BEFORE WE START

Talk to your neighbors:
Best place for boba on the Ave? near campus?

Music: 122 24wi Lecture Tunes

Instructors
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TAs
Lecture Outline

• Announcements

• Review: ADTs, Stacks & Queues

• Queue Manipulation

• Stack Manipulation
  - Problem Solving
Announcements

• Quizzes
  - Feedback released in a couple weeks
  - Metacognition: Did it go like you wanted?

• Creative Project 1 is due tomorrow by 11:59pm

• Programming Assignment 1 releasing on Friday
  - Due next Thursday, February 1st by 11:59pm

• Resubmission Cycle 1 opens tonight
  - Eligible assignments: C0 and P0 (upon P0 feedback being released)

• Friday lecture we’re going to get mid-quarter feedback from you
  - Will still be touching on required content, so don’t skip!

• Viewing feedback in Ed...
Lecture Outline

• Announcements

• **Review: Stacks & Queues**

• Queue Manipulation

• Stack Manipulation
  - Problem Solving
Stacks & Queues

• PCM focused on these new data structures!
• Some collections are constrained, only use optimized (but limited) operations
  - **Stack**: retrieves elements in reverse order as added
  - **Queue**: retrieves elements in same order as added
Abstract Data Types

• **Abstract Data Type (ADT):** A **specification** of a collection of data and the operations that can be performed on it.
  - Describes *what* a collection does, not *how* it does it (not implementation!)
  - Think of it as an *idea* of a data type

• We don't know exactly how a stack or queue is implemented, and we don't need to.
  - Only need to understand high-level idea of what a collection does

  - **Stack:** retrieves elements in reverse order as added.
  - **Queue:** retrieves elements in same order as added.
Wait, ADT? Interfaces?

• **Abstract Data Type (ADT)**: A *description of the idea* of a data structure including what operations are available on it and how those operations should behave. For example, the English explanation of what a list should be.

• **Interface**: Java construct that lets programmers *specify what methods a class should have*. For example the `List` interface in Java.

• **Implementation**: *Concrete code* that meets the specified interface. For example, the `ArrayList` and `LinkedList` classes that implement the `List` interface.
Stacks

• **Stack**: A collection based on the principle of adding elements and retrieving them in the **opposite** order.
  - Last-In, First-Out ("LIFO")
  - Elements are stored in order of insertion.
    - We do not think of them as having indexes.
  - Client can only add/remove/examine the last element added (the "top")

**Basic Stack operations:**
• **push**: Add an element to the top
• **pop**: Remove the top element
• **peek**: Examine the top element
Stacks in Computer Science

• Programming languages and compilers:
  - method calls are placed onto a stack (call ↔ push, return ↔ pop)
  - compilers use stacks to evaluate expressions

• Matching up related pairs of things:
  - find out whether a string is a palindrome
  - examine a file to see if its braces { } match
  - convert "infix" expressions to pre/postfix

• Sophisticated algorithms:
  - searching through a maze with "backtracking”
  - many programs use an "undo stack" of previous operations
Programming with Stacks

Stack\(<E>\)(\(())\) constructs a new stack with elements of type \(E\)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>push((value))</td>
<td>places given value on top of stack</td>
</tr>
<tr>
<td>pop()</td>
<td>removes top value from stack and returns it;</td>
</tr>
<tr>
<td></td>
<td>throws EmptyStackException if stack is empty</td>
</tr>
<tr>
<td>peek()</td>
<td>returns top value from stack without removing it;</td>
</tr>
<tr>
<td></td>
<td>throws EmptyStackException if stack is empty</td>
</tr>
<tr>
<td>size()</td>
<td>returns number of elements in stack</td>
</tr>
<tr>
<td>isEmpty()</td>
<td>returns true if stack has no elements</td>
</tr>
</tbody>
</table>

```
Stack<String> s = new Stack<String>();
s.push("a");
s.push("b");
s.push("c");
System.out.println(s.pop());
```

- Stack has other methods that we will ask you not to use 😬
Queue

- **Queue**: Retrieves elements **in the order** they were added.
  - First-In, First-Out ("FIFO")
  - Elements are stored in order of insertion but don't have indexes.
  - Client can only add to the end of the queue, and can only examine/remove the front of the queue.

- **Basic Queue operations**:
  - **add** (enqueue): Add an element to the back.
  - **remove** (dequeue): Remove the front element.
  - **peek**: Examine the front element.
Queues in Computer Science

• Operating systems:
  - queue of print jobs to send to the printer
  - queue of programs / processes to be run
  - queue of network data packets to send

• Programming:
  - modeling a line of customers or clients
  - storing a queue of computations to be performed in order

• Real world examples:
  - people on an escalator or waiting in a line
  - cars at a gas station (or on an assembly line)
Programming with Queues

<table>
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<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>add(value)</td>
<td>places given value at back of queue</td>
</tr>
<tr>
<td>remove()</td>
<td>removes value from front of queue and returns it; throws a NoSuchElementException if queue is empty</td>
</tr>
<tr>
<td>peek()</td>
<td>returns front value from queue without removing it; returns null if queue is empty</td>
</tr>
<tr>
<td>size()</td>
<td>returns number of elements in queue</td>
</tr>
<tr>
<td>isEmpty()</td>
<td>returns true if queue has no elements</td>
</tr>
</tbody>
</table>

Queue<Integer> q = new LinkedList<Integer>();
qu.add(42);
qu.add(-3);
qu.add(17);
System.out.println(q.remove());

🚨 IMPORTANT: When constructing a queue you must use a new LinkedList object instead of a new Queue object. (More on that with Interfaces.)
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What does this method return?

```java
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        numbers.push(number);
    }
    return total;
}
```

A) 0  
B) 5  
C) 15  
D) 25  
E) Error / Exception
What does this method return?

```java
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        numbers.push(number);
    }

    return total;
}
```

A) 0  
B) 5  
C) 15  
D) 25  
E) Error / Exception
What does this method return?

```
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    Queue<Integer> q = new LinkedList<>();
    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        q.add(number);
    }
    return total;
}
```

A) 0  
B) 5  
C) 12 
D) 15 
E) Error / Exception
What does this method return?

```java
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    Queue<Integer> q = new LinkedList<>();

    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        q.add(number);
    }

    return total;
}
```

A) 0  
B) 5  
C) 12 
D) 15 
E) Error / Exception
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Problem Solving

• On their own, Stacks & Queues are quite simple with practice (few methods, simple model)

• Some of the problems we ask are complex because the tools you have to solve them are restrictive
  - sum(Stack) is hard with a Queue as the auxiliary structure

• We challenge you on purpose here to practice problem solving

Common Problem-Solving Strategies

• **Analogy** – Is this similar to a problem you’ve seen?
  - sum(Stack) is probably a lot like sum(Queue), start there!

• **Brainstorming** – Consider steps to solve problem before writing code
  - Try to do an example “by hand” → outline steps

• **Solve Sub-Problems** – Is there a smaller part of the problem to solve?
  - Move to queue first

• **Debugging** – Does your solution behave correctly on the example input.
  - Test on input from specification
  - Test edge cases (“What if the Stack is empty?”)

• **Iterative Development** – Can we start by solving a different problem that is easier?
  - Just looping over a queue and printing elements
Common Stack & Queue Patterns

• Stack → Queue and Queue → Stack
  - We give you helper methods for this on problems

• Reverse a Stack with a S→Q + Q→S

• “Cycling” a queue: Inspect each element by repeatedly removing and adding to back size times
  - Careful: Watch your loop bounds when queue’s size changes

• A “splitting” loop that moves some values to the Stack and others to the Queue