs.

Which of Two is a Better Design?

- Should implement all functionalities of the system correctly.
- Should be easily understandable.
- Should be efficient.
- Should be easily amenable to change,
  - ✓ i.e. easily maintainable.

Which of Two is a Better Design? (CONT.)

- Understandability of a design is a major issue:
  - ✓ Determines goodness of design:
  - ✓ A design that is easy to understand:
    - ❑ Also easy to maintain and change.
- Unless a design is easy to understand,
  - ✓ Tremendous effort needed to maintain it
  - ✓ We already know that about 60% effort is spent in maintenance.
- If the software is not easy to understand:
  - ✓ Maintenance effort would increase many times.

Understandability

- Use consistent and meaningful names:
  - ✓ For various design components.
- Should make use of abstraction and decomposition principles in ample measure.

Cohesion and Coupling

- Cohesion is a measure of:
  - ✓ functional strength of a module.
  - ✓ A cohesive module performs a single task or function.
- Coupling between two modules:
  - ✓ A measure of the degree of the interdependence or interaction between the two modules.
- A module having high cohesion and low coupling:
  - ✓ functionally independent of other modules:
    - ❑ A functionally independent module has minimal interaction with other modules.

Advantages of Functional Independence

- Better understandability and good design:
- Complexity of design is reduced,
- Different modules easily understood in isolation:
  - ✓ Modules are independent
- Functional independence reduces error propagation.
  - ✓ Degree of interaction between modules is low.
  - ✓ An error existing in one module does not directly affect other modules.

Advantages of Functional Independence (CONT.)

- Reuse of modules is possible.
- A functionally independent module:
  - ✓ Can be easily taken out and reused in a different program.
    - ❑ Each module does some well-defined and precise function
    - ❑ The interfaces of a module with other modules is simple and minimal.

Functional Independence

- Unfortunately, there are no ways:
  - ✓ To quantitatively measure the degree of cohesion and coupling.
  - ✓ Classification of different kinds of cohesion and coupling:
    - ❑ Can give us some idea regarding the degree of cohesiveness of a module.

Classification of Cohesiveness

- Classification is often subjective:
  - ✓ Yet gives us some idea about cohesiveness of a module.
- By examining the type of cohesion exhibited by a module:
  - ✓ We can roughly tell whether it displays high cohesion or low cohesion.

Classification of Cohesiveness (CONT.)

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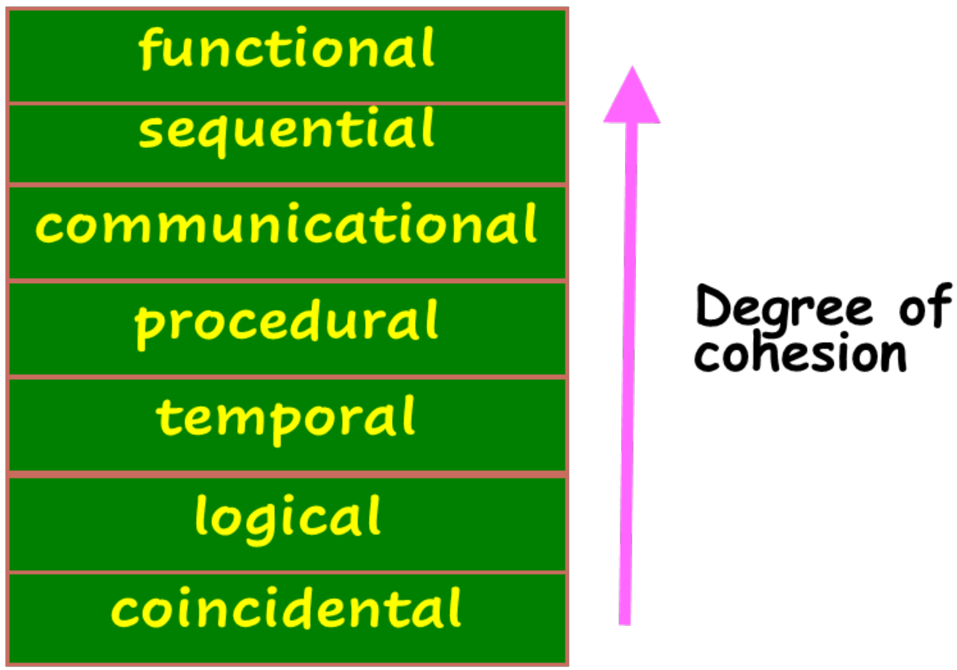
Classification of Cohesiveness (CONT.)



Coincidental Cohesion

- The module performs a set of tasks:
  - ✓ Which relate to each other very loosely, if at all.
    - ❑ The module contains a random collection of functions.
    - ❑ Functions have been put in the module out of pure coincidence without any thought or design.

Logical Cohesion

- All elements of the module perform similar operations:
  - ✓ e.g. error handling, data input, data output, etc.
- An example of logical cohesion:
  - ✓ A set of print functions to generate an output report arranged into a single module.

Temporal Cohesion

- The module contains tasks that are related by the fact:
  - ✓ All the tasks must be executed in the same time span.
- Example:
  - ✓ The set of functions responsible for
    - ❑ initialization,
    - ❑ start-up, shut-down of some process, etc.

Procedural Cohesion

- The set of functions of the module:
  - ✓ All part of a procedure (algorithm)
  - ✓ Certain sequence of steps have to be carried out in a certain order for achieving an objective,
    - ❑ e.g. the algorithm for decoding a message.

Communicational Cohesion

- All functions of the module:
  - ✓ Reference or update the same data structure,
- Example:
  - ✓ The set of functions defined on an array or a stack.

Sequential Cohesion

- Elements of a module form different parts of a sequence,
  - ✓ Output from one element of the sequence is input to the next.
  - ✓ Example:

Functional Cohesion

- Different elements of a module cooperate:
  - ✓ To achieve a single function,
  - ✓ e.g. managing an employee's pay-roll.
- When a module displays functional cohesion,
  - ✓ We can describe the function using a single sentence.

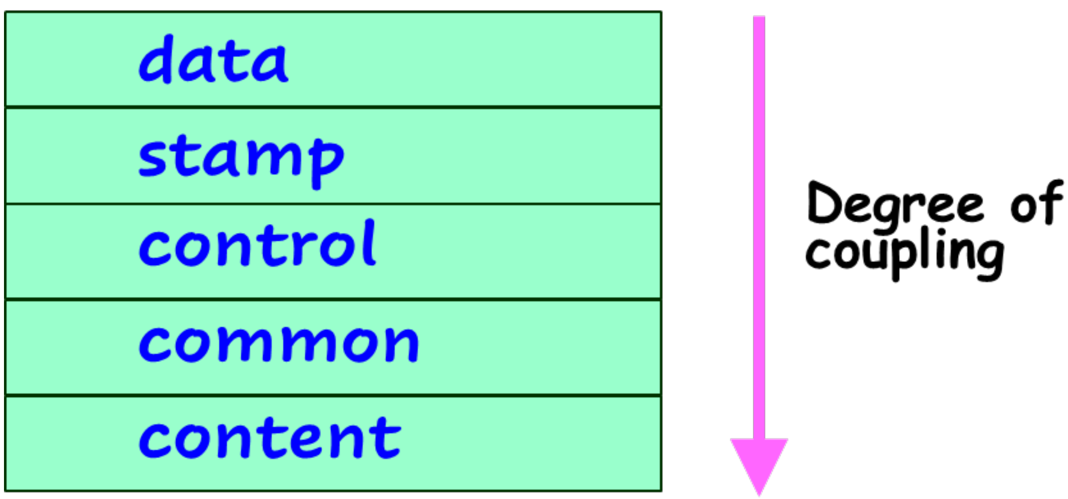
Determining Cohesiveness

- Write down a sentence to describe the function of the module
  - ✓ If the sentence is compound,
    - ❑ It has a sequential or communicational cohesion.
  - ✓ If it has words like "first", "next", "after", "then", etc.
    - ❑ It has sequential or temporal cohesion.
  - ✓ If it has words like initialize,
    - ❑ It probably has temporal cohesion.

Coupling

- Coupling indicates:
  - ✓ How closely two modules interact or how interdependent they are.
  - ✓ The degree of coupling between two modules depends on their interface complexity.
- There are no ways to precisely determine coupling between two modules:
  - ✓ Classification of different types of coupling will help us to approximately estimate the degree of coupling between two modules.
- Five types of coupling can exist between any two modules.

Classes of coupling



Data coupling

- Two modules are data coupled,
  - ✓ If they communicate via a parameter:
    - ❑ an elementary data item,
    - ❑ e.g., an integer, a float, a character, etc.
- The data item should be problem related:
  - ✓ Not used for control purpose.

Stamp Coupling

- Two modules are stamp coupled,
  - ✓ If they communicate via a composite data item
    - ❑ such as a record in PASCAL
    - ❑ or a structure in C.

Control Coupling

- Data from one module is used to direct:
  - ✓ Order of instruction execution in another.
- Example of control coupling:
  - ✓ A flag set in one module and tested in another module.

Common Coupling

- Two modules are common coupled,
  - ✓ If they share some global data.

Content Coupling

- Content coupling exists between two modules:
  - ✓ If they share code,
  - ✓ e.g, branching from one module into another module.
- The degree of coupling increases
  - ✓ from data coupling to content coupling.

How are Abstraction and Decomposition Principles Used in Design?

- Two principal ways:
  - ✓ Modular Design
  - ✓ Layered Design

Modularity

- a fundamental attributes of any good design.
  - ✓ Decomposition of a problem cleanly into modules:
  - ✓ Modules are almost independent of each other
  - ✓ Divide and conquer principle.
- If modules are independent:
  - ✓ Modules can be understood separately,
    - ❑ Reduces the complexity greatly.
- To understand why this is so,
  - ✓ Remember that it is very difficult to break a bunch of sticks but very easy to break the sticks individually.

Modularity (CONT.)

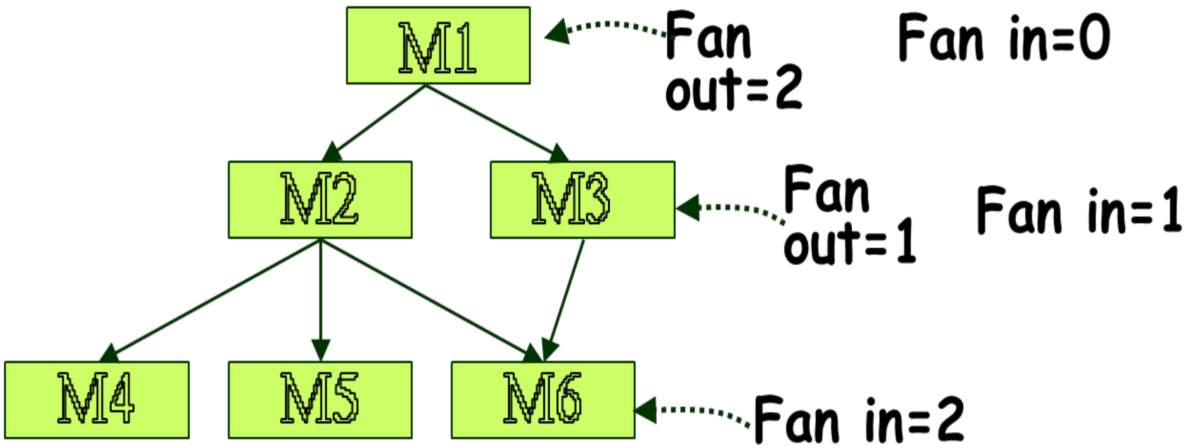
- In technical terms, modules should display:
  - ✓ High cohesion
  - ✓ Low coupling.
- We already discussed before
  - ✓ cohesion and coupling.

Characteristics of Module Hierarchy

- Depth:
  - ✓ Number of levels of control
- Width:
  - ✓ Overall span of control.
- Fan-out:
  - ✓ A measure of the number of modules directly controlled by given module.
- Fan-in:
  - ✓ Indicates how many modules directly invoke a given module.
  - ✓ High fan-in represents code reuse and is in general

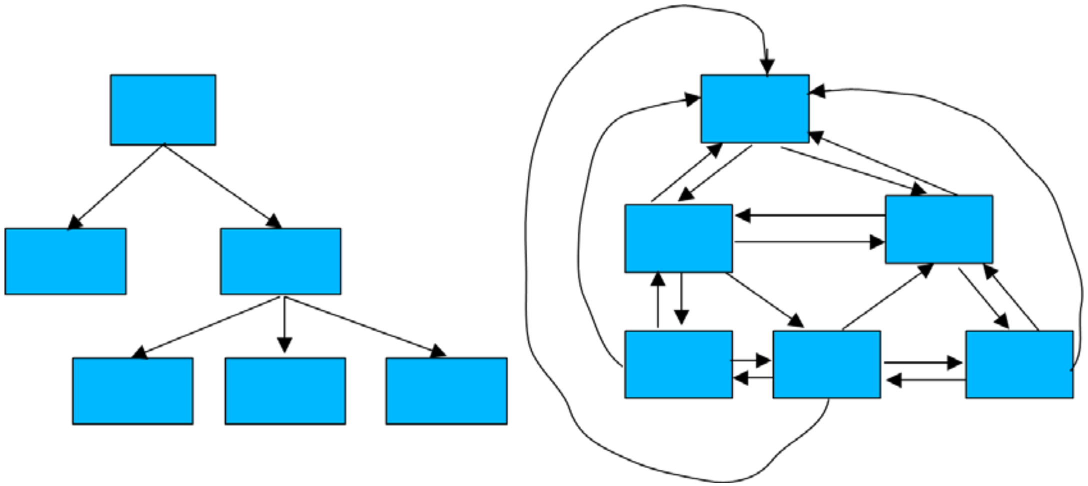
Module Hierarchy

- A module that controls another module:
  - ✓ Said to be superordinate to it.
- Conversely, a module controlled by another module:
  - ✓ Said to be subordinate to it.



Layered Design

- A design having modules:
  - ✓ With high fan-out numbers is not a good design:
  - ✓ A module having high fan-out lacks cohesion.
- Neat arrangement of modules in a hierarchy means:
  - ✓ Low fan-out
  - ✓ Control abstraction



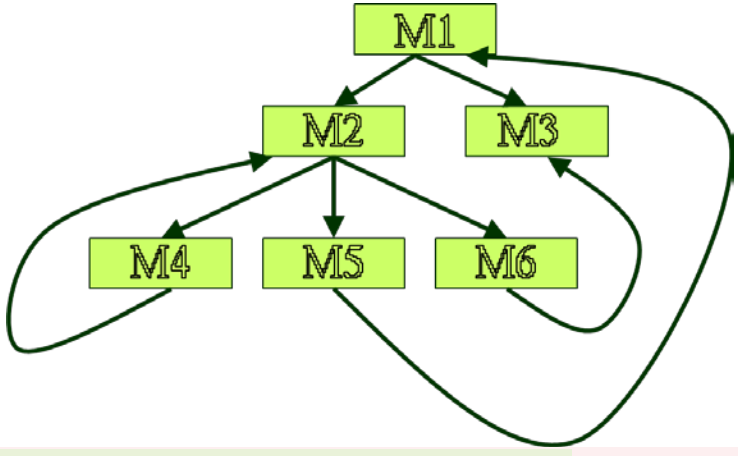
Visibility and Layering

- A module A is said to be visible by another module B,
  - ✓ If A directly or indirectly calls B.
- The layering principle requires
  - ✓ Modules at a layer can call only the modules immediately below it.

Goodness of Design

- A module that invokes a large number of other modules:
  - ✓ Likely to implement several different functions:
  - ✓ Not likely to perform a single cohesive function.

- **Bad Design**

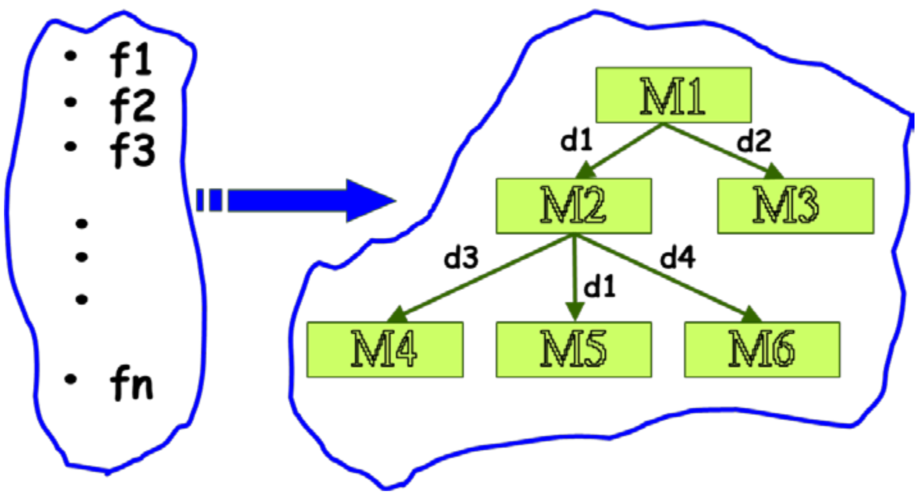


Abstraction

- A module is unaware (how to invoke etc.) of the higher level modules.
- Lower-level modules:
  - ✓ Do input/output and other low-level functions.
- Upper-level modules:
  - ✓ Do more managerial functions.
- The principle of abstraction requires:
  - ✓ Lower-level modules do not invoke functions of higher level modules.
  - ✓ Also known as layered design.

High-Level Design (CONT.)

- High-level design maps functions into modules {fi} {mj} such that:
  - ✓ Each module has high cohesion
  - ✓ Coupling among modules is as low as possible
  - ✓ Modules are organized in a neat hierarchy



Design Approaches

- Two fundamentally different software design approaches:
  - ✓ Function-oriented design
  - ✓ Object-oriented design
- These two design approaches are radically different.
  - ✓ However, are complementary
    - ❑ Rather than competing techniques.
- Each technique is applicable at
  - ✓ Different stages of the design process.

Function-Oriented Design

- A system is looked upon as something
  - ✓ That performs a set of functions.
- Starting at this high-level view of the system:
  - ✓ Each function is successively refined into more detailed functions.
  - ✓ Functions are mapped to a module structure.

Function-Oriented Design: Example

- The function create-new-library- member:
  - ✓ Creates the record for a new member,
  - ✓ Assigns a unique membership number
  - ✓ Prints a bill towards the membership
- Create-library-member function consists of the following sub-functions:
  - ✓ Assign-membership-number
  - ✓ Create-member-record
  - ✓ Print-bill

Function-Oriented Design (CONT.)

- Each subfunction:
  - ✓ Split into more detailed subfunctions and so on.

- The system state is centralized:
  - ✓ Accessible to different functions,
  - ✓ Member-records:
    - ❑ Available for reference and updation to several functions:
      - ❖ Create-new-member
      - ❖ Delete-member
      - ❖ Update-member-record

Function-Oriented Design (CONT.)

- Several function-oriented design approaches have been developed:
  - ✓ Structured design (Constantine and Yourdon, 1979)
  - ✓ Jackson's structured design (Jackson, 1975)
  - ✓ Warnier-Orr methodology
  - ✓ Wirth's step-wise refinement
  - ✓ Hatley and Pirbhai's Methodology

Object-Oriented Design

- System is viewed as a collection of objects (i.e. entities).
- System state is decentralized among the objects:
  - ✓ Each object manages its own state information.

Object-Oriented Design: Example

- Library Automation Software:
  - ✓ Each library member is a separate object
    - ❑ With its own data and functions.
  - ✓ Functions defined for one object:
    - ❑ Cannot directly refer to or change data of other objects.

Object-Oriented Design

- Objects have their own internal data:
  - ✓ Defines their state.
- Similar objects constitute a class.
  - ✓ Each object is a member of some class.
- Classes may inherit features
  - ✓ From a super class.
- Conceptually, objects communicate by message passing.

Object-Oriented versus Function-Oriented Design

- Unlike function-oriented design,
  - ✓ In OOD the basic abstraction is not functions such as “sort”, “display”, “track”, etc.,
  - ✓ But real-world entities such as “employee”, “picture”, “machine”, “radar system”, etc.
- In OOD, Software is not developed by designing functions such as:
  - ✓ update-employee-record,
  - ✓ get-employee-address, etc.

Object-Oriented versus Function-Oriented Design (CONT.)

- But by designing objects such as:
  - ✓ employees,
  - ✓ departments, etc.

- Grady Booch sums up this fundamental difference saying:
  - ✓ "Identify verbs if you are after procedural design and nouns if you are after object-oriented design."

Object-Oriented versus Function-Oriented Design (CONT.)

- In OOD:
  - ✓ State information is not shared in a centralized data.
  - ✓ But is distributed among the objects of the system.

Example:

- In an employee pay-roll system, the following can be global data:
  - ✓ employee names,
  - ✓ code numbers,
  - ✓ basic salaries, etc.
- Whereas, in object oriented design:
  - ✓ Data is distributed among different employee objects of the system.

Object-Oriented versus Function-Oriented Design (CONT.)

- Objects communicate by message passing.
  - ✓ One object may discover the state information of another object by interrogating it.

- Of course, somewhere or other the functions must be implemented:
  - ✓ The functions are usually associated with specific real-world entities (objects)
  - ✓ Directly access only part of the system state information.

Object-Oriented versus Function-Oriented Design (CONT.)

- Function-oriented techniques group functions together if:
  - ✓ As a group, they constitute a higher level function.
- On the other hand, object-oriented techniques group functions together:
  - ✓ On the basis of the data they operate on.

Object-Oriented versus Function-Oriented Design (CONT.)

- To illustrate the differences between object-oriented and function-oriented design approaches,
  - ✓ let us consider an example ---
  - ✓ An automated fire-alarm system for a large building.

Object-Oriented versus Function-Oriented Design (CONT.)

Example: Fire-Alarm System

- We need to develop a computerized fire alarm system for a large multi-storied building:
  - ✓ There are 80 floors and 1000 rooms in the building.
- Different rooms of the building:
  - ✓ Fitted with smoke detectors and fire alarms.
- The fire alarm system would monitor:
  - ✓ Status of the smoke detectors.

Object-Oriented versus Function-Oriented Design (CONT.)

Example: Fire-Alarm System

- Whenever a fire condition is reported by any smoke detector:
  - ✓ the fire alarm system should:
    - ❑ Determine the location from which the fire condition was reported
    - ❑ Sound the alarms in the neighboring locations.

- The fire alarm system should:
  - ✓ Flash an alarm message on the computer console:
    - ❑ Fire fighting personnel man the console round the clock.

Object-Oriented versus Function-Oriented Design (CONT.)

Example: Fire-Alarm System

- After a fire condition has been successfully handled,
  - ✓ The fire alarm system should let fire fighting personnel reset the alarms.

Object-Oriented versus Function-Oriented Design (CONT.)

Function-Oriented Approach on Example: Fire-Alarm System

- /* Global data (system state) accessible by various functions */

```
BOOL  detector_status[1000];
int   detector_locs[1000];
BOOL  alarm-status[1000]; /* alarm activated when status set */
int   alarm_locs[1000]; /* room number where alarm is located */
int   neighbor-alarms[1000][10];/*each detector has at most*/
                                 /* 10 neighboring alarm locations */
```

The functions which operate on the system state:

```
interrogate_detectors();
get_detector_location();
determine_neighbor();
ring_alarm();
reset_alarm();
report_fire_location();
```

Object-Oriented versus Function-Oriented Design (CONT.)

Object-Oriented Approach on Example: Fire-Alarm System

- class detector

  attributes: status, location, neighbors

  operations: create, sense-status, get-location, find-neighbors

- class alarm

  attributes: location, status

  operations: create, ring-alarm, get_location, reset-alarm

- In the object oriented program,
- appropriate number of instances of the class detector and alarm should be created.

Object-Oriented versus Function-Oriented Design (CONT.)

- In the function-oriented program :
  - ✓ The system state is centralized
  - ✓ Several functions accessing these data are defined.

- In the object oriented program,
  - ✓ The state information is distributed among various sensor and alarm objects.

Object-Oriented versus Function-Oriented Design (CONT.)

- Use OOD to design the classes:
  - ✓ Then applies top-down function oriented techniques
    - ❑ To design the internal methods of classes.

- Though outwardly a system may appear to have been developed in an object oriented fashion,
  - ✓ But inside each class there is a small hierarchy of functions designed in a top-down manner.

Summary

- We started with an overview of:
  - ✓ Activities undertaken during the software design phase.
- We identified:
  - ✓ The information need to be produced at the end of the design phase:
    - ❑ So that the design can be easily implemented using a programming language.

Summary (CONT.)

- We characterized the features of a good software design by introducing the concepts of:
  - ✓ fan-in, fan-out,
  - ✓ cohesion, coupling,
  - ✓ abstraction, etc.

- We classified different types of cohesion and coupling:
  - ✓ Enables us to approximately determine the cohesion and coupling existing in a design.

Summary (CONT.)

- Two fundamentally different approaches to software design:
  - ✓ Function-oriented approach
  - ✓ Object-oriented approach
- We looked at the essential philosophy behind these two approaches
  - ✓ These two approaches are not competing but complementary approaches.