Introduction

CSE 326
Data Structures
Lecture 1

Administrative

- Instructor
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- TA
  - › Ian Simon
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- Class info is on the web site
  - › http://www.cs.washington.edu/326
  - › also known as
    - http://www.cs.washington.edu/education/courses/326/05au
- Email Lists
  - › cse326 (must signup to receive announcements)
  - › Cse326-open (optional for class discussion)

Office Hours

- Richard Ladner – CSE 632
  - › Mondays 1 to 2:30 or by appointment
- Ian Simon - CSE 216
  - › Tuesdays 12 to 2

Class Overview

- Introduction to many of the basic data structures used in computer software
  - › Understand the data structures
  - › Analyze the algorithms that use them
  - › Know when to apply them
- Practice design and analysis of data structures.
- Practice using these data structures by writing programs.
- Data structures are the plumbing and wiring of programs.

Goal (1)

- You will understand
  - › what the tools are for storing and processing common data types
  - › which tools are appropriate for which need
- So that you will be able to
  - › make good design choices as a developer, project manager, or system customer

Goal (2)

- Be able to:
  - › Reason formally about algorithms
  - › Communicate ideas about programs clearly and precisely
- Homeworks are mostly written
  - › Need more than “correct” answer—need to effectively communicate the ideas

Weekly Assignments

- Weekly homeworks
  - Involve algorithms design and analysis
  - No coding
  - Pseudocoding is preferred
  - Due on Wednesdays

Pseudocode

- The algorithms you design in homework will be read by a person, not a computer
- The No Code Rule:
  - Do not turn in Java or C code when asked for pseudocode
  - Explain algorithm precisely, but without all the details needed for computer code

Pseudocode example (good)

```
• reversePrint( string s )
   Create an empty stack A
   For each character c in s
      Push c onto A
   While A is not empty
      Pop c from A
      Print c
```


Pseudocode example (bad)

```
• void reversePrint( String s) {
   Stack A = new Stack();
   for (int i = 0; i < s.length(); i++) {
      A.push( s.get(i) );
   }
   While ( ! A.isEmpty() ) {
      Print( A.pop() );
   }
```


Projects

- First project will be done in C in Linux
  - Will use profiler and cache simulator CacheGrind
  - TA will provide preparation in section
- Other projects can be done in C++ or Java.
- Project involve
  - Writing code
  - Experimenting
  - Writing

Assignments, Projects, Exams

- Assignments 25%
  - Due on Wednesdays, no late assignments
- Projects 25%
  - 3 programming projects
- Midterm 20%
  - Friday, November 4, 2005
- Final 30%
  - 2:30-4:20 p.m. Wednesday, Dec. 14, 2005

Course Topics

- Introduction to Algorithm Analysis
- Sorting
- Memory Hierarchy
- Search Algorithms and Trees
- Hashing and Heaps
- Disjoint Sets
- Graph Algorithms
- Computational Geometry

Reading

- Reading in *Data Structures and Algorithm Analysis in C*, by Weiss
  - › Chapter 1 – Mathematical preliminaries
  - › Chapter 2 – Algorithm Analysis
  - › Chapter 7 - Sorting
    - Insertion Sort
    - Quicksort
    - Mergesort

Data Structures: What?

- Need to organize program data according to problem being solved
- Abstract Data Type (ADT) - A data object and a set of operations for manipulating it
  - › List ADT with operations **`insert`** and **`delete`**
  - › Stack ADT with operations **`push`** and **`pop`**
- Note similarity to Java classes
  - › private data structure and public methods

Data Structures: Why?

- Program design depends crucially on how data is structured for use by the program
  - › Implementation of some operations may become easier or harder
  - › Speed of program may dramatically decrease or increase
  - › Memory used may increase or decrease
  - › Debugging may be become easier or harder

Terminology

- Abstract Data Type (ADT)
  - › Mathematical description of an object with set of operations on the object. Useful building block.
- Algorithm
  - › A high level, language independent, description of a step-by-step process
- Data structure
  - › A specific family of algorithms for implementing an abstract data type.
- Implementation of data structure
  - › A specific implementation in a specific language

Algorithm Analysis: Why?

- Correctness:
  - › Does the algorithm do what is intended.
  - › How well does the algorithm complete its goal
- Performance:
  - › What is the running time of the algorithm.
  - › How much storage does it consume.
- Different algorithms may correctly solve a given task
  - › Which should I use?

Iterative Algorithm for Sum

- Find the sum of the first **n** integers stored in an array **v**.

```
sum(integer array v, integer n) returns integer
  let sum = 0
  for i = 1...n
   sum := sum + v[i]
  return sum
```

Note the use of pseudocode

Programming via Recursion

- Write a *recursive* function to find the sum of the first **n** integers stored in array **v**.

```
sum(integer array v, integer n) returns integer
 if n = 0 then
   sum := 0
 else
   sum := v[n] + sum(v,n-1)
   //sum := n-th number + sum of first n-1 numbers
 return sum
```


Pseudocode

- In the lectures I will be presenting algorithms in pseudocode.
  - This is very common in the computer science literature
  - Pseudocode is usually easily translated to real code.
  - This is what I'm used to.
- Pseudocode should also be used for homework

Proof by Induction

- **Basis Step:** The algorithm is correct for a base case or two by inspection.
- **Inductive Hypothesis:** Assume that the algorithm works correctly for the first n-1 cases.
- **Inductive Step:** Given the hypothesis above, show that the n-th case will be calculated correctly.

Program Correctness by Induction

- Basis Step: sum(v,0) = 0. ü
- Inductive Hypothesis:
  - Assume sum(v,n-1) correctly returns sum of first n-1 elements of v, i.e. v[1]+v[2]+…+v[n-1]
- Inductive Step:
  - sum(v,n) = v[n]+sum(v,n-1) (by program)
    = v[n]+(v[1]+…+v[n-1]) (by inductive hyp.)
    = v[1]+…+v[n-1]+v[n] (by algebra) ü

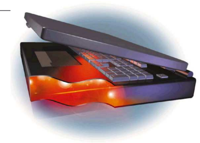
Algorithms vs Programs

- Proving correctness of an algorithm is very important
  - a well designed algorithm is guaranteed to work correctly and its performance can be estimated
- Proving correctness of a program (an implementation) is fraught with weird bugs
  - Abstract Data Types are a way to bridge the gap between mathematical algorithms and programs

Defining Efficiency

- Asymptotic Complexity - how running time scales as function of size of input
  - Order of magnitude notation
  - $O(n^2)$ is better than $O(n^3)$ in the long run
- Why is this a reasonable definition?
  - Definition is independent of any possible advances in computer technology

The Apocalyptic Laptop



Speed $\propto$ Energy Consumption

$E = m c^2$

25 million megawatt-hours

Quantum mechanics:
Switching speed = πh / (2 * Energy)

h is Planck's constant

5.4 x 10^{50} operations per second

Seth Lloyd, SCIENCE, 31 Aug 2000

Asymptotic Scaling