Programming in Java

9. Java Collections

Data Structures and Algorithms

- In computer science, there exist a number of standard data structures and algorithms
  - Standard structures include linked lists, stacks, maps, hash tables, sets, etc.
  - Standard algorithms include searching, sorting, reversing, etc
- These are independent of any programming language
- They are independent of the type of data being stored or operated on.
  - A linked list properties, for example, do not depend on the type of data in a linked list
  - How we execute a sort does not depend on what is being sorted even though the type does determine what we mean by “comes before.”

Java Collections

- This is a Java class library for using and manipulating collections data
  - Provides all the standard computer science data structures and algorithms
  - Inspired by the C++ Standard Template Library (STL)
  - Has analogues in other programming languages
  - Data structures and algorithms are not programming language specific
- Structures and algorithms are generic
  - How we add, read, modify and delete elements depends only on the type of structure not on the elements in the structure
  - A linked list collection works the same way for integers as for user defined Customer objects
  - Sorting, reversing and other operations don't depend on what we are sorting or reversing
  - However, there are a restriction that we can only sort structures where the elements can be compared to each other
    - We can't sort People objects unless we define a way to compare them: by age or by weight for example

Why Use Collections

- Avoids us writing the same boilerplate code over and over again
- The library implementations are usually more efficient that a hand coded solution
- Lets us work with data structures through interfaces without having to know the details or anything about the underlying implementation
- Since we work through interfaces, we can easily switch implementations without having to rewrite code
  - Each implementation will have different performance characteristics
- The collections framework consists of
  - **Interfaces**: abstract data types that represent collections
  - **Implementations**: these are the concrete classes that implement the interfaces
  - **Algorithms**: methods that perform useful computations, such as searching and sorting, on objects that implement collection interfaces

Java Generics

- Generics allow us to use a generic container
  - We specify the type of object this is contained only when we create an instance of the container
  - In the example shown, we have a simple box that can hold any type of data
  - The ‘T’ parameter is a placeholder that is replaced by the actual type when we create a box of something of a specific type
  - As shown in the lab, this does not work if ‘T’ is a primitive type like int or float
  - We have to use the corresponding class like Integer or Float

```java
// Generic Box class
public class Box<T> {
    private T content;

    public void setContent(T content) {
        this.content = content;
    }

    public T getContent() {
        return content;
    }

    public static void main(String[] args) {
        // Box of Integer
        Box<Integer> intBox = new Box<>();
        intBox.setContent(123);
        System.out.println("Integer value: " + intBox.getContent());

        // Box of String
        Box<String> strBox = new Box<>();
        strBox.setContent("Hello, Generics!");
        System.out.println("String value: " + strBox.getContent());
    }
}
```

Java Type Classes

- Generics use the fact that every class inherits from Object
  - Except for the primitive data types line int, float, boolean, etc.
- Wrapper classes are provided for all the primitive data types
  - Integer for int, Float for float, etc
  - These object hold a primitive data value
  - And also provide a set of methods for that data type
  - Whenever the value is needed, it is automatically accessed
  - Called automatic boxing and unboxing

```java
public class IntegerExample {
    public static void main(String[] args) {
        // Creating an Integer object
        Integer num = Integer.valueOf(42);

        // Auto-unboxing to int
        int result = num + 8;

        // Printing values
        System.out.println("Integer object: " + num);
        System.out.println("Result after adding 8: " + result);
    }
}
```

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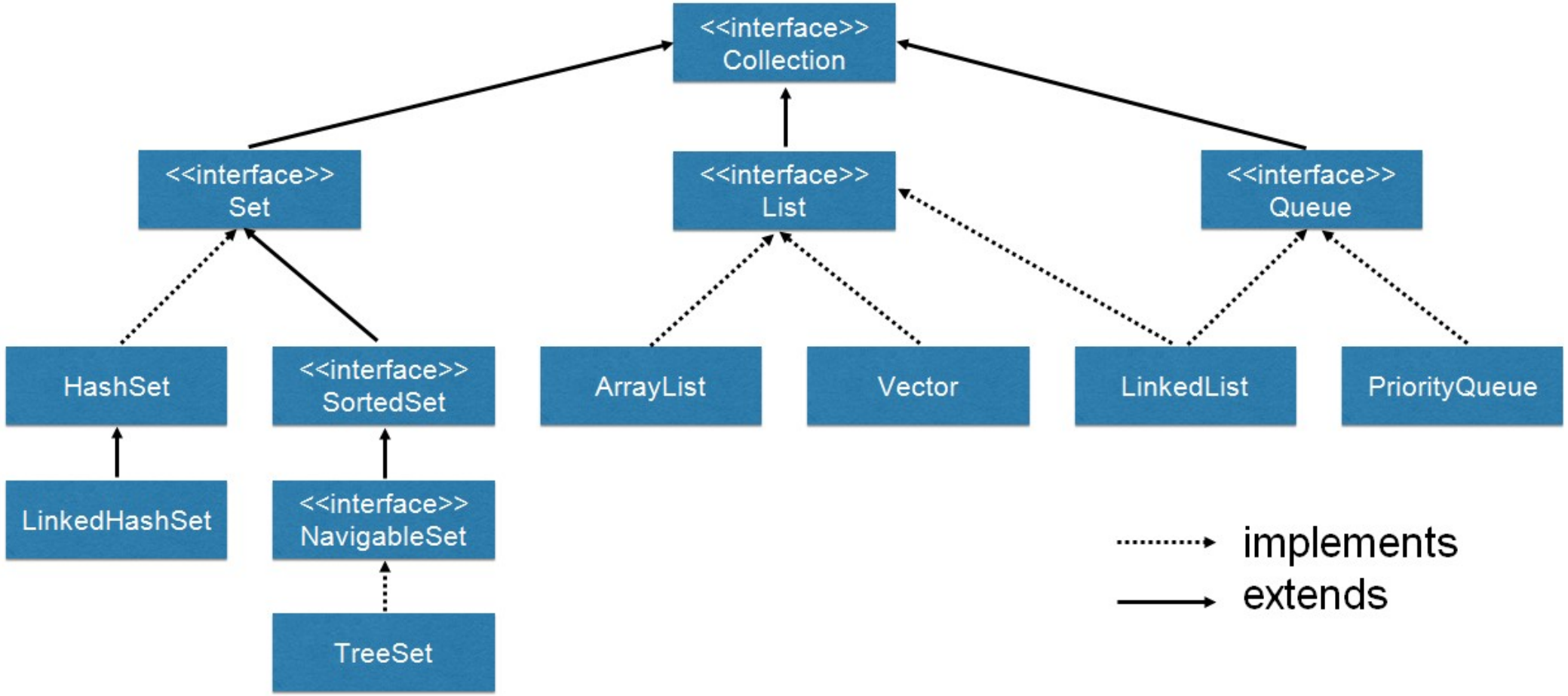
Generics

Collections Interfaces

- Collections are more flexible and powerful structures than arrays.
  - For example, arrays can only be created with a fixed length while collections increase in size automatically as elements are added
- Collections are implemented by using generics and interfaces that describe behaviour without reference to the underlying implementation of the collection
- There are three major types of Collections
  - Sets, lists and maps, each of which has a corresponding interface
  - Each is intended to satisfy different a different set of use cases
  - Each interface can be implemented by a range of implementation classes
  - Each implementation class has its own performance characteristics

Interfaces



Collection Interfaces

- **Collection**: the abstract root of the collection hierarchy
  - A collection represents a group of objects known as its elements
  - The Collection interface is the least common denominator that every collection object implements
    - Used to pass collections around and to manipulate them when maximum generality is desired
  - Some types of collections allow duplicate elements, and others do not.
  - Some are ordered and others are unordered
- **Set**: a collection that cannot contain duplicate elements.
- **List**: an ordered collection that can contain duplicate elements with precise control over where the position of the elements in the list
- **Queue** and **Deque**: specialized lists that provides additional insertion, extraction, and inspection operations often use a FIFO or LIFO ordering
- **Map**: an associative array of keys and values.

Collection Implementations

- An “implementation” is a Java class that implements one of the Collections interfaces
- For example, the “List” interface is implemented by both *ArrayList* and *LinkedList*
- Each implementation has different performance characteristics
  - The choice of which implementation to use depends on your non-functional requirements
- We always write code to the interface, not the implementation
  - This allows us to swap implementations without changing our code

Collection Interface

- The Collection interface defines a series of basic operations that are valid for any type of collection, except a map
- The iterator is a special object that we can reference
  - It has two methods
    - hasNext() which is true if there is a next element in the collection, ie. we haven't reached the end
    - T next() which return the next object T and increments the Iterator to point to the next object
  - We use iterators because how we determine the next object in a collection varies from implementation to implementation

```
public interface Collection<E> {
 // Basic Operations
        int size();
        boolean boolean isEmpty();
        contains(Object o);
        boolean add(E e);
        boolean remove(Object o);
        Iterator<E> iterator();
 // Bulk Operations
        boolean containsAll(Collection<?> c);
        boolean addAll(Collection<? Extends E>
        boolean removeAll(Collection<?> c);
        boolean retainAll(Collection<?> c);
        void clear();
 // Array Operations
        Object[] toArray();
        Object[] toArray(T[] a);
}
```

Set Interface

- A Set is a Collection which contains no duplicate elements
  - Because a set is optimized for retrieval, there is no guarantee objects will be stored in the some order that you added them
  - Implemented by the classes HashSet, LinkedHashSet and TreeSet
- The sub-interface SortedSet provides a way to create sets in which the objects are ordered
  - Implemented by the TreeSet class
  - Note that in the example the output is

```java
import java.util.*;

public class SetExample {
    public static void main(String[] args) {
        // Set implemented with HashSet (unordered, no duplicates)
        Set<String> hashSet = new HashSet<>();
        hashSet.add("Banana");
        hashSet.add("Apple");
        hashSet.add("Orange");
        hashSet.add("Apple"); // duplicate, will be ignored

        System.out.println("HashSet (no guaranteed order): " + hashSet);

        // SortedSet implemented with TreeSet (sorted order, no duplicates)
        SortedSet<String> treeSet = new TreeSet<>();
        treeSet.add("Banana");
        treeSet.add("Apple");
        treeSet.add("Orange");
        treeSet.add("Apple"); // duplicate, will be ignored

        System.out.println("TreeSet (sorted order): " + treeSet);
    }
}
```

```
HashSet (no guaranteed order): [Orange, Banana, Apple]
TreeSet (sorted order): [Apple, Banana, Orange]
```

Iterator Example

- The example shows the use of an iterator on the set object we just saw
- Stale iterators
  - If the underlying collection is changed after we get an iterator
  - The iterator is no longer valid and may produce inaccurate results or an error
  - This is rectified by getting a fresh copy of the iterator after an operation that changes the elements of the collection

```java
import java.util.*;

public class HashSetIteratorExample {
    public static void main(String[] args) {
        // Create a HashSet of strings
        Set<String> fruits = new HashSet<>();
        fruits.add("Banana");
        fruits.add("Apple");
        fruits.add("Orange");
        fruits.add("Apple"); // duplicate, will be ignored

        // Use an Iterator to traverse the HashSet
        Iterator<String> iterator = fruits.iterator();
        System.out.println("Iterating over HashSet:");

        while (iterator.hasNext()) {
            String fruit = iterator.next();
            System.out.println(fruit);
        }
    }
}
```

```
Iterating over HashSet:
Orange
Banana
Apple
```

List Interface

- A List is a collection in which the elements can be referenced by an index
  - Elements placed in a specific order specified by the user
- Lists are implemented with the classes
  - LinkedList, ArrayList, Vector and Stack.
- The List interface extends the Collections interface
  - All of the methods in the Collections interface are available in the List interface

```
public interface List<E> extends Collection {
        E get(int index);
        E set(int index, E element);
        void add(int index, E element);
        boolean remove(Object o);
        boolean addAll(int index, Collection<? extends E> c);
// indexes specific elements
        int indexOf(Object o);
        int lastIndexOf(Object o);
// provides listiterator references
        ListIterator<E> listIterator();
        ListIterator<E> listIterator(int index);
}
// gets a sublist from the current list
        List subList(int fromIndex, int toIndex);
```

List Example

- With a list we can access an element by position
- The elements are also in the same order we added them to the list

```java
import java.util.*;

public class LinkedListAsListExample {
    public static void main(String[] args) {
        // List interface implemented by LinkedList class
        List<String> names = new LinkedList<>();

        // Adding elements
        names.add("Alice");
        names.add("Bob");
        names.add("Charlie");

        // Accessing elements
        System.out.println("First name: " + names.get(0));

        // Iterating through the list
        System.out.println("All names:");
        for (String name : names) {
            System.out.println(name);
        }
    }
}
```

```
First name: Alice
All names:
Alice
Bob
Charlie
```

Map Interface

- The Map collections contain key value pairs as elements.
  - Also called dictionaries
  - Values can be duplicated; keys can not.
- Maps are implemented by the classes
  - HashMap
  - LinkedHashMap
  - IdentityHashMap,
  - TreeMap
  - WeakHashMap.

```
public interface Map {
        Object put(Object key, Object value);
        Object get(Object key);
        Object remove(Object key);
        boolean containsKey(Object key);
        boolean containsValue(Object value);
        int size();
        boolean isEmpty();
// Bulk Operations
        void putAll(Map t);
        void clear();
        public Set keySet();
        public Collection values();
        public Set entrySet();
}
```

Map Example

- The example show is a Map implemented with the HashMap class
- The keys can be any type as long as it
  - Implements equals() properly so that it can test for key equality.
  - Implements hashCode() consistently with equals() (for HashMap, Hashtable, etc.)
    - Two equal keys must return the same hash code.
  - Immutable while in the map
  - Does not change its fields that affect equals() or hashCode() once it's been added to the map.
  - Implements Comparable or has a Comparator (only for TreeMap)
    - Required for sorted order in TreeMap.

```java
import java.util.*;

public class HashMapExample {
    public static void main(String[] args) {
        // Map interface implemented by HashMap
        Map<String, Integer> ageMap = new HashMap<>();

        // Adding key-value pairs
        ageMap.put("Alice", 30);
        ageMap.put("Bob", 25);
        ageMap.put("Charlie", 35);

        // Accessing a value by key
        System.out.println("Alice's age: " + ageMap.get("Alice"));

        // Iterating over the map
        System.out.println("All entries in the map:");
        for (Map.Entry<String, Integer> entry : ageMap.entrySet()) {
            System.out.println(entry.getKey() + " => " + entry.getValue());
        }
    }
}
```

```
Alice's age: 30
All entries in the map:
Alice => 30
Bob => 25
Charlie => 35
```

Collection Algorithms

- There are a number of standard algorithms that are part of the collections class
  - Saves programmers from having to write this low-level code over and over
  - The library implementation is optimized for execution in a JRE
- Algorithms are organized into categories
  - Sorting
  - Shuffling
  - Routine Data Manipulation
  - Searching
  - Composition
  - Finding Extreme Values
- Within each category are different implementations that have different performance characteristics

Lab 9-2

Collections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