Software Design

Deriving a solution which
satisfies software requirements

Objectives

- To introduce the process of software design
- To describe the different stages in this design process
- To show how object-oriented and functional design strategies are complementary
- To discuss some design quality attributes

Topics covered

- The design process and design methods
- Design strategies including object-oriented design and functional decomposition
- Design quality attributes

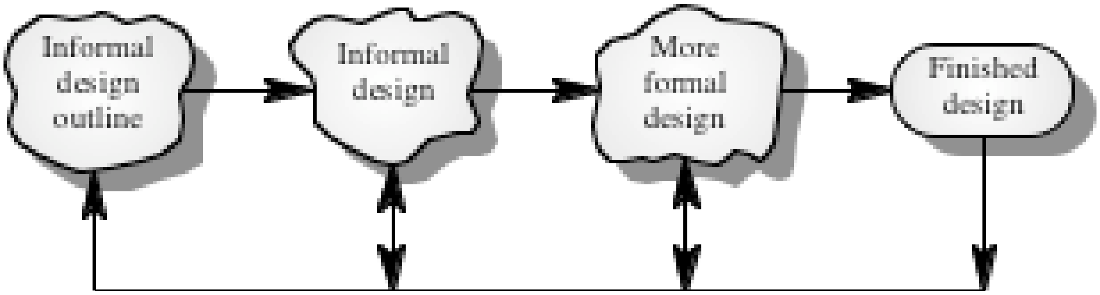
Stages of design

- Problem understanding
  - Look at the problem from different angles to discover the design requirements
- Identify one or more solutions
  - Evaluate possible solutions and choose the most appropriate depending on the designer's experience and available resources
- Describe solution abstractions
  - Use graphical, formal or other descriptive notations to describe the components of the design
- Repeat process for each identified abstraction until the design is expressed in primitive terms

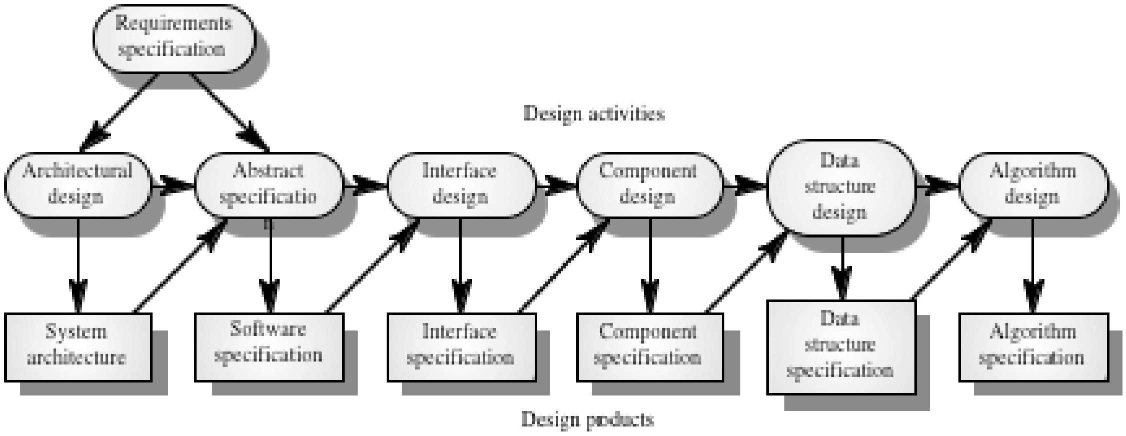
The design process

- Any design may be modeled as a directed graph made up of entities with attributes which participate in relationships
- The system should be described at several different levels of abstraction
- Design takes place in overlapping stages. It is artificial to separate it into distinct phases but some separation is usually necessary

From informal to formal design



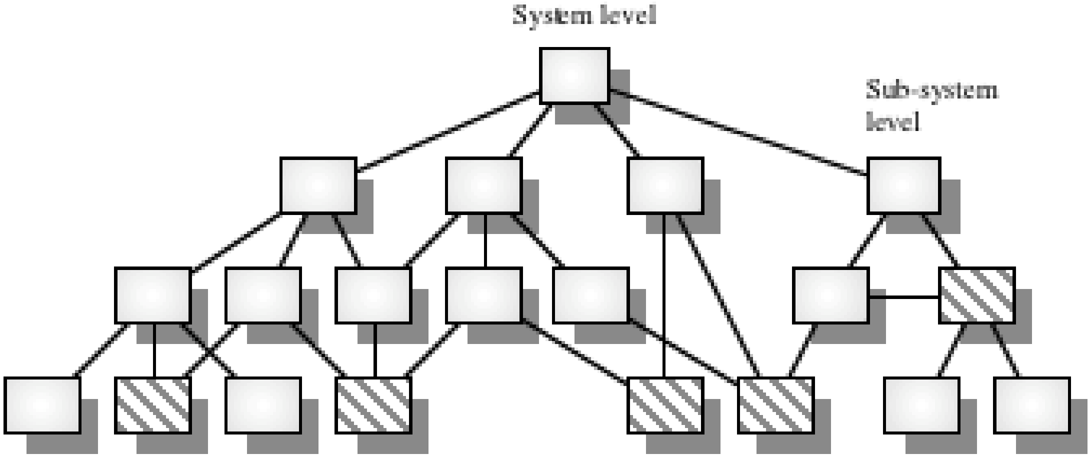
Phases in the design process



Design phases

- *Architectural design* Identify sub-systems
- *Abstract specification* Specify sub-systems
- *Interface design* Describe sub-system interfaces
- *Component design* Decompose sub-systems into components
- *Data structure design* Design data structures to hold problem data
- *Algorithm design* Design algorithms for problem functions

Hierarchical design structure



Top-down design

- In principle, top-down design involves starting at the uppermost components in the hierarchy and working down the hierarchy level by level
- In practice, large systems design is never truly top-down. Some branches are designed before others. Designers reuse experience (and sometimes components) during the design process

Design methods

- Structured methods are sets of notations for expressing a software design and guidelines for creating a design
- Well-known methods include Structured Design (Yourdon), and JSD (Jackson Method)
- Can be applied successfully because the support standard notations and ensure designs follow a standard form
- Structured methods may be supported with CASE tools

Method components

- Many methods support comparable views of a system
- A data flow view (data flow diagrams) showing data transformations
- An entity-relation view describing the logical data structures
- A structural view showing system components and their interactions

Method deficiencies

- They are guidelines rather than methods in the mathematical sense. Different designers create quite different system designs
- They do not help much with the early, creative phase of design. Rather, they help the designer to structure and document his or her design ideas

Design description

- *Graphical notations.* Used to display component relationships
- *Program description languages.* Based on programming languages but with more flexibility to represent abstract concepts
- *Informal text.* Natural language description.
- All of these notations may be used in large systems design

Design strategies

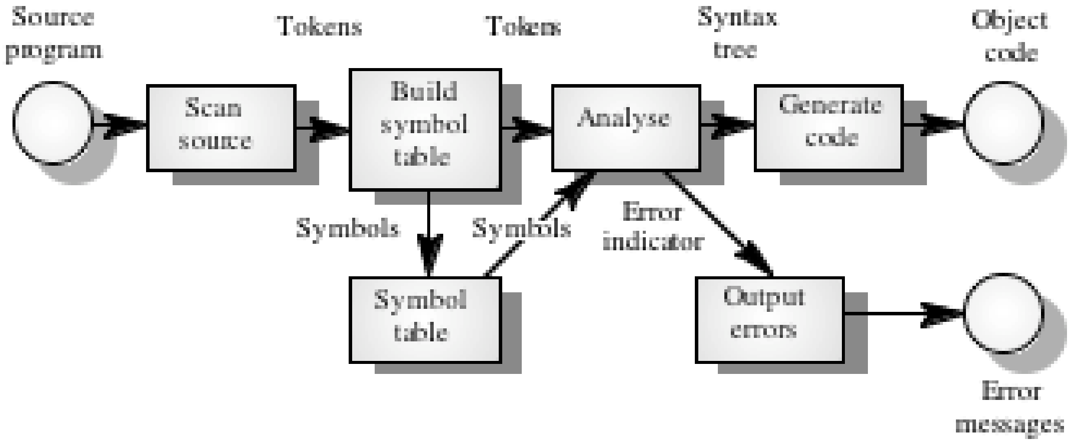
- Functional design

  The system is designed from a functional viewpoint. The system state is centralized and shared between the functions operating on that state

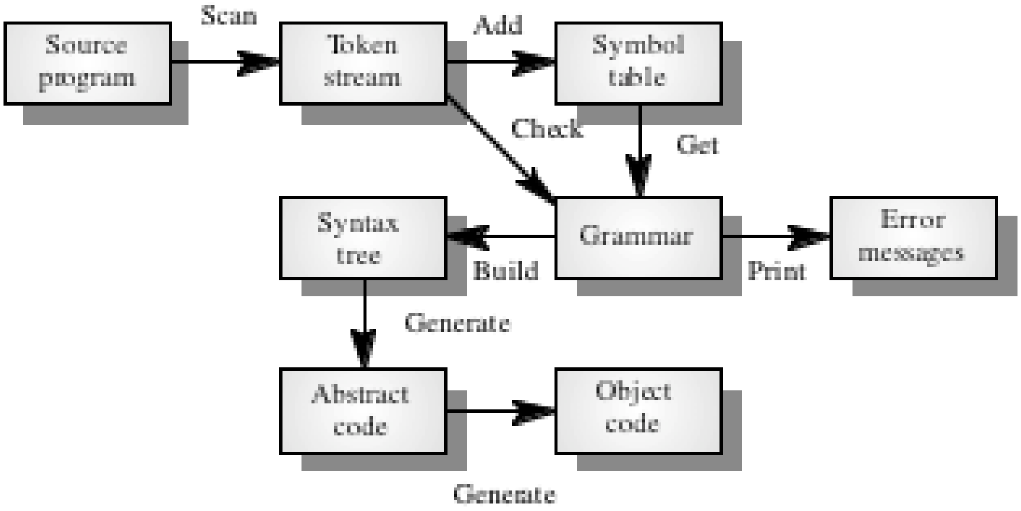
- Object-oriented design

  The system is viewed as a collection of interacting objects. The system state is de-centralized and each object manages its own state. Objects may be instances of an object class and communicate by exchanging messages.

Functional view of a compiler



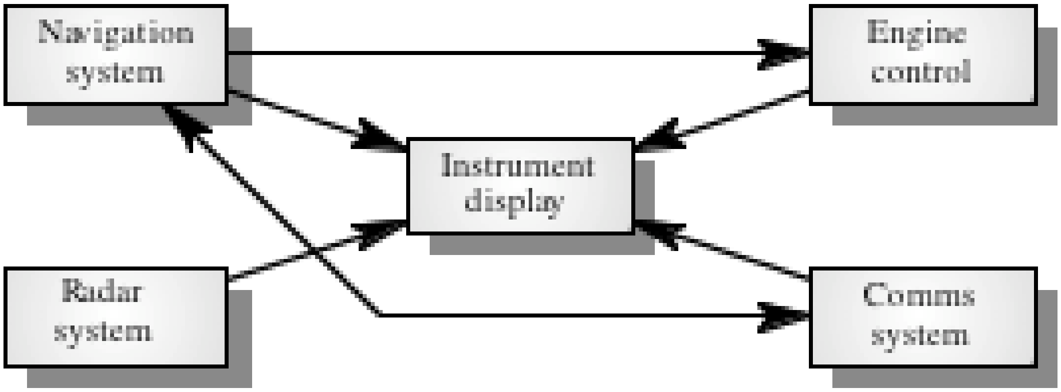
Object-oriented view of a compiler



Mixed-strategy design

- Although it is sometimes suggested that one approach to design is superior, in practice, an object-oriented and a functional-oriented approach to design are complementary
- Good software engineers should select the most appropriate approach for whatever sub-system is being designed

Aircraft sub-systems



High-level objects

- The navigation system
- The radar system
- The communications system
- The instrument display system
- The engine control system
- ...

System functions (sub-system level)

- Display track (radar sub-system)
- Compensate for wind speed (navigation sub-system)
- Reduce power (engine sub-system)
- Indicate emergency (instrument sub-system)
- Lock onto frequency (communications sub-system)
- ...

Low-level objects

- The engine status
- The aircraft position
- The altimeter
- The radio beacon
- ...

Design quality

- Design quality is an elusive concept. Quality depends on specific organizational priorities
- A 'good' design may be the most efficient, the cheapest, the most maintainable, the most reliable, etc.
- The attributes discussed here are concerned with the maintainability of the design
- Quality characteristics are equally applicable to function-oriented and object-oriented designs

Cohesion

- A measure of how well a component 'fits together'
- A component should implement a single logical entity or function
- Cohesion is a desirable design component attribute as when a change has to be made, it is localized in a single cohesive component
- Various levels of cohesion have been identified

Cohesion levels

- Coincidental cohesion (weak)
  - Parts of a component are simply bundled together
- Logical association (weak)
  - Components which perform similar functions are grouped
- Temporal cohesion (weak)
  - Components which are activated at the same time are grouped
- Procedural cohesion (weak)
  - The elements in a component make up a single control sequence

Cohesion levels

- Communicational cohesion (medium)
  - All the elements of a component operate on the same input or produce the same output
- Sequential cohesion (medium)
  - The output for one part of a component is the input to another part
- Functional cohesion (strong)
  - Each part of a component is necessary for the execution of a single function
- Object cohesion (strong)
  - Each operation provides functionality which allows object attributes to be modified or inspected

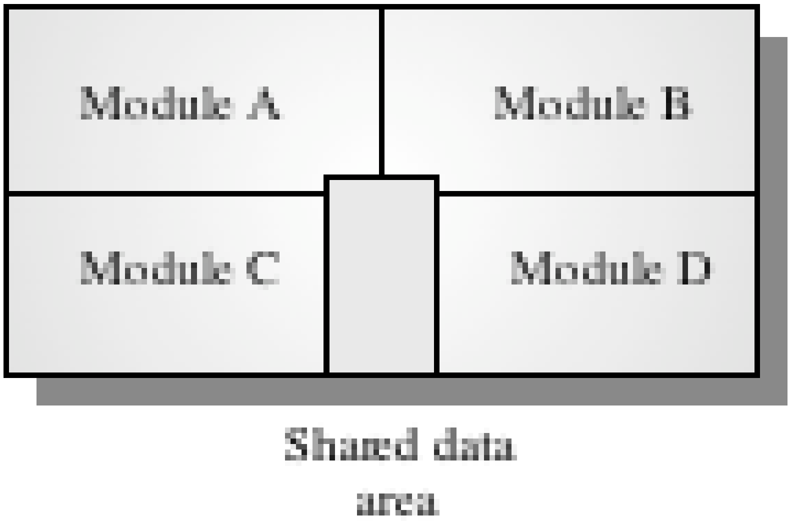
Cohesion as a design attribute

- Not well-defined. Often difficult to classify cohesion
- Inheriting attributes from super-classes weakens cohesion
- To understand a component, the super-classes as well as the component class must be examined
- Object class browsers assist with this process

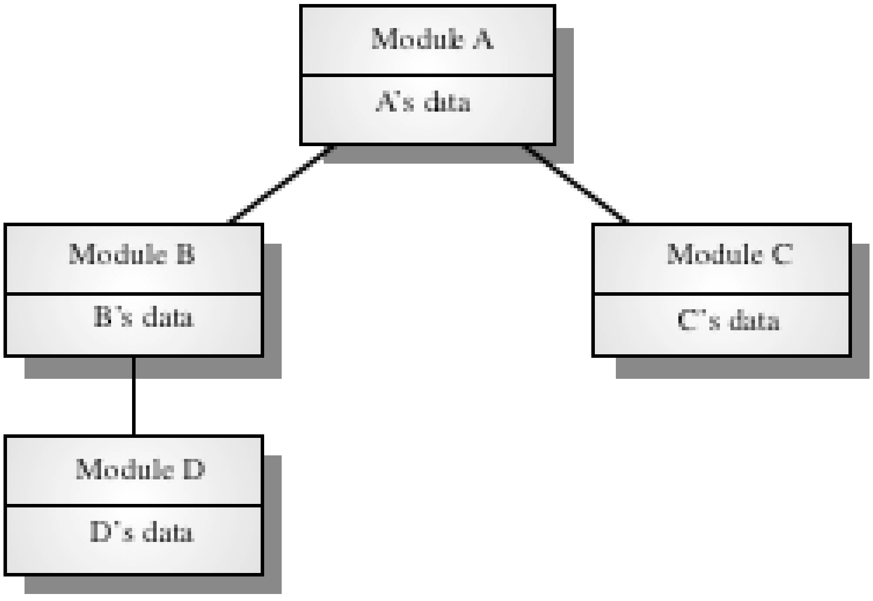
Coupling

- A measure of the strength of the inter-connections between system components
- Loose coupling means component changes are unlikely to affect other components
- Shared variables or control information exchange lead to tight coupling
- Loose coupling can be achieved by state decentralization (as in objects) and component communication via parameters or message passing

Tight coupling



Loose coupling



Coupling and inheritance

- Object-oriented systems are loosely coupled because there is no shared state and objects communicate using message passing
- However, an object class is coupled to its super-classes. Changes made to the attributes or operations in a super-class propagate to all sub-classes. Such changes must be carefully controlled

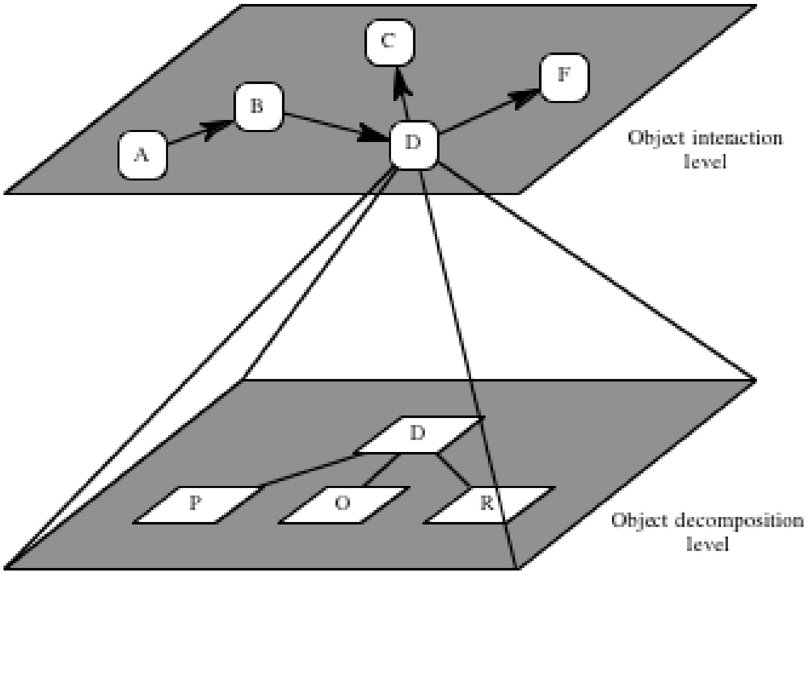
Understandability

- Related to several component characteristics
  - *Cohesion*. Can the component be understood on its own?
  - *Naming*. Are meaningful names used?
  - *Documentation*. Is the design well-documented?
  - *Complexity*. Are complex algorithms used?
- Informally, high complexity means many relationships between different parts of the design. hence it is hard to understand
- Most design quality metrics are oriented towards complexity measurement. They are of limited use

Adaptability

- A design is adaptable if:
  - Its components are loosely coupled
  - It is well-documented and the documentation is up to date
  - There is an obvious correspondence between design levels (design visibility)
  - Each component is a self-contained entity (tightly cohesive)
- To adapt a design, it must be possible to trace the links between design components so that change consequences can be analyzed

Design traceability



Adaptability and inheritance

- Inheritance dramatically improves adaptability. Components may be adapted without change by deriving a sub-class and modifying that derived class
- However, as the depth of the inheritance hierarchy increases, it becomes increasingly complex. It must be periodically reviewed and restructured

Key points

- Design is a creative process
- Design activities include architectural design, system specification, component design, data structure design and algorithm design
- Functional decomposition considers the system as a set of functional units
- Object-oriented decomposition considers the system as a set of objects