Welcome to CSE 326!
Data Structures

Pick up…
- First day survey
- Copy of lecture slides
- Textbook errata
- Course syllabus

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Today's Outline

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

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Who am I?

<u>Ashish</u> Sabharwal

n^{th} year grad student, CSE [currently n = 6]
Please *don't* call me "professor"… yet!

- Research — Theory: Algorithms, complexity
  Applications: Solvers for AI, model checking, etc.
- Teaching — TA'ed several courses
  My first full class!

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What's this tabletPC thing I'm walking around with?

Classroom Presenter system
- Richard Anderson, Steve Wolfman, et al.

Allows cool stuff such as
- Presenter and viewer modes
- Writing on slides

Still under construction.
Will it fail? I don't know…

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Course Staff and Textbook

- **Instructor**: Ashish Sabharwal, Allen Center 214, *ashish@cs*
  Office hours: TBD
- **Teaching Assistants**:

Ethan Phelps-Goodman	*ethanpg@cs*	Sections, concepts
Albert J. Wong	*awong@cs*	Programming guru, special tutorials (eg. unix)

  Office hours: TBD
- **Textbook**: *Data Structures & Algorithm Analysis in Java*
  - by Mark Allen Weiss

Course Mechanics

- Web page: `http://www.cs.washington.edu/326`
- Mailing aliases
  - announcement list *cse326-announce@cs*
  - discussion list *cse326@cs*
  - staff alias *cse326-staff@cs*
  - <u>subscribe to the lists</u> using web interface; see webpage
- Course laboratories are 002, 006, 022 Allen Center
  - labs have NT machines with X servers to access UNIX
  - All programming projects graded on UNIX server <u>attu.cs</u>
  - OK to develop using other tools (e.g. under Windows) but make sure you test under UNIX

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Course Policies

- Written assignments
  - Due at the start of class on due date; late homeworks not accepted!
- Programming assignments
  - 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

– Assignments:	30%	
– Midterm:	20%	Monday Nov 3, in class
– Final:	30%	Monday Dec 15, in class (2 hours)
– **Best of above 3:**	10%	
– Participation & quizzes:	10%	

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A quick break before we delve into course material!

- Fill out the survey
- Tell me times that are BAD for office hours

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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?

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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	

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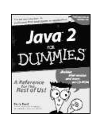
Theory
Graphics
AI
Systems
Applications

Used Everywhere!

Mastery of this material separates you from:



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

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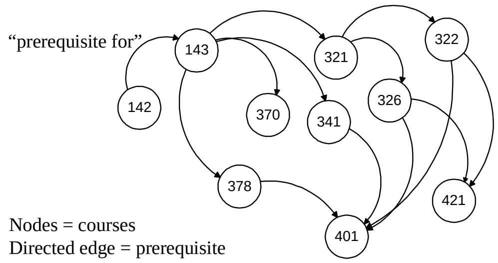
Example 1: Representing Course Prerequisites



Nodes = courses
Directed edge = prerequisite

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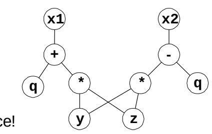
Example 2: Representing Expressions in Compilers

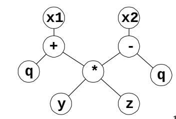
```
x1 = q + y*z
x2 = y*z - q
```

Naive:



y*z calculated twice!

Common Subexpression Eliminated:



Nodes = symbols/operators
Edges = relationships

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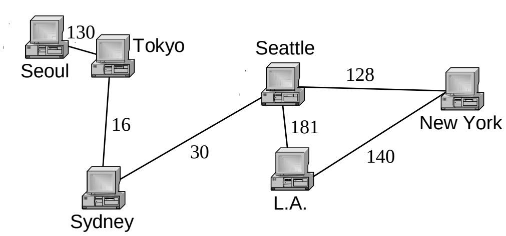
Example 3: Information Transmission in a Network



Nodes = computers
Edges = transmission rates

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Efficiency: Asymptotic Complexity

Run the program and measure time:

- *Typically insufficient!*
- How big is the sample input? What about other inputs?

Our notion of efficiency:
How does the running time of an algorithm *scale* with the size of its input?

Several ways to further refine:

- worst case
- average case
- amortized over a series of runs

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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)

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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!

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A Second Hurdle

2. Unix

Experience 1975 all over again!

– Try to login on *attu.cs*, edit, and compile your favorite "hello world" program right away

Get help at the UNIX tutorial (tomorrow?)

– Programming Assignment 1 (to be released Wed)

– Bring your questions and frustrations to Section on Thursday!

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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)

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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)!

Very little about Java in class.

Weiss textbook's code – don't get bogged down!

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What is an Algorithm?

- ???

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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

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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.

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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?

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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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ADT Presentation Algorithm

1. Present an ADT
2. Motivate with some applications
3. Repeat until it's time to move on:
   a. analyze its properties
   b. develop a data structure and algorithms for the ADT
      i. efficiency
      ii. correctness
      iii. limitations
      iv. ease of programming
4. Contrast strengths and weaknesses

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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

<u>FIFO</u>: First In First Out

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Applications of the Q

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

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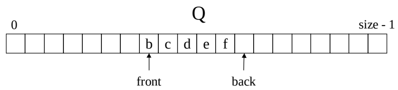
Circular Array Q Data Structure




```
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?

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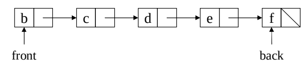
Linked List Q Data Structure




```
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
}
```

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Circular Array vs. Linked List

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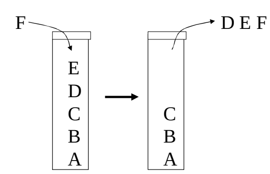
Second Example: Stack ADT

- **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

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Stacks in Practice

- Function call stack
- Converting recursion to iteration
- Balancing symbols (parentheses)
- Evaluating Reverse Polish (postfix) Notation
- Depth first search

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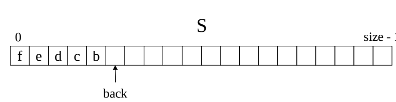
Array Stack Data Structure




```
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
}
```

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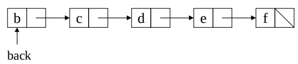
Linked List Stack Data Structure




```
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 - TBD
- Sign up for the cse326 mailing lists
- Log on to the PCs in rooms 002, 006 or 022 and access instructional UNIX server *attu.cs*
  - 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!