

Course Outline

- Goals:
 1. Learn the commonly used data structures
 2. To learn how to measure the merits of these data structures
 3. To learn/reinforce the concept that every data structure has costs and benefits
- Methodology:
 - ☐ Algorithm analysis techniques
 - ☐ Algorithm design techniques
 - ☐ Implementation/analysis of data structures:
 - Lists, stacks, and queues
 - Trees
 - Hashing
 - Priority queues (heaps)
 - Sorting
 - Graphs

Why Study Data Structures?

Any organization for a collection of records can be searched, processed in any order, or modified.

- Data structures organize data:
 - ☐ Good choice: more efficient programs
 - ☐ Bad choice: poor program performance
 - The choice can make a difference between the program running in a few seconds or many days
- Justification: over time, there are
 - ☐ More powerful computers
 - ☐ More complex applications
 - ☐ Complex tasks unlike everyday experience
- Characteristics of a problem's solution
 - ☐ efficient: if it solves problem within resource constraints
 - time
 - space
 - ☐ Cost: amount of resources a solution consumes

Why Study Algorithms?

- Algorithms solve problems
 - ☐ Good choice: more efficient programs
 - ☐ Bad choice: poor program performance
 - ☐ Example:
 - Selection problem: find the largest k out of N integers
 - Easy algorithm: sort all integers, then list the first (or last) k
 - Better algorithm: sort first k then read through the list...
 - ☐ Different algorithms perform better on different inputs
 - ☐ Input *size* can also affect the performance

Algorithm Design Techniques

Most chapters focus on *implementation* of algorithms. The *design* of algorithms is also an important focus.

- Types of algorithms:
 - ☐ Greedy algorithms
 - ☐ Divide and Conquer
 - ☐ Dynamic programming
 - ☐ Randomized algorithms
 - ☐ Backtracking

Abstract Data Types

- Basic definitions:
 - ☐ **type**: a set of objects
 - ☐ **data item** or **element**: a piece of information or a record
 - ☐ **member**: a data item is said to be a *member* of a data type
 - ☐ **simple data item**: a data item containing no subparts.
 - ☐ **aggregate data item**: a data item that may contain several pieces of information
 - ☐ **abstract data type**: a type and a collection of operations to manipulate that type

ADTs are mathematical abstractions; an ADT only mentions what is to be done, not how.

Data Structure

- A *data structure* is the physical implementation of an ADT.
 - ☐ Each ADT operation is implemented by one or more subroutines
 - ☐ Data structures are organizations for data in main memory
- File structures organize data on peripheral storage

Selecting a Data Structure

- Analyze the problem to determine its basic operations
- Quantify the resource constraints for each operation
- Select a data structure best meeting these requirements
- Some questions to consider:
 - ☐ At what time(s) in the program run do inserts occur
 - ☐ Are deletes allowed?
 - ☐ Is there any order to the data processing?

Algorithm/Data Structure Philosophy

- Each data structure requires:
 - ☐ space to store each item, including *overhead*
 - ☐ time to perform basic operations
 - ☐ programming effort
- Algorithms are closely related:
 - ☐ poor data structure choice can make *higher complexity* algorithm
 - ☐ good data structure choice can make the algorithm trivial

Problems, Algorithms, and Programs

What is the difference among these?

- Key questions that relate:
 - ☐ Can a problem be solved efficiently?
 - ☐ What is efficient?
 - ☐ Which algorithms are more efficient?
 - ☐ How to answer the above?
 - ☐ How to estimate the time required for a program
 - ☐ How to reduce the running time of a program
 - ☐ The consequences of careless use of recursion

Problems

- **Problem:** a task to be performed
 - ☐ One view: a set of inputs and matching outputs
 - ☐ Problem definition includes resource constraints
- Problems are analagous to mathematical functions
 - ☐ **Function:** mapping of inputs (*domain*) to outputs (*range*)
 - ☐ The input to a function can vary:
 - single number
 - multiple numbers
 - set of information
 - ☐ **Parameters:** the values making up an input
 - ☐ A given input must always map to the same output

Algorithms and Programs

Algorithm: a method or process followed to solve a problem

- Algorithm transforms the input of a problem to its output
- Algorithm properties:
 1. It must be correct
 2. It must be composed of a series of concrete steps
 3. There can be no ambiguity about which step is next
 4. It must be finite in length
 5. It must terminate
- **Program:** an instance of an algorithm, written in some programming language