Design Overview

- Design is a trial-and-error process
- The process is not the same as the outcome of that process
- There is an interaction between requirements engineering and design

Software Design Caveats

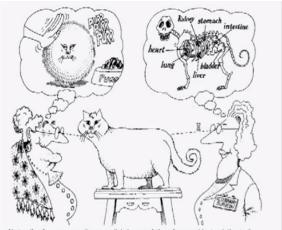
- There is no definite formulation
- There is no stopping rule
- Solutions are not simply true or false

Software Design Principles

- Abstraction
- Modularity, coupling, and cohesion
- Information hiding
- Limited complexity
- Hierarchical structure

Abstraction

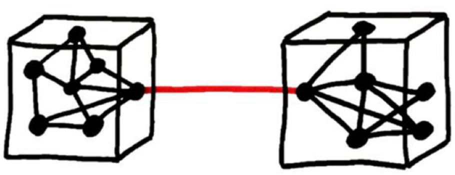
- Procedural abstraction
  - A natural consequence of stepwise refinement
  - Name of procedure denotes the sequence of actions
- Data abstraction
  - Goal is to find a hierarchy in the data (e.g., the range from general purpose data structures to application-oriented data structures)



Abstraction focuses upon the essential characteristics of some object, relative to the perspective of the viewer.

Modularity

- Modularity identifies structural criteria that tell something about individual modules and their interconnections
- Key concepts: cohesion and coupling
  - Cohesion: the glue that keeps a module together
  - Coupling: the strength of the connections between modules



聚合：使模块内部粘合
成对：模块之间的关联强度

Information Hiding

- Information hiding is a principle for breaking a program into modules

Design decisions that are likely to change independently should be ***secrets*** *of separate modules*

The only assumptions that should appear in the ***interfaces*** *between modules are those that are considered unlikely to change*

- Each module has a secret
- The design involves a series of decisions
  - For each decision, consider what other modules need to know and what others can be kept in the dark
- Information hiding is strongly related to
  - Abstraction: if you hide something, the user may abstract from that fact
  - Coupling: the secret decreases coupling between a module and the environment
  - Cohesion: the secret is what binds the parts of the module together

信息隐藏需将程序分成模块

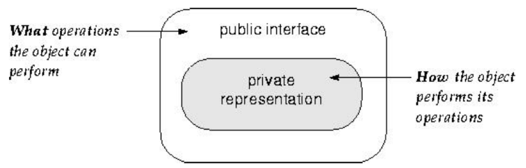
不同模块的设计是独立的且相互隐藏

接口的内容是不太会改变的.

Motivation for Information Hiding

- A fundamental cost in software engineering is accommodating change
  - Changes that require modifications to more modules are more costly than changes that are isolated to single modules
- The goal:
  - Anticipate likely changes
  - Define interfaces that capture the stable aspects and implementations that capture the changeable aspects

实际上是为了解耦



Example

```
double sqrt (int)
```

- Can be implemented using bisection methods, Newton's method, factoring, etc.
- The client doesn't care (or need to know) how it is implemented
- The implementation ought to be able to change entirely without impacting the client code (and requiring only relinking)

在不同的地方该函数可能有不同

但是用户不关心具体是如何实现的.

Design Case Study: Key Word in Context (KWIC)

- "The KWIC [Key Word in Context] index system accepts an ordered set of lines, each line is an ordered set of words, and each word is an ordered set of characters. Any line may be "circularly shifted" by repeatedly removing the first word and appending it at the end of the line. The KWIC index system outputs a listing of all circular shifts of all lines in alphabetical order."
  - Parnas 1972

- Consider KWIC applied to the title of this slide:

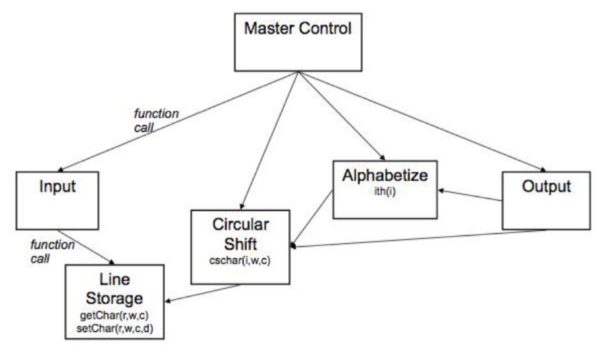
	→	
Design Case Study:		(KWIC) Key Word In Context
Case Study: Design		Case Study: Design
Study: Design Case		Context (KWIC) Key Word In
Key Word In Context (KWIC)		Design Case Study:
Word In Context (KWIC) Key		In Context (KWIC) Key Word
In Context (KWIC) Key Word		Key Word In Context (KWIC)
Context (KWIC) Key Word In		Study: Design Case
(KWIC) Key Word In Context		Word In Context (KWIC) Key

Modularization #1

This is a modularization in the sense meant by all proponents of modular programming. The system is divided into a number of modules with well-defined interfaces; each one is small enough and simple enough to be thoroughly understood and well programmed. Experiments on a small scale indicate that this is approximately the decomposition which would be proposed by most programmers for the task specified.

Changes	MasterControl	Input	CircularShift	Alphabetizer	Output
InputFormat		X			
Storage		X	X	X	X
Packing characters		X	X	X	X
Index for CircularShift			X	X	X
Search				X	X

KWIC Modularization #2 (Information Hiding)



Modularization #2

- Line storage abstracts the storage/representation of the input
- Circular shift is analogous to the circular shift in modularization #1, but…
  - The module gives the *impression* that we have a line holder creating all of the circular shifts

Changes	Master Control	Input	Circular Shift	Alphabetizer	Output	LineStorage
InputFormat						
Storage						
Packing characters						
Index for CircularShift						
Search						
Line Storage		X	X	X	X	

KWIC Observations

- Similar at runtime
  - May have identical data representations, algorithms, even compiled code
- Different in code
  - Understanding
  - Documenting
  - Evolving
- The two versions are different in the way they divide work assignments and the interfaces between the modules

But Software Changes …

- "… accept the fact of change as a way of life, rather than an untoward and annoying exception."
  - Brooks 1974

- "Software that does not change becomes useless over time."
  - Belady and Lehman

- For successful software projects, most of the cost is in evolving the system, not in initial development
  - Therefore, reducing the cost of change is one of the most important principles in software design

Other Compounding Factors

- Independent development
  - Data formats (in design #1) are more complex than data access interfaces (in design #2)
  - Easier to agree on the interfaces in design #2
  - More work in design #2 is independent (because less is shared)
- Comprehensibility
  - Design of data formats in design #1 depends on the details of each module (and vice versa)
  - More difficult to understand each module in isolation in design #1

Summary: Decomposition Criteria

- Functional decomposition
  - Break down by major processing steps
- Information hiding decomposition
  - Each module is characterized by a design decision it hides from others
  - Interfaces chosen and designed to reveal as little as possible about the hidden secrets

Information Hiding Summary

- Decide what design decisions are likely to change and which are likely to be stable
- Put each design decision likely to change in its own module
- Assign each module an interface that hides the decision likely to change and exposes only stable design decisions
- Ensure that the clients of a module depend only on the stable interface and not the implementation

- Benefit: ***if*** you can correctly predict what may change and hide information properly, each change will affect one module

Types of Secrets

- Algorithms (procedural abstraction)
- Data representations (abstract data types)
- Characteristics of a hardware device (virtual machines, hardware abstraction layers, etc.)
  - E.g., whether a thermometer measures in Fahrenheit or Celsius
- Where information is acquired
  - E.g., which search engine is used
- User interface (e.g., model-view pattern)

- What are other examples?
  - What about in the context of your projects?