Introduction to Object-Oriented Programming

Iterators and Streams

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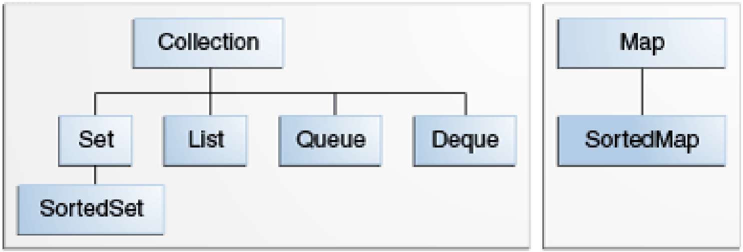
The Collections Framework



- A *collection* is an object that represents a group of objects.
- The collections framework allows different kinds of collections to be dealt with in an implementation-independent manner.

Collection Framework Components

The Java collections framework consists of:

- Collection interfaces representing different types of collections (sets, lists, etc)
- General purpose implementations (like `ArrayList` or `HashSet`)
- Absract implementations to support custom implementations
- Algorithms defined in static utility methods that operate on collections (like `Collections.sort(List<T> list)`)
- **Infrastructure interfaces that support collections (like `Iterator`)**

Today we'll learn a few basic concepts, then tour the collections library.

The `Collection` Interface

`Collection` is the root interface of the collections framework, declaring basic operations such as:

- `add(E e)` to add elements to the collection
- `contains(Object key)` to determine whether the collection contains `key`
- `isEmpty()` to test the collection for emptiness
- `iterator()` **to get an interator over the elements of the collection**
- `remove(Object o)` to remove a single instance of `o` from the collection, if present
- `size()` to find out the number of elements in the collection

None of the collection implementations in the Java library implement `Collection` directly. Instead they implement `List` or `Set`.

Iterators

Iterators are objects that provide access to the elements in a collection. In Java iterators are represented by the `Iterator` interface, which contains three methods:

- `hasNext()` returns true if the iteration has more elements.
- `next()` returns the next element in the iteration.
- `remove()` removes from the underlying collection the last element returned by the iterator (optional operation).

The most basic and common use of an iterator is to traverse a collection (visit all the elements in a collection):

```java
ArrayList tasks = new ArrayList();
// ...
Iterator tasksIter = tasks.iterator();
while (tasksIter.hasNext()) {
    Object task = tasksIter.next();
    System.out.println(task);
}
```

See ArrayListBasics.java for examples.

The Iterable Interface

An instance of a class that implements the `Iterable` interface can be the target of a for-each loop. The `Iterable` interface has one abstract method, `iterator`:

```
public interface Iterable<T> {
    Iterator<T> iterator();
}
```

Let's see how we can implement an iterator for DynamicArray.java

DynamicArray

DynamicArray.java is like an `ArrayList`

```
public class DynamicArray<E> implements Iterable<E> {

    private class DynamicArrayIterator implements Iterator<E> {
        ???
    }
    private Object[] elements;
    private int lastIndex;

    public DynamicArray() { this(10); }
    public DynamicArray(int capacity) { ... }
    public Iterator<E> iterator() { return new DynamicArrayIterator();
    }
    public void add(E item) { ... }
    public E get(int index) { ... }
    public void set(int index, E item) { ... }
    public int size() { ... }
    public E remove(int index) { ... }
}
```

Assuming the methods above are defined, how do we write

DynamicArrayIterator

The key component of an iterator is a *cursor*: a pointer to the next element in the collection.

- Since `DynamicArray` uses an array as its backing data store, the cursor is simply an index into this array
- The first element to be accessed is at index 0

```
public class DynamicArray<E> implements Iterable<E> {
    private class DynamicArrayIterator implements Iterator<E> {
        private int cursor = 0;

        public boolean hasNext() {
            return cursor <= lastIndex;
        }
        public E next() {
            if (!hasNext()) { throw new NoSuchElementException(); }
            E answer = get(cursor++);
            return answer;
        }
        public void remove() {
            DynamicArray.this.remove(cursor - 1);
        }
```

DynamicArrayIterator's `next` Method

An `Iterator`'s `next` method

- returns the element the cursor currently points to, and
- moves the cursor to the next element in the collection

```java
public class DynamicArray<E> implements Iterable<E> {
    private class DynamicArrayIterator implements Iterator<E> {
        private int cursor = 0;

        public boolean hasNext() { ... }
        public E next() {
            if (!hasNext()) { throw new NoSuchElementException(); }
            E answer = get(cursor++);
            return answer;
        }
        public void remove() { ... }
    }
    private Object[] elements;
    private int lastIndex;
```

DynamicArrayIterator's `hasNext` Method

An `Iterator`'s `hasNext` method

- is used by clients of the `Iterator` to determine whether unvisited elements of the collection remain
- for `DynamicArray` we simply test whether the cursor is still a valid array index

```
public class DynamicArray<E> implements Iterable<E> {
    private class DynamicArrayIterator implements Iterator<E> {
        private int cursor = 0;

        public boolean hasNext() {
            return cursor <= lastIndex;
        }
        public E next() {
            if (!hasNext()) { throw new NoSuchElementException(); }
            E answer = get(cursor++);
            return answer;
        }
        public void remove() { ... }
    }
    private Object[] elements;
```

DynamicArrayIterator's `remove` Method

- removes the last element returned by the iterator
- the only safe way to modify a collection being iterated over

We simply use the `DynamicArray`'s '`remove` method

```
public class DynamicArray<E> implements Iterable<E> {
    private class DynamicArrayIterator implements Iterator<E> {
        private int cursor = 0;
        public boolean hasNext() { return cursor <= lastIndex; }
        public E next() {
            if (!hasNext()) { throw new NoSuchElementException(); }
            E answer = get(cursor++);
            return answer;
        }
        public void remove() {
            DynamicArray.this.remove(cursor - 1);
        }
    }
```

Notice the syntax for distinguishing between the enclosing class's `remove` method and the inner class's `remove` method.

What if we called the inner class's `remove` method recursively?

The Iterable Interface and teh For-Each Loop

An instance of a class that implements `Iterable` can be the target of a for-each loop.

```
DynamicArray<String> da = new DynamicArray<>(2);
da.add("Stan");
da.add("Kenny");
da.add("Cartman");
System.out.println("da contents:");
for (String e: da) {
    System.out.println(e);
}
```

See DynamicArray.java for implementation details.

Streams and Pipelines

A stream is a sequence of elements.

- Unlike a collection, it is not a data structure that stores elements.
- Unlike an iterator, streams do not allow modification of the underlying source

A stream carries values from a source through a pipeline.

A pipeline contains the following components:

- A source: This could be a collection, an array, a generator function, or an I/O channel.
- Zero or more intermediate operations. An intermediate operation, such as filter, produces a new stream
- A terminal operation. A terminal operation, such as forEach, produces a non-stream result, such as a primitive value (like a double value), a collection, or in the case of forEach, no value at all.

Stream Example: How Many Mustaches?

Consider this simple example from SuperTroopers.java:

```
long mustaches =
    troopers.stream().filter(Trooper::hasMustache).count();
System.out.println("Mustaches: " + mustaches);
```

- `troopers.stream()` is the *source*
- `.filter(Trooper::hasMustache)` is an *intermediate operation*
- `.count()` is the *terminal operation*

The terminal operation yields a new value which results from applying all the intermediate operations and finally the terminal operation to the source.

A Bigger Stream Example: WordCount Pipeline

Consider this example from `WordCounts`:

```
Set<String> stopWords = new HashSet<>(Arrays.asList(
    "a", "an", "and", "are", "as", "be", "by", "is", "in", "of",
    "for", "from", "not", "to", "the", "that", "this", "with", "which"
));
wc.wordCounts.entrySet().stream()
    .filter(entry -> !stopWords.contains(entry.getKey().toLowerCase()))
    .sorted((e1, e2) -> e1.getValue() - e2.getValue())
    .forEach(entry ->
        System.out.printf("%s occurs %d times%n", entry.getKey(),
                                                  entry.getValue()));
```

This code does the same tasks we did before with classes and for loops.

WordCount Pipeline - Stop Words

```
Set<String> stopWords = new HashSet<>(Arrays.asList(
    "a", "an", "and", "are", "as", "be", "by", "is", "in", "of",
    "for", "from", "not", "to", "the", "that", "this", "with", "which"
));
```

- Every document has information-carrying words and grammatical words that carry no information, like prepositions, verbs like to be or have, pronouns
- In document processing we call these non-information-carrying words *stop words*

Here we've implemented a naiive and terribly incomplete stop words list.

BTW, why a `HashSet`?

WordCount Pipeline - filter

Consider this example from `WordCount`s:

```
Set<String> stopWords = new HashSet<>(Arrays.asList(
    "a", "an", "and", "are", "as", "be", "by", "is", "in", "of",
    "for", "from", "not", "to", "the", "that", "this", "with", "which"
));
wc.wordCounts.entrySet().stream()
    .filter(entry -> !stopWords.contains(entry.getKey().toLowerCase()))
    .sorted((e1, e2) -> e1.getValue() - e2.getValue())
    .forEach(entry ->
        System.out.printf("%s occurs %d times%n", entry.getKey(),
                                                  entry.getValue()));
```

The filter operation takes a predicate function.

- A predicate function returns a `boolean`
- If predicate function returns `true`, element is retained in the stream

Notice that we're also normalizing words to lower case.

WordCount Pipeline - sorted

Consider this example from `WordCount`s:

```
Set<String> stopWords = new HashSet<>(Arrays.asList(
    "a", "an", "and", "are", "as", "be", "by", "is", "in", "of",
    "for", "from", "not", "to", "the", "that", "this", "with", "which"
));
wc.wordCounts.entrySet().stream()
    .filter(entry -> !stopWords.contains(entry.getKey().toLowerCase()))
    .sorted((e1, e2) -> e1.getValue() - e2.getValue())
    .forEach(entry ->
        System.out.printf("%s occurs %d times%n", entry.getKey(),
                                                  entry.getValue()));
```

The sorted operation takes a `Comparator` that defines the ordering over the stream's elements.

WordCount Pipeline - forEach

Consider this example from `WordCount`s:

```
Set<String> stopWords = new HashSet<>(Arrays.asList(
    "a", "an", "and", "are", "as", "be", "by", "is", "in", "of",
    "for", "from", "not", "to", "the", "that", "this", "with", "which"
));
wc.wordCounts.entrySet().stream()
    .filter(entry -> !stopWords.contains(entry.getKey().toLowerCase()))
    .sorted((e1, e2) -> e1.getValue() - e2.getValue())
    .forEach(entry ->
        System.out.printf("%s occurs %d times%n", entry.getKey(),
                                                  entry.getValue()));
```

`forEach` is the terminal operation.

- Called for its effect - no return value

The underlying source is not modified.

Homework: Make the WordCount Pipeline Clearer

Notice that we use anonymous lambda expressions in our WordCOunt pipeline:

```
wc.wordCounts.entrySet().stream()
    .filter(entry -> !stopWords.contains(entry.getKey().toLowerCase()))
    .sorted((e1, e2) -> e1.getValue() - e2.getValue())
    .forEach(entry ->
        System.out.printf("%s occurs %d times%n", entry.getKey(),
                                                  entry.getValue()));
```

- Functional-style code can easily become hard to read.
- You can improve readability by introducing intermediate helper variables with informative names.

Rewrite the WordCount pipeline with intermediate helper variables so that the pipeline is easy to understand. You'll need to look up these aggregate operations in the Java API to get the types for these variables.