CSE 332 Data Abstractions:

Introduction and ADTs

Kate Deibel

Summer 2012

Welcome!

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

- Classic data structures and algorithms: queues, trees, graphs, sorting, etc.
- Rigorously analyze their efficiency
- Determine when to use them
- Parallelism and concurrency (!)

Today in Class

- Course mechanics
- What this course is about
  - And how it fits into the CSE curriculum
- What is an ADT?
- Review of Stacks and Queues
- Mystery Topics!?

Concise to-do list

In next 48 hours, you should:

- Adjust class email-list settings
- Do homework 0 (worth 5 bonus pts)
- Read all course policies
- Read/skim Chapters 1 & 3 of Weiss book
    - Relevant to Project 1, due next week
    - Will start Chapter 2 on Wednesday

Socket wrench… scalpel… snarky comments…

COURSE MECHANICS

Instructor: Kate Deibel

Not me but my cute calico Susie

- PhD in CSE (2011), University of Washington
- Research:
  Digital literacies
  Educational Technologies
  Assistive technologies
  Disability and education
- Office: CSE 210
- Hours: TBD or drop-by
- E-mail: deibel@cs or @uw

Teaching Assistant: David Swanson

Not David but Susie again. Isn't she cute?

- Let's let him introduce himself…
- E-mail: swansond@cs

D-E-I-B-E-L

- Pronunciation:

  DIE-BULL

- Spelling:

  Decibel minus the ‘c’

When in doubt…

- Consult the course webpage

http://www.cs.washington.edu/education/courses/cse332/12su/

Or, if you want the quicker URL:

http://www.cs.washington.edu/332

Communication

- Course email list: **`cse332a_su12@u`**
  - You are already subscribed (your @uw e-mail)
  - You must get announcements sent there
  - Fairly low traffic
- Course staff: **`cse332-staff@cs`** or Kate's and David's individual emails
- Discussion board
  - For appropriate discussions; TAs will monitor
  - Optional but can be enlightening
- Anonymous feedback link
  - If you don’t tell me (good or bad), I don’t know

Course meetings

- Lecture (Kate)
  - Materials posted usually before class (95% guarantee) to aid your note-taking
  - Lectures focus on key ideas & proofs
  - Some interactive problem-solving
- Section (David)
  - Often focus on software (Java features, programming tools, project/HW issues)
  - Reinforce key issues from lecture
  - Answer homework questions, etc.
  - An important part of the course (not optional)

NOTICE!!!

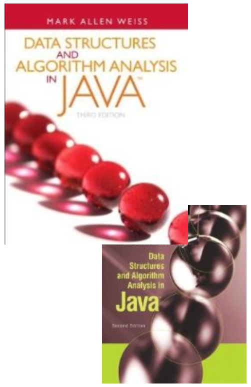
- Locations for one or more quiz sections will likely change
  - Goal is to have both in the same room or at least the same building
  - Will announce over course e-mail list before Thursday
  - Website will update when we know

Office Hours

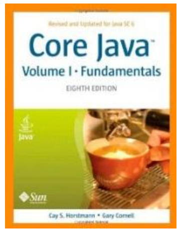
- David's Office Hours
  - TBD but will students for time
- Kate's Office Hours
  - TBD after David's are set
  - I frequently hold open-door hours:

If my door is open, come on in!

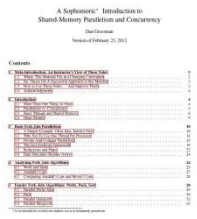
Course materials


MARK ALLEN WEISS
DATA STRUCTURES AND ALGORITHM ANALYSIS IN JAVA
THIRD EDITION
Data Structures and Algorithm Analysis in Java
Second Edition

- 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



- 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 use a free notes written by Dan Grossman (linked on website)

Course Work

- 8 written/typed homeworks (25%)
  - Due at end of lecture the day it is due
  - No late homeworks accepted
- 3 programming projects (25%)
  - Projects have phases (parts)
  - First phase of Project 1 due next week (TBD)
  - Use Java (see this week's section)
  - Two 24-hour late-days for the quarter
- Midterm Exam (20%)
- Final Exam (30%)

Collaboration & Academic Integrity

- Read the course policy very carefully to understand how you can and cannot get/provide help to/from others
- Be proactive and always explain (when you submit) any unconventional action on your part when it happens

Respect Policy

- If you respect me, I will respect you
- I am here to teach you and help you learn about data abstractions
- I make a promise to have good lectures, polished assignments, etc. on time and in good humor
- In return, you should be
  - Respectful in lab and lecture
  - Do not cheat

Academic Accommodations (formal)

To request personal academic accommodations due to a disability, please contact Disability Resources for Students: 448 Schmitz, 206-543-8924 (or 206-543-8925 for TTY).

If you have a letter from DRS indicating that you have a disability which requires academic accommodations, please present the letter to me so we can discuss how to meet your needs for this course.

Academic Accommodations (proper)

- My goal is for you to learn productively
- If you have problems, ask me or a TA
- Accommodations:
  - We are not mean
  - We understand that life happens beyond this class, this major, this university, …
  - We can make reasonable accommodations for individual students
  - This offer is open for everyone
- Just talk to us…

Unsolicited Advice

- Get to class on time!
- Learn this stuff
  - You need it for so many later classes/jobs
  - Falling behind only makes more work for you
- Have fun
  - So much easier to be motivated and learn
  - Get used to my bad jokes
  - Yes, they really are that bad
  - If you don't laugh, they just get worse

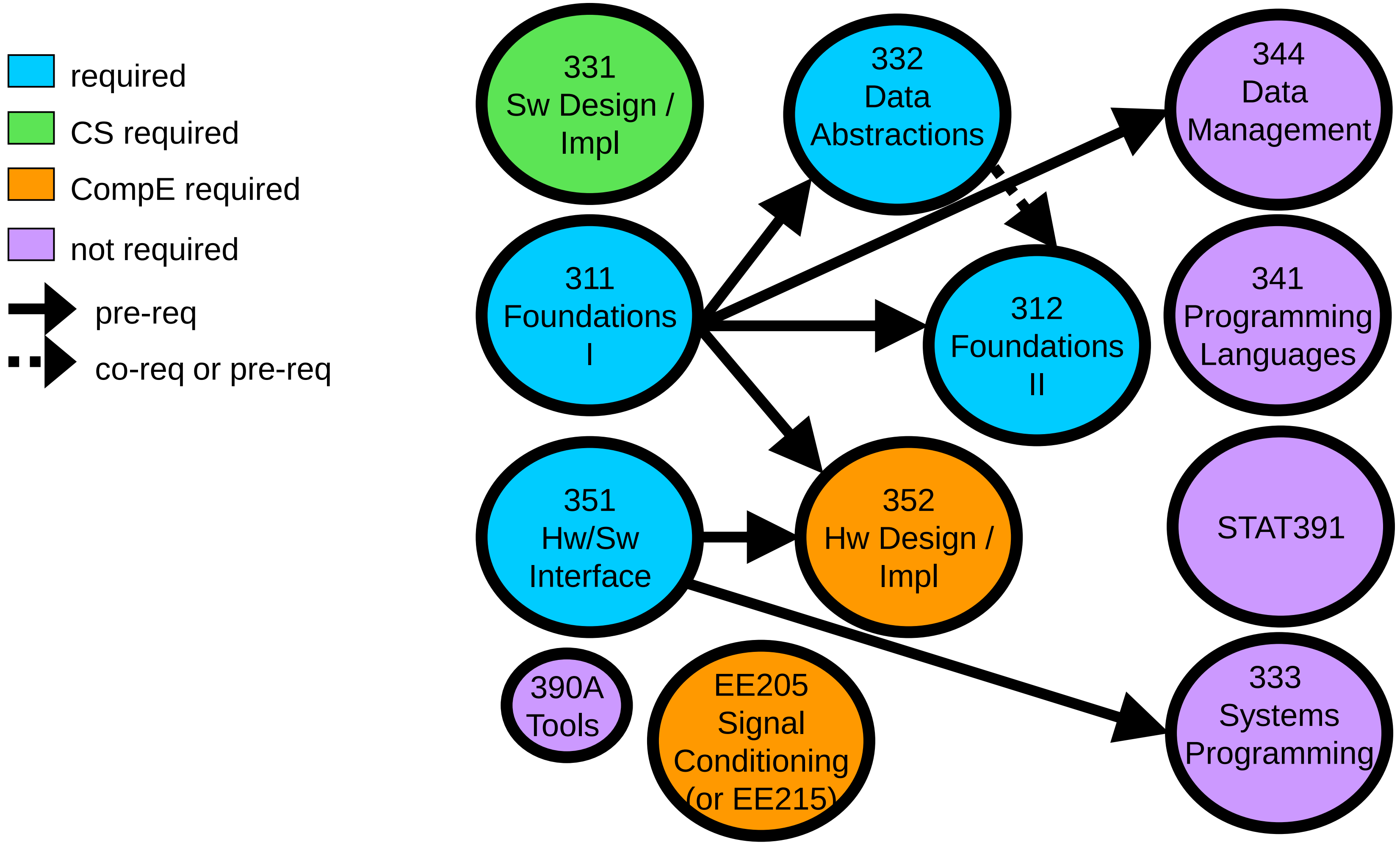
It's not about teaching penguins to limbo…

WHAT THIS CLASS IS ABOUT?

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
  - Parallelism: Use multiple processors
  - Concurrency: Access to shared resources
  - 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 trade-offs
  - 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

- 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

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 where it actually matters how you solve them

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

My View on the 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 linked list problem, etc.
  - You realize that little assumptions make big differences in performance
  - You realize there is no absolutely best solution for a problem

Data structures, ADTs, etc. (sorry, no weird joke here)

TERMINOLOGY

Data structures

[Often highly *non-obvious*] ways to organize information to enable *efficient* computation over that information

- Key goal of the next lecture is introducing asymptotic analysis to *precisely* and *generally* describe efficient use of time and space

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 performance vs. space usage
  - Getting one operation to be more efficient makes others 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

- Algorithm
    - A high level, language-independent description of a step-by-step process
- Abstract Data Type (ADT)
    - Mathematical description of a “thing” with set of operations
- Data structure
    - A specific family of algorithms for implementing an ADT
- Implementation of a data structure
    - A specific implementation in a specific language on a specific machine (both matter!)

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 isEmpty, 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`**

The Stack is a Useful Abstraction

- 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
- 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

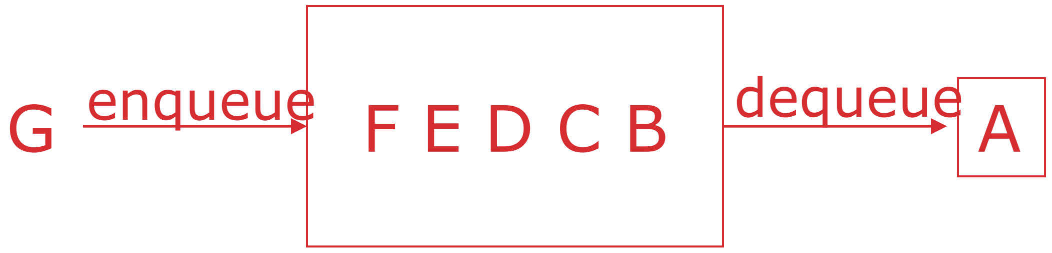
  `create`

  `destroy`

  `enqueue`

  `dequeue`

  `is_empty`

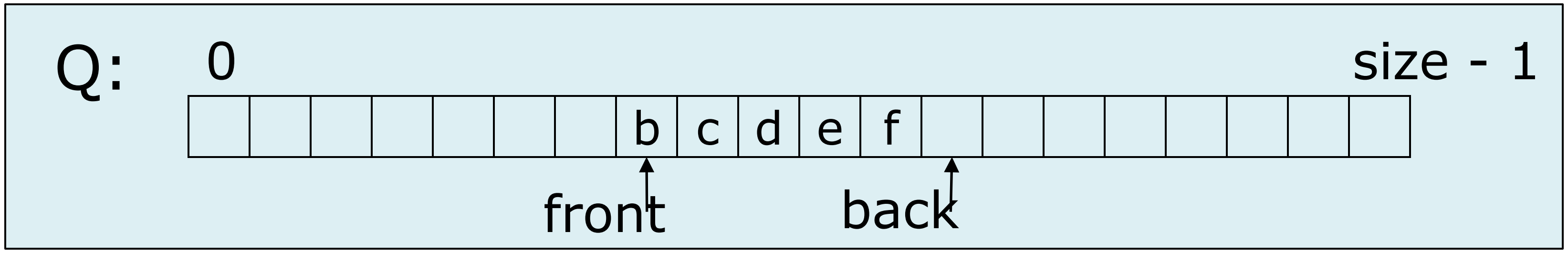


- Just like a stack except:
  - Stack: LIFO (last-in-first-out)
  - Queue: FIFO (first-in-first-out)
- Just as useful and ubiquitous

Get in line right now for the best offers!

LET'S MAKE A QUEUE DATA STRUCTURE!

Circular Array Queue Data Structure

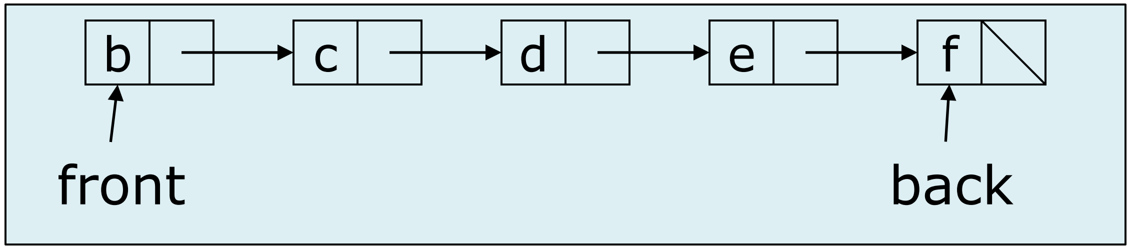


```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

```
// 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

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

Operations:

`create`

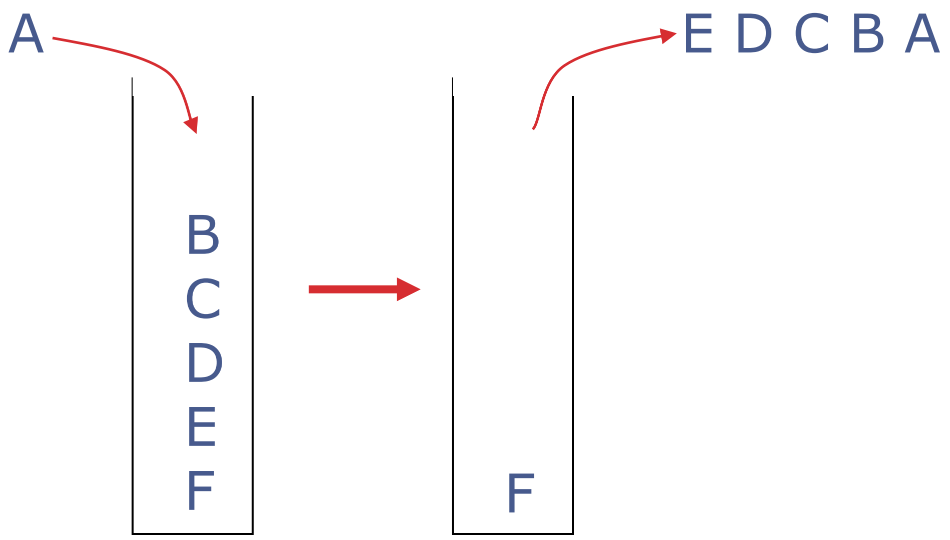
`destroy`

`push`

`pop`

`top`

`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)

Conclusions

- Welcome again!
- This will be a fun class.
- Read Chapter 1-3 for Wednesday
  - Chapter 1 is about Java
  - Chapter 3 is what we talked about today
  - Chapter 2 is discussed on Wednesday