CSE 332: Data Structures & Parallelism
Lecture 1: Intro, Stacks & Queues

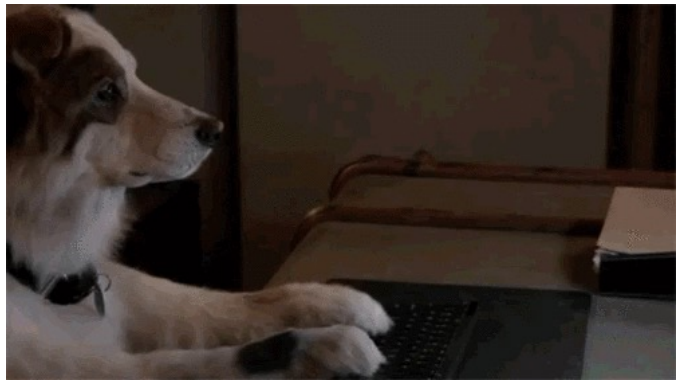
Arthur Liu

Summer 2022

Welcome!

We have 9 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:

Arthur Liu

Teaching Assistants:

- Nathan Akkaraphab
- Hans Easton
- Winston Jodjana
- Neel Jog
- Dara Stotland
- Thien Kim Tran

Me

- just call me Arthur
- BS/MS graduate
- 9+ quarters TA
- Previously: Amazon, Microsoft, Startup
- Meta
- Soccer, Triathlon

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Course Information

- **Instructor:** Arthur Liu, CSE210
  - Office Hours: see course web page, and by appointment
  - artliu@cs.washington.edu
- **Course Web Page:**
  - 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 lists:
  cse332a_su22@uw
  - You are already subscribed
- Ed Discussion board
  - Your first stop for questions about course content & assignments
  - Ed Announcement Emails - You must get and read announcements sent there
- Anonymous feedback link
  - For good and bad: if you don't tell us, we won't know!

Course Meetings

- Lecture
  - Take notes, materials posted (sometimes afterwards)
  - Ask questions, focus on key ideas (rarely coding details)
  - Attend synchronously as much as possible and interact with peers!

- 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
  - They are visual aids, so 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 2nd is fine
- Parallelism / concurrency topics in separate free resource designed for 332

Course Work

- ~15 weekly individual homework exercises (25%)
- Programming Projects (37%)
  - Use Java and IntelliJ, Gitlab
  - Done in partners*, o.k. if partner is in other quiz section

    *Can do individually, but projects designed for partners
- Midterm (15%) (Week 5 Monday 7/18)
- Final (20%) (last Thursday section 8/18 and Friday of quarter 8/19)
- Course-Wide Participation (3%)
  - Many ways to earn credit here, relatively lenient on this

Late Policy and Student Conduct

- Late Policy
  - Exercises: No late submissions allowed
  - Projects: 4 late day tokens for the entire quarter, max 2 per project

- Academic Conduct (see syllabus)
  - In short: don't attempt to gain credit for something you didn't do and don't help others to do so either
  - This does ***not*** mean suffer in silence!
    - Learn from course staff and peers, talk, share ideas; *but* don't share or copy work that is supposed to be yours

- Extenuating Circumstances

Poll Everywhere

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Who is your favorite superhero?

- Make sure you are logged in with your uw netid account
- If you might have an issue with in-lecture polling, reach out to the instructor as soon as possible
- Only need to vote on 60% of questions to get full credit!
  - 1.05 points for correct answer, 1 point otherwise

- If you are sick, stay home!

Homework for Today!!

1. **Project #1**: Fill out partner request survey by Thursday 6pm
   - Partner Mixer Thursday 12-1 @ CSE2 271
2. Preliminary Survey: fill out by Friday night
3. **Exercise #1**: Due SUNDAY at 11:59pm

4. **Make sure you are on Ed**
5. **Review Java & install Intellij**
6. **Reading** (optional) in Weiss (see website)

Reading

- Reading in Weiss
- For this week:
  - Weiss 3.1-3.7 – Lists, Stacks & Queues (Topic for Project #1)
  - (Friday) Weiss 2.1-2.4 – Algorithm Analysis
  - (Useful) Weiss 1.1-1.6 – Mathematics and Java (NOT covered in lecture, will use some of these baseline facts)

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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
  - Implement them

- 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

Goals

- You will understand:
  - What the tools are for storing and processing common data types
  - Which tools are appropriate for which need (read: tradeoffs)
- So that you will be able to:
  - Make good design choices
  - Justify and communicate your design decisions

One view on this course

- This is the class where you being 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.
  - Feel more comfortable not having “right” answers

Data Structures?

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

Example Datastructures and Their Trade-Offs

- LinkedList, ArrayList

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; educated CSEers internalize their maind trade-offs and techniques
  - Recognize and reason about logarithmic < linear < quadratic < exponential

Getting Serious: Terminology

- Abstract Data Type (ADT)
  - Mathematical description of a ”thing” with set of operations on that “thing”
- Data Structures
  - A specific organization of data and family of algorithms for implementing an ADT
- Implementation of a data structure
  - The actual code implementation in a specific language
- Algorithm
  - A high level, language-independent description of a step-by-step process

Getting Serious: Terminology

- Abstract Data Type (ADT) List
  - Mathematical description of a ”thing” with set of operations on that “thing”
- Data Structures ArrayList, LinkedList
  - A specific organization of data and family of algorithms for implementing an ADT
- Implementation of a data structure
  - The actual code implementation in a specific language Your CSE143 code, Java Util Library
- Algorithm How to remove node, How to resize
  - A high level, language-independent description of a step-by-step process

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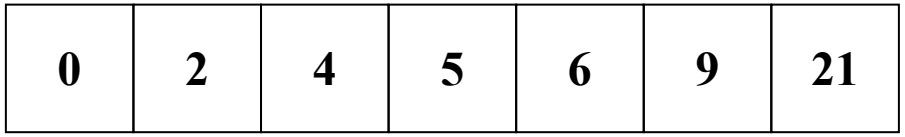

- Algorithm

Linear search
Binary search

  - A high level, language-independent description of a step-by-step process

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Terminology Example: Stack and Queue ADT

Stack ADT
State: • Set of elements Operations: • **push(element)** • **pop()** – returns the most recent element that was added to the stack

Queue ADT
State: • Set of elements Operations: • **enqueue(element)** • **dequeue()** – deletes and returns the element that has been in the queue the longest

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…”

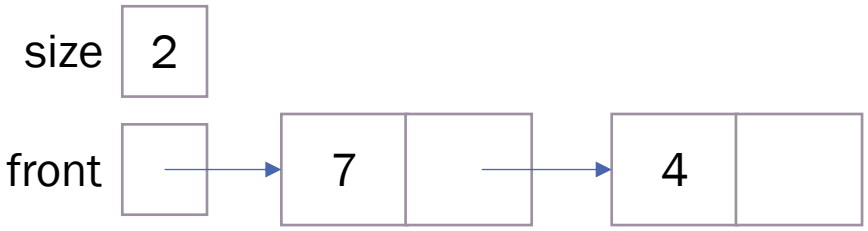
Balancing Parenthesis

{([])}

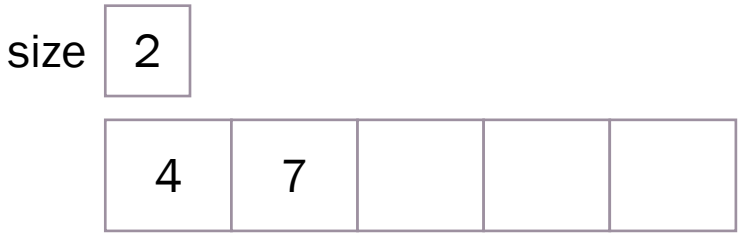
((()()))

Stack Datastructures

- Singly Linked List Implementation

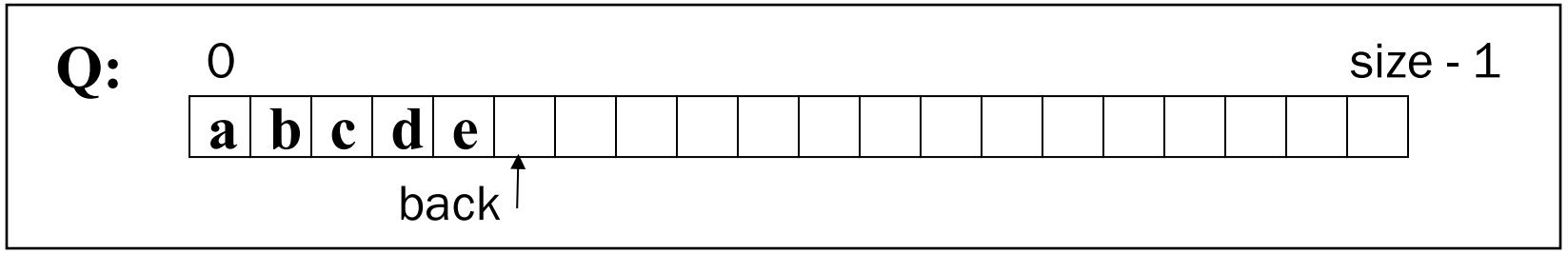


- Array Implementation



Queue Datastructures

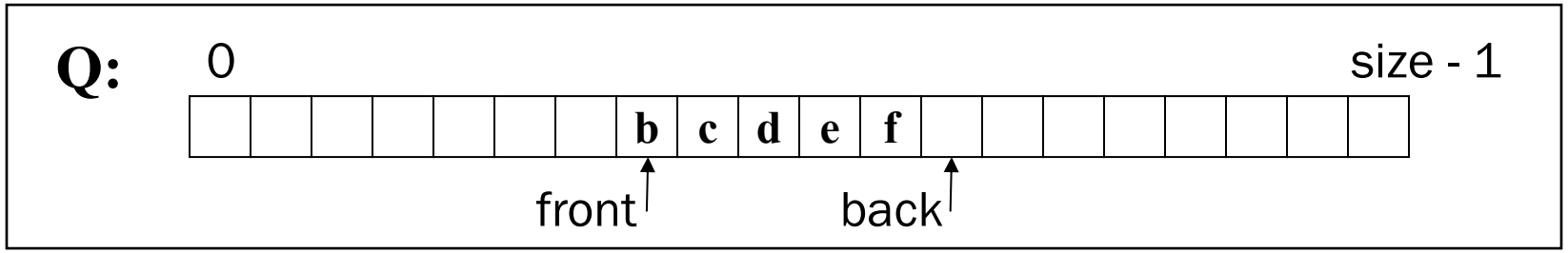
Array Queue Data Structure



- Idea:
  - Enqueue by adding to back
  - Dequeue by removing from index 0 and shifting elements down

- Dequeue inefficient :(

Circular Array Queue Data Structure

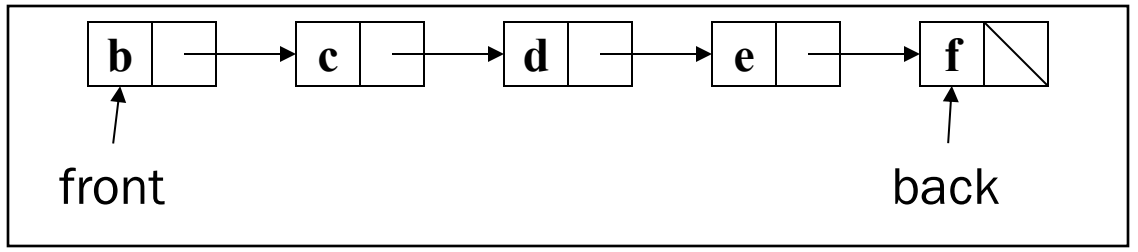



```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

```
// 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?

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What are advantages and disadvantages of using CircularArray vs. LinkedList datastructure to implement the Queue ADT?

Array:

Linked List:

Circular Array vs. Linked List

Array:

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

Operations not in Queue ADT, but also:

- Constant-time “access to kth element”
- For operation “insertAtPosition”, must shift all later elements

Linked 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 kth element”
- For operation “insertAtPosition”, must traverse all earlier elements

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