Lab 5: Java Collection Framework, Skip List and Apache Maven

Objectives

- Getting familiar with Java collection framework
- Getting familiar with skip list
- Compile and run the code using Apache Maven
- Full mark: 40 points

Source files

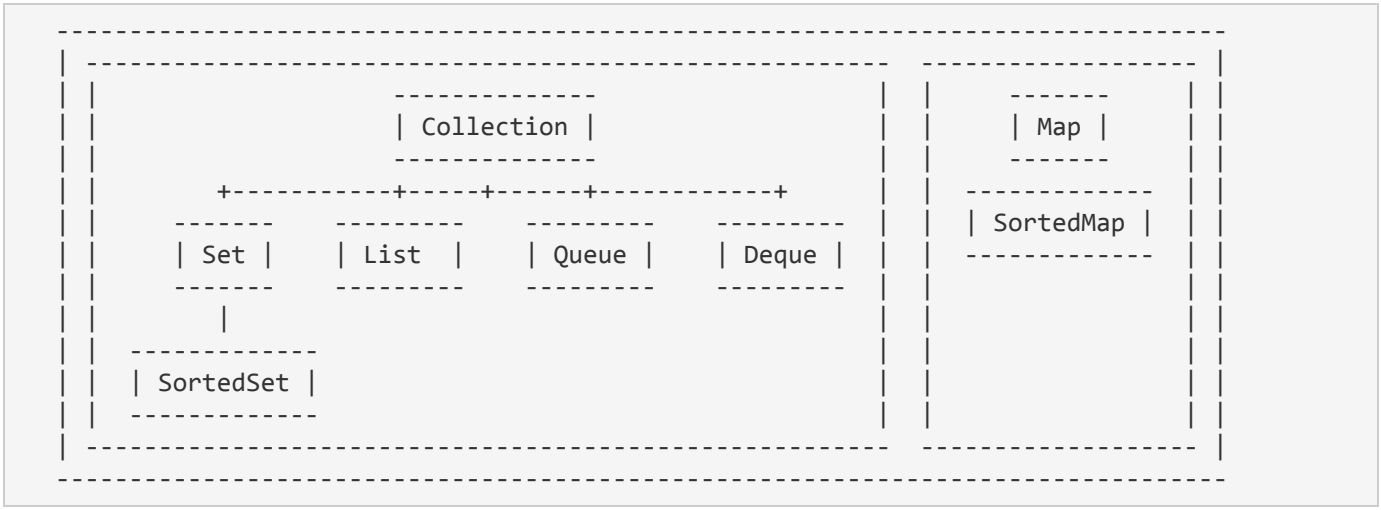
- `SkipList.java`
- `Benchmark.java`
- `ExecTime.java`
- `Range.java`
- `SkipListList.java`
- `pom.xml`

1 Collections

A *collection* (sometimes called a container) is simply an object that groups multiple elements into a single unit. Collections are used to store, retrieve, manipulate, and communicate aggregate data. Typically, they represent data items that form a natural group, such as a poker hand (a collection of cards), a mail folder (a collection of letters), or a telephone directory (a mapping of names to phone numbers).

A *collection framework* is a unified architecture for representing and manipulating collections. All collection frameworks contain the following:

- **Interfaces**: These are abstract data types that represent collections. Interfaces allow collections to be manipulated independently of the details of their representation. In object-oriented languages, interfaces generally form a hierarchy.
- **Implementations**: These are the concrete implementations of the collection interfaces. In essence, they are reusable data structures.
- **Algorithms**: These are the methods that perform useful computations, such as searching and sorting, on objects that implement collection interfaces. The algorithms are said to be *polymorphic*: that is, the same method can be used on many different implementations of the appropriate collection interface. In essence, algorithms are reusable functionality.



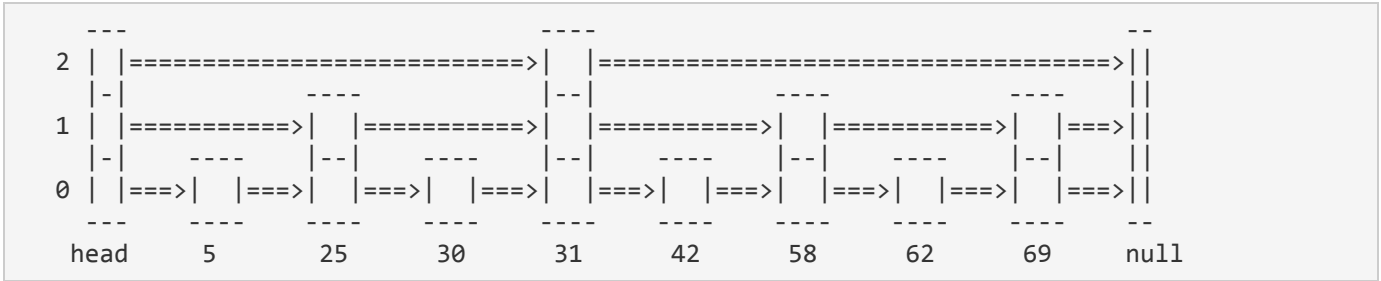
The *core collection interfaces* encapsulate different types of collections, which are shown in the figure below. These interfaces allow collections to be manipulated independently of the details of their representation. Core collection interfaces are the foundation of the *Java Collections Framework*. Note that all the core collection interfaces are **generic**.

2 Skip Lists

Skip lists are designed to overcome the basic limitations of array-based and linked lists -- either search or update operations require linear time. It is also an example of a probabilistic data structure, because it makes some of its decisions at random.

As *balanced trees* (an example is the red black tree) have been used to efficiently implement `Set` and `HashMap` style data structures, skip list can be an alternative solution. Traditional balanced tree algorithms require continually rebalancing the tree, while skip list provides improved constant time overhead. Besides, search, insert and deletion are rather simple to understand and implement.

In a traditional linked list, each node contains one pointer to the next node. However, a node in a skip list contains an array of pointers. The size of this array, also called the *level* of the node, is chosen at random at the time when the node is created. For example, a level 3 node has 3 forward pointers, indexed from 0 to 2. The pointer at index 0 (called the level 0 forward pointer) always points to the immediate next node in the list, and the other pointers point to further nodes. A level`i` pointer points to the next node in the list that satisfy `level >= i`. Level of the skip list equals to the max level of all its nodes.



3 Apache Maven

A defined build process is one of the most necessary tools in the software development process, ensuring that the software you produce is built to the required specifications. You should establish, document, and automate the exact series of steps required to correctly build your product.

A defined build process helps close the gap between the development, integration, test and production environments. A build process alone will speed the migration of software from one environment to another. It also removes many issues related to compilation, library paths, or properties that cost many projects considerable time and money.

From this, Maven, a Java-based build tool with special support for Java programming language, has emerged. It helps programmers to build complex applications and place the files in the desired location with less effort. Maven executes different tasks using Java classes and XML-based configuration files.

A Maven build file comes in the form of an XML document. All you need is a simple text editor to edit a Maven build file (`pom.xml`). A brief introduction of using Maven can be found in https://maven.apache.org/guides/getting-started/maven-in-five-minutes.html

4 Deliverable 1 -- Skip List

Please refer to *SkipList.java*. For this lab assignment, you need to explore the Java Collections Framework to write a skip list class.

Note: it is acceptable if you use the `ArrayList` or `Vector` to store elements. However, remember a skip list is a linked list -- this means **the only element that can be directed accessed is the head**, and you have to travel through elements to find the one you need. Elements in `ArrayList` or `Vector` can be accessed by indexes.

DEMO this deliverable to the lab instructor.

5 Deliverable 2 -- Maven Build File

In this step, you need to compile and run your code using Maven.

Step 1:

Copy and paste your source code (all java files) into `src` folder in your home directory.

Step 2:

Consider the sample Maven build file *pom.xml*. Put it in the same directory with your `src` folder.

Maven works on stages. A phase is a step in the build lifecycle, which is an ordered sequence of phases. When a phase is given, Maven will execute every phase in the sequence up to and including the one defined. For example, if we execute the *compile* phase, the phases that actually get executed are:

1. validate
2. generate-sources

3. process-sources
4. generate-resources
5. process-resources
6. compile

Step 3:

You may test the newly compiled and packaged JAR with the following command:

```
$ mvn exec:java -Dexec.mainClass="SkipList"
```

Step 4:

During compilation, Maven creates a `target` directory where the compiled class are stored, as well as the JAR file after execute the *package* phase. To manually run the programs you can use:

```
$ java -cp target/SkipList-1.0-SNAPSHOT.jar SkipList
```

DEMO this deliverable to the lab instructor.

6 Deliverable 3 -- Performance comparison

As was discussed during the lectures, a way to compare different implementations is through benchmarking the different alternatives. As part of this Lab you need to benchmark your Skip List implementation. For doing it, you can use the provided `Benchmark.java` file. Since the Benchmark uses collections that implement the `List` interface, and the interface provided by SkipList.java does not implement `List`, you will use the `SkipListList.java` that works as an adapter for your SkipList class (SkipListList is an example of using the *Adapter* design pattern).

After implementing your SkipList use Maven to generate the JAR file and execute:

```
$ mvn exec:java -Dexec.mainClass="Benchmark"
```

The program will generate the output of testing `ArrayList`, `LinkedList`, `Vector` and your `SkipList` implementation using `SkipListList` adaptor.

Using the output of the Benchmark program, generate a performance comparison plot (using Google sheets, Excel, etc.), one for adding elements and another for removing elements, similarly to the one presented in the Lecture.

SHOW the plots to the lab instructor.

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Marking sheet

Deliverable 1 -- Skip List				
Implementation `insert` works correctly				/5
Implementation `remove` works correctly				/5
Implementation `search` works correctly				/5
Implementation `toString` works correctly				/5
Deliverable 2 -- Maven Build File				
Generation of JAR file works correctly				/4
Deliverable 3 -- Performance comparison				
Insert elements plot				
	The results are plotted but the performance of SkipList is worst or equal than LinkedList (1-2)	The results are plotted showing better performance of SkipList over LinkedList (3-5)		/5
Remove elements plot				
	The results are plotted but the performance of SkipList is worst or equal than LinkedList (1-2)	The results are plotted showing better performance of SkipList over LinkedList (3-5)		/5
Naming and usage of variables (in both derivables)				/2
Documentation (in both derivables)				
	No documentation (0)	One line comments but not using proper javadoc (1-2)	Clear documentation about what the function/procedure does using javadoc style (3-4)	/4
			Total:	**/40**