# CS 310: Stack and Queue (Part I)

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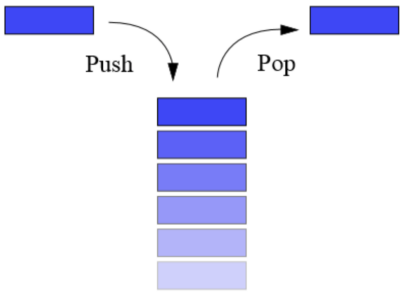
## Review

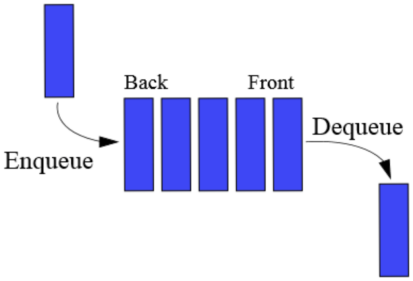
- `Iterators`
  - Motivation: why do we need iterators?
    - They can provide a specialized and performant method of traversing over some list.
  - Implementation: how do we support efficient iterations?
    - Use a nested class or an inner (anonymous) class. Doing so allows access to otherwise private members, and a deeper understanding of the internal workings of the class provides for a more efficient iterator (at the cost of higher coupling).
- Take-home
  - When you use a data structure, use an `Iterator` to improve efficiency and uniformity
  - When you design or implement a data structure, consider providing an `Iterator` for the above reason

## New Topic

- Stack
  - A data structure that works like a stack (what a twist!)

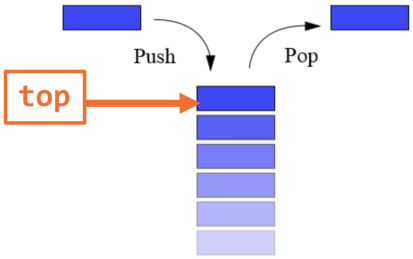



- Queue
  - A data structure that works like people waiting in a line (or queue if you're British)




## Stack

- Features
  - LIFO
  - Always operates at the top of the stack
- Basic operations
  - `.push(T t)`: add `t` to the top of the stack (grows the stack)
  - `.pop()`: remove the top of the stack (shrinks the stack)
  - `.top()`: return the top of the stack (size is not changed)
  - `.isEmpty()`: true when nothing is in it, false otherwise
- Implementation
  - Based on array / linked list




## Stack Example

- You need to be able to draw the stack contents

```
s = new Stack();
s.push(4);
s.push(10);
s.push(5);
s.pop();
s.push(11);
```

## Stacks based on Arrays

```
class AStack<T>{
    private ArrayList<T> stuff;
    public AStack(); // Constructor
    public void push(T x); // like add(x) or append(x)
    public void pop(); // like remove(size()-1)
```

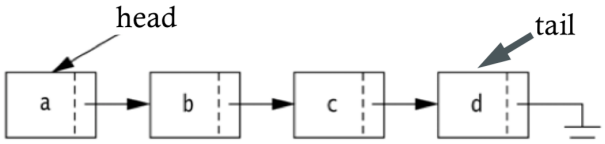
```
    public T top(); // like get(size()-1)
    public boolean isEmpty(); // like size()==0
}
```

- Use an `ArrayList` as the underlying storage
- The top of the stack is the end of the array
  - Operations are performed only at the end which makes it faster with an array based implementation
- What's the Big-O?
  - $O(1)$

## Stack Based on Linked List

```
Class LStack<T>{
    private LinkedList<T> stuff;
    public LStack(); // Assume head as stack top
    public void push(T x); // like insert(0,x)
    public void pop(); // like remove(0)
    public T top(); // like get(0)
    public boolean isEmpty(); // like size()==0
}
```

- Use a Linked List as the underlying storage
  - Operate only at one end
- Big-O?
  - $O(1)$

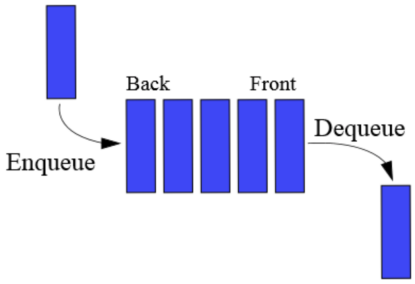



## Stack Applications

- Check the symbolic balancing of an equation
  - {(<> [{<>}]){}} vs. {(< [{<>>}]){}}
- Postfix calculation
  - 6 5 2 3 + 8 × + 3 + × =
- Infix to Postfix conversion
  - $a + b \times c + (d \times e + f) \times g \rightarrow abc \times + de \times f + g \times +$
- Call stack
  - `fib(4)`
- Tree traversal – preorder traversal
- Graph search – depth first search
- And a bunch of over applications

## Queue

- Features
  - FIFO
  - Only remove from front
  - Only add to back
- Basic operations
  - `.enqueue(T t)` or `.add(T t)`: `t` enters at the back
  - `.dequeue()` or `.poll()`: front leaves
  - `.getFront()` or `.peek()`: returns the item at the front
  - `.isEmpty()`: true when nothing is in it, false otherwise

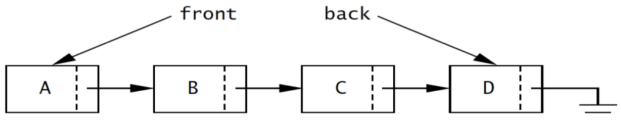



## Queue Example

- You need to be able to draw the queue contents
- What is the value of `v`?

```
q = new Queue(); // Empty queue
q.enqueue(4); // 4
q.enqueue(10); // 4 10
q.enqueue(5); // 4 10 5
q.dequeue(); // 10 5
v = getFront(); // v == 10
q.dequeue(); // 5
q.enqueue(11); // 5 11
q.enqueue(25); // 5 11 25
```

## Queue Based on Linked Lists

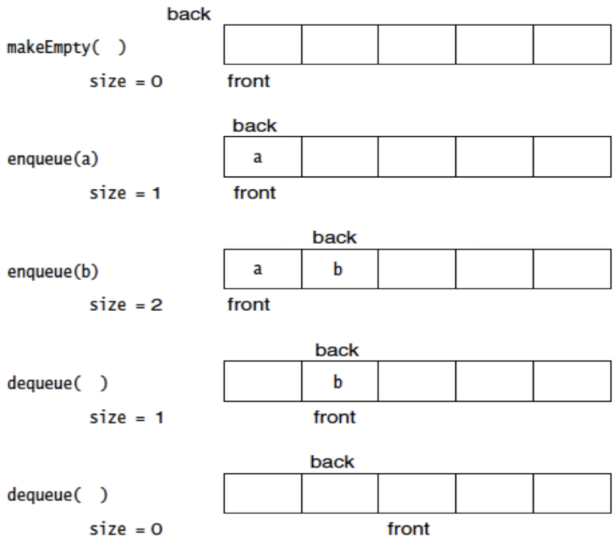



- Append to one end, and remove from the other end
  - For example, `head`→`front`, `tail`→`back`
  - `.enqueue(T t)`: insert at the tail
  - `.dequeue()`: remove from head
  - `.getFront()`: return head contents
  - `.isEmpty()`: `.size() == 0`

## Queue Based on Arrays

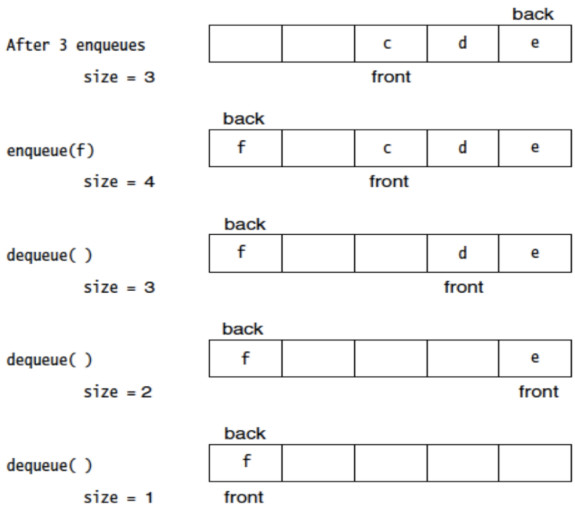
- Naive implementation:
  - `.enqueue(T t)`: insert at the end
  - `.dequeue()`: remove from start and shifting internally
    - In fact, a *lot* of shifting! Shifting is done for every single `.dequeue()`!
  - Alternatively, we could just mark the front and the back in the array and update them with `.enqueue()` and `.dequeue()`

## Queue Based on Arrays




- Between the front and the back, we have a valid queue
  - There's no shifting: $O(1)$ for `.dequeue()`!
  - But it does use a sizeable amount of space – this makes it a good structure for fixed size queues

## Queue: Array with Wraparound




- Exercise: what needs to be changed to implement the wraparound functionality?

  - Our mutator and accessor methods – unless we do all of these through an iterator, in which case only the iterators understanding of its position relative to the front and end of the queue need to change.

## Big-O Comparison

- Stack

| Implementation | `.push()` | `.pop()` | `.top()` | `.isEmpty()` | `.size` |
|---|---|---|---|---|---|
| Array | 1* | 1 | 1 | 1 | 1 |
| Linked List | 1 | 1 | 1 | 1 | 1 |

*Amortized analysis

- Queue

| Implementation | `.enqueue()` | `.dequeue()` | `.getFront()` | `.isEmpty()` | `.size` |
|---|---|---|---|---|---|
| Array | 1* | 1 | 1 | 1 | 1 |
| Linked List | 1 | 1 | 1 | 1 | 1 |

*Amortized analysis

## Why use a Stack or Queue

- Restricted operations give us good worst cases
  - $O(1)$ for all supported operations
  - $O(n)$ for space
- Simple data structures
  - Focus on limited operations
  - Can be made out of primitive data structures (arrays and linked lists)
- Good for representing time-related data
  - Call stack
  - Packet queues

## Review: Queues

- FIFO
- Supported operations:
  - `.enqueue(x)`: insert at the tail
  - `.dequeue()`: remove from head
  - `.getFront()`: return head contents
  - `.size()`: returns the size of the queue
  - `.isEmpty()`
- Applications:
  - Simulate a process with a FIFO order
  - Scheduling queue of a CPU or disk or printer
  - Serve as a buffer for file I/O, network communications, etc.

## Priority Queues

- Much of the time tasks that we use a queue for have different priorities
  - It is convention that the lower the priority, the better
  - Symmetric code if higher is better
  - Dequeue the ones with the "best" priority first
- Common priority queue operations
  - `void insert(T t, int p)`: insert `t` with priority `p`
  - `T findMin()`: return the object with the "best" priority
  - `void deleteMin()`: remove the object with the "best" priority

## Priority Queue Design

| Data Structure | `.insert()` | `.findMin()` | `.deleteMin()` | Notes |
|---|---|---|---|---|
| Sorted Array | $O(n)$ | $O(1)$ | $O(1)$ | min at high index |
| Sorted Linked List | $O(n)$ | $O(1)$ | $O(1)$ | min at head or tail |

- Other data structures exist as good candidates of priority queues
  - Binary search trees
  - Heaps
  - We'll cover these later

## Summary

- Stacks and queues
  - Try implementing them
  - Project 2
- Next lecture: Trees, recursion
  - Reading: Chapter 18, Chapter 7