Principles of Software Construction: Objects, Design and Concurrency

The Java Collections Framework

15-214

toad

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Administrivia

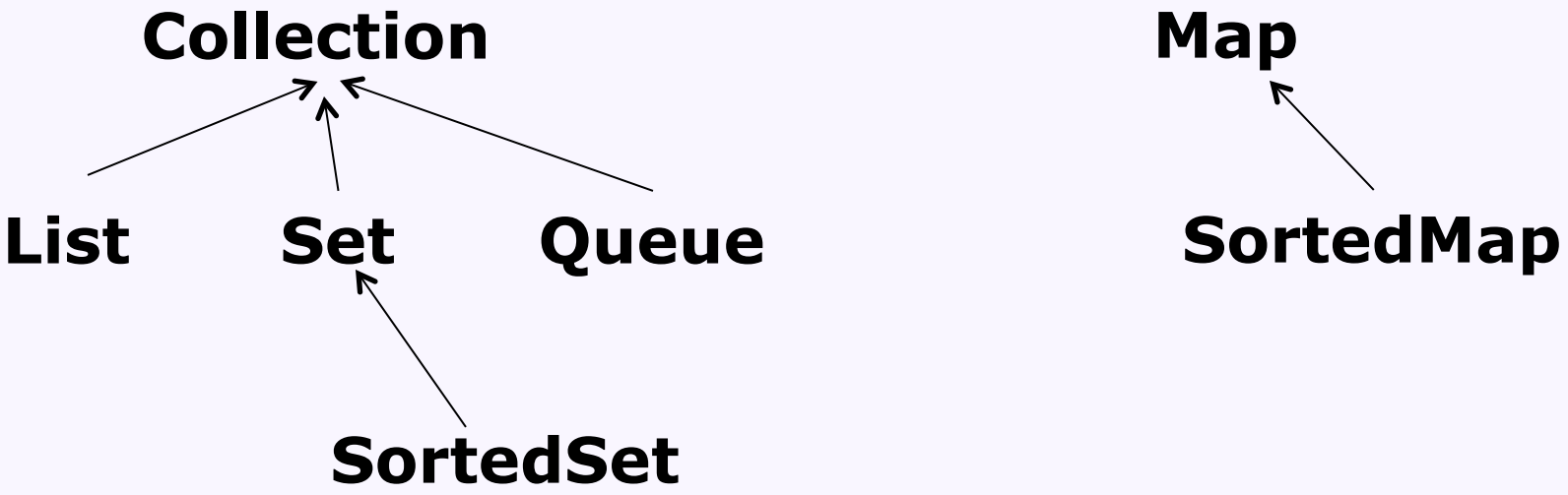
- Homework 5 due tonight
  - But you may use late days…
- Homework 6 coming soon
  - Design (and later implement) a plugin framework for social network applications
- Midterms will be handed back in recitation tomorrow
- Rabbits vs. Foxes

15-214 from 10,000 feet

- Where we've been
  - Java introduction
  - Proving a program's correctness
  - Design patterns
  - Frameworks
- Where we're going
  - More Java Framework examples
  - Concurrency
  - Distributed systems

Today: The Java Collections Framework

- Interfaces (in java.util)



- Default Implementations
  - ArrayList, LinkedList, HashSet, TreeSet, PriorityQueue, HashMap, TreeMap, LinkedHashSet, LinkedHashMap, …
- Algorithms
  - min, max, sort, reverse, binarySearch, shuffle, rotate, …

Today's goals

- A tour of the Java Collections Framework
  - Some of the features
  - Some of the common usage patterns
- See some design patterns in use
- See the big Collections picture

The philosophy of the Collections framework

- Powerful and general
- Small in size and conceptual weight
  - Only include fundamental operations
  - "Fun and easy to learn and use"

The java.util.Collection<E> interface

```
boolean      add(E e);
boolean      addAll(Collection<E> c);
boolean      remove(E e);
boolean      removeAll(Collection<E> c);
boolean      retainAll(Collection<E> c);
boolean      contains(E e);
boolean      containsAll(Collection<E> c);
void         clear();
int          size();
boolean      isEmpty();
Iterator<E>  iterator();
Object[]     toArray()
E[]          toArray(E[] a);
```

The java.util.List<E> interface

- Extends java.util.Collection<E>:

```
boolean add(int index, E e);
E       get(int index);
E       set(int index, E e);
int     indexOf(E e);
int     lastIndexOf(E e);
List<E> sublist(int fromIndex, int toIndex);
```

The java.util.Set<E> interface

- Extends java.util.Collection<E>:
- Enforces uniqueness of each element in set

The java.util.Queue<E> interface

- Extends java.util.Collection<E>:

```
boolean add(E e);     // These three methods
E       remove();     // might throw exceptions
E       element();

boolean offer(E e);
E       poll();       // These two methods
E       peek();       // might return null
```

The java.util.Map<K,V> interface

- Does not extend java.util.Collection<E>

```
V        put(K key, V value);
V        get(Object key);
V        remove(Object key);
boolean  containsKey(Object key);
boolean  containsValue(Object value);
void     putAll(Map<K,V> m);
int      size();
boolean  isEmpty();
void     clear();
Set<K>                  keySet();
Collection<V>           values();
Set<Map.Entry<K,V>>     entrySet();
```

One problem: Java arrays are not Collections

- To convert a Collection to an array
  - Use the toArray method

```
List<String> arguments = new LinkedList<String>();
…                    // puts something into the list
String[] arr = (String[]) arguments.toArray();
String[] brr = arguments.toArray(new String[0]);
```

- To view an array as a Collection
  - Use the java.util.Arrays.asList method

```
String[] arr = {"foo", "bar", "baz", "qux"};
List<String> arguments = Arrays.asList(arr);
```

What do you want to do with your Collection today?

Traversing a Collection

- Old-school Java for loop for ordered types

```
List<String> arguments = …;
for (int i = 0; i < arguments.size(); ++i) {
  System.out.println(arguments.get(i));
}
```

- Modern standard Java for-each loop

```
List<String> arguments = …;
for (String s : arguments) {
  System.out.println(s);
}
```

- Use an Iterator

Using a java.util.Iterator<E>

```
public interface Iterator<E> {
  boolean hasNext();
  E next();
  void remove();  // removes previous returned item
}                 // from the underlying collection
```

- To use, e.g.:

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator();
     it.hasNext();  ) {
  String s = it.next();
  System.out.println(s);
}
```

Using a java.util.Iterator<E>

```
public interface Iterator<E> {
  boolean hasNext();
  E next();
  void remove();  // removes previous returned item
}                 // from the underlying collection
```

- To use to remove items, e.g.:

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator();
     it.hasNext();  ) {
  String s = it.next();
  if (s.equals("Charlie"))
    it.remove();
}
// The next line will always print false
System.out.println(arguments.contains("Charlie"));
```

Using a java.util.Iterator<E>: A warning

- The default Collections implementations are mutable
- The java.util.Iterator assumes the Collection does not change while the Iterator is being used
  - You will get a `ConcurrentModificationException`

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator();
     it.hasNext();  ) {
  String s = it.next();
  if (s.equals("Charlie"))
    arguments.remove("Charlie"); // runtime error
}
```

Sorting a Collection

- Use the Collections.sort method:

```
public static void main(String[] args) {
  List<String> lst = Arrays.asList(args);
  Collections.sort(lst);
  for (String s : lst) {
    System.out.println(s);
  }
}
```

- Abuse the SortedSet:

```
public static void main(String[] args) {
  SortedSet<String> set =
        new TreeSet<String>(Arrays.asList(args));
  for (String s : lst) {
    System.out.println(s);
  }
}
```

Sorting your own types of objects

```
public interface Comparable<T> {
   int compareTo(T o);
}
```

- General contracts:
  - `a.compareTo(b)` should return:
    - `<0` if `a` is less than `b`
    - `0` if `a` and `b` are equal
    - `>0` if `a` is greater than `b`
  - Should define a total order
    - If `a.compareTo(b)` < 0 and `b.compareTo(c)` < 0, then `a.compareTo(c)` should be < 0
    - If `a.compareTo(b)` < 0, then `b.compareTo(a)` should be > 0
  - Should usually be consistent with `.equals`
    - `a.compareTo(b)` == 0 iff `a.equals(b)`

Comparable objects – an example

```
public class Integer implements Comparable<Integer> {
  private int val;
  public Integer(int val) { this.val = val; }
  …
  public int compareTo(Integer o) {
    if (val < o.val) return -1;
    if (val == o.val) return 0;
    return 1;
  }
}
```

- Aside: Why did I not just `return val – o.val`?

Comparable objects – another example

- Make Name comparable:

```
public class Name                                          {
  private String first;
  private String last;
  public Name(String first, String last) {   // should
    this.first = first;  this.last = last;   // check
  }                                          // for null
  …




}
```

- Hint: Strings implement `Comparable<String>`

Comparable objects – another example

- Make Name comparable:

```
public class Name implements Comparable<Name> {
  private String first;
  private String last;
  public Name(String first, String last) {   // should
    this.first = first;  this.last = last;   // check
  }                                          // for null
  …
  public int compareTo(Name o) {
    int lastComparison = last.compareTo(o.last);
    if (lastComparison != 0) return lastComparison;
    return first.compareTo(o.first);
  }
}
```

Alternative comparisons

```
public class Employee implements Comparable<Employee> {
   private Name name;
   private int  salary;
   …
}
```

- What if we want to sort Employees by name, usually, but sometimes sort by salary?

Alternative comparisons

```
public class Employee implements Comparable<Employee> {
  private Name name;
  private int  salary;
  …
}
```

- What if we want to sort Employees by name, usually, but sometimes sort by salary?
- Answer: There's an app^H^H^Hinterface for that

```
public interface Comparator<T> {
  public int     compare(T o1, T o2);
  public boolean equals(Object obj);
}
```

Writing a Comparator object

```
public class Employee implements Comparable<Employee> {
  private Name name;
  private int  salary;
  public int compareTo(Employee o) {
    return name.compareTo(o.name);
  }
}

public class EmpSalComp implements Comparator<Employee> {
  public int compare (Employee o1, Employee o2) {
    return o1.getSalary() – o2.getSalary();
    // Why is it OK to return the difference of salaries?
  }
  public boolean equals(Object obj) {
    return obj instanceof EmpSalComp;
  }
}
```

Using a Comparator

- Order-dependent classes and methods take a Comparator as an argument

```
public class Main {
  public static void main(String[] args) {
    SortedSet<Employee> byName =    // sorts by name
          new TreeSet<Employee>();

    SortedSet<Employee> bySalary =  // sorts by salary
          new TreeSet<Employee>(new EmpSalComp());
  }
}
```

Aside: The java.util.SortedSet<E> interface

- Extends java.util.Set<E>:

```
Comparator<E> comparator();
E             first();
E             last();
SortedSet<E>  subSet(E fromElement, E toElement);
SortedSet<E>  headSet(E toElement);
SortedSet<E>  tailSet(E fromElement);
```

- The `comparator` method returns null if the natural ordering is being used

The java.util.Collections class

- Standard implementations of common algorithms
  - binarySearch, copy, fill, frequency, indexOfSubList, min, max, nCopies, replaceAll, reverse, rotate, shuffle, sort, swap, …

```
public class Main() {
  public static void main(String[] args) {
    List<String> lst = Arrays.asList(args);
    Collections.sort(lst);
    for (String s : lst) {
      System.out.println(s);
    }
  }
}
```

The java.util.Collections class

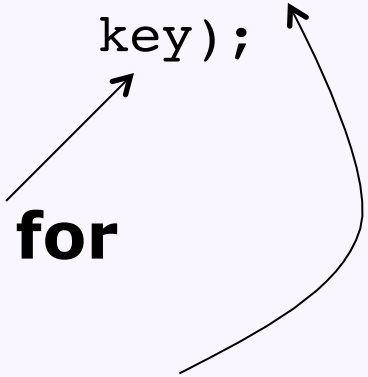
- Standard implementations of common algorithms
  - binarySearch, copy, fill, frequency, indexOfSubList, min, max, nCopies, replaceAll, reverse, rotate, shuffle, sort, swap, …

```
public class Main() {
  public static void main(String[] args) {
    List<String> lst = Arrays.asList(args);
    int x = Collections.frequency(lst, "Charlie");
    System.out.println("There are " + x +
                       " students named Charlie");
  }
}
```

The java.util.Collections class

- Standard implementations of common algorithms
- An actual method declaration

```
static int binarySearch(
        List<? extends Comparable<? super T>> list,
        T                                     key);
```



An object of some type T to search for

A List of objects of some type that has a compareTo method that can take an object of type T as an argument

A task for you (now):

- Grab a partner
- Use a laptop to look at the Java 7 API
  - java.util….Collection, List, Set, Queue, Map, Deque, *List, *Set, *Map, Abstract*, Collections, Arrays, Comparator,
  - java.lang….Comparable, Iterable
- Find three examples of design pattern use