CSE 332: Data Structures & Parallelism

Ruth Anderson

Autumn 2020

Lecture 1

Welcome!

We have 10 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.
- Parallelism and concurrency (!)

Today's Outline

- Introductions
- Administrative Info
- What is this course about?
- Review: Queues and stacks

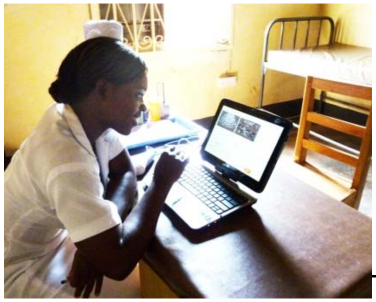
CSE 332 Course Staff!!

Instructor:

Ruth Anderson

Teaching Assistants:

- Richard Jiang
- Kevin Pham
- Winston Jodjana
- Diya Joy
- Aayushi Modi
- Sashu Shankar
- Hamsa Shankar
- Jeffery Tian
- Hans Zhang



Me (Ruth Anderson)

- Grad Student at UW in Programming Languages, Compilers, Parallel Computing
- Taught Computer Science at the University of Virginia for 5 years
- Grad Student at UW: PhD in Educational Technology, Pen Computing
- Current Research: Computing and the Developing World, Computer Science Education
- Recently Taught: data structures, architecture, compilers, programming languages, 142 & 143, data programming in Python, Unix Tools, Designing Technology for Resource-Constrained Environments

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Course Information

- **Instructor**: Ruth Anderson, CSE 558

  Office Hours: see course web page, and by appointment, (rea@cs.washington.edu)
- **Text**: *Data Structures & Algorithm Analysis in Java*, (Mark Allen Weiss), 3rd edition, 2012 (2nd edition also o.k.)
- **Course Web page**: **`http://www.cs.washington.edu/332`**

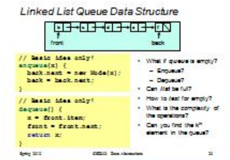
Communication

- Course email list: **`cse332a_au20@uw`**
  - › You are already subscribed
  - › You must get and read announcements sent there
- Ed STEM Discussion board
  - › Your first stop for questions about course content & assignments
- Anonymous feedback link
  - › For good and bad: if you don’t tell me, I won’t know!

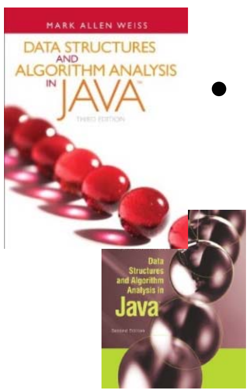
Course Meetings

- Lecture
  - Materials posted (sometimes afterwards), but take notes
  - Ask questions, focus on key ideas (rarely coding details)
- Section
  - Practice problems!
  - Answer Java/project/homework questions, etc.
  - Occasionally may introduce new material
  - An important part of the course (not optional)
- Office hours
  - Use them: *please visit us!*

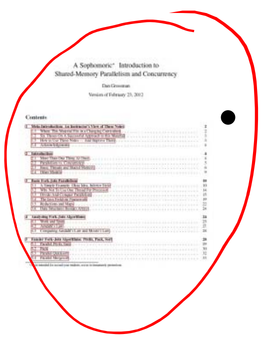
Course Materials



- 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 3rd Edition in Java
  - › Good read, but only responsible for lecture/section/hw topics
  - › 3rd edition improves on 2nd, but we'll also support the 2nd



- Parallelism / concurrency units in separate free resources designed for 332

Course Work

- ~20 Weekly individual homework exercises (25%)
- 3 programming projects (with phases) (40%)
  - Use Java 11 and IntelliJ, Gitlab
  - Done in partners, o.k. if partner is in other quiz section
- No midterm or final exam!!! (30%)
  - Instead, we will have 3 quizzes
  - Released on Wednesday, due on Friday
  - Open book, small-group collaboration allowed
  - *More details announced as we get closer to 1st quiz*
- Participation (5%) – available asynchronously

Homework for Today!!

0) **Project #1:** Fill out partner request survey(s) by 5pm TOMORROW
1) **Review Java & install IntelliJ**
2) **Exercise #1 –** Due MONDAY at 11:59pm
3) **Preliminary Surveys**: fill out by Friday evening
4) **Reading** in Weiss (see Syllabus)

Reading

- Reading in *Data Structures and Algorithm Analysis in Java*, 3rd Ed., 2012 by Weiss
- For this week:
  - › (Topic for Project #1) Weiss 3.1-3.7 – Lists, Stacks, & Queues
  - › (Fri) Weiss 2.1-2.4 –Algorithm Analysis
  - › (Useful) Weiss 1.1-1.6 –Mathematics and Java (Not covered in lecture – READ THIS)

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Data Structures + Parallemism

- About 70% of the course is a “classic data-structures course”
  - Timeless, essential stuff
  - Core data structures and algorithms that underlie most software
  - How to analyze algorithms
- Plus a serious first treatment of programming with *multiple threads*
  - For *parallelism*: Use multiple processors to finish sooner
  - For *concurrency*: Correct access to shared resources
  - Will make many connections to the classic material

What 332 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"

- Experience the purposes and headaches of multithreading

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

Goals

- You will understand:
  - › what the tools are for storing and processing common data types
  - › which tools are appropriate for which need
- So that you will be able to:
  - › make good design choices as a developer, project manager, or system customer
  - › justify and communicate your design decisions

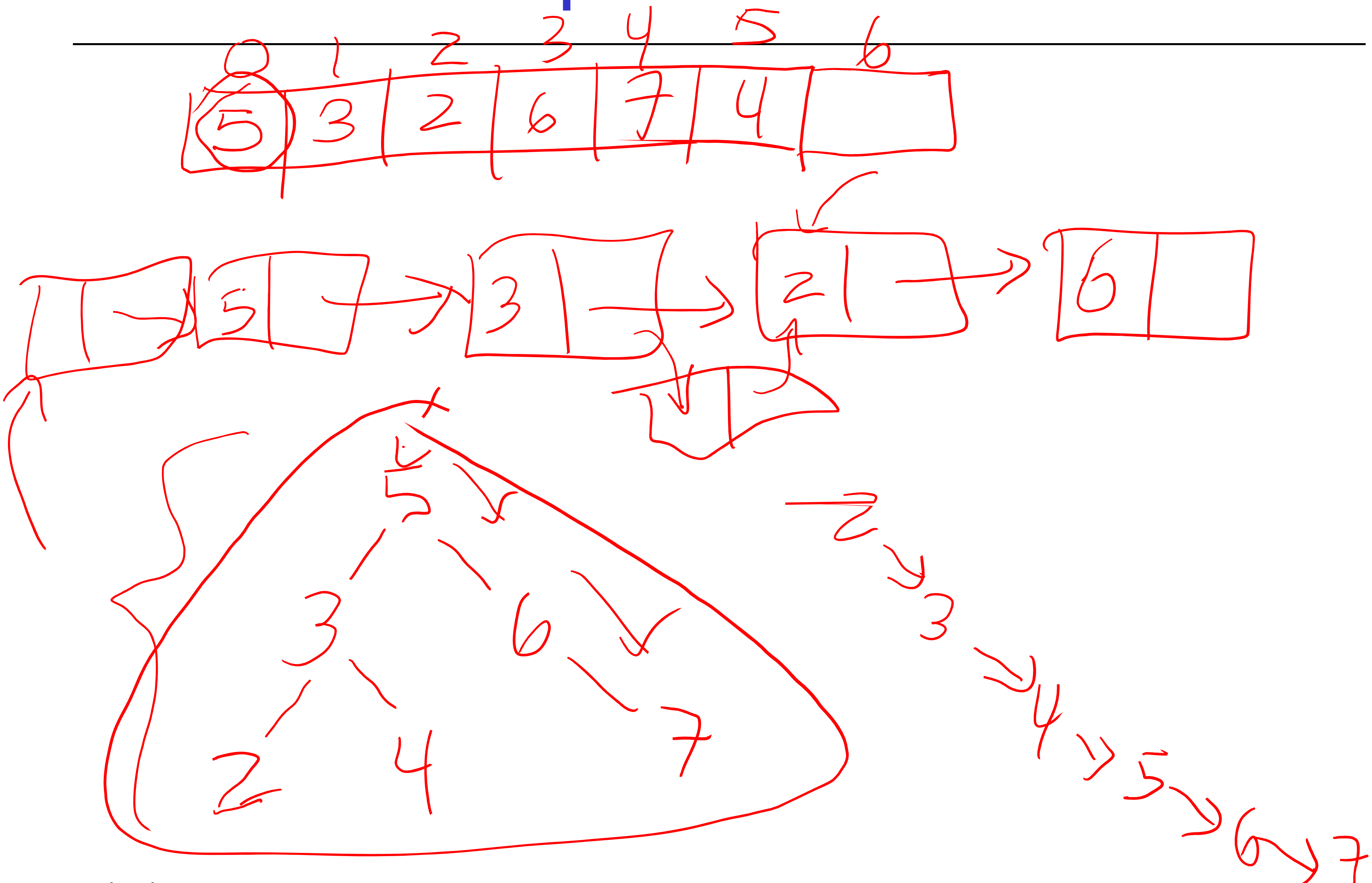
One view on this course

- This is the class where you begin to think like a computer scientist
  - › You stop thinking in Java code
  - › You start thinking that this is a hashtable problem, a stack problem, etc.

Data Structures?

"Clever" ways to organize information in order to enable *efficient* computation over that information.

Example Trade-Offs



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

That is why there are many data structures and educated CSEers internalize their main trade-offs and techniques

- And recognize logarithmic < linear < quadratic < exponential

Most Abstract

Getting Serious: Terminology

- Abstract Data Type (ADT)
  - › Mathematical description of a “thing” with set of operations on that “thing”
- 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

Most Concrete

The Stack ADT

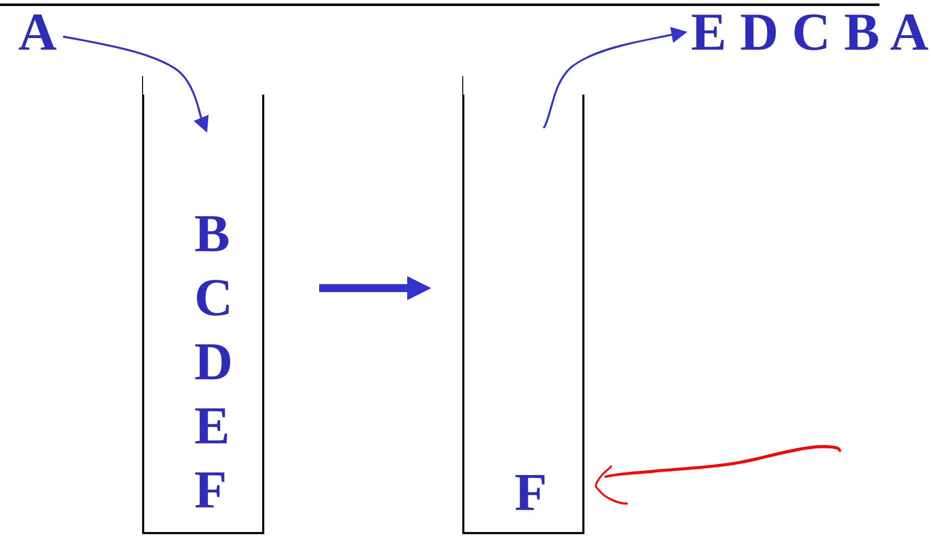
- Stack Operations:

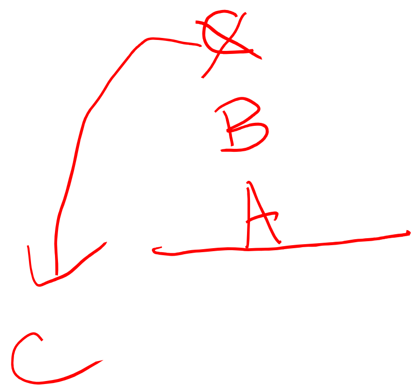
  push

  pop

  top/peek

  is_empty





Terminology Example: Stacks

- The ***Stack*** ADT supports operations:
  - **`push`**: adds an item
  - **`pop`**: raises an error if isEmpty, else returns *most-recently pushed item* not yet returned by a pop
  - **`isEmpty`**: initially true, later true if there have been same number of pops as pushes
  - … (Often some 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 (see Weiss for more)
  - › Recursive function calls
  - › Balancing symbols (parentheses)
  - › Evaluating postfix notation: 3 4 + 5 *
  - › Clever: Infix ((3+4) * 5) to postfix conversion (see Weiss)
- 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…"

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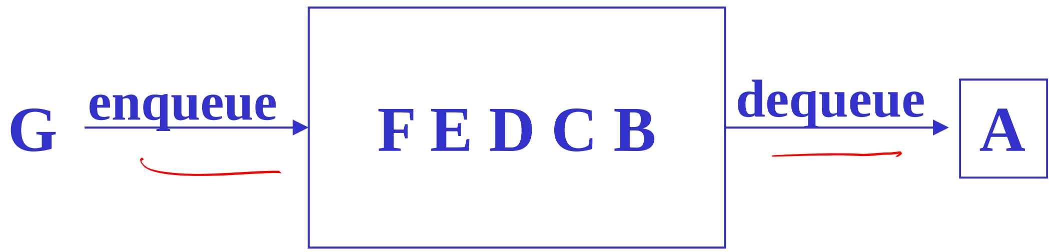
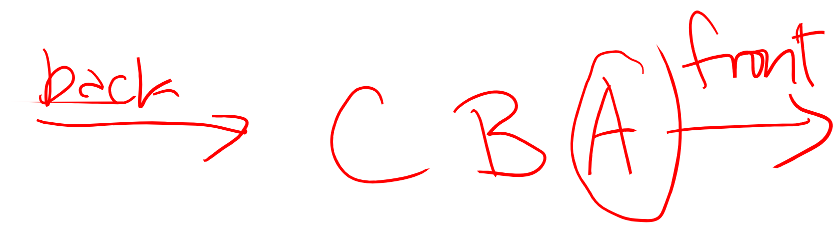
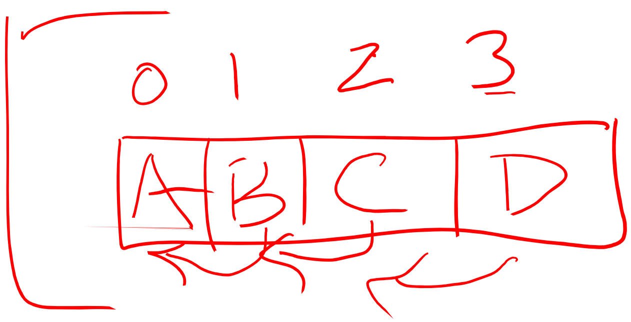
The Queue ADT

Queue Operations:

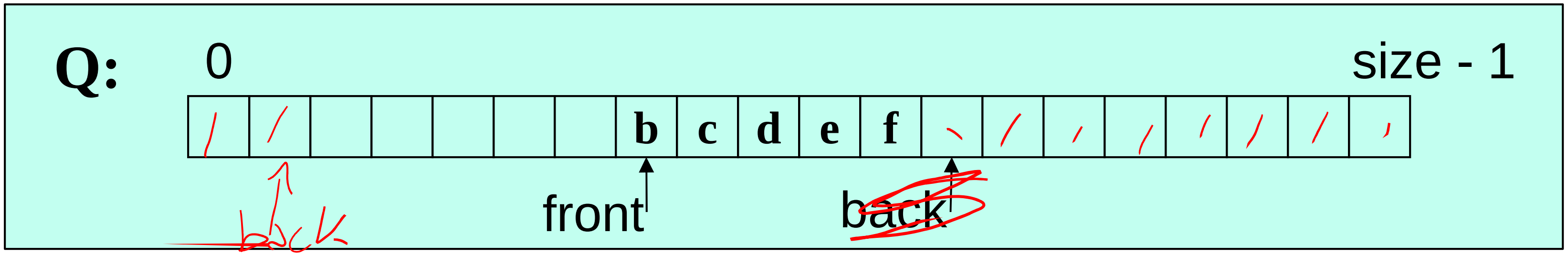
- **enqueue**
- **dequeue**
- **is_empty**







Circular Array Queue Data Structure

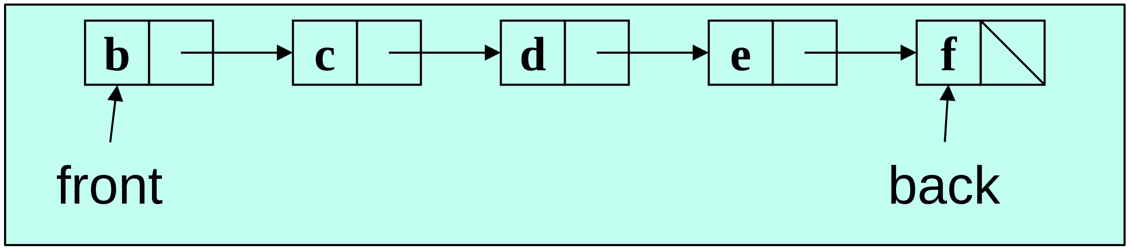



```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

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

- What if ***queue*** is empty?
  - Enqueue?
  - Dequeue?
- What if ***array*** is full?
- How to *test* for empty?
- What is the *complexity* of the operations?

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?

Circular Array vs. Linked List

Circular Array vs. Linked List

Array:

- May waste unneeded space or run out of space
- Space per element excellent
- Operations very simple / fast

Operations not in Queue ADT, but also:

- Constant-time “access to k^{th} element”
- For operation “insertAtPosition”, must shift all later elements

List:

- Always just enough space
- But more space per element
- Operations very simple / fast

Operations not in Queue ADT, but also:

- No constant-time “access to k^{th} element”
- For operation “insertAtPosition” must traverse all earlier elements

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