COMP6700/2140 Abstract Data Types: Queue, Set, Map

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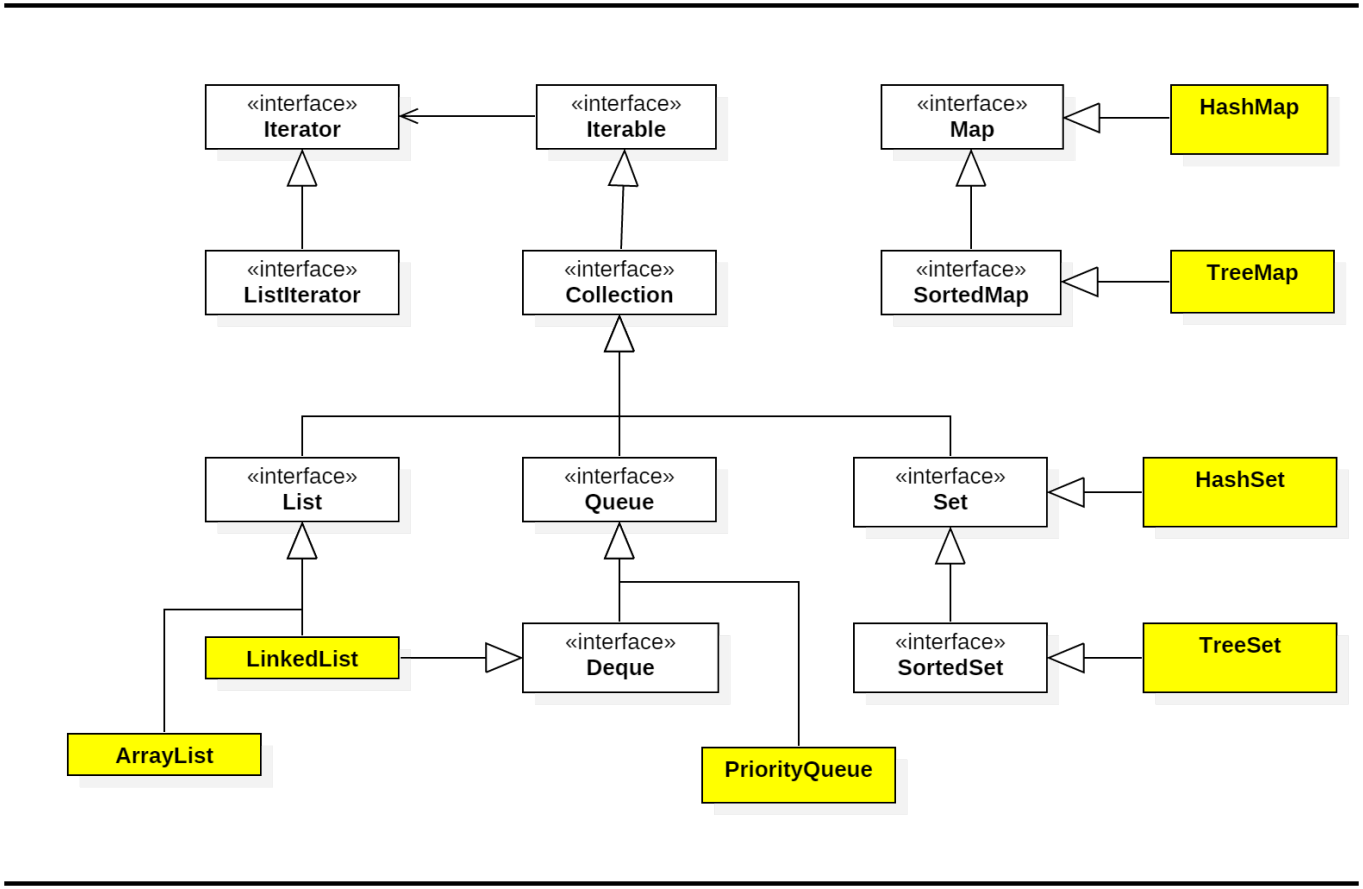
Java Collection Interfaces

The Java Collections Framework (JCF) includes interfaces (ADTs), implementations (data structures), and algorithms. The main interfaces are:

- Iterable — most basic interface to use a data type for iteration and nothing else
- Collection (proper) — allows adding, removing and testing for elements
- List — collection whose elements are ordered and accessible by their location in the collection
- Set — a collection with no duplicates
- SortedSet — an ordered collection which contains no duplicates
- Queue — a collection where elements are removed according to some order (typically first-in, first-out (FIFO))
- Deque — a double-ended queue
- Map — a collection where elements are stored and retrieved not by an index, but via a key

Collections: Class Diagram

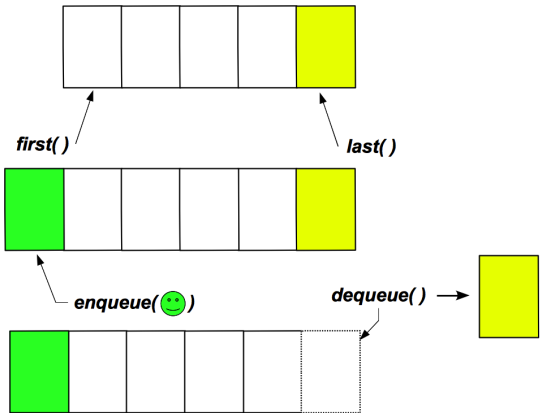
Key interfaces of the Java Collections Framework and *some* implementations:



Queues

A *Queue* is a "first-in, first-out" (FIFO) type which can be implemented by adding objects to the head of a list and removing them from its tail. The interface:

- `int size();`
- `boolean isEmpty();`
- `E first(E element);`
- `E last(E element);`
- `void enqueue(E newEl);`
- `void dequeue();`
- `String toString();`



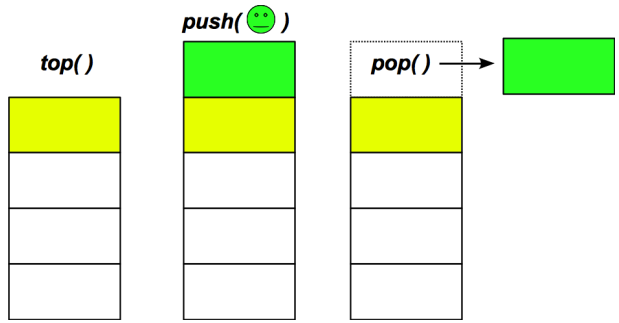
The JCF `Queue` interface has slightly different names for the above operations, as well as allowing different orderings (defined by the constructor with `Comparator` parameter), for instance, in the `PriorityQueue` class.

Stacks

Queues and stacks are widely used in systems level programming (for managing memory and processes) and other applications.

A *Stack* is a "last-in, first-out" (LIFO) collection type which can be implemented by adding to and removing from the head of a list. The interface:

- `int size();`
- `boolean isEmpty();`
- `int search(E el);// similar to indexOf()`
- `E top(E el); // JCF calls it peek()`
- `void push(E newEl);`
- `void pop();`
- `String toString();`

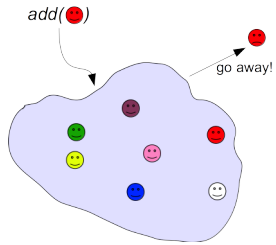


There is a legacy `Stack` class in JCF, however, the recommended implementation is the `Deque` class. `Deque` implements `addFirst`, `removeFirst` and `peekFirst` methods.

Set and *SortedSet*

The extensions of *Collection* type which disallow duplicates (identical elements): a repeated invocation of `add(elem)` with the same element `elem` (or such `elem1`, that `elem.equals(elem1)` returns `true`) returns `false`, and the collection remains unchanged. *Set* types, therefore, are sets in the mathematical sense (some computer scientists call them "bags"). The elements of a set are unordered. The subtype *SortedSet* (extension of the *Set* interface) represents a collection, whose elements can be *compared* — they implement *Comparable* interface. The ordering allows to introduce additional methods:

- `comparator()` — returns the comparator used with this sorted set (`null` in case of *natural ordering*)
- `first()`, `last()` — smallest and largest elements
- `subset(eMin,eMax)`, `headSet(eMax)`, `tailSet(eMin)` — subsets of elements in given ranges

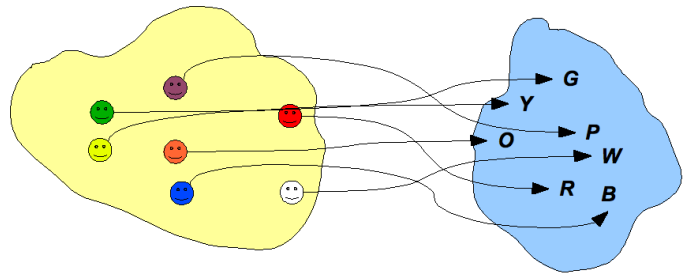


Set is implemented by the *HashSet* class with a hash table as the DS. Content modification (`add`, `set`) and testing (`contains`) are $\mathcal{O}(1)$ operations. *SortedSet* is implemented by the *TreeSet* class with a binary tree as the DS. If the implementation can maintain the *balanced tree*, the search and modify operations are $\mathcal{O}(\log_2 N)$. Example — SetTest.java.

Map and *SortedMap*

Unlike all previous types from JCF, the *Map* family of types does not extends the *Collection* interface: their contract is different — to represent not a collection of elements, but a *correspondence between two collections*. So, a map contains **key/value pairs**, with *no duplicate keys* (the keys form a set) and *at most one value* for each key. *Map* is a model of a mathematical abstraction called *function*. The interface Map<K,V> operations are:

- `V put(K key, V value)`
- `V get(K key)` and `V remove(K key)`
- `boolean containsKey(K key)`
- `boolean containsValue(V value)`
- `public Set keySet()` — returns a **view** of the set of keys
- `public Collection values()` — returns a **view** of the collection of stored values



Map of Smiley to Character

The *SortedMap* extension requires the set of keys be sorted. Methods like `firstKey()` and `lastKey()` are added. The *Map* interface has two major implementation classes (similar to *Set*) — *HashMap* which uses a hash table DS for the implementation (with similar $\mathcal{O}(1)$ performance for `put`/`get` operations), and *TreeMap* which implements *SortedMap* in the similar to *TreeSet* way (with $\mathcal{O}(\log_2 N)$ efficiency). Example — MapTest.java.

Bulk operations of *Collection* interface

The basic *Collection* operations were listed above (slide *Collection* Interface). They allow to examine and manipulate the collection element by element. The **bulk operations** allow to manipulate the whole part of the collection in one go:

- `boolean containsAll(Collection<?> c);`
- `boolean addAll(Collection<? extends E> c);` — adds all elements from `c` to `this`
- `boolean retainAll(Collection<?> c);` — retains only those elements that are found in `c`
- `boolean removeAll(Collection<?> c);` — opposite to `retainAll()`
- `List<E> subList(int, int)` — like a `String.substring(int,int)`, figure out the rest...
- `void clear();` — removes all elements ("clean start")

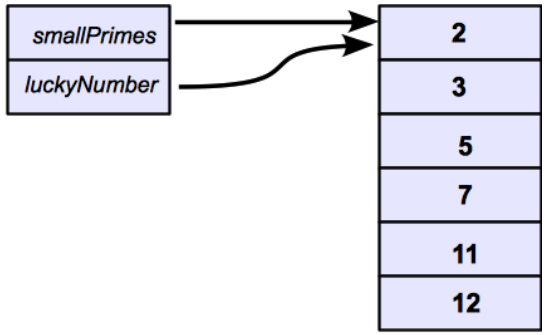
Another category of operations are **array operations**:

- `Object[ ] toArray();` — returns an array of all the elements in this list in the correct order
- `<T> T[ ] toArray(T[ ] dest);` — the list elements are placed in the array `dest`, which is returned (if `dest` isn't big enough to accommodate all elements of the collection, a new, properly sized array is created and returned)

How to copy arrays properly

Arrays are objects, therefore when one array is assigned to another, the two identifiers point to the *same memory location*. How to copy elements of an array into a *different* array?

```
int[] smallPrimes = {2,3,5,7,11,12};
int[] luckyNumbers = smallPrimes;
luckyNumbers[5] = 12;
System.out.println(smallPrimes[5]);// Prints 12
```



To achieve *element-by-element* copying, one has to use the `System.arraycopy()`method: To copy `count` elements from `source` array starting with index `from` to `target` array beginning with index `to`, make the following call: `System.arraycopy(source,from,target,to,count);`

```
int[] smallPrimes = {2,3,5,7,11,13};
int[] luckyNumbers = {1001,1002,1003,1004,1005,1006,1007};
System.arraycopy(smallPrimes,2,luckyNumbers,3,4);
for (int i=0; i<luckyNumbers.length; i++)
    System.out.println(i + ":" + luckyNumbers[i]);
```

Further Reading

- Hortsmann *Core Java for the Impatient*, Ch. 7.3–7.5
- Oracle *The Java Tutorials*: Collections (Sections 1-3)