CSE 326: Data Structures and Algorithms

Luke McDowell
Summer Quarter 2003

Today's Outline

- Administrative Info
- Survey
- Overview of the Course
- What is an algorithm? ADT? Data structure?
- Review: Stacks and queues

Course Information

- Instructor: Luke McDowell, Sieg 226C
  lucasm@cs.washington.edu
  Office hours: Tuesday 11:00-12:00, Wed 1-2 p.m., or by appt.
- Teaching Assistants:
  AA: Aiman Erbad erbad@cs.washington.edu Mon 1-2 p.m.
  AB: Steven Martin stevaroo@cs.washington.edu Fri 2-3 p.m.
  Office hours in Sieg 226A
  Go to any office hours you like.
- Text: *Data Structures & Algorithm Analysis in Java*, 2nd edition (Mark Allen Weiss)
  or
  Data Structures & Algorithm Analysis in C++ (Weiss)

Course Policies

- Written homeworks
  - Due at the start of class on due date
  - No late homeworks accepted
- Programming homeworks
  - Turned in electronically before 11pm on due date
  - Once per quarter: use your "late day" for extra 24 hours – **Must email TA**
- Work in teams only on explicit team projects
  - Appropriate *discussions* encouraged – see website
- Approximate Grading
  - Weekly assignments: 35%
  - Midterm: 20% Friday July 25, in class
  - Final: 30% Friday Aug. 22 in class
  - **Best of above 3:** 10%
  - Participation: 5%

Course Mechanics

- 326 Web page: `http://www.cs.washington.edu/326`
- 326 mailing lists
  - announcement list: *cse326-announce@cs.washington.edu*
  - discussion list: *cse326@cs.washington.edu*
  - subscribe to these using web interface, see homepage
- Course laboratories are 232 and 329 Sieg Hall
  - labs have NT machines w/X servers to access UNIX
- All programming projects graded on UNIX
  - OK to develop using other tools (e.g. under Windows) but make sure you test under UNIX
  - Program in Java, or talk to the instructor

That Survey Thing

- Why are you taking my picture?
- What if I forgot everything?
- What if I know this all already?
- What if I'm the famous one?

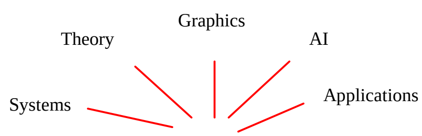
What is this Course About?

Clever ways to organize information in order to enable efficient computation

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

Clever? Efficient?

Data Structures	Algorithms
Lists, Stacks, Queues	Insert
Heaps	Delete
Binary Search Trees	Find
AVL Trees	Merge
Hash Tables	Shortest Paths
Graphs	Union
Disjoint Sets	

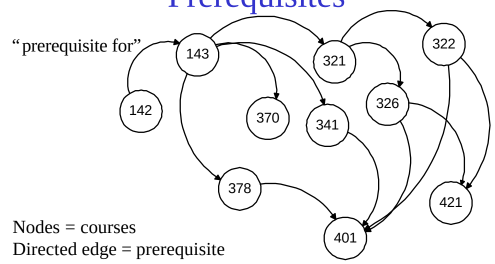


Used Everywhere!

Mastery of this material separates you from:

- ***Perhaps the most important course in your CS curriculum!***
- ***Guaranteed non-obsolescence!***

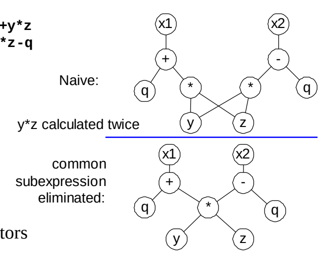
E.g. 1: Representing Course Prerequisites



Nodes = courses
Directed edge = prerequisite

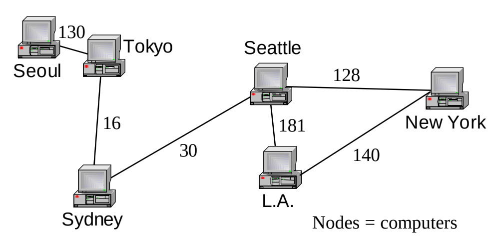
E.g. 2: Representing Expressions in Compilers

```
x1=q+y*z
x2=y*z-q
```



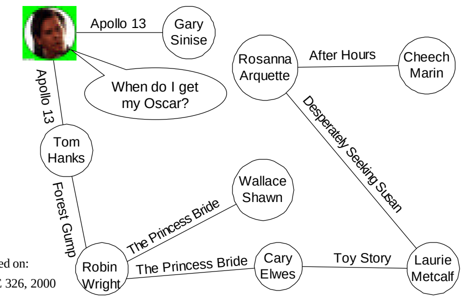
Nodes = symbols/operators
Edges = relationships

E.g. 3: Information Transmission in a Network



Nodes = computers
Edges = transmission rates

E.g. 4: Six Degrees of Separation from Kevin Bacon



Based on:
CSE 326, 2000

From R. Rao, CSE 326 Winter 2003

Asymptotic Complexity

Our notion of efficiency:

How the running time of an algorithm scales with the size of its input

- several ways to further refine:
  - worst case
  - average case
  - amortized over a series of runs

Specific Goals of the Course

- Become familiar with some of the fundamental data structures in computer science
- Improve ability to solve problems abstractly
  - data structures are the building blocks
- Improve ability to analyze your algorithms
  - prove correctness
  - gauge (and improve) time complexity
- Become modestly skilled with the UNIX operating system (you'll need this in upcoming courses)

One Preliminary Hurdle

1. Recall what you learned in CSE 321 …
   - proofs by mathematical induction
   - proofs by contradiction
   - formulas for calculating sums and products of series
   - recursion

   Know Sec 1.1 – 1.3 of text by heart!

A Second Hurdle

2. Unix

   Experience 1975 all over again!
   - Try to login, edit, and compile your favorite "hello world" program right away

     Get help at the UNIX tutorial tomorrow!
   - Programming Assignment 1 due next Monday
   - Bring your questions and frustrations to Section on Thursday!

A Third Hurdle: Java

```
Public class Set_of_ints {
  Public void insert( int x );
  Public void remove( int x ); … }
```

Review the syntax (see chapter 1)

Run your first program (assignment 1)

Java ? Data Structures

One of the all time great books in computer science:

The Art of Computer Programming (1968-1973)

by Donald Knuth

Examples in assembly language (and English)!

American Scientist says: in top 12 books of the CENTURY!

Very little about Java in class.
Weiss textbook's code – don't get bogged down!

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- What is an algorithm? ADT? Data structure?
- Stacks and queues

What is an Algorithm?

- ???

According to …

- According to Mirriam-Webster, an *algorithm* is …
  - a procedure for solving a mathematical problem (as of finding the greatest common divisor) in a finite number of steps that frequently involves repetition of an operation
  - (*broadly*) a step-by-step procedure for solving a problem or accomplishing some end especially by a computer
- So …
  - What's the difference between an "algorithm" and a "program?"

Concepts vs. Mechanisms

- Algorithm
  - A sequence of high-level, language independent operations, which may act upon an abstracted view of data.
- Program
  - A sequence of operations in a specific programming language, which may act upon real data in the form of numbers, images, sound, etc.
- Abstract Data Type (ADT)
  - A mathematical description of an object and the set of operations on the object.
- Data structure
  - A specific way in which a program's data is represented, which reflects the programmer's design choices/goals.

ADT's vs Data Structures

- List ADT
  - Stack ADT
  - Queue ADT
- Collection ADT
  - Stores objects without duplicates
- Dictionary ADT
  - Stores (Key, Value) pairs
  - *Alternatively*: Maps Keys to Values
- Priority Queue ADT
  - Stores objects, and supports efficient removal of objects based upon some kind of ordering
- Graph ADT
- … and even more!

- Linked List
- Circular Array
- Binary Search Tree
- Splay Tree
- Hash Table
- Leftist Heap
- Skew Heap
- Adjacency Matrix
- … and lots more!

So … which ADT's do these data structures implement?

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!

ADT Presentation Algorithm

- Present an ADT
- Motivate with some applications
- Repeat until it’s time to move on:
  - develop a data structure and algorithms for the ADT
  - analyze its properties
    - efficiency
    - correctness
    - limitations
    - ease of programming
- Contrast strengths and weaknesses

First Example: Queue ADT

- Queue operations
  - create
  - destroy
  - enqueue
  - dequeue
  - is_empty

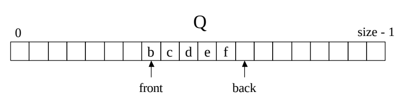
- Queue property: if x is enQed before y is enQed, then x will be deQed before y is deQed

  FIFO: First In First Out

Applications of the Q

- Hold jobs for a printer
- Store packets on network routers
- Make waitlists fair
- Breadth first search

Circular Array Q Data Structure




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

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

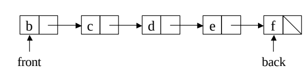
How test for empty list?

How to find K-th element in the queue?

What is complexity of these operations?

Limitations of this structure?

Linked List Q Data Structure



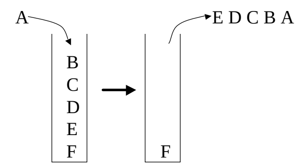

```
void enqueue(Object x) {
  if (is_empty())
      front = back = new Node(x)
  else
      back->next = new Node(x)
      back = back->next
}
```

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

Circular Array vs. Linked List

Second Example: Stack ADT

- Stack operations
  - create
  - destroy
  - push
  - pop
  - top
  - is_empty



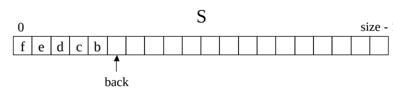
- Stack property: if x is on the stack before y is pushed, then x will be popped after y is popped

LIFO: Last In First Out

Stacks in Practice

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

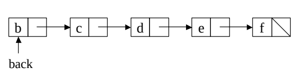
Array Stack Data Structure




```
void push(Object x) {
   assert(!is_full())
   S[back] = x
   back++
}
Object top() {
   assert(!is_empty())
   return S[back - 1]
}
```

```
Object pop() {
   back--
   return S[back]
}
bool is_empty() {
   return back == 0
}
bool is_full() {
   return back == size
}
```

Linked List Stack Data Structure




```
void push(Object x) {
   temp = back
   back = new Node(x)
   back->next = temp
}
Object top() {
   assert(!is_empty())
   return back->data
}
```

```
Object pop() {
   assert(!is_empty())
   return_data = back->data
   temp = back
   back = back->next
   return return_data
}
bool is_empty() {
   return back == null
}
```

Data structures you should already know

- Arrays
- Linked lists
- Queues
- Stacks

To Do

- Return your survey before leaving!
- Check out the web page
- Come to the Unix tutorial **tomorrow (Tuesday), Sieg 232, 12-2 p.m.**
- Sign up on the cse326 mailing lists
- Log on to the PCs in rooms 232 or 329 and access an instructional UNIX server
  - If you don't have a CSE account, sign up today!
- Read 1.1-1.3, Chapters 2 and 3 in the book
  - Don't worry, it gets better!
- HW 1 due this Monday, June 30!