CSE 326: Data Structures

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Summer Quarter 2006
Lecture 1

Introduction

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Today's Outline

- Introductions
- What is this course about?
- Administrative Info
- Review: Queues and stacks

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.
- Make the transformation from programmer to computer scientist

Goal

- You will understand
  - what the tools are for storing and processing common data types
  - which tools are appropriate for which need
- So that you can
  - make good design choices as a developer, project manager, or system customer
- You will be able to
  - *Justify* your design decisions via formal reasoning
  - *Communicate* ideas about programs clearly and precisely

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Course Information

- **Text**: *Data Structures & Algorithm Analysis in Java*, (Mark Allen Weiss), 2006
- **Web page**: `http://www.cs.washington.edu/326`
- **Mailing Lists:**
  - `cse326-announce@cs.washington.edu`
  - `cse326@cs.washington.edu`
- **EPost Message Board:** Follow link from homepage

Course Mechanics

- Written homeworks (8 total)
  - Due at the start of class on due date
  - Pseudocode, no code!
- Programming homeworks (3 total, with phases)
  - In Java
  - Turned in electronically and on paper
- Work in teams only on explicit team projects
  - Appropriate *discussions* encouraged – see website
  - Anytime you use someone else's work, it's cheating

(Approximate) Grading

25% - Written Homework Assignments

Due every Wednesday at the start of class

25% - Programming Assignments

3 projects, broken into phases

20% - Midterm Exam

In class July 17

30% - Final Exam

In class August 18 (last day)

Project and homework guidelines

- On the website - note especially
  - Homeworks: use pseudocode, not code. A human being is reading your homeworks
  - See website for pseudocode examples
  - Projects: execution is only 40% of your grade!
  - Spend time commenting your code as you write - it will help you be a better programmer

Homework for Today!!

1) **Sign up for mailing lists (immediately)**
2) **Project #1:** Implement Stacks and Queues. Due in one week.
3) **Reading** in Weiss
   1) Chapter 1 (review): Mathematics and Java
   2) Chapter 3 (Project #1): Stacks and Queues
   3) Chapter 2 (Homework #1): Algorithm Analysis
4) **Homework #1** is based off of reading and will be released next class.

Project 1

- Soundblaster! Reverse a song
- Implement a stack and a queue to make the "Reverse" program work
- **Read the website**
  - Detailed description of assignment
  - Detailed description of how programming projects are graded

Data Structures

"Clever" ways to organize information in order to enable efficient computation

- What do we mean by clever?
- What do we mean by efficient?

Picking the best data structure for the job

- The data structure you pick needs to *support* the operations you need
- Ideally it supports the operations you will use most often in an *efficient* manner
- 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`**

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

Terminology examples

- A stack is an *abstract data type* supporting push, pop and isEmpty operations
- A stack *data structure* could use an array, a linked list, or anything that can hold data
- One stack *implementation* is found in java.util.Stack

Concepts vs. Mechanisms

- Abstract
- Pseudocode
- Algorithm
  - A sequence of high-level, language independent operations, which may act upon an abstracted view of data.
- Abstract Data Type (ADT)
  - A mathematical description of an object and the set of operations on the object.

- Concrete
- Specific programming language
- Program
  - A sequence of operations in a specific programming language, which may act upon real data in the form of numbers, images, sound, etc.
- Data structure
  - A specific way in which a program's data is represented, which reflects the programmer's design choices/goals.

Why So Many Data Structures?

Ideal data structure:

"fast", "elegant", memory efficient

Generates tensions:

- time *vs.* space
- performance *vs.* elegance
- generality *vs.* simplicity
- one operation's performance *vs.* another's

The study of data structures is the study of tradeoffs. That's why we have so many of them!

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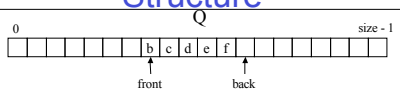
First Example: Queue ADT

- FIFO: First In, First Out
- Queue operations
  - create
  - destroy
  - enqueue
  - dequeue
  - is_empty

Circular Array Queue Data Structure




```
enqueue(Object x) {
   Q[back] = x ;
   back = (back + 1) % size
   }
dequeue() {
   x = Q[front] ;
   front = (front + 1) % size;
   return x ;
   }
```

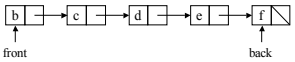
How test for empty list?

How to find K-th element in the queue?

What is complexity of these operations?

Limitations of this structure?

Linked List Queue Data Structure




```
void enqueue(Object x) {
   if (is_empty())
      front = back = new Node(x)
   else
      back->next = new Node(x)
      back = back->next
}
bool is_empty() {
   return front == null
}
```

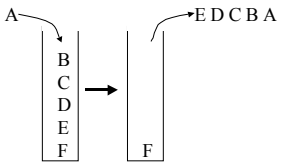
```
Object dequeue() {
   assert(!is_empty)
   return_data = front->data
   temp = front
   front = front->next
   delete temp
   return return_data
}
```


Circular Array vs. Linked List

Too much space	Can keep growing
Kth element accessed in O(1)	No back going around to front
Not as complex	Linked list code more complex
Could make array more robust	

Second Example: Stack ADT

- LIFO: Last In, First Out
- Stack operations
  - create
  - destroy
  - push
  - pop
  - top
  - is_empty



Stacks in Practice

- Function call stack
- Removing recursion
- Balancing symbols (parentheses)
- Evaluating Reverse Polish Notation

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 + ith number
  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 = nth number + sum of first n-1 numbers
 return sum
```


Proof by Induction

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

Program Correctness by Induction

- **Basis Step:** sum(v,0) = 0. ✓
- **Inductive Hypothesis (n=k):** Assume sum(v,k) correctly returns sum of first k elements of v, i.e. **`v[0]+v[1]+…+v[k-1]`**
- **Inductive Step (n=k+1):** sum(v,n) returns
  `v[k]+sum(v,k)= (by inductive hyp.)`
  `v[k]+(v[0]+v[1]+…+v[k-1])=`
  `v[0]+v[1]+…+v[k-1]+v[k]` ✓

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