CSE 332: Data Structures & Parallelism

Lecture 1: Intro, Stacks & Queues

Ruth Anderson

Spring 2023

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

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

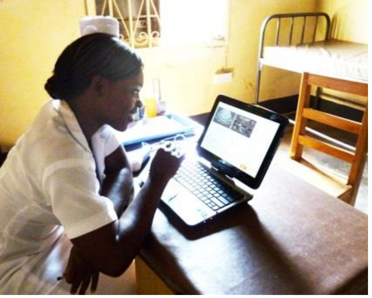
CSE 332 Course Staff!!

Instructor:

Ruth Anderson

Teaching Assistants:

- Aditi Joshi
- Allyson Mangus
- Amanda Yuan
- Ariel Fu
- Arya Krisna GJ
- Dara Stotland
- Mohamed Awadalla
- Neel Jog
- Nile Camai
- Winston Jodjana
- Youssef Ben Taleb



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
- Recent 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)
- **Course Web page:**
  - **`http://www.cs.uw.edu/332`**
- **Text (optional)**:
  Data Structures & Algorithm Analysis in Java, (Mark Allen Weiss), 3rd edition, 2012
  (2nd edition also o.k.)

Communication

- Course email list:
  `cse332a_sp23@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 us, we 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

- ~15 Weekly individual homework exercises (25%)
- 3 programming projects (with phases) (35%)
  - Use Java and IntelliJ, Gitlab
  - Done individually
- Midterm and final exam (40%)
  - In-person, in this room (CSE2 G20)
  - Dates:
    - Midterm: Friday April 28, during lecture
    - Final Exam: Thursday June 8, 8:30-10:20am

Homework for Today!!

1. **Preliminary Survey: due Thursday**
2. **Project #1: Checkpoint 0 due Friday**
3. **Review Java & install IntelliJ**
4. **Reading** (optional) in Weiss (see course web page)

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
  - (Wed) 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

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

The Stack ADT

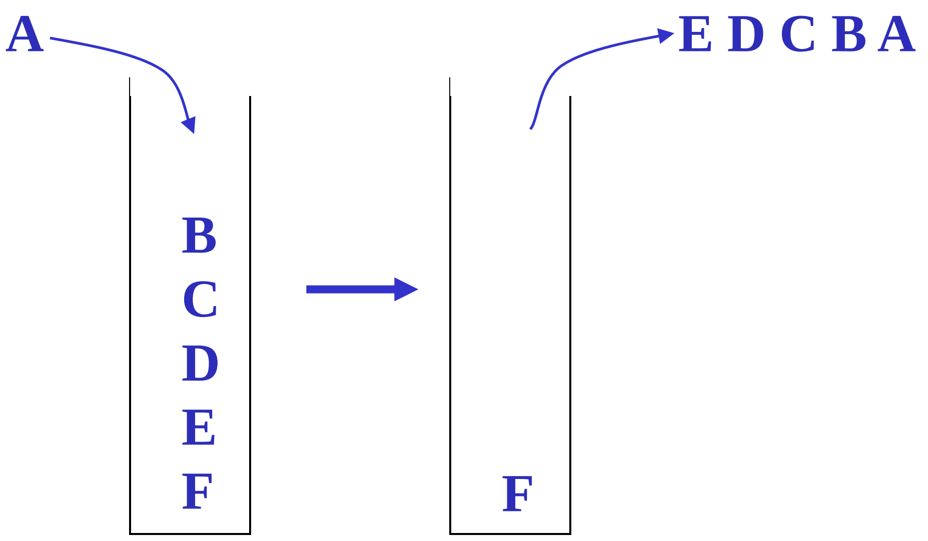
- Stack Operations:

  `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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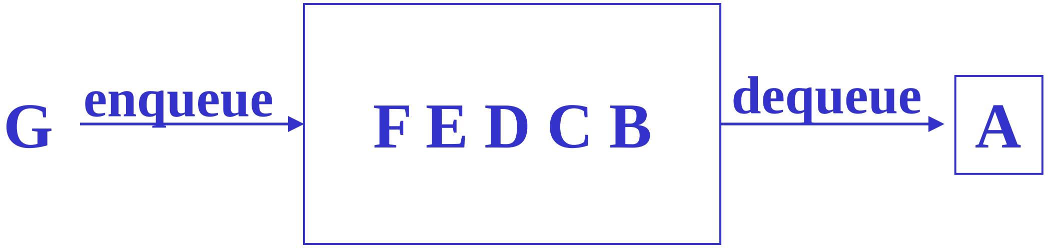
The Queue ADT

Queue Operations:

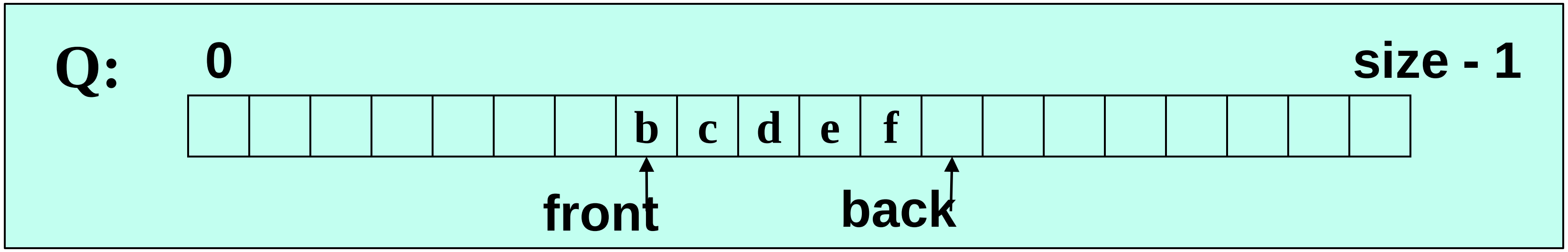
`enqueue`

`dequeue`

`is_empty`



Circular Array *Queue* *Data Structure*

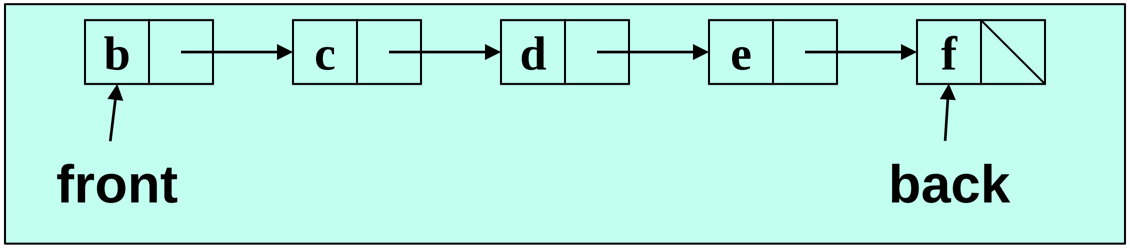



```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

```
// 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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