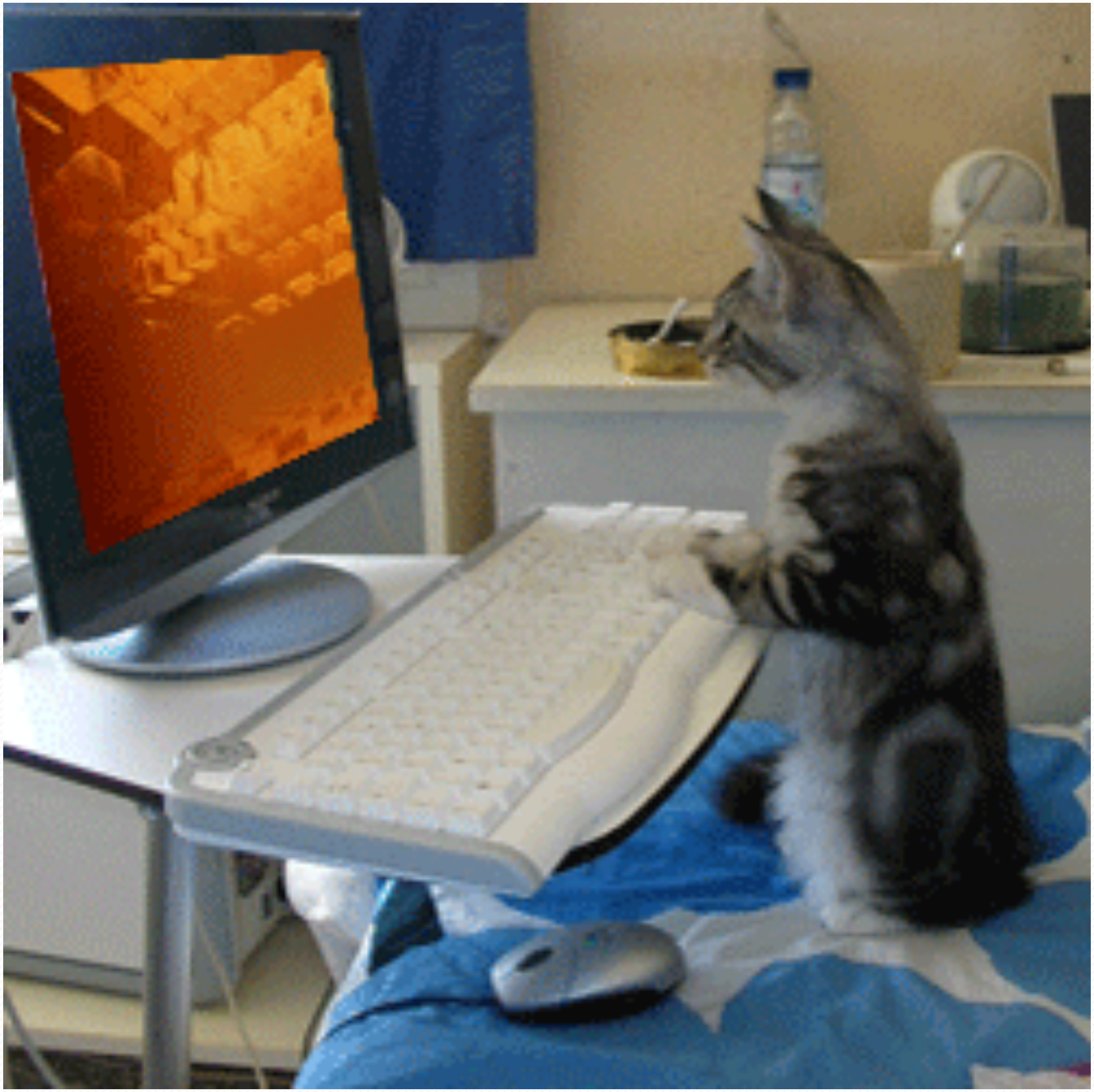
Building Java Programs

Chapter 14

stacks and queues

reading: 14.1-14.4



Runtime Efficiency (13.2)

- **efficiency**: measure of computing resources used 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 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.

Collection efficiency

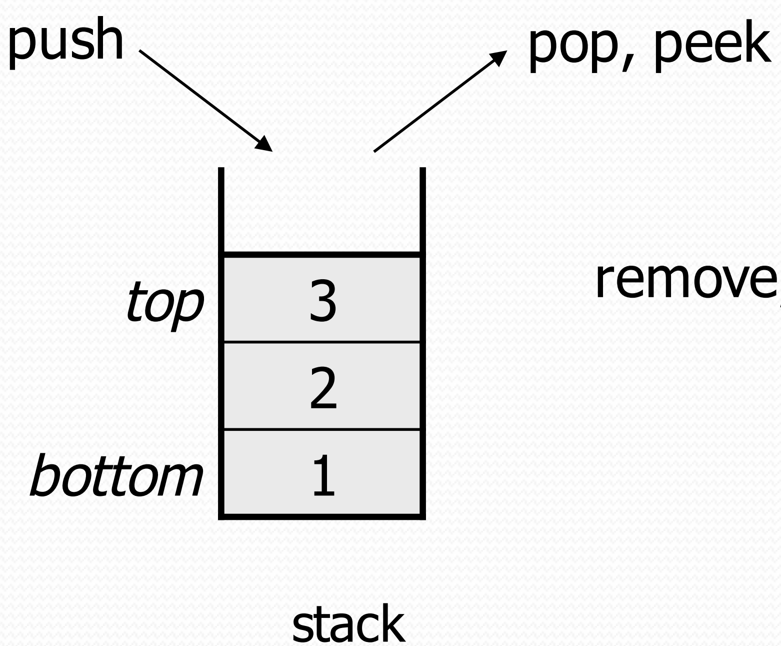
- Efficiency of our `ArrayIntList` or Java's `ArrayList`:

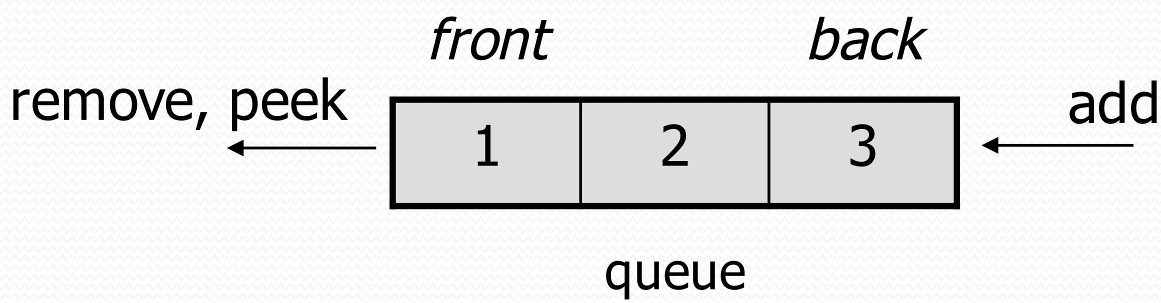
Method	**ArrayList**
`add(`**value**`)`	O(1)
`add(`**index value**`)`	O(N)
`indexOf(`**value**`)`	O(N)
`get(`**index)**	O(1)
`remove(`**index)**	O(N)
`set(`**index, value)**	O(1)
`size`	O(1)

- Which operations should we try to avoid?

Stacks and queues

- Some collections are constrained so clients can only use optimized operations
  - **stack**: retrieves elements in reverse order as added
  - **queue**: retrieves elements in same order as added





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

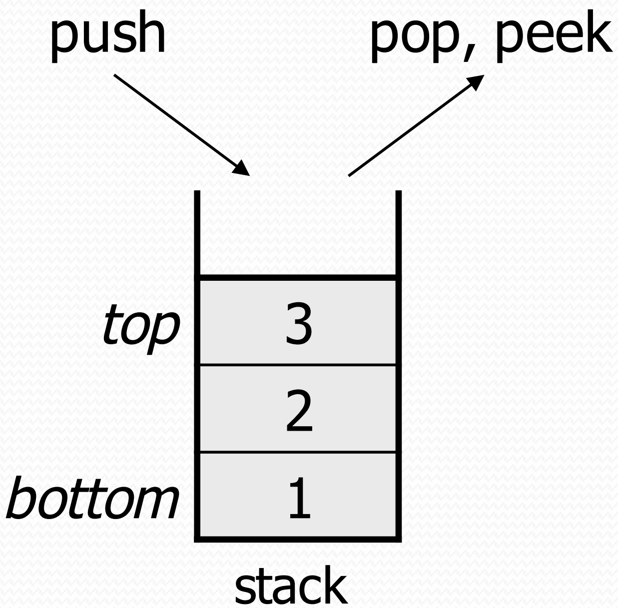
- We don't know exactly how a stack or queue is implemented, and we don't need to.
  - We just need to understand the idea of the collection and what operations it can perform.

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

Stacks

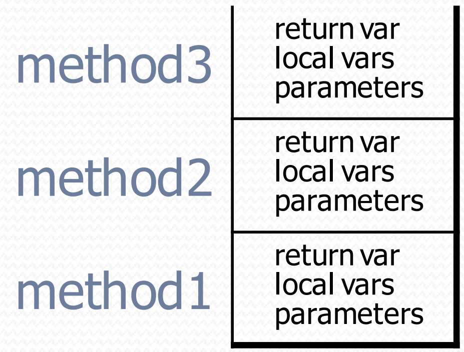
- **stack**: A collection based on the principle of adding elements and retrieving them in the opposite order.
  - Last-In, First-Out ("LIFO")
  - Elements are stored in order of insertion.
    - We do not think of them as having indexes.
  - Client can only add/remove/examine the last element added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

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<String> s = new Stack<String>();
s.push("a");
s.push("b");
s.push("c");                    // bottom ["a", "b", "c"] top
System.out.println(s.pop()); // "c"
```

- `Stack` has other methods that are off-limits (not efficient)

Collections of primitives

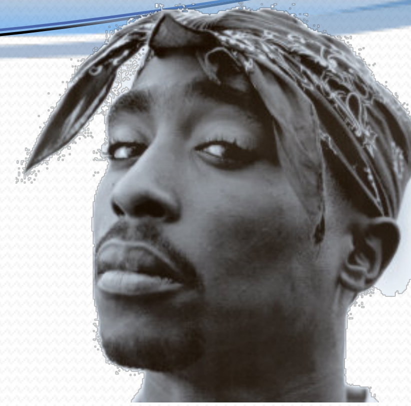
- The type parameter specified when creating a collection (e.g. `ArrayList`, `Stack`, `Queue`) must be an object type

```
// illegal -- int cannot be a type parameter
Stack<int> s = new Stack<int>();
ArrayList<int> list = new ArrayList<int>();
```

- Primitive types need to be "wrapped" in objects

```
// creates a stack of ints
Stack<Integer> s = new Stack<Integer>();
```

Wrapper classes



Primitive Type	Wrapper Type
`int`	`Integer`
`double`	`Double`
`char`	`Character`
`boolean`	`Boolean`

- Wrapper objects have a single field of a primitive type
- The collection can be used with familiar primitives:

```
ArrayList<Double> grades = new ArrayList<Double>();
grades.add(3.2);
grades.add(2.7);
...
double myGrade = grades.get(0);
```

Stack limitations/idioms

- 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 pull elements out of the stack one at a time.
  - common idiom: Pop each element until the stack is empty.

```
// process (and destroy) an entire stack
while (!s.isEmpty()) {
    do something with s.pop();
}
```

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:

```
// Precondition: !s.isEmpty()
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?

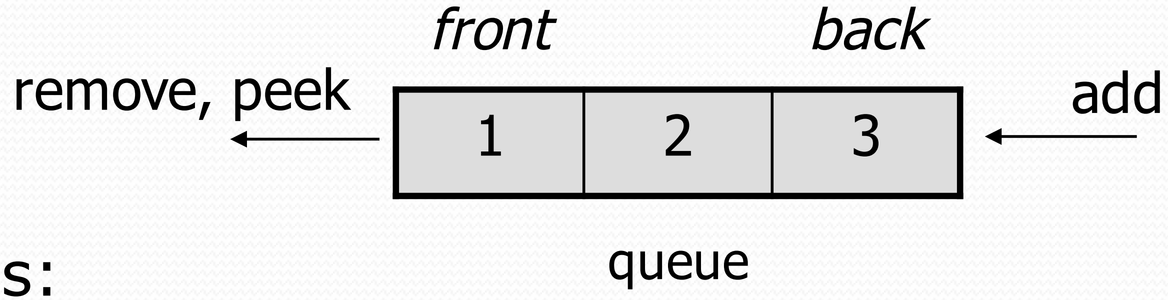
What happened to my stack?

- 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()) {    // restore
        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.
  - **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

`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.

```
// process (and destroy) an entire queue
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]
```

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`