CS 310: Stack and Queue

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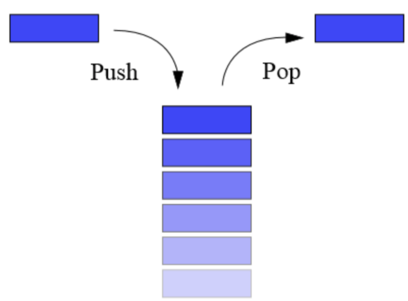
Review

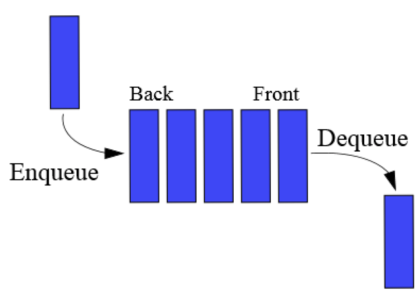
- `Iterators`
  - Motivation: why do we need iterators?
  - Implementation: how do we support efficient iterations?
  - Nested class / inner (anonymous) class
- Take-home
  - When you use a data structure, use an `Iterator` to improve efficiency and uniformity
  - When you design or implement a data structure, consider providing an `Iterator` for the above reason

New Topic

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

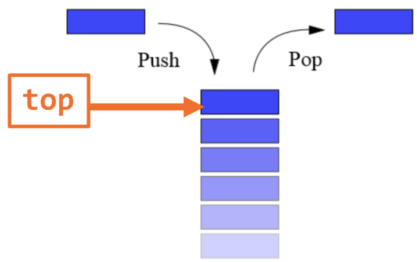


- Queue
  - A data structure that works like people waiting in a line (or queue if you're British)



Stack

- Features
  - LIFO
  - Always operates at the top of the stack
- Basic operations
  - `push(x)`: add `x` 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

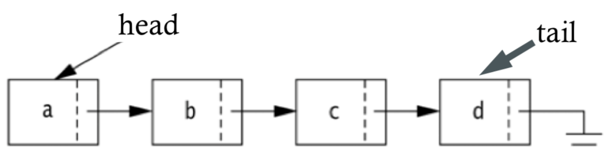
```
class AStack<T>{
    private ArrayList<T> stuff;
    public AStack(); // Constructor
    public void push(T x); // like add(x) or append(x)
    public void pop(); // like remove(size()-1)
    public T top(); // like get(size()-1)
    public boolean isEmpty(); // like size()==0
}
```

- 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?
  - $O(1)$



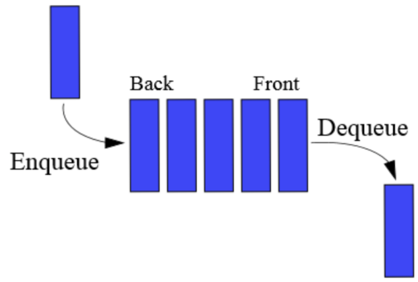
Stack Applications

- Check the symbolic balancing of an equation
  - $\{(<>[\{<>\}])\{\}\}$ vs. $\{(<[\{<>>\}])\{\}\}$
- Postfix calculation
  - $6\ 5\ 2\ 3\ +\ 8\ \times\ +\ 3\ +\ \times\ =$
- 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(x)` or `add(x)`: `x` 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

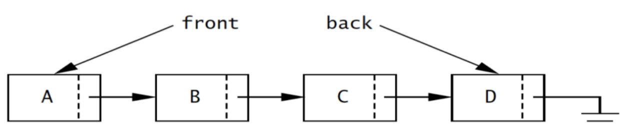


Queue Example

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

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

Queue Based on Linked Lists

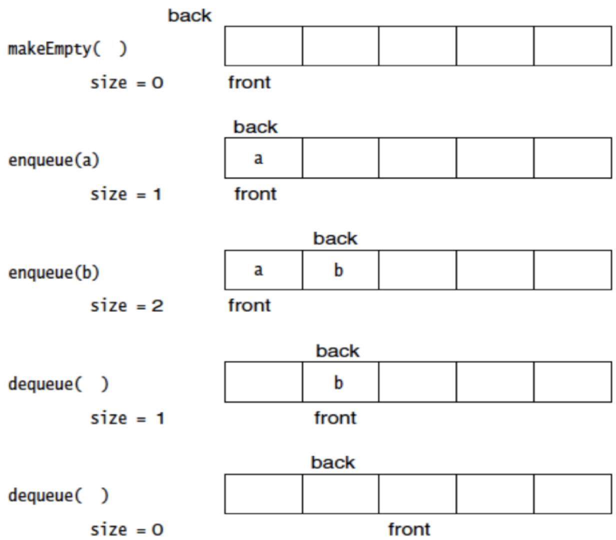


- Append to one end, and remove from the other end
  - For example, `head`→`front`, `tail`→`back`
  - `enqueue(x)`: insert at the tail
  - `dequeue()`: remove from head
  - `getFront()`: return head contents
  - `isEmpty()`: `size() == 0`

Queue Based on Arrays

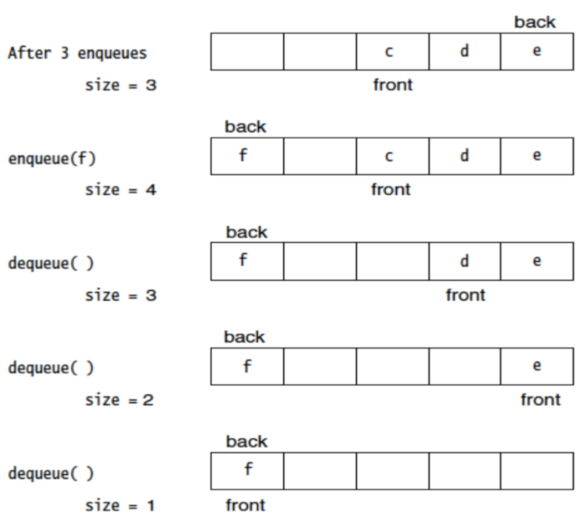
- Naive implementation:
  - `enqueue(x)`: insert at the end
  - `dequeue()`: remove from start and shifting internally
    * In fact, a *lot* of shifting! Shifting is done for every single `dequeue()`!
  - Alternatively, we could just mark the front and the back in the array and update them with `enqueue`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

Queue: Array with Wraparound



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

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 x, int p)`: insert `x` with priority `p`
  - `T findMin()`: return the object with the "best" priority
  - `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