CSE 326: Data Structures Introduction

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Summer Quarter 2002

Today's Outline

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

Course Information

- Instructors: Hannah Tang and Brian Tjaden
  226C Sieg Hall
  hctang@cs.washington.edu *and* tjaden@cs.washington.edu
  Hannah's office hours: Tuesday 10-11:00, Friday 1-2:00
  Brian's office hours: Monday 1-2:00, Thursday 1-2:00
- Grader/Consultant extraordinaire:
  Albert Wong awong@cs.washington.edu
- Text: *Data Structures & Algorithm Analysis in C++*, 2nd edition, by Mark Allen Weiss

  or

  Data Structures & Algorithm Analysis in Java, by Mark Allen Weiss

C++ or Java...

you make the call!

Course Assessment

- Homeworks or projects due each week
- Weekly written homework due at the start of class on the due date
- Projects due by 10PM on the due date
- Quizzes each Thursday in section!!!
- Final Exam: August 23 in class!!!
- Grading
  - homework: 20%
  - projects: 30%
  - quizzes: 20%
  - final: 25%
  - participation: 5%

Course Mechanics

- 326 Web page: `http://www.cs.washington.edu/326`
- 326 course directory: `/cse/courses/cse326/02su`
- 326 mailing lists
  - announcement list: *cse326announce*
  - discussion list: *cse326*
  - extra topics list: *cse326beyond*
  - subscribe to the mailing list 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

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.
- Abstract Data Type (ADT)
  - A mathematical description of an object and the set of operations on the object.
- Program
  - A sequence of operations in a specific programming language, which may act upon real data in the form of numbers, images, sound, etc.
  - Each program must decide how to store its data, and these choices influence the program at every level:
    - Execution speed
    - Memory requirements
    - Maintenance (debugging, extending, etc)
- 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!

Goals of the Course

- Learn some of the fundamental data structures in computer science
  - And understand their tradeoffs!
- Learn to see and solve problems abstractly
  - Be able to see the intrinsic problem behind real-world scenarios, or vice versa, be able to realize an abstract solution in the real world
  - Data structures are your problem-solving building blocks!
- Learn to analyze and improve algorithms
  - Prove correctness
  - Gauge and improve time complexity
- Become modestly skilled with the UNIX operating system
- Appreciate that all languages are not created equal...

Learning Concepts vs. Learning Code

CSE 326 balances concepts with mechanisms
- Grade is 65% concepts and plans, 30% coding skill, but …
- Coding *greatly* improves grasp of concepts and plans

Different approaches
- *Weiss* is code-centric: emphasizes mechanisms
- *Introduction to Algorithms* by Cormen, Leiserson, Rivest is pseudocode-centric: emphasizes concepts
- *The Art of Computer Programming* (1968-1973) by Donald Knuth emphasizes concepts and mechanisms
  - Examples in assembly language (and English)!
  - American Scientist ranks in top 12 books of century!
- Many, many more!

Translating Concepts Into Mechanisms

- In a perfect world …
  - An interface (or abstract base class) describes ADT
  - Inherited classes implement data structures
  - Can change data structures transparently (to client code)
- In the real world …
  - Different implementations sometimes suggest different interfaces (generality *vs.* simplicity)
  - Performance of a data structure may influence form of client code (time *vs.* space, one operation *vs.* another)

Data Structure Presentation Algorithm

- Present data structure
- Motivate with some applications
- Repeat until you see visions of the data structure in your sleep
  - Determine which ADT's this data structure can implement
  - Analyze its properties
    - Efficiency
    - Correctness
    - Limitations
    - Ease of programming
- Contrast data structure's strengths and weaknesses
  - Understand when to use each one

And now, the moment you've been waiting for:
Your first ADT!

Queue ADT

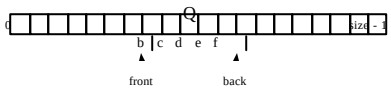
- Queue operations
  - create
  - destroy
  - enqueue
  - dequeue
  - is_empty

- 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
- Hold memory " freelists"
- Make waitlists fair
- Breadth first search

Circular Array Q Data Structure

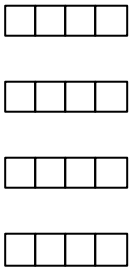



```
void enqueue(Object x) {
   Q[back] = x
   back = (back + 1) % size
}
Object dequeue() {
   x = Q[front]
   front = (front + 1) % size
   return x
}
```

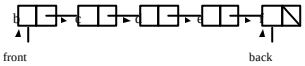
```
bool is_empty() {
   return (front == back)
}

bool is_full() {
   return front ==
        (back + 1) % size
}
```

Q Example

enqueue R
enqueue O
dequeue
enqueue T
enqueue A
enqueue T
dequeue
dequeue
enqueue E
dequeue



Linked List Q Data Structure



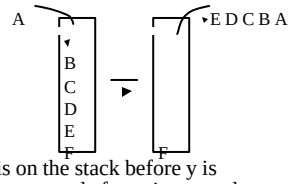

```
void enqueue(Object x) {
   if (is_empty())
        front = back = new Node(x)
   else
        back->next = new Node(x)
        back = back->next
}
```

```
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

LIFO Stack ADT

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



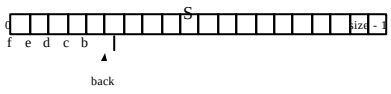
- Stack property: if x is on the stack before y is pushed, then x will be popped after y is popped

  LIFO: Last In First Out

Stacks in Practice

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

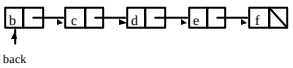
Array Stack Data Structure




```
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

- Check out the web page
- Come to the Unix tutorial tommorrow (Tuesday, June 25), Sieg 322, 4:30-5:30
- Sign up on the cse326 mailing lists
- Log on to the PCs in rooms 232 or 329 and access an instructional UNIX server
- Read Chapters 2 and 3 in the book
- Project 1 due this Monday, July 1!