CSE373: Data Structures and Algorithms

Lecture 1: Introduction; ADTs; Stacks/Queues

Linda Shapiro

Winter 2015

Registration

- We have 140 students registered and 140+ on the wait list!
- If you're thinking of dropping the course please decide *soon!*

Wait listed students

- Please sign up on the paper waiting list after class, so I know who you are.
- If you think you absolutely have to take the course this quarter, speak to the CSE undergraduate advisors.
- The CSE advisors and I will decide by end of Friday who gets in.

Welcome!

We have 10 weeks to learn *fundamental data structures and algorithms for organizing and processing information*

- – "Classic" data structures / algorithms
- – How to rigorously analyze their efficiency
- – How to decide when to use them
- – Queues, dictionaries, graphs, sorting, etc.

Today in class:

- Introductions and course mechanics
- What this course is about
- Start *abstract data types* (ADTs), *stacks*, and *queues*
  - – Largely review

To-do list

In next 24-48 hours:

- Read the web page
- Read all course policies
- Read Chapters 3.1 (lists), 3.6 (stacks) and 3.7 (queues) of the Weiss book
  - Relevant to Homework 1, due next week

- Set up your Java environment for Homework 1

  http://courses.cs.washington.edu/courses/cse373/15wi/

Course staff

Linda Shapiro
CSE Professor with research in computer vision.
Have taught CS&E for 40 years.
First course I ever taught was Data Structures.
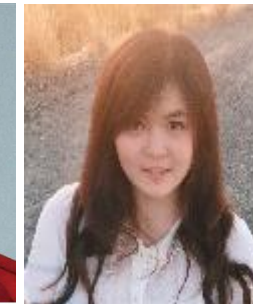
**Evan McCarty**   Eden Ghirmai   Andy Li   Rama Gokhale   Luyi Lu   Cyndi Ai   Megan Hopp

Office hours, email, etc. on course web-page

Communication

- Course email list: **cse373a_15wi@u.washington.edu**
  - Students and staff already subscribed
  - You must get announcements sent there
  - Fairly low traffic

- Course staff: **cse373-staff@cs.washington.edu** plus individual emails

- Discussion board
  - For appropriate discussions; TAs will monitor
  - Encouraged, but won't use for important announcements

- Anonymous feedback link
 - For good and bad, but please be gentle.
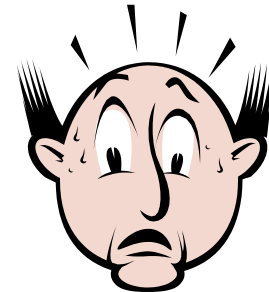
Course meetings

- Lecture
  - Materials posted, but take notes
  - Ask questions, focus on key ideas (rarely coding details)

- Optional help sessions
  - Help on programming/tool background
  - Helpful math review and example problems
  - Again, optional but helpful
  - May cancel some later in course (experimental)

- Office hours
  - Use them: *please visit me for talking about course concepts or just CSE in general.*
  - *See the TAs for Java programming questions.*
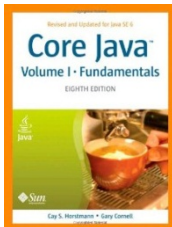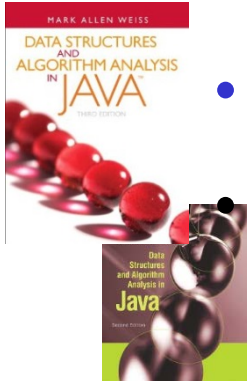
Course materials

- All lecture will be posted
  - But they are visual aids, not always a complete description!
  - If you have to miss, find out what you missed
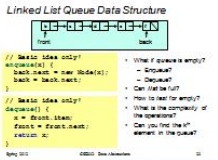
- Textbook: Weiss 3rd Edition in Java

- A good Java reference of your choosing
  - Don't struggle Googling for features you don't understand

Computer Lab

- College of Arts & Sciences Instructional Computing Lab
  - http://depts.washington.edu/aslab/
  - Or your own machine

- Will use Java for the programming assignments

- Eclipse is recommended programming environment

Course Work

- 5-6 homeworks (50%)
  - Most involve programming, but also written questions
  - Higher-level concepts than "just code it up"
  - First programming assignment due next week

- Midterm Week of Feb 9, in class (20%)
- Final exam: Tuesday June 10, 2:30-4:20PM (30%)

Collaboration and Academic Integrity

- Read the course policy very carefully
  - Explains quite clearly how you can and cannot get/provide help on homework and projects

- Always explain any unconventional action on your part
  - When it happens, when you submit, not when asked

- The CSE Department and I take academic integrity extremely seriously.

Some details

- You are expected to do your own work
  - Exceptions (group work), if any, will be clearly announced

- Sharing solutions, doing work for, or accepting work from others is cheating

- Referring to solutions from this or other courses from previous quarters is cheating

- But you can learn from each other: see the policy

What this course will cover

- Introduction to Algorithm Analysis

- Lists, Stacks, Queues

- Trees, Hashing, Dictionaries

- Heaps, Priority Queues

- Sorting

- Disjoint Sets

- Graph Algorithms

- Introduction to Parallelism and Concurrency

Goals

- Be able to make good design choices as a developer, project manager, etc.
  - Reason in terms of the general abstractions that come up in all non-trivial software (and many non-software) systems
- Be able to justify and communicate your design decisions

You will learn the key abstractions used almost every day in just about anything related to computing and software.

- This is not a course about Java! We use Java as a tool, but the data structures you learn about can be implemented in any language.

Data structures

A data structure is a (often *non-obvious*) way to organize information to enable *efficient* computation over that information

A data structure supports certain *operations*, each with a:
- Meaning: what does the operation do/return
- Performance: how efficient is the operation

Examples:
- *List* with operations `insert` and `delete`
- *Stack* with operations `push` and `pop`

Trade-offs

A data structure strives to provide many useful, efficient operations

But there are unavoidable trade-offs:
– Time vs. space
– One operation more efficient if another less efficient
– Generality vs. simplicity vs. performance

We ask ourselves questions like:
– Does this support the operations I need efficiently?
– Will it be easy to use (and reuse), implement, and debug?
– What assumptions am I making about how my software will be used? (E.g., more lookups or more inserts?)

Terminology

- Abstract Data Type (ADT)
  - Mathematical description of a "thing" with set of operations
  - Not concerned with implementation details

- Algorithm
  - A high level, language-independent description of a step-by-step process

- Data structure
  - A specific organization of data and family of algorithms for implementing an ADT

- Implementation of a data structure
  - A specific implementation in a specific language

Example: Stacks

- The ***Stack*** ADT supports operations:
  - **isEmpty**: have there been same number of pops as pushes
  - **push**: adds an item to the top of the stack
  - **pop**: raises an error if empty, else removes and returns most-recently pushed item not yet returned by a pop
  - What else?

- A Stack data structure could use a linked-list or an array and associated algorithms for the operations

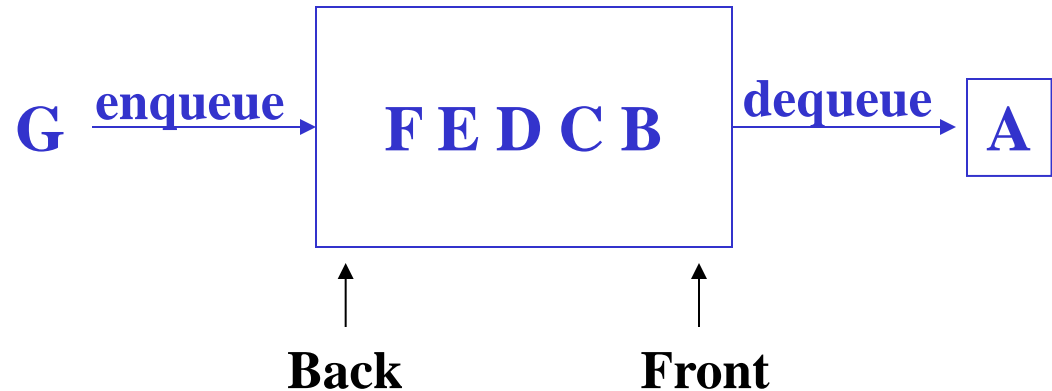- One implementation is in the library **java.util.Stack**

Why useful

The Stack ADT is a useful abstraction because:

- It arises all the time in programming (e.g., see Weiss 3.6.3)
  - Recursive function calls
  - Balancing symbols in programming (parentheses)
  - Evaluating postfix notation: 3 4 + 5 *
  - Clever: Infix ((3+4) * 5) to postfix conversion (see text)

- We can code up a reusable library

- We can communicate in high-level terms
  - "Use a stack and push numbers, popping for operators…"
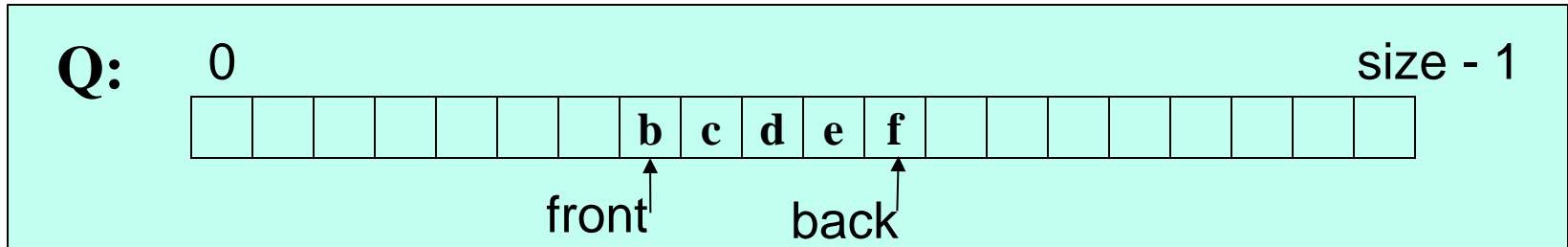 - Rather than, "create an array and keep indices to the…"

Stack Implementations

- stack as a linked list

- stack as an array

The Queue ADT

- Operations
  create

  destroy

  enqueue

  dequeue

  is_empty

  What else?

G → enqueue → [F E D C B] → dequeue → A

↑ Back   ↑ Front

- Just like a stack except:
  - Stack: LIFO (last-in-first-out)
  - Queue: FIFO (first-in-first-out)

Circular Array Queue Data Structure

Q: 0   size - 1

| | | | | | | | b | c | d | e | f | | | | | | | | |

              front   back

```
// Basic idea only!
enqueue(x) {
  next = (back + 1) % size
  Q[next] = x;
  back = next
}
```
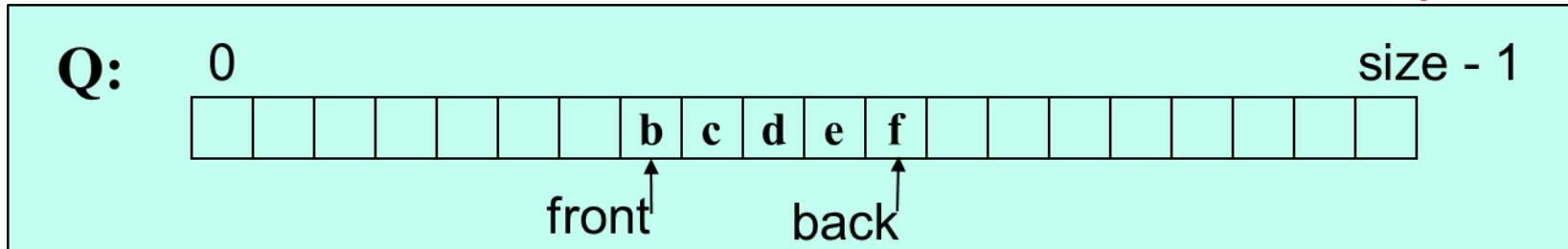
```
// Basic idea only!
dequeue() {
  x = Q[front];
  front = (front + 1) % size;
  return x;
}
```

- What if *queue* is empty?
  - Enqueue?
  - Dequeue?
- What if *array* is full?
- How to *test* for empty?
- What is the *complexity* of the operations?
- Can you find the kth element in the queue?

Circular Array Example *(text p 94 has another one)*

Q: 0 ... size - 1

array: b c d e f with **front** pointing to b and **back** pointing to f

enqueue('g')

o1 = dequeue( )

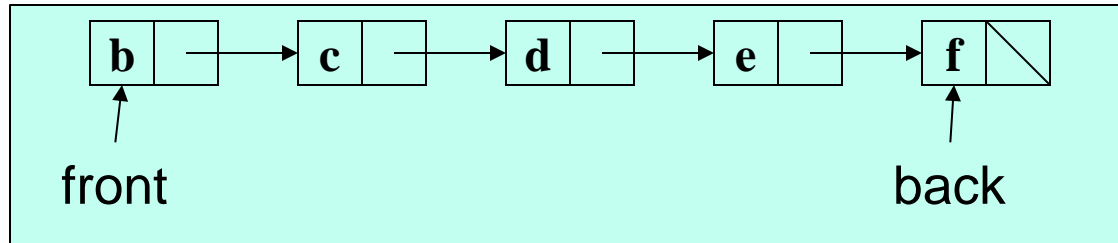**o2 = dequeue( )**

o3 = dequeue( )

o4 = dequeue( )

o5 = dequeue( )

o6 = dequeue( )

Linked List Queue Data Structure


```
// Basic idea only!
enqueue(x) {
  back.next = new Node(x);
  back = back.next;
}
```

```
// Basic idea only!
dequeue() {
  x = front.item;
  front = front.next;
  return x;
}
```

- What if ***queue*** is empty?
  - Enqueue?
  - Dequeue?
- Can ***list*** be full?
- How to *test* for empty?
- What is the *complexity* of the operations?
- Can you find the kth element in the queue?

Circular Array vs. Linked List

Array:
- May waste unneeded space or run out of space
- Space per element excellent
- Operations very simple / fast
- Constant-time access to k^{th} element

- For operation insertAtPosition, must shift all later elements
  - Not in Queue ADT

List:
- Always just enough space
- But more space per element
- Operations very simple / fast
- No constant-time access to k^{th} element

- For operation insertAtPosition must traverse all earlier elements
  - Not in Queue ADT

This is stuff you should know after being awakened in the dark

Conclusion

- Abstract data structures allow us to define a new data type and its operations.

- Each abstraction will have one or more implementations.

- Which implementation to use depends on the application, the expected operations, the memory and time requirements.

- Both stacks and queues have array and linked implementations.

- We'll look at other ordered-queue implementations later.