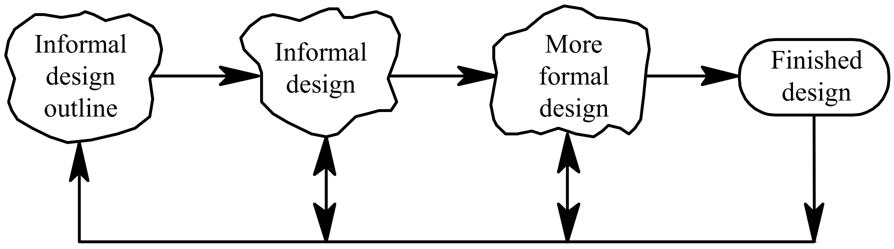
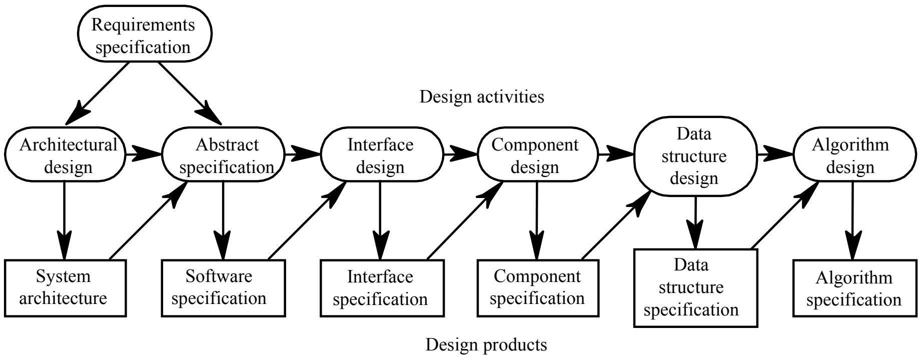
Stages of design

- 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

From informal to formal design



Phases in the design process（例）



Requirements specification

Design activities

Architectural design → Abstract specification → Interface design → Component design → Data structure design → Algorithm design

System architecture

Software specification

Interface specification

Component specification

Data structure specification

Algorithm specification

Design products

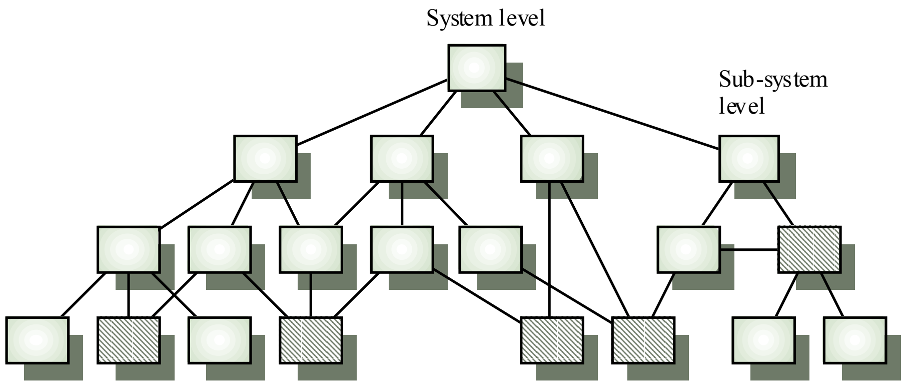
アーキテクチャ設計　概要仕様　インタフェース設計　コンポーネント設計　データ構造設計　アルゴリズム設計

基本設計　¦　詳細設計

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 they 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

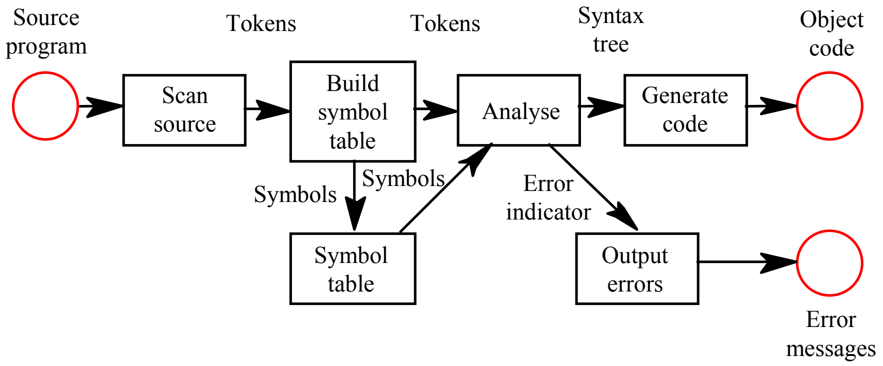
Design description

- *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（機能指向）
  - The system is designed from a functional viewpoint. The system state is centralised and shared between the functions operating on that state
- Object-oriented design（オブジェクト指向）
  - The system is viewed as a collection of interacting objects. The system state is de-centralised and each object manages its own state. Objects may be instances of an object class and communicate by exchanging methods

Functional view of a compiler



Source program

Tokens

Tokens

Syntax tree

Object code

Scan source

Build symbol table

Analyse

Generate code

Symbols

Symbols

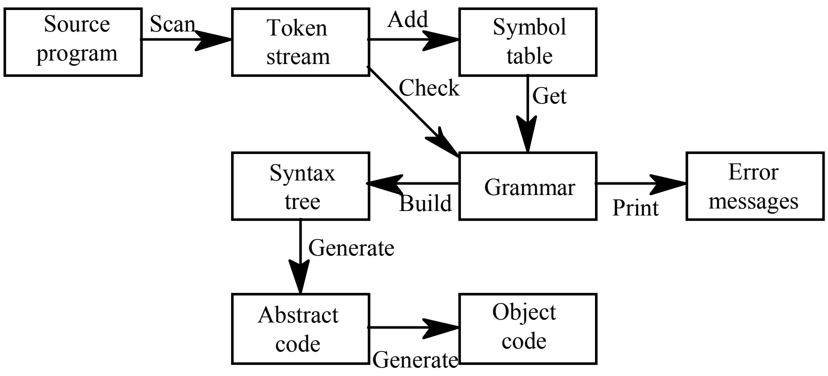
Error indicator

Symbol table

Output errors

Error messages

Object-oriented view of a compiler

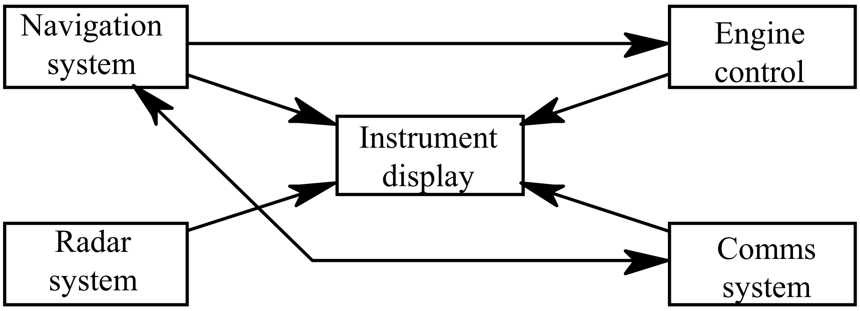


Mixed-strategy design

- 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

オブジェクトの検討→機能の検討→実装レベルオブジェクトの検討



High-level objects

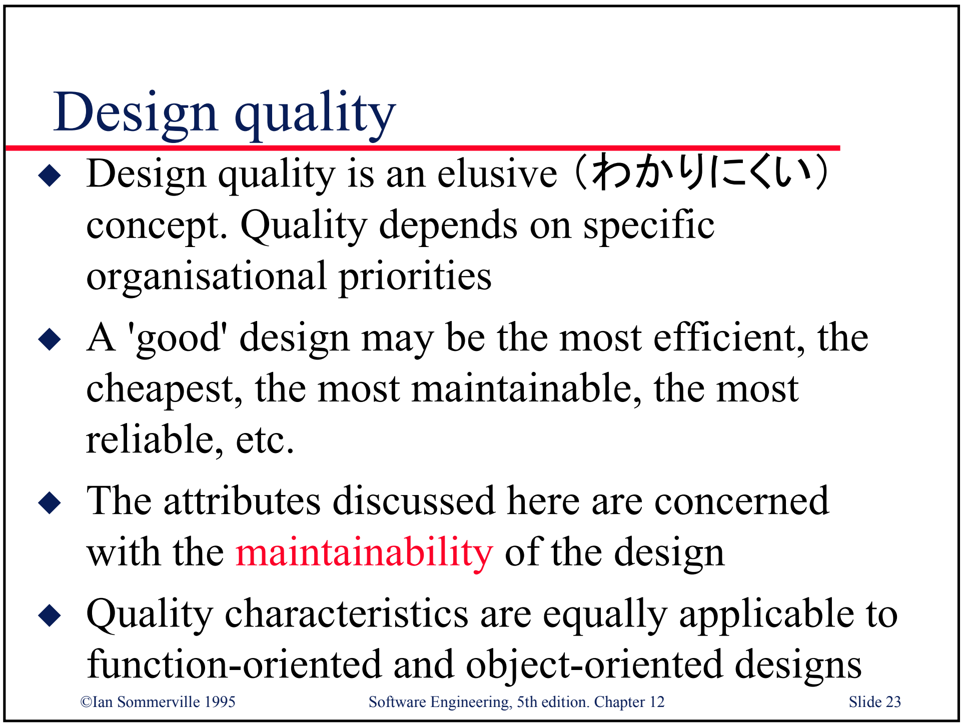
- The navigation system
- The radar system
- The communications system
- The instrument display system
- The engine control system
- ...

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)
- ...

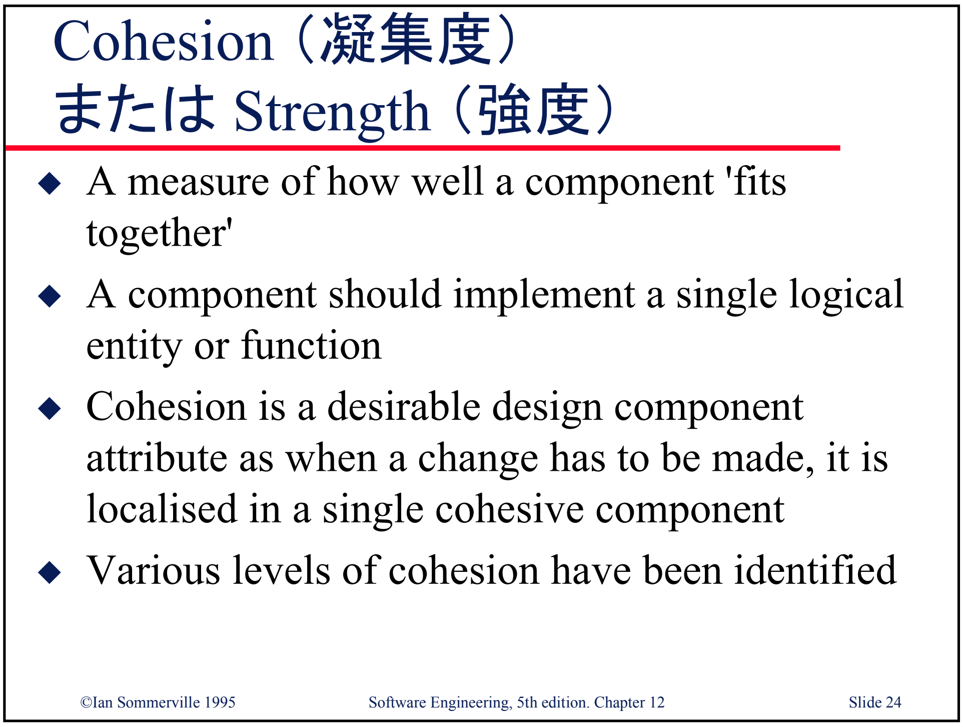
Low-level objects

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



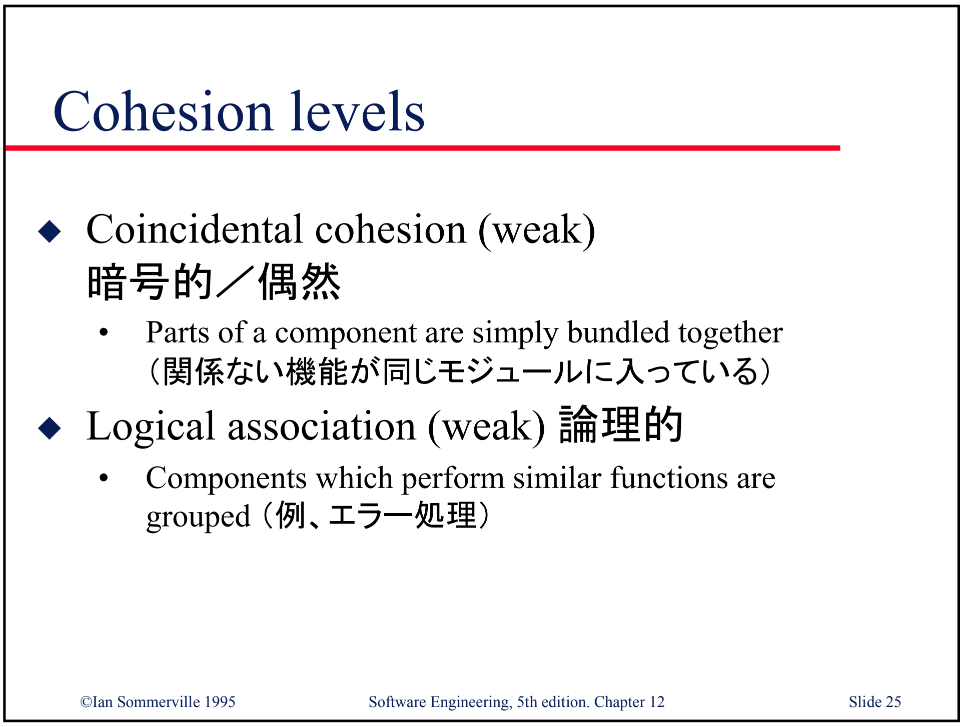
Design quality

- Design quality is an elusive（わかりにくい）concept. Quality depends on specific organisational 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



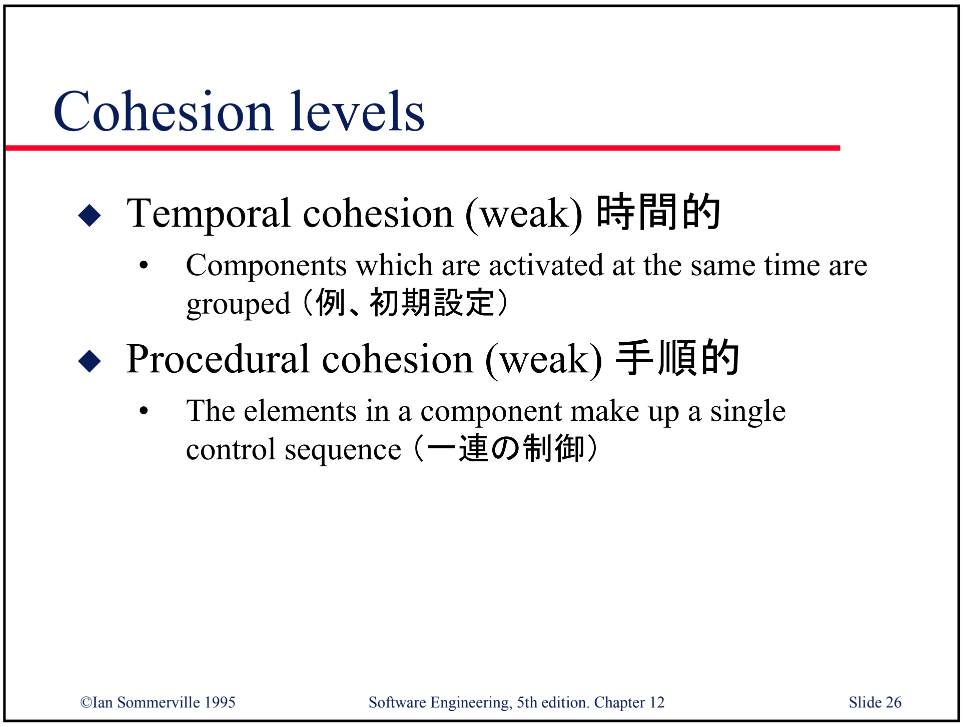
Cohesion（凝集度）
または Strength（強度）

- 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 localised in a single cohesive component
- Various levels of cohesion have been identified



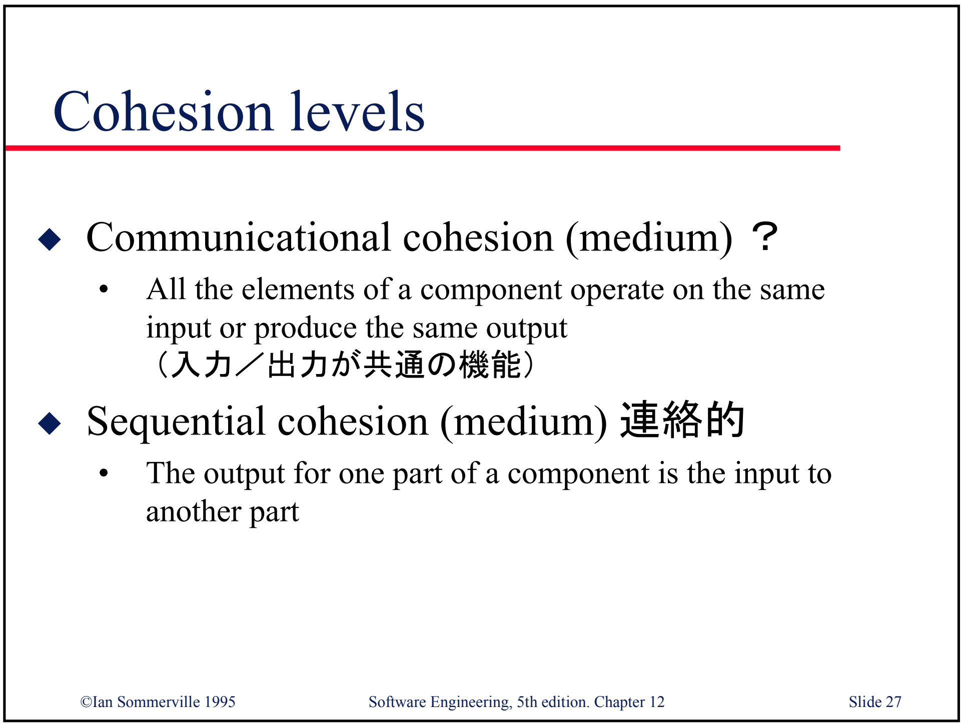
Cohesion levels

- Coincidental cohesion (weak)
  暗号的／偶然
  - Parts of a component are simply bundled together （関係ない機能が同じモジュールに入っている）
- Logical association (weak) 論理的
  - Components which perform similar functions are grouped（例、エラー処理）



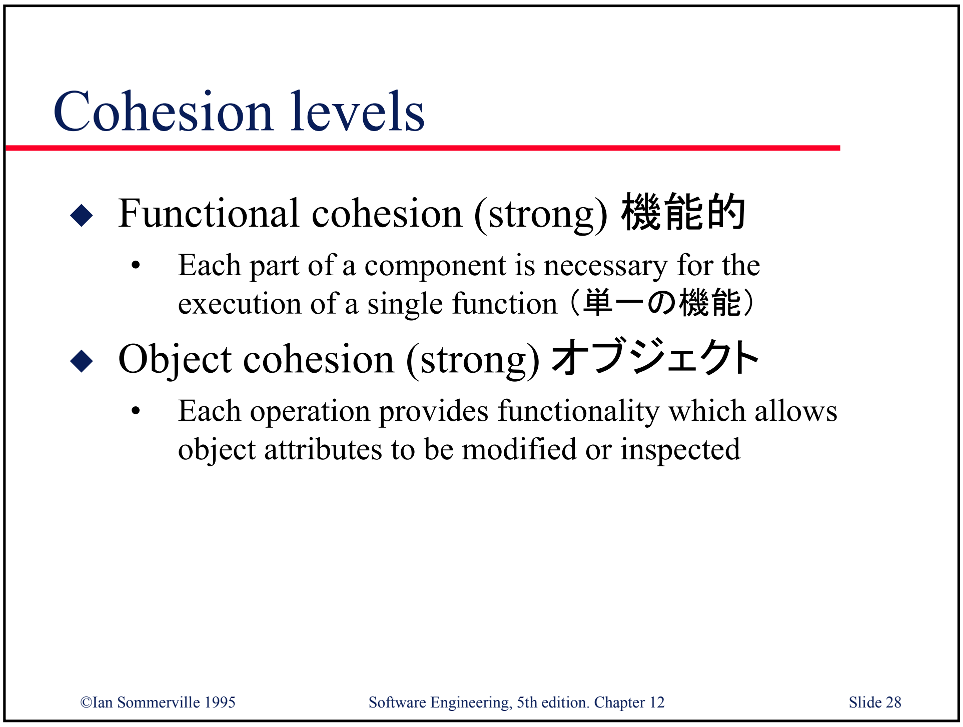
Cohesion levels

- Temporal cohesion (weak) 時間的
  - Components which are activated at the same time are grouped（例、初期設定）
- Procedural cohesion (weak) 手順的
  - The elements in a component make up a single control sequence（一連の制御）



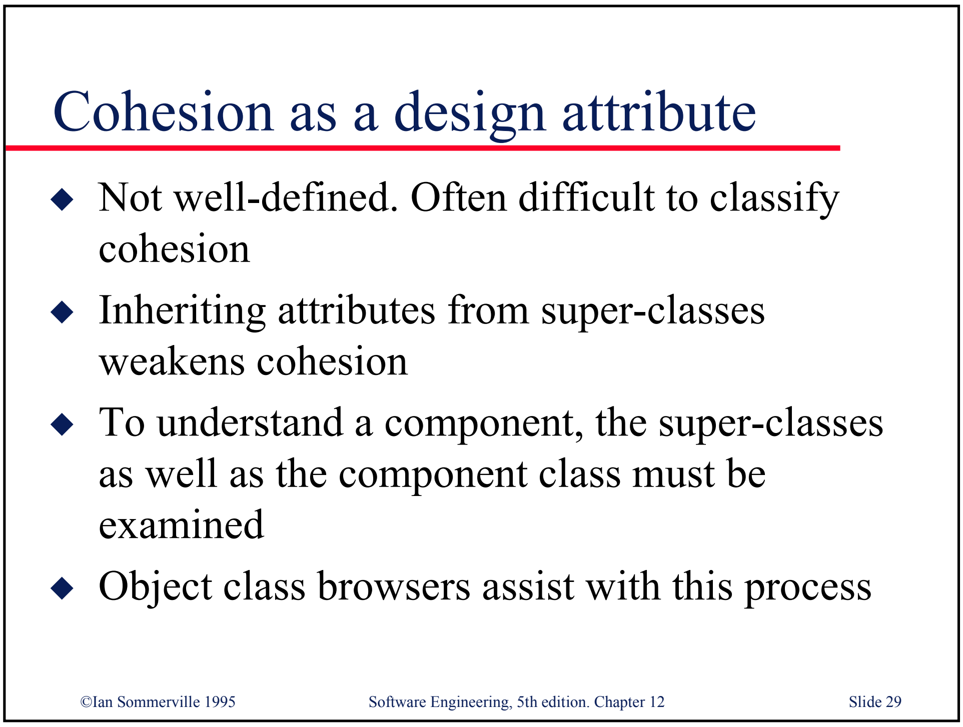
Cohesion levels

- Communicational cohesion (medium) ？
  - All the elements of a component operate on the same input or produce the same output （入力／出力が共通の機能）
- Sequential cohesion (medium) 連絡的
  - The output for one part of a component is the input to another part



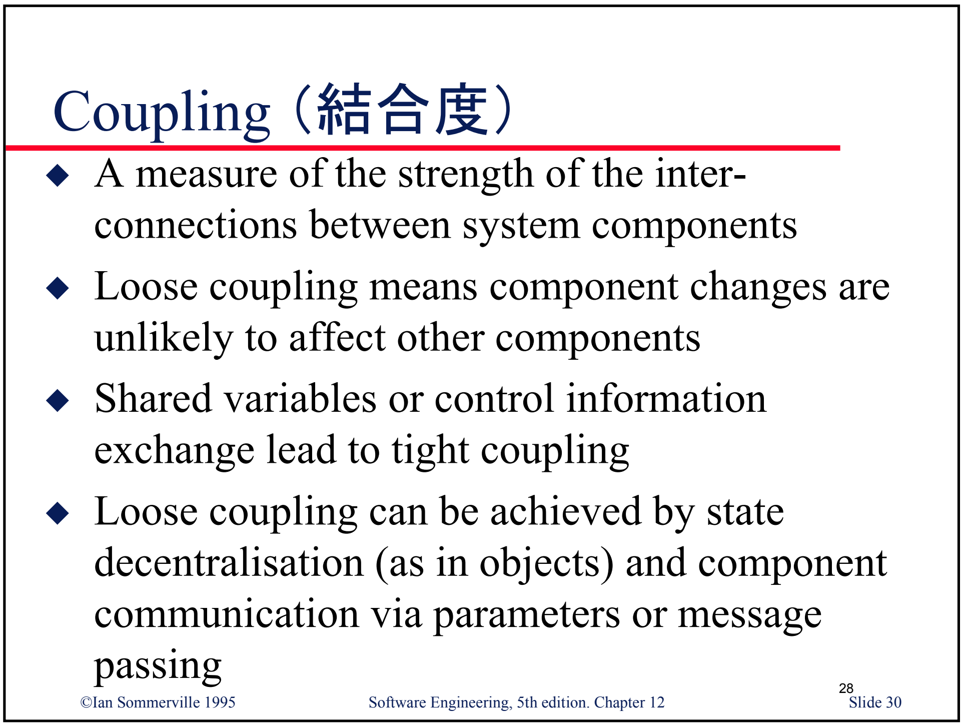
Cohesion levels

- Functional cohesion (strong) 機能的
  - Each part of a component is necessary for the execution of a single function（単一の機能）
- Object cohesion (strong) オブジェクト
  - Each operation provides functionality which allows object attributes to be modified or inspected



Cohesion as a design attribute

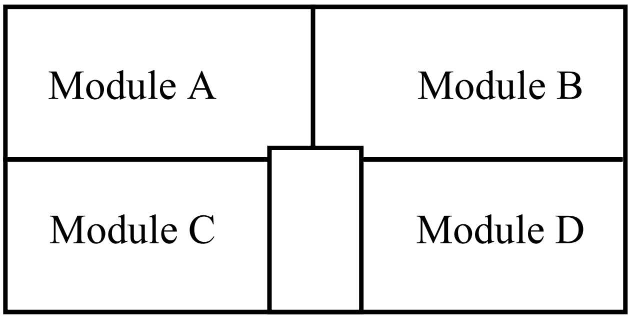
- Not well-defined. Often difficult to classify cohesion
- Inheriting attributes from super-classes weakens cohesion
- To understand a component, the super-classes as well as the component class must be examined
- Object class browsers assist with this process



Coupling（結合度）

- 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 decentralisation (as in objects) and component communication via parameters or message passing

Tight coupling



Module A

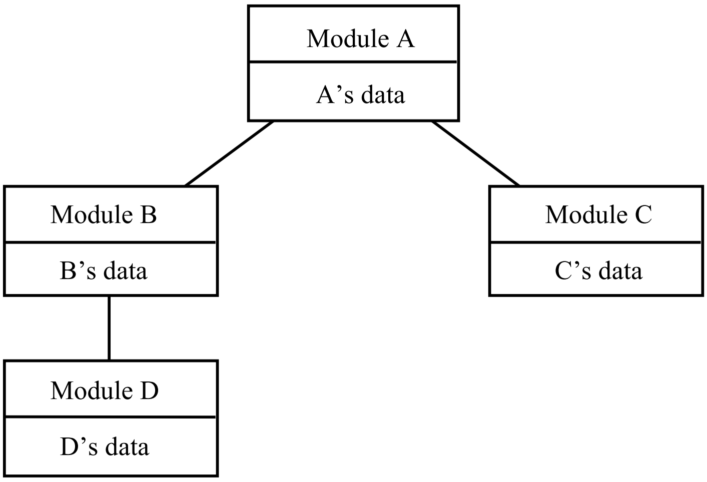
Module B

Module C

Module D

Shared data area

Loose coupling



Module A

A’s data

Module B

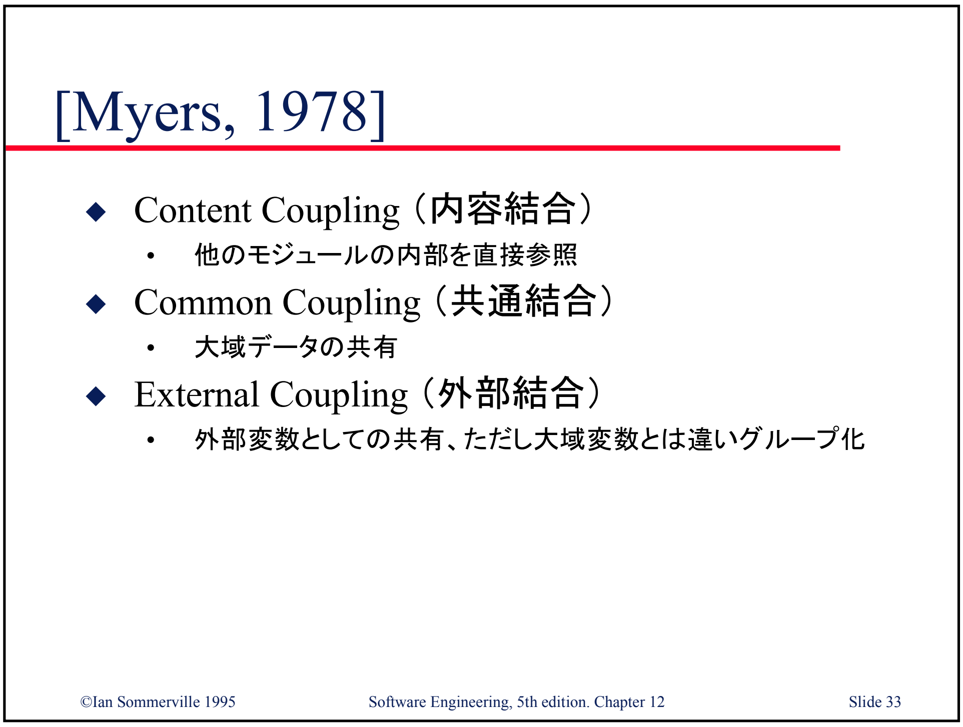
B’s data

Module C

C’s data

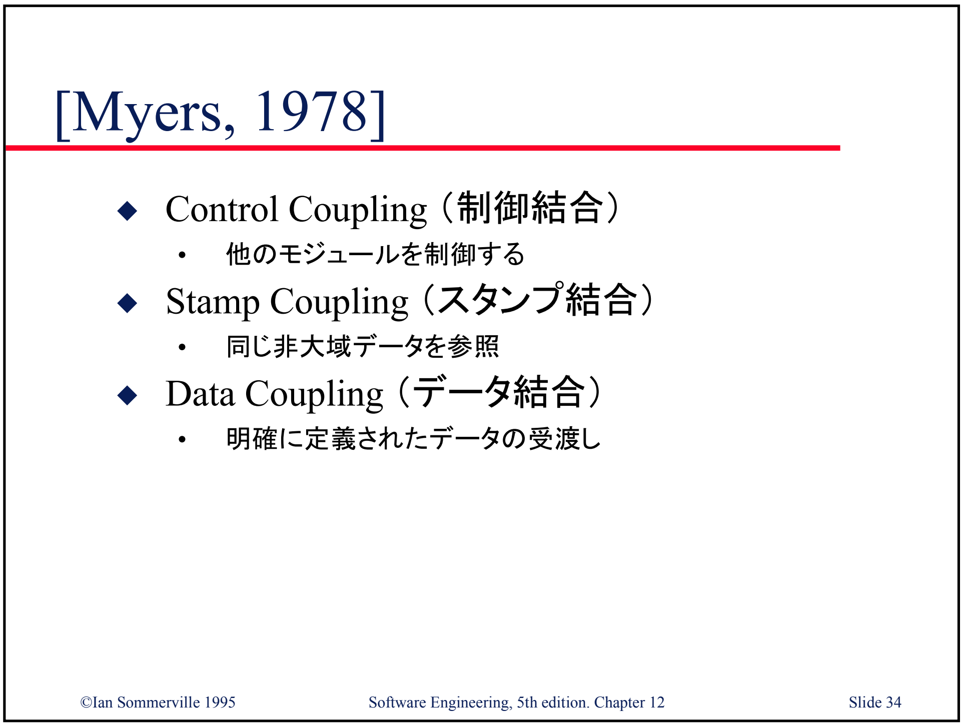
Module D

D’s data



[Myers, 1978]

- Content Coupling（内容結合）
  - 他のモジュールの内部を直接参照
- Common Coupling（共通結合）
  - 大域データの共有
- External Coupling（外部結合）
  - 外部変数としての共有、ただし大域変数とは違いグループ化



[Myers, 1978]

- Control Coupling（制御結合）
  - 他のモジュールを制御する
- Stamp Coupling（スタンプ結合）
  - 同じ非大域データを参照
- Data Coupling（データ結合）
  - 明確に定義されたデータの受渡し

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

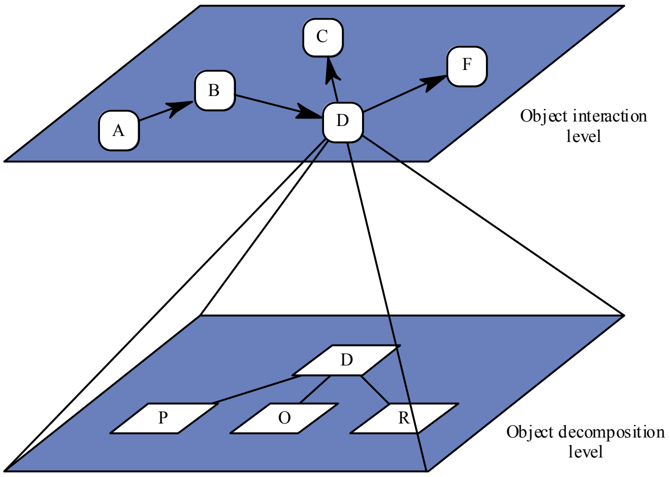
Understandability

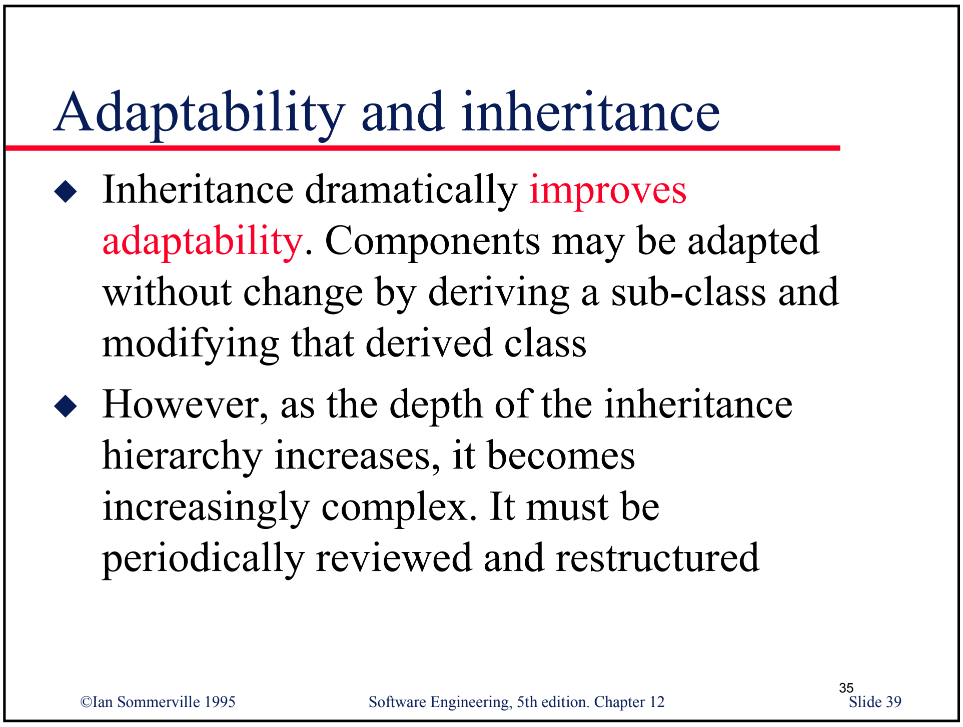
- Related to several component characteristics
  - *Cohesion*. Can the component be understood on its own?
  - *Naming*. Are meaningful names used?
  - *Documentation*. Is the design well-documented?
  - *Complexity*. Are complex algorithms used?
- Informally, high complexity means many relationships 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 analysed

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