

CSE 332: Data Structures & Parallelism

Ruth Anderson

Winter 2019

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

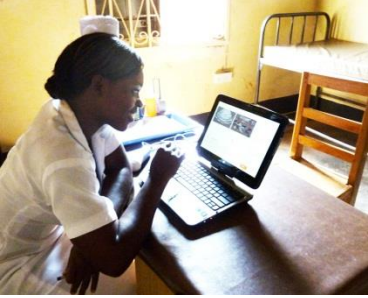
CSE 332 Course Staff!!

Instructor:

Ruth Anderson

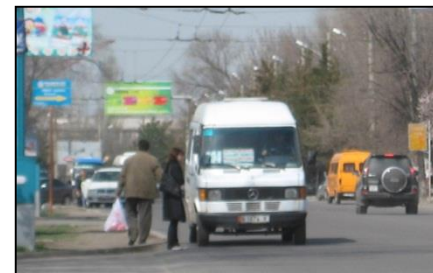
Teaching Assistants:

- Daniel Allen
- Amulya Bhattarai
- Chris Choi
- John Feltrup
- Jeff Da
- Richard Jiang
- Annie Mao
- Andrew Li
- Sherry Prawiro
- Kat Wang
- Yin Yin Low
- Frank Qin
- Lucas Wotton
- Casey Xing



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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- **Administrative Info**
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Course Information

- **Instructor:** Ruth Anderson, CSE 460
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

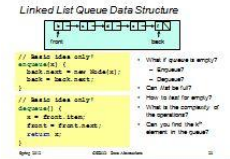
- Course email list: `cse332a_wi19@uw`
`cse332b_wi19@uw`
 - › You are already subscribed
 - › You must get and read announcements sent there
- Piazza Discussion board
 - › Your first stop for questions about course content & assignments
- Anonymous feedback link
 - › For good and bad: if you don't tell me, I won't know!

Course Meetings

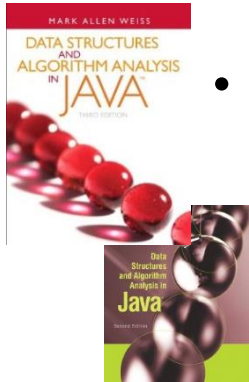
- Lecture
 - › Materials posted (sometimes afterwards), but take notes
 - › Ask questions, focus on key ideas (rarely coding details)
- Section
 - › Practice problems!
 - › Answer Java/project/homework questions, etc.
 - › Occasionally may introduce new material
 - › An important part of the course (not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

Course Materials

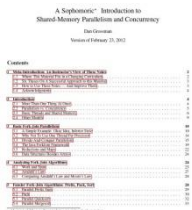
- Lecture and section materials will be posted
 - › But they are visual aids, not always a complete description!
 - › If you have to miss, find out what you missed



- 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) (30%)
 - › Use Java 11 and Eclipse, Gitlab
 - › Done in partners, o.k. if partner is in other lecture section
- Midterm - (20%)
- Final Exam - (25%)
- **Midterm exam:** Thursday February 7, 2019, time TBA (afternoon/eve)
- **Final exam:** Thursday March 21, 2019, 12:30-2:20pm
- Locations TBA. ***Contact the instructor immediately if you have a conflict with either of these times.***

Collaboration & Academic Integrity

- Read the course policy very carefully
 - › Explains quite clearly how you can and cannot get/provide help on homework and projects
 - › Looking at solutions from previous quarters is cheating
 - › Gilligan's Island rule applies.
- Always proactively explain any unconventional action on your part. When it happens, (not when asked)

Homework for Today!!

- 0) Project #1:** (released later today) Fill out partner request survey by 12pm TOMORROW
- 1) Review Java & install Eclipse**
- 2) Exercise #1 – Due FRIDAY at 11:59pm**
- 3) Preliminary Survey:** fill out by Tues evening
- 4) Reading** in Weiss (see handout)

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 + Parallelism

- 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.

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

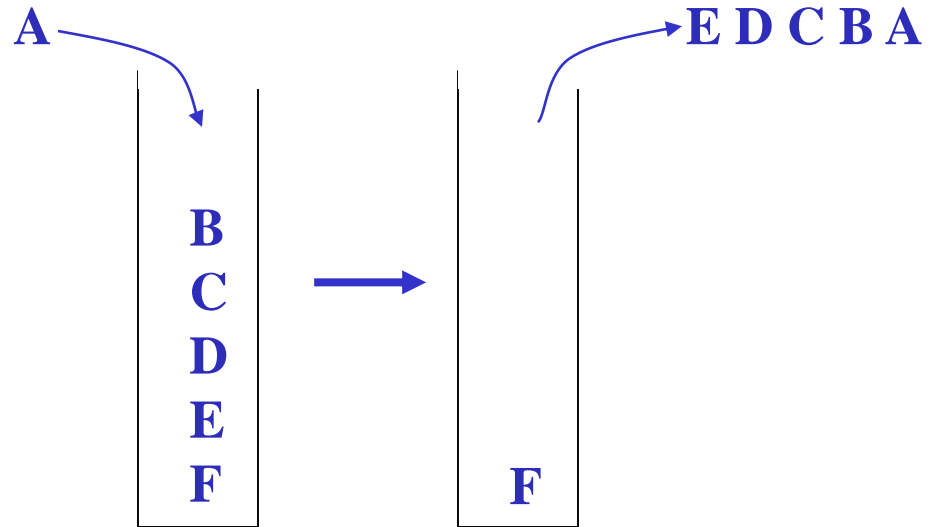
- Stack Operations:

`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:

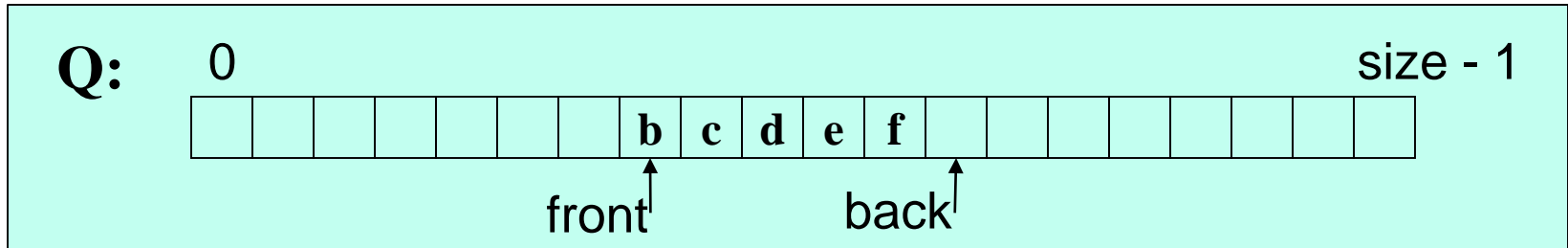
`enqueue`

`dequeue`

`is_empty`



Circular Array Queue Data Structure

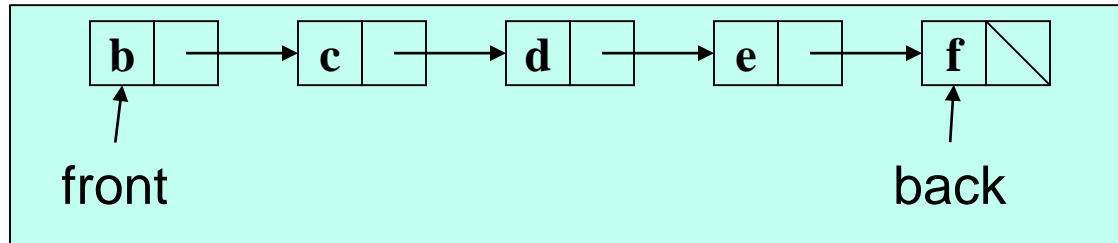


```
// Basic idea only!  
enqueue(x) {  
    Q[back] = x;  
    back = (back + 1) % size  
}
```

```
// 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

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

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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