Detailed Design

(Chapter 7)

Software Design

- Process of converting the requirements into the design of the system.
- Definition of how the software is to be structured or organized.
- For large systems, this is divided into two parts:
  - **Architectural design** defines main components of the system and how they interact.
  - **Detailed design** components are decomposed and described at a much finer level of detail.

Design and Implementation

- Software **Design**:
  - Creative activity, in which you:
  - Identify software components and their relationships
  - Based on requirements.
- **Implementation** is the process of realizing the design as a program.
- Design may be
  - Documented in UML (or other) models
  - Informal sketches (whiteboard, paper)
  - In the programmer's head.
- How detailed and formal it is depends on the process that is in use.

Design Processes

- Functional Decomposition
  - aka: Top down design
- Relational Database Design
- Object-oriented design and UML
  - class diagrams
  - state diagrams
  - etc.
- [User Interface design]

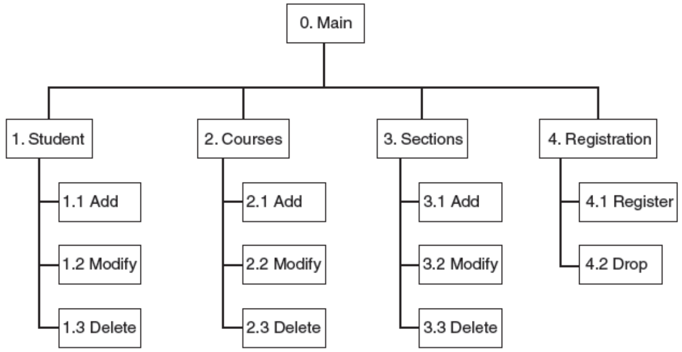
Functional Decomposition

- Used in **structural programming** (aka procedural programming)
  - Start with a “main module”
  - Repeatedly decompose into sub-modules.
  - Lowest level modules can be implemented as functions.
- Can be used in Object-oriented design
  - to do initial decomposition of a system
  - to decompose methods that are particularly hard to implement.

Functional Decomposition: example student registration system

- Design a system for managing course registration and enrollment.
- Requirements specify four tasks
  - add, modify and delete students from the database
  - add, modify and delete courses from the database
  - add, modify, and delete sections for a given course
  - register and drop students from a section.
- Main module divided into four submodules (students, courses, sections, registration)
- Decompose each into its tasks.

Functional Decomposition: example student registration system



Relational Database Design

- Many software systems must handle large amounts of data
- Data is stored in tables
  - row corresponds to an object or entity
  - columns correspond to attributes of the entities
  - (basically an array of structs)
- Structured Query Language (SQL), a set of statements that
  - create the tables
  - add and modify data in the tables
  - retrieve data that match specified criteria

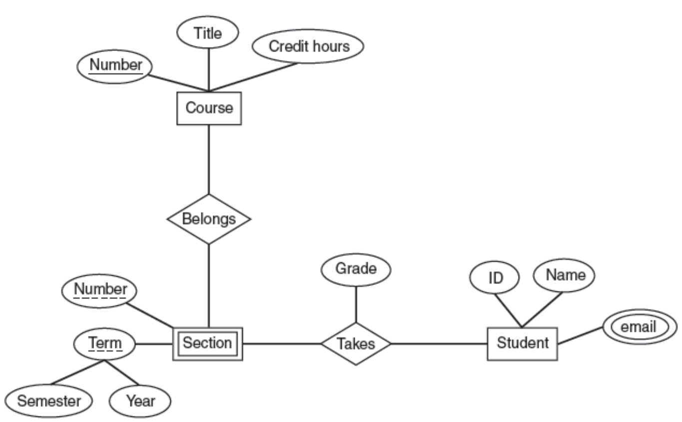
Relational Database Design

- Database design concentrates on
  - how to represent the data of the system, and
  - how to store it efficiently
- Data modeling
  - create a model showing the entities with their attributes, and how the entities are related to each other
- Logical database design
  - maps the model to a set of tables
  - relationships are represented via attributes called foreign keys
- Physical database design
  - deciding on types of attributes, how tables are stored, etc.

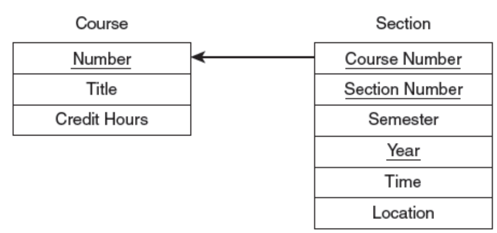
Relational Database Design

- Data modeling: ER diagram
  - Entities: rectangles
  - Attributes: ovals
  - Relationships: diamonds
- Identifier
  - attribute that has a unique value for each entity (underlined)
- Multi-valued attribute
  - can have several values at one time (double oval)
  - i.e. email addresses,

Relational Database design: ER diagram student registration system

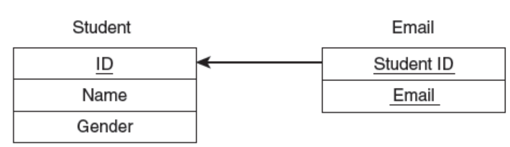


Student registration system: tables



Course Number is a foreign key, used to implement the “Belongs” relationship

Figure 7.12 A relational schema diagram for course and section.



Student ID is a foreign key, used to implement the multi-valued attribute

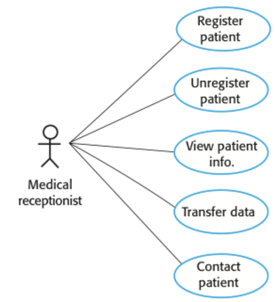
Figure 7.13 A relational schema diagram for students and email.

Object-oriented design

- Object-oriented system is made up of interacting objects
  - Maintain their own local state (private).
  - Provide operations over that state.
- Object-oriented design process involves
  - Designing classes (for objects) and their interactions.
- Previous to the design phase:
  - Requirements are usually expressed using use cases and use case diagrams.
  - Preliminary class diagrams have often been produced during requirements analysis.

1 Requirements elicitation

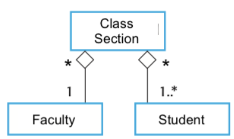
- Client and developers define the purpose of the system:
  - Develop use cases
  - Determine functional and non-functional requirements
- Major activities
  - Identifying actors.
  - Identifying scenarios.
  - Identifying use cases.
  - Refining use cases.



Use case diagrams

2 Object Oriented Analysis

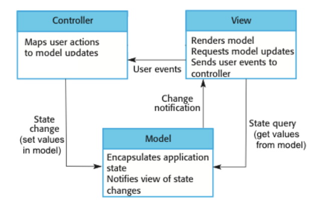
- Developers aim to produce a model of the system
  - Model is a class diagram
  - Describing real world objects (only)



- Goal: transform use cases to objects
- Major activities
  - Identifying objects: entities from the real world
    - Look for nouns in use cases
  - Drawing the class diagram, with relationships
  - Drawing state diagrams as necessary

3 System Design (architecture)

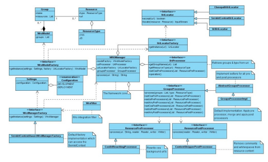
- Developers decompose the system into smaller subsystems



- Major activities
  - Identify major components of the system and their interactions (including interfaces).
    - Use architectural patterns
  - Identify design goals (non-functional requirements)
  - Refine the subsystem decomposition to address design goals

4 Object Design

- Developers complete the object model by adding implementation classes to the class diagram.



- Major activities
  - Interface specification: define public interface of objects
  - Reuse:
    - frameworks, existing libraries (code)
    - design patterns (concepts)
  - Restructuring: maintainability, extensibility

5 Implementation

- Developers translate the class diagram into source code.
- Goal: map object model to code.

```
#include <string>
#include <iomanip>
#include <sstream>
#include<iostream>
using namespace std;

// models a 12 hour clock
class Time        //new data type
{
private:
    int hour;
    int minute;
    void addHour();

public:
    void setHour(int);
    void setMinute(int);
    int getHour() const;
    int getMinute() const;

    string display() const;
    void addMinute();
};

// class function implementations

void Time::setHour(int hr) {
    hour = hr;           // hour is a member var
}
void Time::setMinute(int min) {
    minute = min;        // minute is a member var
}
int Time::getHour() const {
    return hour;
}
int Time::getMinute() const {
    return minute;
}

void Time::addHour() {  // a private member func
    if (hour == 12)
        hour = 1;
    else
        hour++;
```

- Major activities
  - Map classes in model to classes in source language
  - Map associations in model to collections in source language
    - OO languages don’t have “associations”
    - tricky: maintaining bidirectional associations
  - Refactoring

Design characteristics and metrics

- Some characteristics of a good software design:
  - Consistency:
    - ensure common terminology used across software elements.
    - common approach to help facility
    - common approach to error detection and diagnostic processing
  - Completeness:
    - All the requirements must be in the design
    - Design must include enough detail for the developers to know what to do.

Legacy characteristics of design attributes

- Targeted at detail design and coding level
- **Halstead Complexity Metric**
  - analyzes source code
  - n1 = number of distinct operators
  - n2 = number of distinct operands
  - N1 = total number of operators (counting duplicates)
  - N2 = total number of operands (counting duplicates)
- From these numbers, we calculate
  - Program vocabulary: n = n1+n2
  - Program length: N = N1+N2

Halstead Complexity Metric, cont.

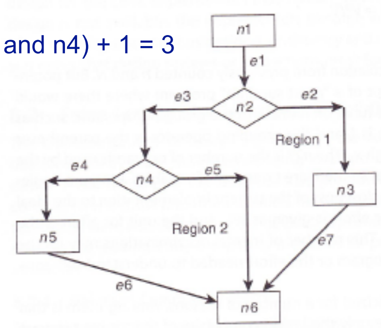
- Three more measurements
  - Volume: V = N * (Log2 n)
  - Difficulty: D = n1/2 * N2/n2
    The difficulty to write or understand the program
  - Effort: E = D * V
    A measure of actual coding time.
- Criticisms:
  - These metrics really measure only the lexical complexity of the source program and not the structure or the logic.
  - Therefore not useful for analyzing design characteristics.

McCabe's Cyclomatic Complexity

- Basic idea: program quality is directly related to the complexity of the control flow (branching)
- Computed from a control flow diagram
  - Cyclomatic complexity = E - N + 2p
  - E = number of edges of the graph
  - N = number of nodes of the graph
  - p = number of connected components (usually 1)
- Alternate computations:
  - number of binary decision + 1
  - number of closed regions +1

McCabe's Cyclomatic Complexity example

- Using the different computations:
  - 7 edges - 6 nodes + 2*1 = 3
  - 2 regions + 1 = 3
  - 2 binary decisions (n2 and n4) + 1 = 3



McCabe's Cyclomatic Complexity

- What does the number mean?
- It's the maximum number of linearly independent paths through the flow diagram
  - used to determine the number of test cases needed to cover each path through the system
- The higher the number, the more risk exists (and more testing is needed)
  - 1-10 is considered low risk
  - greater than 50 is considered high risk

Good Design attributes

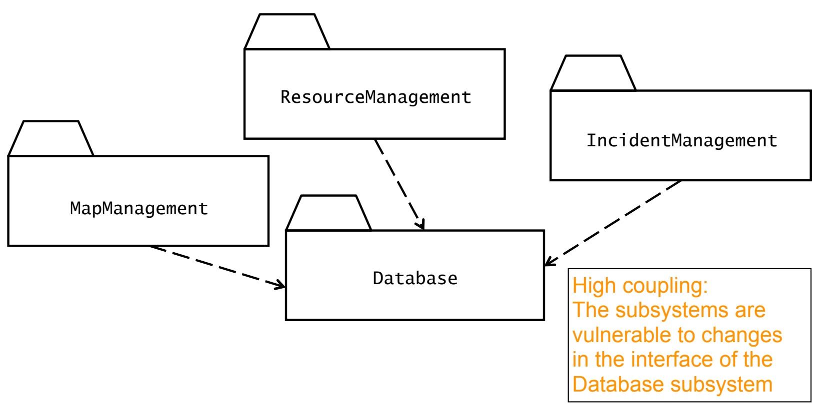
- Main goal: Simplicity
  - Easy to understand
  - Easy to change
  - Easy to reuse
  - Easy to test
  - Easy to code
- How do we measure simplicity of a design?
  - Coupling (goal: loose coupling)
  - Cohesion (goal: strong cohesion)

Coupling

- **Coupling** is the number of dependencies between two subsystems.
  - It measures the dependencies between two subsystems.
- If two subsystems are loosely coupled, they are relatively independent
  - Modifications to one of the subsystems will have little impact on the other.
- If two subsystems are strongly coupled, modifications to one subsystem is likely to have impact on the other.
- **Goal**: subsystems should be as loosely coupled as is reasonable.

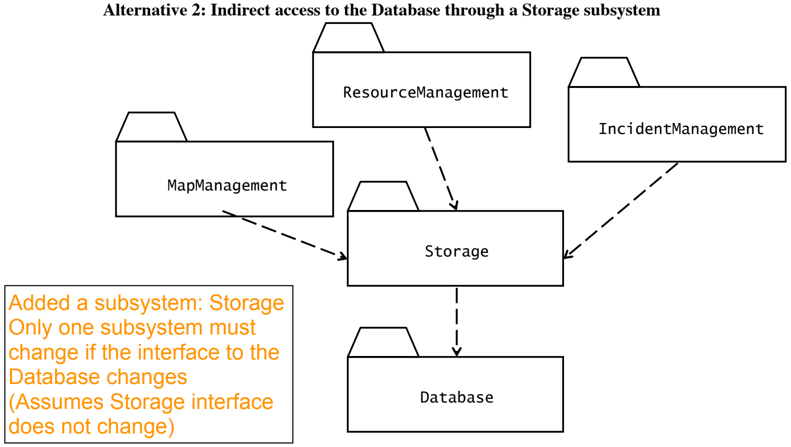
Example: reducing the coupling of subsystems

Alternative 1: Direct access to the Database subsystem



Example: reducing the coupling of subsystems

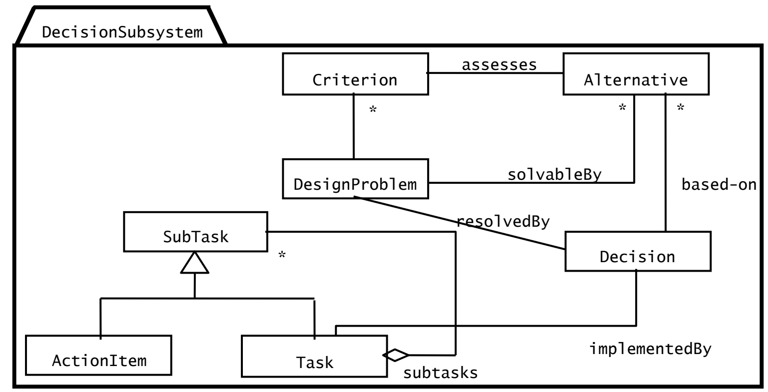
Alternative 2: Indirect access to the Database through a Storage subsystem



Cohesion

- **Cohesion** is the number of dependencies within a subsystem.
  - It measures the dependencies among classes within a subsystem.
- If a subsystem contains many objects that are related to each other and perform similar tasks, its cohesion is high.
- If a subsystem contains a number of unrelated objects, its cohesion is low.
- **Goal**: decompose system so that it leads to subsystems with high cohesion.
  - These subsystems are more likely to be reusable

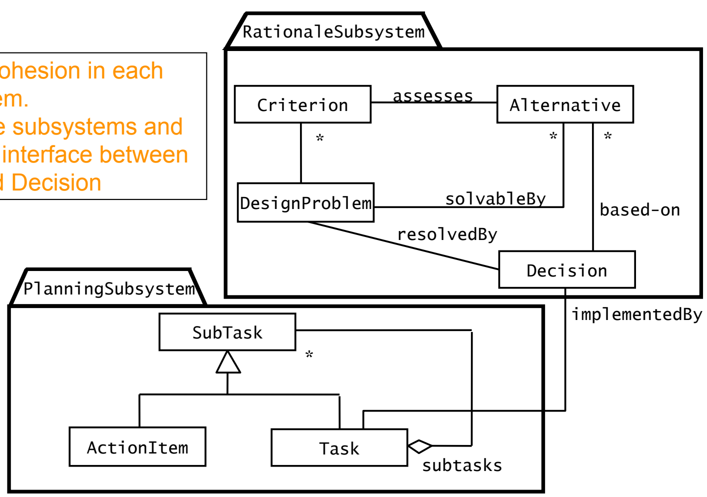
Example: Decision tracking system



Low Cohesion:
Criterion, Alternative, and DesignProblem have No relationships with SubTask, ActionItem, and Task

Alternative decomposition: Decision tracking system

Higher cohesion in each subsystem.
But more subsystems and an extra interface between Task and Decision



Law of Demeter

- Good guideline for object-oriented design
- An object should send messages to only the following
  - the object itself
  - the objects attributes (instance variables)
  - the parameters of member functions of the object
  - Any object created by this object
  - Any object returned from a call to one of this objects member function
  - Any object in any collection that is in one of the preceding categories.
- "Only talk to your immediate neighbors"
  "Don't talk to strangers"