CSSE 220 Day 18

Continue Data Structures Grand Tour

Work on Hardy's Taxi

CSSE 220 Day 18

- BinaryInteger due now (commit, please)
- Hardy due Monday

- Questions:
  - Hardy
  - Reading?
  - Big-oh for finding things in an array?

- Today:
  - Review solution to BinaryInteger.
  - Start the Data Structures tour
  - Work on Hardy's taxi

Hardy Grading Script …

- … appears to be ready. Let me know if you have any problems with it.

```
addiator 4:53am > cd /class/csse/csse220/200820/
addiator 4:55am > ./check Hardy
Checking Hardy
Clearing
/afs/rh/class/csse/csse220/200820/turnin/mrozekma/Hardy/extract/
Copying *.java... done

Compiling project...
No compile errors found
mrozekma - Summary for Hardy
Graded on Tue Jan 15 04:55:28 EST 2008

N    Points  Your Answer
1    15/15     1729 = 1^3 + 12^3 = 9^3 + 10^3
5    18/18     32832 = 4^3 + 32^3 = 18^3 + 30^3
30   10/10     515375 = 15^3 + 80^3 = 54^3 + 71^3
100  4/4     4673088 = 25^3 + 167^3 = 64^3 + 164^3
500  3/3     106243219 = 307^3 + 426^3 = 363^3 + 388^3

Points earned: 50/50
```

Some basic data structures

What is "special" about each data type?

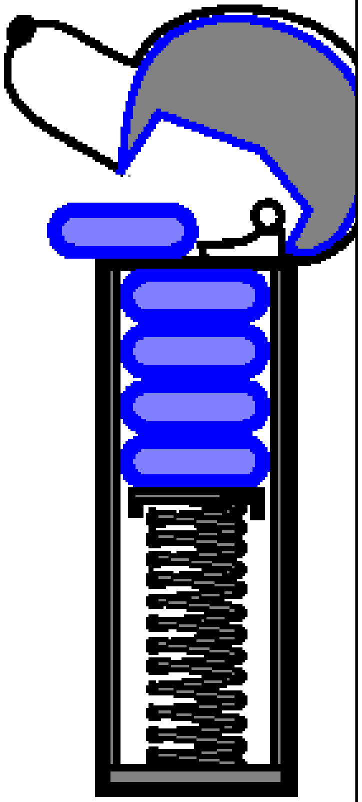
What is each used for?

What can you say about time required for
- adding an element?
- removing an element?
- finding an element?

- Array (1D, 2D, …)
- Stack

You should be able to answer all of these by the end of this course.

Stack



- Last-in-first-out (LIFO)
- Only top element is accessible
- Operations: push, pop, top, topAndPop
  - All **constant-time.**
- Easy to implement as a (growable) array with the last filled position in the array being the top of the stack.
- Applications:
  - Match parentheses and braces in an expression
  - Keep track of pending function calls with their arguments and local variables.
  - Depth-first search of a tree or graph.

- Note: these terms are general.
- Java uses: push, pop, and **peek**().

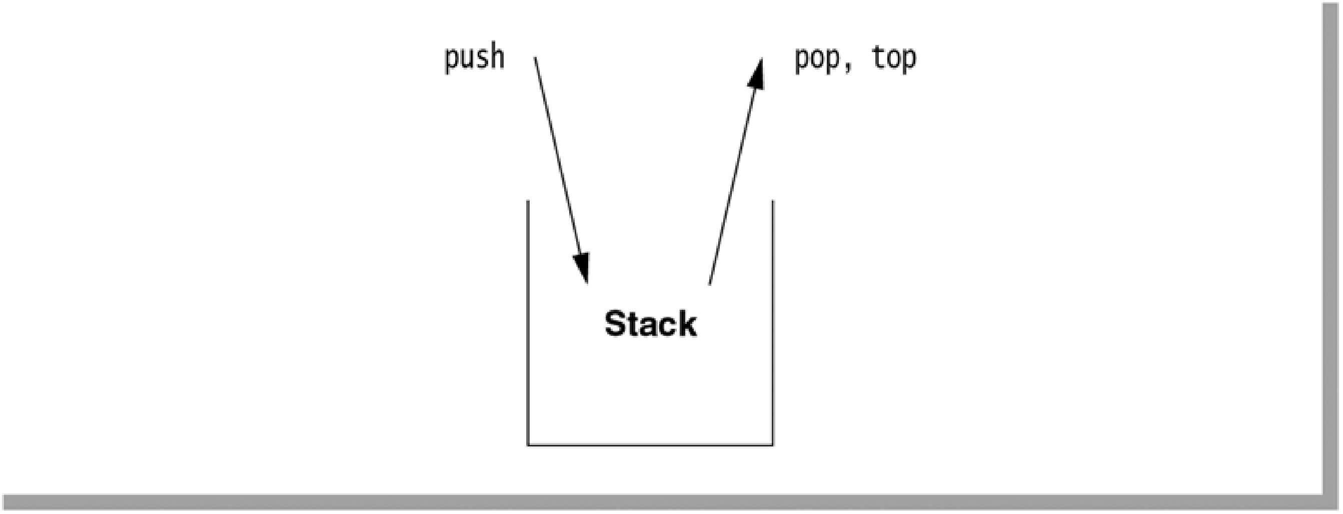


figure 6.20

The stack model: Input to a stack is by `push`, output is by `top`, and deletion is by `pop`.

Some basic data structures

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- Queue

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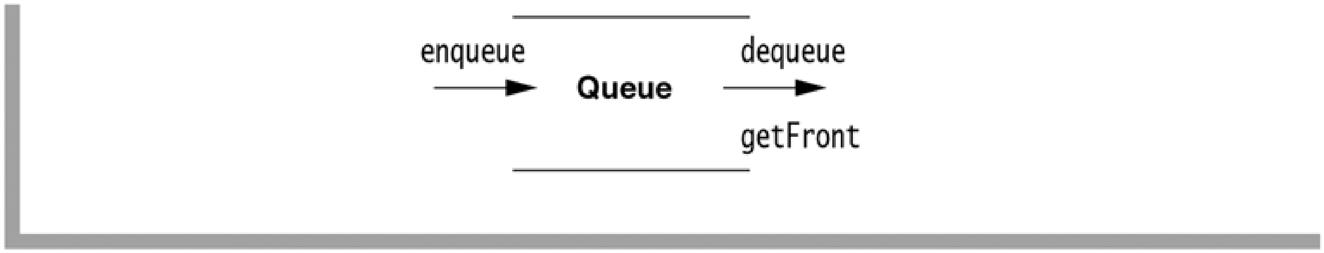
Queue

- First-in-first-out (FIFO)
- Only oldest element in the queue is accessible
- Operations: enqueue, dequeue (offer() and poll() in Java)
  - All constant-time.
- Can be implemented as a (growable) "circular" array
  - http://maven.smith.edu/~streinu/Teaching/Courses/112/Applets/Queue/myApplet.html
- Applications:
  - Simulations of real-world situations
  - Managing jobs for a printer
  - Managing processes in an operating system.
  - Breadth-first search of a graph.

- In Java, enqueue is **offer()**, dequeue is **poll()** and Queue is an **interface**

figure 6.22

The queue model: Input is by `enqueue`, output is by `getFront`, and deletion is by `dequeue`.



Some basic data structures

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What is each used for?

What can you say about time required for
- adding an element?
- removing an element?
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- Array (1D, 2D, …)
- Stack
- Queue
- List
  - ArrayList
  - LinkedList

You should be able to answer all of these by the end of this course.

List

- A list is an ordered collection where elements may be added anywhere, and any elements may be deleted or replaced.
- **Array List**: Like an array, but growable and shrinkable.
- **Linked List**:

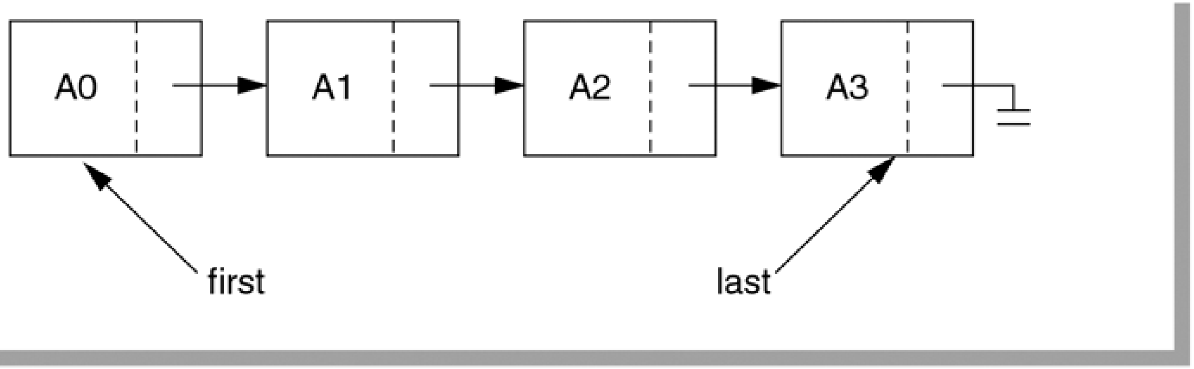

figure 6.19

A simple linked list

- Running time for add, remove, find?

List Code Example

```
LinkedList<String> list = new LinkedList<String> ();
list.add("abc");
list.add("xyz");
list.add(1, "ddd");
list.add(2, "jkl");
System.out.println(list);
list.remove("ddd");
System.out.println(list);
list.remove(2);
System.out.println(list);
```

- Output:

-
  ```
  [abc, ddd, jkl, xyz]
  [abc, jkl, xyz]
  [abc, jkl]
  ```

Some basic data structures

What is "special" about each data type?

What is each used for?

What can you say about time required for
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- removing an element?
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- Stack
- Queue
- List
  - ArrayList
  - LinkedList
- Set
- MultiSet

You should be able to answer all of these by the end of this course.

Tree

- Collection of nodes
- One specialized node is the root.
- A node has one parent (unless it is the root)
- A node has zero or more children.
- Example: directory structure on a hard drive.
- Binary tree: left and right children
- Binary search tree
  - Nodes in left subtree precede the root in item ordering
  - Nodes in right subtree precede the root in item ordering.
- Run time of insertion, deletion, and search?
- Much more on trees in 230.

HashTable

- Create a big array
- Each possible element to be inserted has an index (a calculated “hash code”)
- Since the number of things we could possibly insert into the array >> the size of the array, the hash codes aren’t unique, so we need to deal with this
- So insertion, deletion, and search basically just involve:
  - Calculating the hash code, which is independent of n, the number of things in the array.
  - Indexing into that point of the array.
- What’s the big-Oh runtime?
- So why ever use trees?

Set and MultiSet

- **Set**: A collection that never contains two distinct objects **a** and **b**, such that a.equals(b).
- **Multiset** (a.k.a. bag). An item can occur multiple times, and the collection keeps track of the multiplicity of each.
- Two Java representations of sets
  - TreeSet (based on a Binary Tree) – items ordered
  - HashSet (based on Hash Table) – items not ordered.
- Running times for add, remove, find?
  - Depends on which used

Java Set Example

- Define a class to insert in the set:

```
class Pair implements Comparable<Pair>{
   private  String s1, s2;

   public Pair(String s1, String s2) {
      this.s1 = s1;
      this.s2 = s2;
   }

   @Override public String toString() {
      return String.format("<%s,%s>", this.s1, this.s2);
   }

   public int compareTo(Pair other){
      return this.s1.compareTo(other.s1);
   }

   @Override public boolean equals(Object other) {
      Pair oth = (Pair)other;
      return this.s1.equals(oth.s1);
   }

   @Override public int hashCode() {
      return s1.hashCode();
   }
}
```

Java Set Example – TreeSet

```java
TreeSet<Pair> ts = new TreeSet<Pair> ();
ts.add(new Pair("abc", "1"));
ts.add(new Pair("def", "2"));
System.out.println(ts);
System.out.println(ts.contains(new Pair("abc", "3")));
ts.add(new Pair("abc", "3"));
System.out.println("After duplicate \"add\": " + ts);
ts.remove(new Pair("abc", "3"));
System.out.println(ts);
ts.add(new Pair("abc", "3"));
System.out.println(ts);
ts.add(new Pair("bbb", "4"));
System.out.println(ts);
```

Output:

```
[<abc,1>, <def,2>]
true
After duplicate "add": [<abc,1>, <def,2>]
[<def,2>]
[<abc,3>, <def,2>]
[<abc,3>, <bbb,4>, <def,2>]
```

Java Set Example – HashSet

```java
HashSet<Pair> t2 = new HashSet<Pair> ();
t2.add(new Pair("abc", "1"));
t2.add(new Pair("def", "2"));
System.out.println(t2);
System.out.println(t2.contains(new Pair("abc", "3")));
t2.add(new Pair("abc", "3"));
System.out.println("After duplicate \"add\": " + t2);
t2.remove(new Pair("abc", "3"));
System.out.println(t2);
t2.add(new Pair("abc", "3"));
System.out.println(t2);
t2.add(new Pair("bbb", "4"));
System.out.println(t2);
```

Output:

```
[<abc,1>, <def,2>]
true
After duplicate "add": [<abc,1>, <def,2>]
[<def,2>]
[<abc,3>, <def,2>]
[<abc,3>, <def,2>, <bbb,4>]
```

Note that the elements are not in Comparable order.

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- Array (1D, 2D, …)
- Stack
- Queue
- List
  - ArrayList
  - LinkedList
- Set
- MultiSet
- Map (a.k.a. table, dictionary)
  - HashMap
  - TreeMap

You should be able to answer all of these by the end of this course.

Map

- A Table of key–value pairs.
- Insert and look up things by key.
- Implementations:
  - TreeMap
  - HashMap
- Same running time as the corresponding sets.
- More details next time.

Interlude

- The dedication from *Data Structures and the Java Collections Framework* by William Collins (first edition):
  - To Karen, my wife of 35 years, for giving me 20 of the happiest years of my life.
- Go figure!

- Choose your partner for Markov now:
  - Must be different than your Minesweeper partner.
  - Mark if you have no preference.

  - Angel: Lessons > Project Forms > Markov Partner Declaration

Work on Hardy's Taxi

- Test your interface using the provided code
- Or work on the rest of HW 18 if you have finished Hardy's Taxi.