CompSci 201, L5: Sets and Maps

Logistics, Coming up

- Today, Monday 9/12
  - Project 0: Person201 due
- This Wednesday, 9/14
  - APT2 due
  - Hashing
- This Friday 9/16
  - Discussion
- Next Monday, 9/19
  - Project 1: NBody due
  - Runtime efficiency

WOTO

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Not graded for correctness, just participation.

Try to answer *without* looking back at slides and notes.

But do talk to your neighbors!

Array vs. Collection

Array

- Stores primitives (int, char, etc.) or objects (String, etc.)
- Does not print “nicely” to terminal, print one at a time.
- API static utility methods in `java.util.Arrays`

Collection

- Stores objects only, use wrapper (e.g., Integer) for primitives
- Prints ”nicely” to the terminal.
- API static utility methods in `java.util.Collections`

`ArrayList` <-> `Array` Conversion, Object Types

`ArrayList` is basically an `Array` of objects, easy to convert with API methods.

```
6       ArrayList<String> strList = new ArrayList<>();
7       String[] strArray = {"CS", "201", "is", "the", "best"};
8
9       // Convert a String Array to a List using
10      // the static Arrays.asList method and the
11      // ArrayList addAll method
12      strList.addAll((Arrays.asList(strArray)));
13
14      // Convert a String List to a String Array the
15      // ArrayList toArray() method and casting
16      String[] newStrArray = strList.toArray(new String[0]);
```

`ArrayList` <-> `Array` Conversion, Primitive Types

Primitive types more "manual", remember Lists only use Object types (`int` vs. `Integer`)

```
18        ArrayList<Integer> intList = new ArrayList<>();
19        int[] intArray = {2, 0, 1};
20
21        // Convert a int (or other primitive type) Array
22        // to a List by adding one at a time
23        for (int number : intArray) {
24            intList.add(number);
25        }
26
27        // Convert an Integer list to an int[] or
28        // other primitive type array one at a time
29        int[] newIntArray = new int[intList.size()];
30        for (int i=0; i<intList.size(); i++) {
31            newIntArray[i] = intList.get(i);
32        }
```

Sets

Set Review

```
public interface Set<E>
extends Collection<E>
```

A collection that contains no duplicate elements.

Java API documentation

- Stores UNIQUE elements
- Check if element in Set (using `.contains()`)
- Add element to set (using `.add()`)
  - Returns `false` if already there
- Remove element (with `.remove()`)
- Not guaranteed to store them in the order added

Set FAQs

```
jshell> mySet
mySet ==> [CS, 201]
```

1. How do I loop over a Set?

Enhanced for loop

```
jshell> for (String s : mySet) { System.out.println(s); }
CS
201
```

2. How do I convert between lists and sets?

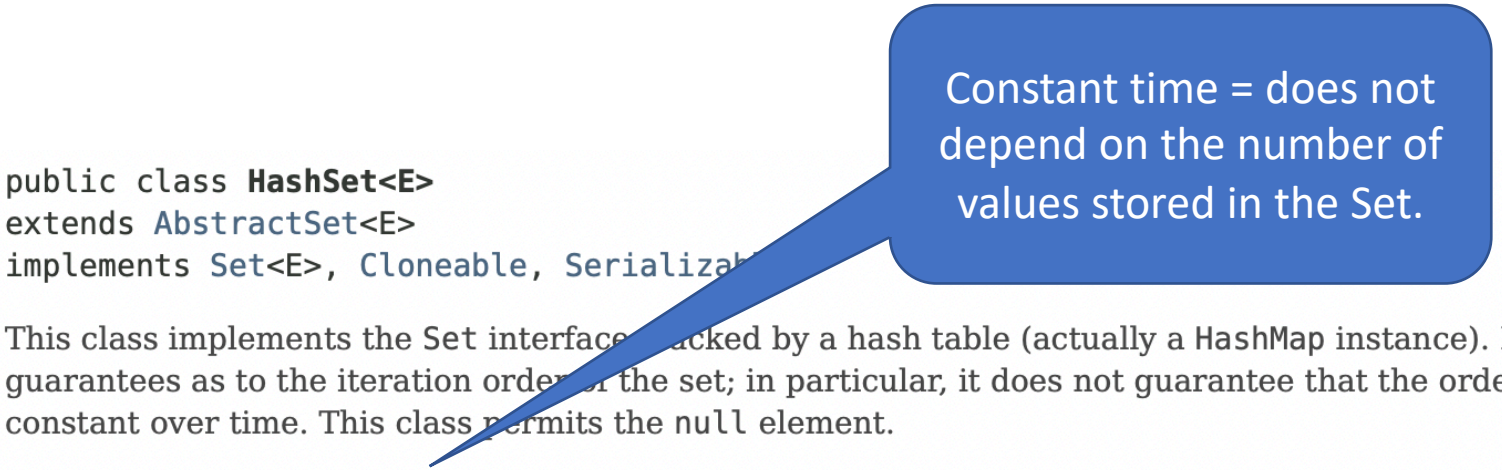
```
jshell> List<String> myList = new ArrayList<>();
myList ==> []

jshell> myList.addAll(mySet);
$21 ==> true

jshell> myList
myList ==> [CS, 201]
```

`addAll()` method convenient, same as looping and adding one at a time

HashSet implementation of Set is very efficient




```
public class HashSet<E>
extends AbstractSet<E>
implements Set<E>, Cloneable, Serializab
```

This class implements the Set interface, backed by a hash table (actually a HashMap instance). It makes no guarantees as to the iteration order of the set; in particular, it does not guarantee that the order will remain constant over time. This class permits the null element.

This class offers constant time performance for the basic operations (add, remove, contains and size), assuming the hash function disperses the elements properly among the buckets. Iterating over this set requires time proportional to the sum of the HashSet instance's size (the number of elements) plus the "capacity" of the backing HashMap instance (the number of buckets). Thus, it's very important not to set the initial capacity too high (or the load factor too low) if iteration performance is important.

Java API documentation

Count Unique Words?

```
public static int countWordsHashSet(String[] words) {
    HashSet<String> mySet = new HashSet<>();
    for (String w : words) {
        mySet.add(w);
    }
    return mySet.size();
}

public static int countWordsArrayList(String[] words) {
    ArrayList<String> myList = new ArrayList<>();
    for (String w : words) {
        if (!myList.contains(w)) {
            myList.add(w);
        }
    }
    return myList.size();
}
```

For each word, constant time operation. "Linear complexity."

For each word, must check all the words so far. "Quadratic complexity."

`TreeSet` stores sorted

Two important implementations of Set interface:

- `HashSet` – Very efficient `add`, `contains`
- `TreeSet` – Nearly as efficient, keeps values sorted.

```
 5        String message = "computer science is so much fun";
 6        char[] messageCharArray = message.toCharArray();
 7        TreeSet<Character> uniqueChars = new TreeSet<>();
 8        for (char c : messageCharArray) {
 9            uniqueChars.add(c);
10        }
11        System.out.println(uniqueChars);
```

```
[ , c, e, f, h, i, m, n, o, p, r, s, t, u]
```

Prints all unique characters *in order*.

`HashSet` and `TreeSet` Implementations

```
public class HashSet<E>
extends AbstractSet<E>
implements Set<E>, Cloneable, Serializable
```

This class implements the Set interface, backed by a hash table (actually a HashMap instance). It makes no guarantees as to the iteration order of the set; in particular, it does not guarantee that the order will remain constant over time. This class permits the null element.

HashSet and HashMap both implemented with a hash table data structure, will discuss next time.

```
public class TreeSet<E>
extends AbstractSet<E>
implements NavigableSet<E>, Cloneable, Serializable
```

A NavigableSet implementation based on a TreeMap. The elements are ordered using their natural ordering, or by a Comparator provided at set creation time, depending on which constructor is used.

TreeSet and TreeMap both implemented using a special kind of *binary tree*, will discuss later in the course.

```
public class TreeMap<K,V>
extends AbstractMap<K,V>
implements NavigableMap<K,V>, Cloneable, Serializable
```

A Red-Black tree based NavigableMap implementation. The map

WOTO

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Maps

Map pairs keys with values

- Like an **address book**, lookup the value (address) of a key (person). Like a dictionary in Python.

Keys	Values
Bob	101 E. Main St.
Naomi	200 Broadway
Xi	121 Durham Ave.

- Map is an interface, must have methods like:
  - `put(k, v)`: Associate value v with key k
  - `get(k)`: Return the value associated with key k
  - `containsKey(k)`: Return true if key k is in the Map

Implementations: HashMap, TreeMap

```
1   import java.util.HashMap;
2   import java.util.Map;
3   import java.util.TreeMap;
```

Two major implementations:

- HashMap: Very efficient put, get, containsKey
- TreeMap: Nearly as efficient, keeps keys sorted

Map<KEY_TYPE, VALUE_TYPE>

Create a TreeMap to implement this Map

```
 8        Map<String, String> addressBook = new TreeMap<>();
 9        addressBook.put("Bob", "101 E. Main St.");
10        addressBook.put("Naomi", "200 Broadway");
11        addressBook.put("Xi", "121 Durham Ave.");
12        System.out.println(addressBook);
```

Sorted by keys due to TreeMap

```
{Bob=101 E. Main St., Naomi=200 Broadway, Xi=121 Durham Ave.}
```

Check before you get

If you call `.get(key)` on a key not in the map, returns `null`, can cause program to crash.

```
6       Map<String, Integer> myMap = new HashMap<>();
7       int val = myMap.get("hi");
```

```
Exception in thread "main" java.lang.NullPointerException: Cannot invoke "java.lang.
Integer.intValue()" because the return value of "java.util.Map.get(Object)" is null
```

Instead, check first with `.containsKey()`.

```
6       Map<String, Integer> myMap = new HashMap<>();
7       if (myMap.containsKey("hi")) {
8           int val = myMap.get("hi");
9       }
```

Adding “default” values

Often want a “default” value associated with new keys (examples: 0, empty list, etc.). Two options:

- `.putIfAbsent(key, val)`
- Check if does not contain key

```
6           Map<String, Integer> myMap = new HashMap<>();
7
8           myMap.putIfAbsent("hi", 0);
9
10          // Equivalent to line 8
11          if (!myMap.containsKey("hi")) {
12              myMap.put("hi", 0);
13          }
```

Updating maps

Single values

- `.get()` returns a *copy of the value.*
- Must use `.put()` again to update.

Collection values

- `.get()` returns *reference to collection.*
- Update the collection directly.

```
 8    Map<String, Integer> myMap = new HashMap<>();
 9    myMap.put("hi", 0);
10    int currentVal = myMap.get("hi");
11    myMap.put("hi", currentVal + 1);
```

```
14    Map<String, List<Integer>> otherMap = new HashMap<>();
15    otherMap.put("hi", new ArrayList<>());
16    otherMap.get("hi").add(0);
```

Counting with a Map

In this example we count how many of each character occur in `message`.

```
5         String message = "computer science is so much fun";
6         char[] messageCharArray = message.toCharArray();
7         TreeMap<Character, Integer> charCounts = new TreeMap<>();
8         for (char c : messageCharArray) {
9             if (!charCounts.containsKey(c)) {
10                charCounts.put(c, 1);
11            }
12            else {
13                int currentVal = charCounts.get(c);
14                charCounts.put(c, currentVal + 1);
15            }
16        }
17        System.out.println(charCounts);
```

```
{ =5, c=4, e=3, f=1, h=1, i=2, m=2, n=2, o=2, p=1, r=1, s=3, t=1, u=3}
```

Check if we have *not* seen c yet

Else get current value and increase

Comes in order because using TreeMap