CSE373: Data Structures and Algorithms

Lecture 1: Introduction; ADTs; Stacks/Queues

Hunter Zahn

Summer 2016

Course staff

Instructor: Hunter Zahn, hzahn93@cs.washington.edu

TA: Dan Butler : djbutler@cs.washington.edu
TA: Lilian de Greef : ldegreef@cs.washington.edu
TA: Alon Milchgrub : alonmil@cs.washington.edu

Welcome!

We have 9 weeks to learn *fundamental data structures and algorithms for organizing and processing information*

- "Classic" data structures / algorithms and how to analyze rigorously their efficiency and 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

Concise to-do list

In next 24-48 hours:

- Verify that you have received an email from me!
- Take homework 0 (worth 0 points) as Catalyst quiz
  - Very helpful for me!
- Read all course policies
- Read/skim Chapters 1 and 3 of Weiss book
  - Relevant to Homework 1, due next week
  - Will start Chapter 2 fairly soon

Possibly:

- Set up your Java environment for Homework 1

http://courses.cs.washington.edu/courses/cse373/16su/

Communication

- Course email list: **`cse373a_su16@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: if you don't tell me, I don't know

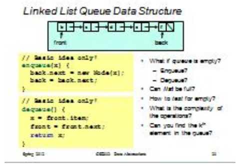
Course meetings

- Lecture
  - Materials posted, but take notes
  - Ask questions, focus on key ideas (rarely coding details)
- Optional meetings on Tuesday/Thursday afternoons
  - Will post rough agenda roughly a day or more in advance
  - Help on programming/tool background
  - Helpful math review and example problems
  - Again, optional but helpful
  - May cancel some later in course (experimental)

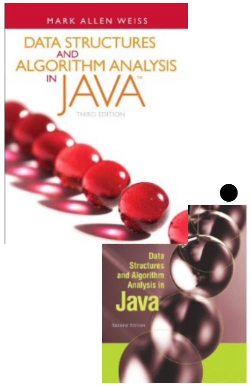
Office Hours

- Hunter: Monday, Wednesday 12:20 – 1:20 in CSE 2:20
  - Today: 1:00 – 2:00
  - Use them: *please visit me*
  - Ideally not *just* for homework questions (but that's OK too)
- TA's: To be determined – will be posted today/tomorrow

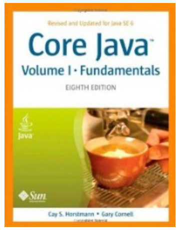
Course materials



- All lecture and section materials 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 3^{rd} Edition in Java
  - Good read, but only responsible for lecture/hw topics
  - 3^{rd} edition improves on 2^{nd}, but we'll support the 2^{nd}



- 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/
    - Communications building
  - Or your own machine

- Will use Java for the programming assignments

- Eclipse is recommended programming environment

Course Work

- 6 homeworks (50%)
  - Most involve programming, but also written questions
  - Higher-level concepts than "just code it up"
  - First programming assignment due week from Friday
- Midterm(s) (20%): TBD. Will announce more about these in the coming week.
- Final exam: Friday, August 19th, in class.

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

I offer great trust but with little sympathy for violations

Honest work is the most important feature of a university

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

Gilligan's Island Rule

You spend at least 30 minutes on each and every problem (or programming assignment) alone, before discussing it with others.

Cooperation is limited to group discussion and brainstorming. No written or electronic material may be exchanged or leave the brainstorming session.

You write up each and every problem in your own writing, using your own words, and fully understanding your solution (similarly you must write code on your own).

You identify each person that you collaborated with at the top of your written homework or in your README file.

(See policy online)

Unsolicited advice

- Get to class on time!
  - Instructor pet peeve (I will start and end promptly)
  - First 2 minutes are *much* more important than last 2!
- Learn this stuff
  - It is at the absolute core of computing and software
  - Falling behind only makes more work for you
- Have fun
  - So much easier to be motivated and learn

Today in Class

- Course mechanics: Did I forget anything?

- What this course is about
- Course Goals

- Start *abstract data types* (ADTs), *stacks*, and *queues*
  – Largely review

Assumed background

- Prerequisite is CSE143

- Topics you should have a basic understanding of:
  - Variables, conditionals, loops, methods, fundamentals of defining classes and inheritance, arrays, single linked lists, simple binary trees, recursion, some sorting and searching algorithms, basic algorithm analysis (e.g., $O(n)$ vs $O(n^2)$ and similar things)

- We can fill in gaps as needed, but if any topics are new, plan on some extra studying

In CSE 143

- Learned fundamentals of computer science
  - Variables, conditions, loops, methods, recursion, etc..
  - Also learned about Data Structures!
    - Which ones?

143 vs 373

- 143: Showed you how to use data structures

- One goal of 373:
  - Provide you with the tools to understand when and why one would use certain data structures/ algorithms over others
    - And to be able to implement your own!

What 373 is about

- Deeply understand the basic structures used in all software
  - Understand the data structures and their trade-offs
  - Rigorously analyze the algorithms that use them (math!)
  - Learn how to pick "the right thing for the job"
  - More thorough and rigorous take on topics introduced in CSE143 (plus more new topics)

- Practice design, analysis, and implementation
  - The elegant interplay of "theory" and "engineering" at the core of computer science

- More programming experience (as a way to learn)

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

Dan Grossman's take:

- Key abstractions used almost every day in just about anything related to computing and software
- It is a vocabulary you are likely to internalize permanently

Data Structures

- Introduction to Algorithm Analysis
- Lists, Stacks, Queues
- Trees, Hashing, Dictionaries
- Heaps, Priority Queues
- Sorting
- Disjoint Sets
- Graph Algorithms
- *May have time for other brief exposure to topics, maybe parallelism*

Data structures

(Often highly *non-obvious*) ways 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, 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
- 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

ADT vs. Data Structure vs. Implementation

"Real life" Example (not perfect)

ADT: Automobile

- Operations: Accelerate, decelerate, etc…

Data Structure: Type of automobile

- Car, Motorcycle, Truck, etc…

Implementation (of Car):

- 2009 Honda Civic, 2001 Subaru Outback, …

Example: Stacks

- The ***Stack*** ADT supports operations:
  - **`isEmpty`**: have there been same number of pops as pushes
  - **`push`**: takes an item
  - **`pop`**: raises an error if empty, else returns most-recently pushed item not yet returned by a pop
  - … (possibly more operations)

- A Stack data structure could use a linked-list or an array or something else, 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:

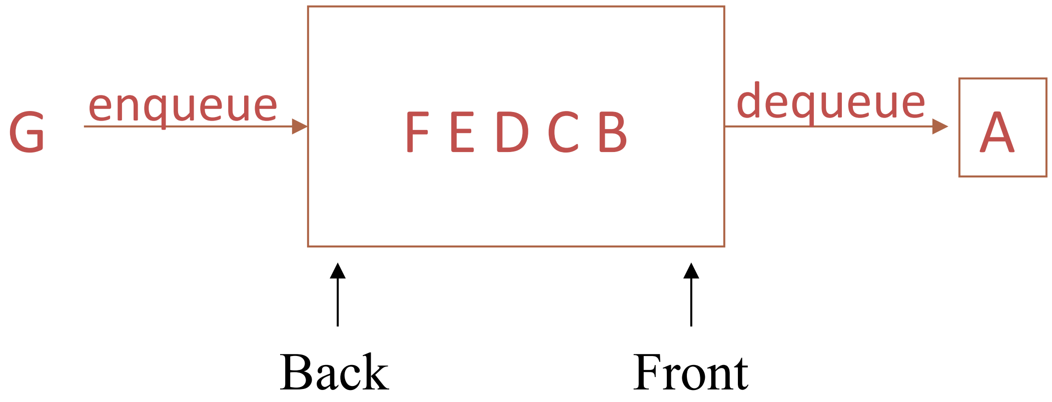
- It arises all the time in programming (e.g., see Weiss 3.6.3)
  - Recursive function calls
  - Balancing symbols (parentheses)
  - Evaluating postfix notation: 3 4 + 5 *
  - Clever: Infix ((3+4) * 5) to postfix conversion (see text)

- 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 a linked list and add a node when…"

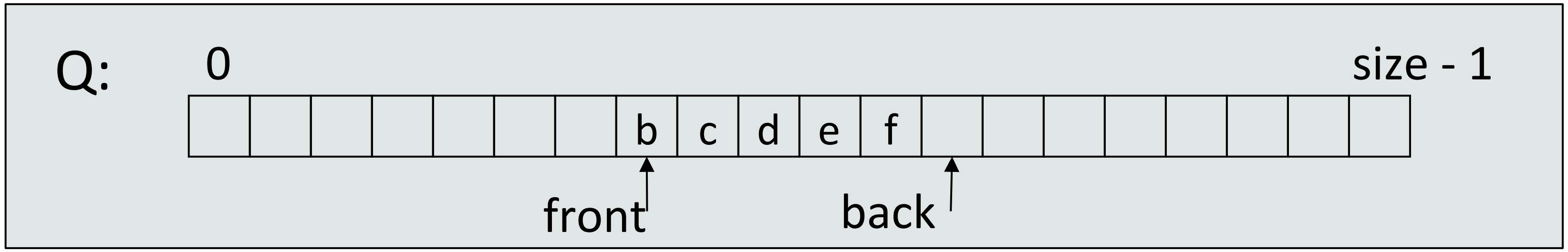
The Queue ADT

- Operations
  create
  destroy
  enqueue
  dequeue
  is_empty



- Just like a stack except:
  – Stack: LIFO (last-in-first-out)
  – Queue: FIFO (first-in-first-out)
- Just as useful and ubiquitous

Circular Array Queue Data Structure



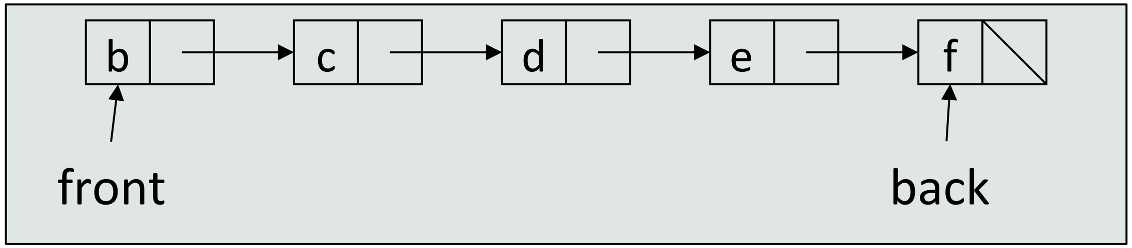

```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

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

Considerations:

- 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 k^{th} element in the queue?

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;
}
```

Considerations:

- 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 k^{th} 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

But wait, there's more!

- So far:
  - Compared different implementations of data structures.

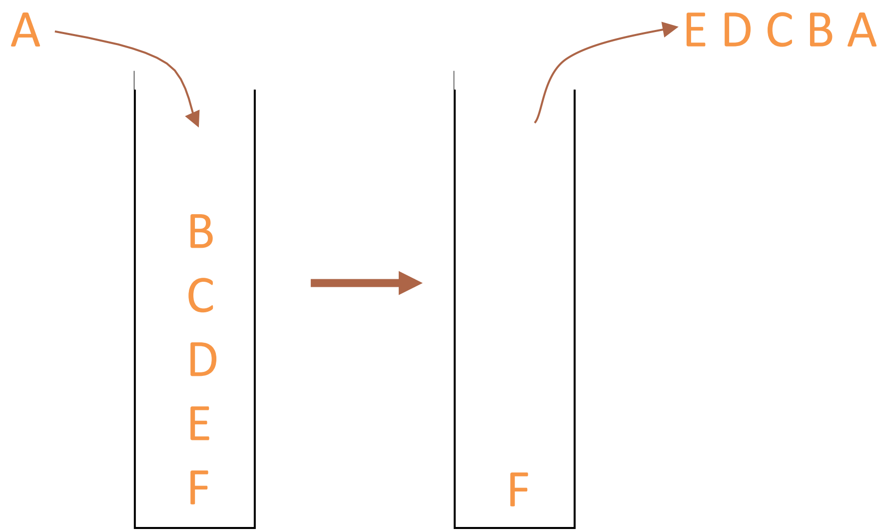
But we should also make sure we're using the right data structure for the job.

- Imagine we need to store some data, and want to access the *kth* element often.
  - Does it make sense to use a Queue or Stack ?

The Stack ADT

Operations:

```
create
destroy
push
pop
top
is_empty
```



Can also be implemented with an array or a linked list

- This is Homework 1!
- Like queues, type of elements is irrelevant