CSE 143
Lecture 5

Stacks and Queues

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Runtime Efficiency

- **efficiency**: A measure of the use of computing resources by code.
  - can be relative to speed (time), memory (space), etc.
  - most commonly refers to run time

- Assume the following:
  - Any single Java statement takes the same amount of time to run.
  - A method call's runtime is measured by the total of the statements inside the method's body.
  - A loop's runtime, if the loop repeats N times, is N times the runtime of the statements in its body.

`ArrayList` methods

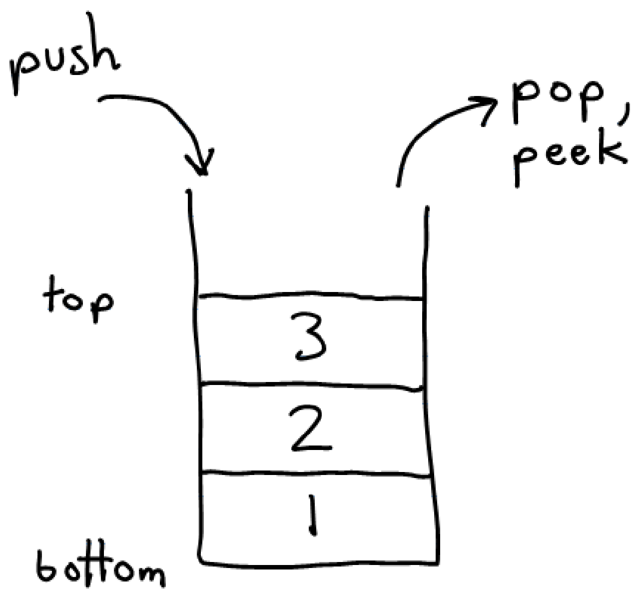
- Which operations are most/least efficient, and why?

`add(`**value**`)`	appends value at end of list
`add(`**index**`, `**value**`)`	inserts given value at given index, shifting subsequent values right
`clear()`	removes all elements of the list
`indexOf(`**value**`)`	returns first index where given value is found in list (-1 if not found)
`get(`**index**`)`	returns the value at given index
`remove(`**index**`)`	removes/returns value at given index, shifting subsequent values left
`set(`**index**`, `**value**`)`	replaces value at given index with given value
`size()`	returns the number of elements in list
`toString()`	returns a string representation of the list such as `"[3, 42, -7, 15]"`

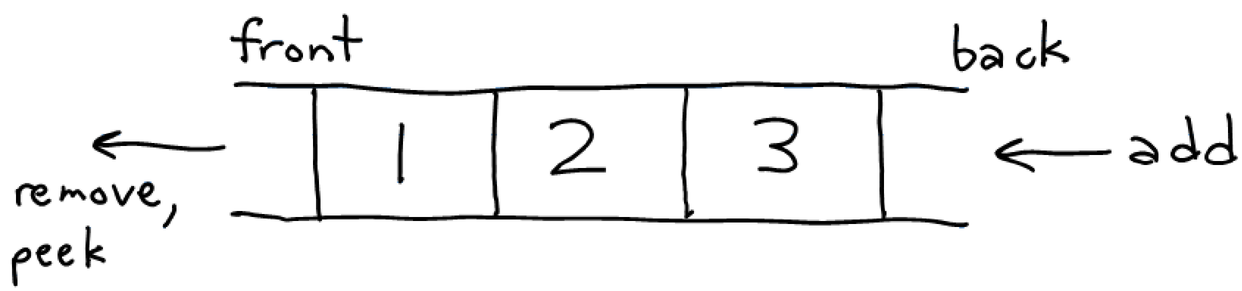
Stacks and queues

- Sometimes it is good to have a collection that is less powerful, but is optimized to perform certain operations very quickly.

- Today we will examine two specialty collections:
  - **stack**: Retrieves elements in the reverse of the order they were added.
  - **queue**: Retrieves elements in the same order they were added.



stack



queue

Abstract data types (ADTs)

- **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

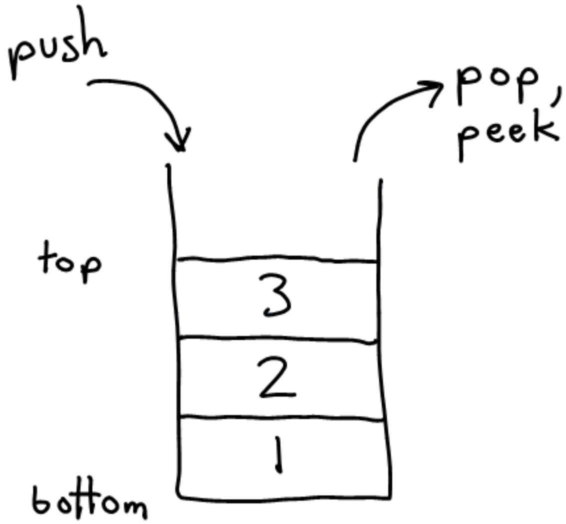
- We don't know exactly how a stack or queue is implemented, and we don't need to.
  - We just need to understand the idea of the collection and what operations it can perform.

(Stacks are usually implemented with arrays; queues are often implemented using another structure called a linked list.)

Stacks

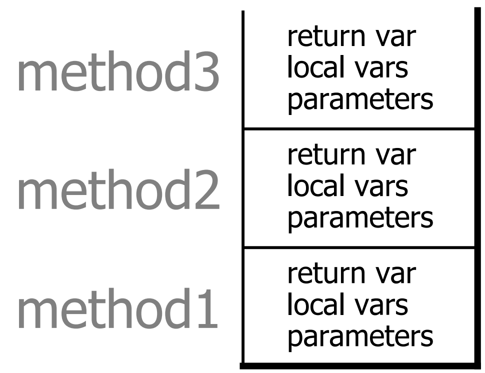
- **stack**: A collection based on the principle of adding elements and retrieving them in the opposite order.
  - Last-In, First-Out ("LIFO")
  - The elements are stored in order of insertion, but we do not think of them as having indexes.
  - The client can only add/remove/examine the last element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

- basic stack operations:
  - **push**: Add an element to the top.
  - **pop**: Remove the top element.



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 { } and other operators match
  - convert "infix" expressions to "postfix" or "prefix"

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

Class Stack

`Stack<E>()`	constructs a new stack with elements of type **E**
`push(`**`value`**`)`	places given value on top of stack
`pop()`	removes top value from stack and returns it; throws `EmptyStackException` if stack is empty
`peek()`	returns top value from stack without removing it; throws `EmptyStackException` if stack is empty
`size()`	returns number of elements in stack
`isEmpty()`	returns `true` if stack has no elements

```
Stack<Integer> s = new Stack<Integer>();
s.push(42);
s.push(-3);
s.push(17);   // bottom [42, -3, 17] top
System.out.println(s.pop());   // 17
```

– `Stack` has other methods, but we forbid you to use them.

Stack limitations/idioms

- Remember: You cannot loop over a stack in the usual way.

```
Stack<Integer> s = new Stack<Integer>();
...
for (int i = 0; i < s.size(); i++) {
    do something with s.get(i);
}
```

- Instead, you must pull contents out of the stack to view them.
  - common idiom: Removing each element until the stack is empty.

```
while (!s.isEmpty()) {
    do something with s.pop();
}
```

Exercise

- Consider an input file of exam scores in reverse ABC order:

```
Yeilding      Janet     87
White         Steven    84
Todd          Kim       52
Tashev        Sylvia    95
...
```

- Write code to print the exam scores in ABC order using a stack.

  - What if we want to further process the exams after printing?

What happened to my stack?

- Suppose we're asked to write a method `max` that accepts a Stack of integers and returns the largest integer in the stack.
  - The following solution is seemingly correct:

```
// Precondition: s.size() > 0
public static void max(Stack<Integer> s) {
    int maxValue = s.pop();
    while (!s.isEmpty()) {
        int next = s.pop();
        maxValue = Math.max(maxValue, next);
    }
    return maxValue;
}
```

  - The algorithm is correct, but what is wrong with the code?

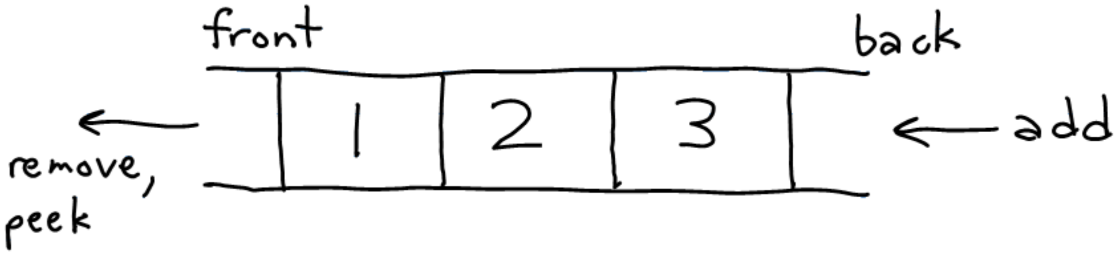
What happened to my stack?

- The code destroys the stack in figuring out its answer.
  - To fix this, you must save and restore the stack's contents:

```
public static void max(Stack<Integer> s) {
    Stack<Integer> backup = new Stack<Integer>();
    int maxValue = s.pop();
    backup.push(maxValue);
    while (!s.isEmpty()) {
        int next = s.pop();
        backup.push(next);
        maxValue = Math.max(maxValue, next);
    }
    while (!backup.isEmpty()) {
        s.push(backup.pop());
    }
    return maxValue;
}
```

Queues

- **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.

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

`add(`**`value`**`)`	places given value at back of queue
`remove()`	removes value from front of queue and returns it; throws a `NoSuchElementException` if queue is empty
`peek()`	returns front value from queue without removing it; returns `null` if queue is empty
`size()`	returns number of elements in queue
`isEmpty()`	returns `true` if queue has no elements

```
Queue<Integer> q = new LinkedList<Integer>();
q.add(42);
q.add(-3);
q.add(17);          // front [42, -3, 17] back
System.out.println(q.remove());   // 42
```

- **IMPORTANT**: When constructing a queue you must use a new `LinkedList` object instead of a new `Queue` object.
  - This has to do with a topic we'll discuss later called *interfaces*.

Queue idioms

- As with stacks, must pull contents out of queue to view them.

```
while (!q.isEmpty()) {
    do something with q.remove();
}
```

  - another idiom: Examining each element exactly once.

```
int size = q.size();
for (int i = 0; i < size; i++) {
    do something with q.remove();
    (including possibly re-adding it to the queue)
}
```

    - Why do we need the `size` variable?

Mixing stacks and queues

- We often mix stacks and queues to achieve certain effects.
  - Example: Reverse the order of the elements of a queue.

```
Queue<Integer> q = new LinkedList<Integer>();
q.add(1);
q.add(2);
q.add(3);                          // [1, 2, 3]

Stack<Integer> s = new Stack<Integer>();

while (!q.isEmpty()) {        // Q -> S
    s.push(q.remove());
}

while (!s.isEmpty()) {        // S -> Q
    q.add(s.pop());
}

System.out.println(q);        // [3, 2, 1]
```

Exercise

- Modify our exam score program so that it reads the exam scores into a queue and prints the queue.
  - Next, filter out any exams where the student got a score of 100.
  - Then perform your previous code of reversing and printing the remaining students.
    - What if we want to further process the exams after printing?

Exercises

- Write a method `stutter` that accepts a queue of integers as a parameter and replaces every element of the queue with two copies of that element.
  - `front [1, 2, 3] back`
    becomes
    `front [1, 1, 2, 2, 3, 3] back`

- Write a method `mirror` that accepts a queue of strings as a parameter and appends the queue's contents to itself in reverse order.
  - `front [a, b, c] back`
    becomes
    `front [a, b, c, c, b, a] back`

Exercise

- A *postfix expression* is a mathematical expression but with the operators written after the operands rather than before.

  `1 + 1` becomes `1 1 +`

  `1 + 2 * 3 + 4` becomes `1 2 3 * + 4 +`

- Write a method `postfixEvaluate` that accepts a postfix expression string, evaluates it, and returns the result.
  - All operands are integers; legal operators are + and *

    `postFixEvaluate("1 2 3 * + 4 +")` returns `11`

  - The algorithm: Use a stack
    - When you see operands, push them.
    - When you see an operator, pop the last two operands, apply the operator, and push the result onto the stack.
    - When you're done, the one remaining stack element is the result.