CSE 332: Data Abstractions

Ruth Anderson

Spring 2013

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

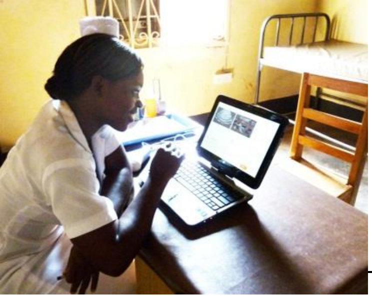
CSE 332 Course Staff!!

Instructor:

Ruth Anderson

Teaching Assistants:

- Hye In Kim
- David Swanson



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
- Recently Taught: majors and non-majors data structures, architecture, compilers, programming languages, cse143, Designing Technology for Resource-Constrained Environments

Today's Outline

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Course Information

- **Instructor**: Ruth Anderson, CSE 360

  Office Hours: M 3:30-4:30pm,
  Tu 11-11:50am, and by appointment,
  (rea@cs.washington.edu)
- **Text**: *Data Structures & Algorithm Analysis in Java*, (Mark Allen Weiss), 3rd edition, 2012
- **Course Web page**: **`http://www.cs.washington.edu/332`**

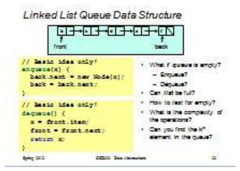
Communication

- Course email list: **`cse332a_sp13@u`**
  - Students and staff already subscribed
  - You must get announcements sent there
  - Fairly low traffic
- Course staff: **`cse332-staff@cs`** plus individual emails
- Discussion board
  - For appropriate discussions; staff will monitor
  - Optional, 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 (Ruth)
  - Materials posted (sometimes afterwards), but take notes
  - Ask questions, focus on key ideas (rarely coding details)
- Section (Hye In)
  - Often focus on software (Java features, tools, project issues)
  - Reinforce key issues from lecture
  - Occasionally introduce new material
  - Answer homework questions, etc.
  - An important part of the course (not optional)
- Office hours
  - Use them: *please visit me*
  - Ideally not *just* for homework questions (but that's great too)

Course materials


Linked List Queue Data Structure

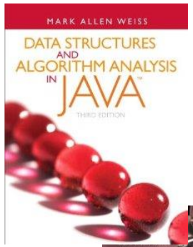
front back

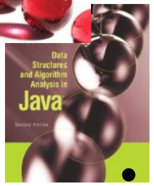
```
// Basic idea only!
enqueue(x) {
  back.next = new Node(x);
  back = back.next;
}
```

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

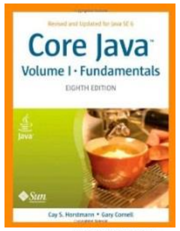
- What if queue is empty?
  - Enqueue?
  - Dequeue?
- Can list be full?
- How to test for empty?
- What is the complexity of the operations?
- Can you find the kth element in the queue?

- 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

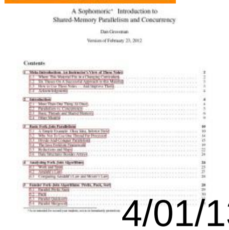




- Textbook: Weiss 3rd Edition in Java
  - › Good read, but only responsible for lecture/section/hw topics
  - › Will assign homework problems from it
  - › 3rd edition improves on 2nd, but we'll support the 2nd


Revised and Updated for Java SE 6
Core Java
Volume I · Fundamentals
EIGHTH EDITION
Java
Sun
Cay S. Horstmann · Gary Cornell

- Core Java book: A good Java reference (there may be others)
  - › Don't struggle Googling for features you don't understand
  - › Same book recommended for CSE331


A Sophomoric* Introduction to
Shared-Memory Parallelism and Concurrency

Dan Grossman

Version of February 23, 2012

Contents

[illegible]

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

Course Work

- 8 written/typed homeworks (25%)
  - Due at beginning of class each Friday (not this week)
  - No late homeworks accepted
- 3 programming projects (with phases) (25%)
  - First phase of first project due next week
  - Use Java and Eclipse (see this week's section)
  - One 24-hour late-day for the quarter
  - Projects 2 and 3 will allow partners
- Midterm - (20%)
- Final Exam - (25%)

Collaboration & Academic Integrity

- Read the course policy very carefully
  - Explains quite clearly how you can and cannot get/provide help on homework and projects
  - Gilligan’s Island rule applies.

- Always proactively explain any unconventional action on your part
  - When it happens, (not when asked)

- I offer great trust but with little sympathy for violations
- Honest work is the most important feature of a university

Unsolicited advice

- Get to class on time!
- Learn this stuff
  - You need it for so many later classes/jobs anyway
  - Falling behind only makes more work for you
- Have fun
  - So much easier to be motivated and learn

Homework for Today!!

0) **Review Java & install Eclipse**
1) **Project #1:** (released by Wednesday) bring questions to section on Thursday
2) **Preliminary Survey**: fill out by evening of Thurs April 4th
3) **Information Sheet**: bring to lecture on or before Friday April 5th
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 1.1-1.6 –Mathematics and Java
  - (Fri) Weiss 2.1-2.4 –Algorithm Analysis

Bring to Class on Friday:

- Name
- Email address
- Year (1,2,3,4,5)
- Hometown
- Interesting Fact or what I did over break.

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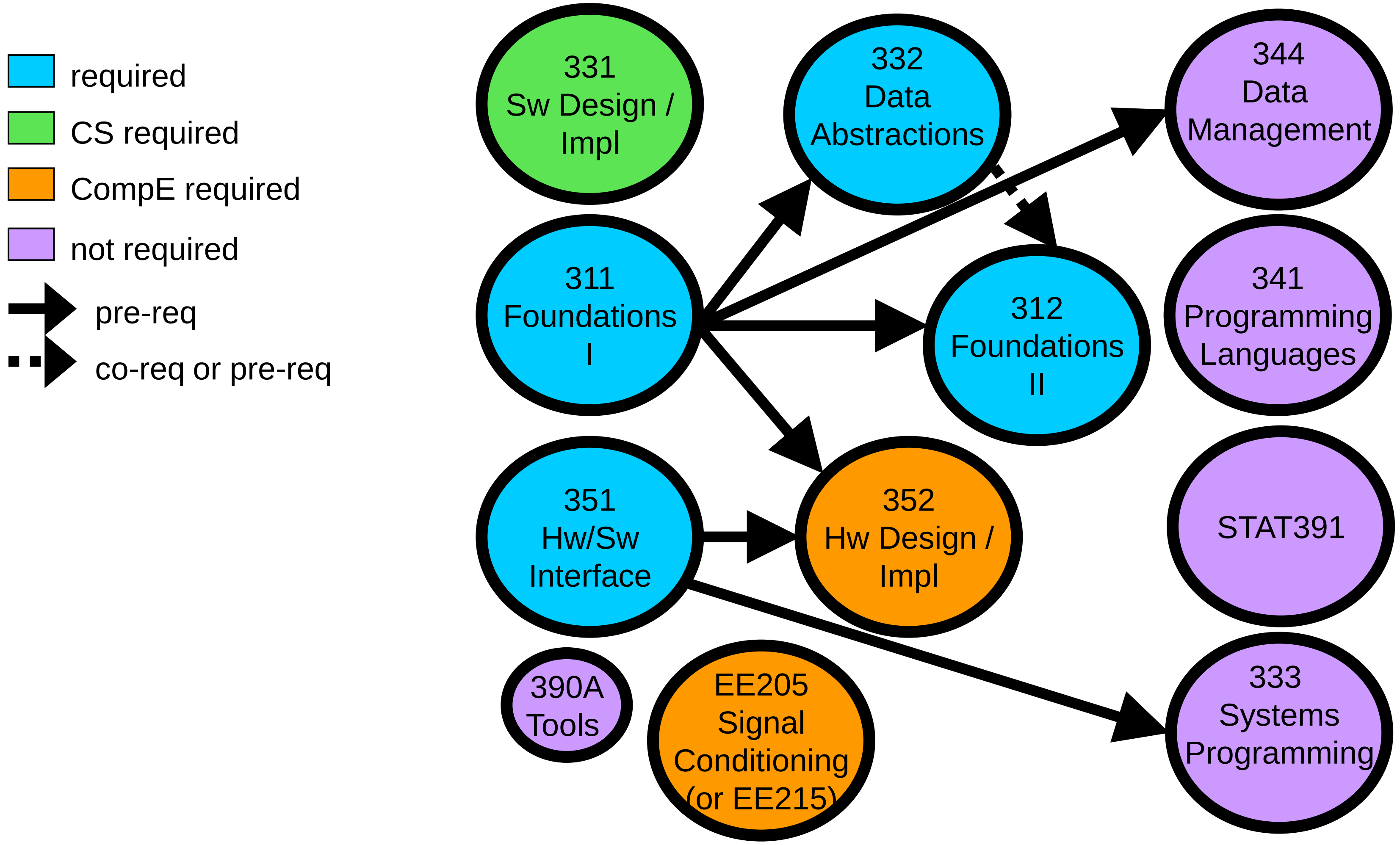
Data Structures + Threads

- 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

Where 332 fits



- Most common pre-req for 400-level courses
  - Essential stuff for many internships too!

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

Views on this course

- Prof. Steve Seitz (graphics):
  - 100-level and some 300-level courses teach how to do stuff
  - 332 teaches **really cool** ways to do stuff
  - 400 level courses teach how to do **really cool** stuff
- Prof. James Fogarty (HCI):
  - Computers are fricking insane
    - Raw power can enable bad solutions to many problems
  - This course is about how to attack non-trivial problems
    - Problems where it actually matters how you do it

Views on this course

- Prof. Dan Grossman (prog. langs.):
  Three years from now this course will seem like it was a waste of your time because you can't imagine not "just knowing" every main concept in it
  - Key abstractions computer scientists and engineers use almost every day
  - A big piece of what separates us from others

Views on this course

- This is the class where you begin to think like a computer scientist
  - You stop thinking in Java or C++ 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.

Data structures!

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

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

- › And recognize logarithmic < linear < quadratic < exponential

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

Example: Stacks

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

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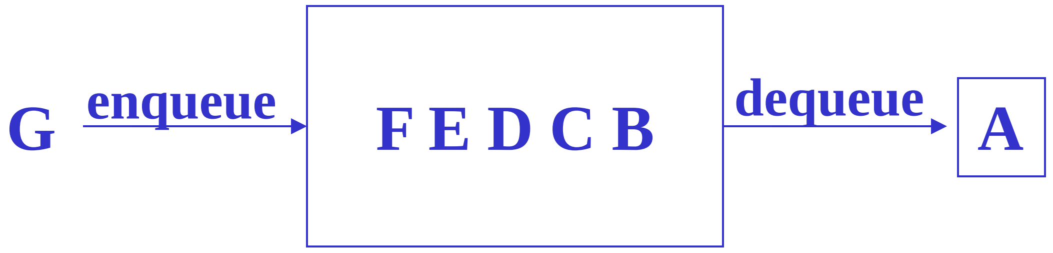
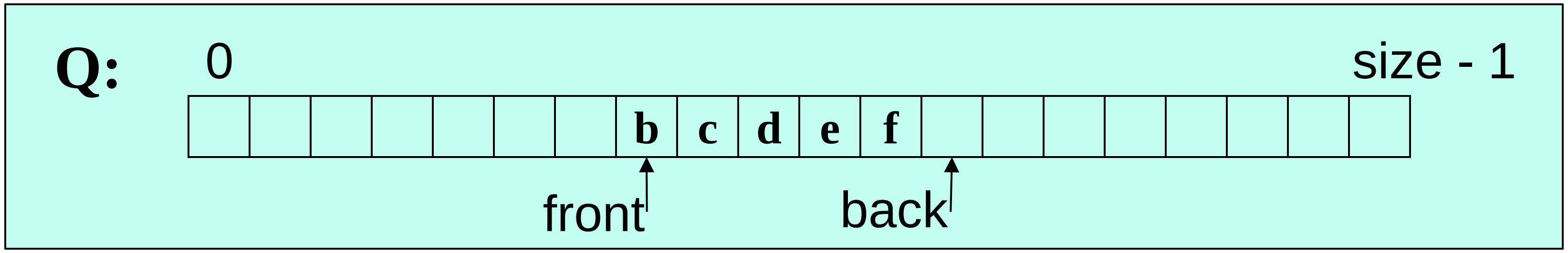
The Queue ADT

Queue Operations:

```
create
destroy
enqueue
dequeue
is_empty
```



Circular Array Queue Data Structure

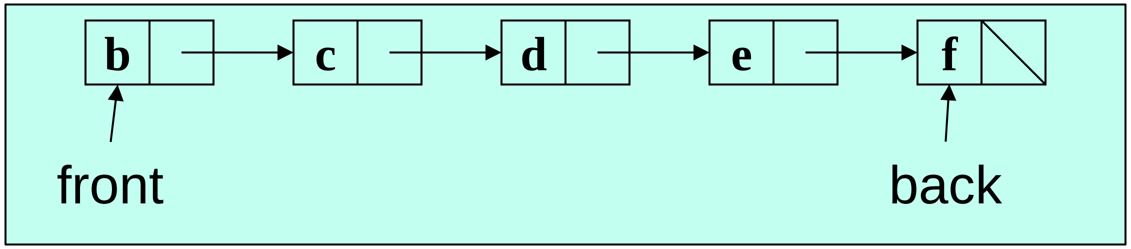


```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

```
// 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?
- Can you find the kth 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;
}
```

- 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

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 kth 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 kth element

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

The Stack ADT

- Stack Operations:

  `create`

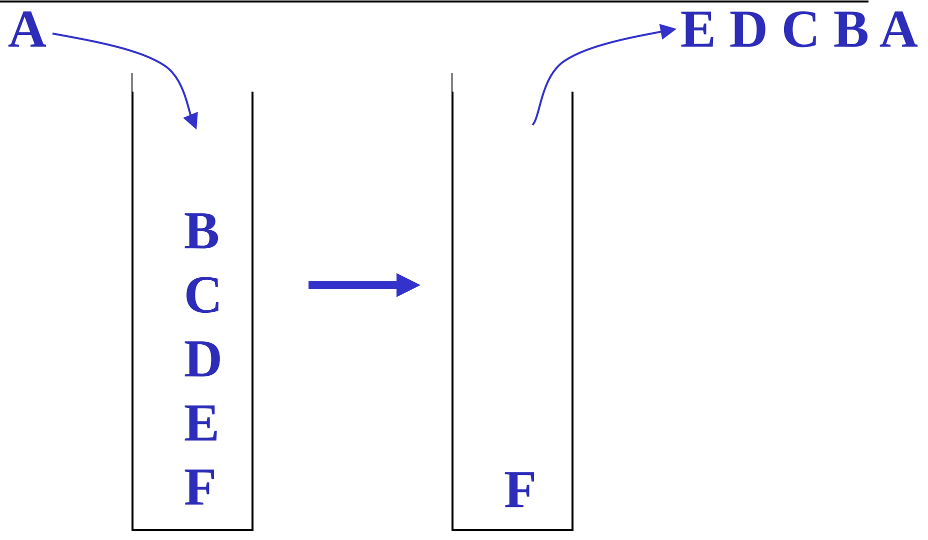
  `destroy`

  `push`

  `pop`

  `top/peek`

  `is_empty`



- Can also be implemented with an array or a linked list
  - › This is Project 1!
  - › Like queues, type of elements is irrelevant
    - Ideal for Java's generic types (section and Project 1B)

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