Overview

Problem specification
- Obstacles

Program design
- How to divide work
- Interface & conditions
Problem Specification

Goal
- Create complete, accurate, and unambiguous statement of problem to be solved

Problems
- Description may not be accurate
- Description may change over time
- Difficult to specify behavior for all inputs
- Natural language description is imprecise
- Formal specification languages limited and difficult to understand
Problem Specification

Example

Specification of input & output for program

Legal Inputs $X$ → Program $P$ → Expected Outputs $Y$

$P(X) = Y$

Legal Inputs $X$ → Program $P$ → Expected Outputs $Y$

Unexpected and Illegal Inputs $X'$ → Program $P$

$P(X') = Y'$

Errors, Warnings, and Unexpected Outputs $Y'$
Problem Specification Problems

- Description may not be accurate
  - Problem not understood by customer
- Description may change over time
  - Customer changes their mind
- Difficult to specify behavior for all inputs
  - Usually only covers common cases
  - Hard to consider all inputs (may be impossible)
  - Example
    - Most UNIX utilities crash with random inputs
Problem Specification Problems

- Description may be ambiguous
  - Natural language description is imprecise
    - Why lawyers use legalese for contracts
  - Formal specification languages are limited and may be difficult to understand
- Examples
  - Find sum of all values in N-element list $L$ between 1 and 100
    $$\sum_{i=0}^{N-1} L_i \in (L_i \geq 1) \land (L_i \leq 100)$$
  - Difficult to write specifications that are both readable and precise
Program Design

Goal
- Break software into integrated set of components that work together to solve problem specification

Problems
- Methods for decomposing problem
  - How to divide work
  - What work to divide
- How components work together
Design – How To Divide Work

Decomposing problem

- Break large problem into many smaller problems
- Cannot solve large problems directly

Divide and conquer

1. Break problem up into simpler sub-problems
2. Repeat for each sub-problem
3. Stop when sub-problem can be solved easily
Design – How To Divide Work

Functional approach

- Treat problem as a collection of functions

Techniques

- Top-down design
  - Successively split problem into smaller problems
- Bottom-up design
  - Start from small tasks and combine
Design – Decomposition Example

Top-down design of banking simulator

[Diagram showing decomposition of banking simulator into sub-processes: Arrivals, Departures, Transactions, Print Results, Input Transaction, Validate, Process Deposit, Process Withdrawal]
Design – How To Divide Work

Object-oriented approach

- Treat problem as a collection of data objects
- Objects
  - Entities that exist in problem
  - Contain data
  - Perform actions associated with data
Bank simulation
- Functional programming
  - Arrivals, departures, transactions
- Object-oriented programming
  - Customers, lines, tellers, transactions
Design – Comparing Approaches

- **Functional approach**
  - Treat problem as a collection of functions
  - Functions perform actions
  - Think of functions as verbs

- **Object-oriented approach**
  - Treat problem as a collection of data objects
  - Objects are entities that exist in problem
  - Think of objects as nouns
Design – Comparing Approaches

Advantages to object-oriented approach
- Helps to abstract problem
  - Simpler high-level view
- Helps to encapsulate data
  - Hides details of internals of objects
  - Centralizes and protects all accesses to data
- Seems to scale better for larger projects

In practice
- Tend to use a combination of all approaches
Design – Components

Components must work together easily

Each component requires

- Interface
  - Specifies how component is accessed & used
  - Specifies what functions (methods) are available
- Pre-conditions
  - What conditions must be true before invocation
- Post-conditions
  - What conditions will be true after invocation

Pre & post conditions represent a contract between designer & programmer
Design – Interface & Conditions

- Function positivePower()
  - Calculate $x^n$ for positive values of $x$ & $n$

- Interface
  - `public static float positivePower(float x, int n)`

- Pre-conditions
  - $x$ has positive floating point value $> 0.0$
  - $n$ has positive integer value $\geq 0$

- Post-conditions
  - Returns $x^n$ if preconditions are met
  - Returns $-1.0$ otherwise