CMSC 206: Data Structures
Lab 4: Exceptions, ArrayList

This lab starts out with a review of exceptions and then continues to introduce ArrayList, a flexibly sized structure for ordered data.

As with all labs, complete this work in a fresh Eclipse project. Unlike other labs, you will submit this on Gradescope. It will not be graded, but it may be helpful for me to see what you're doing.

Part I: Exceptions

This exercise will give you further practice in throwing, catching, and testing exceptions. The exercise is structures around a square-root method that works only on integers (and thus can't work with, say, 8 or -4).

1. Using ZipParseException as a template, make a SquareRootException exception class. Have your constructor take an int which is the number that has no square root. Note that ZipParseException's constructor calls a superclass constructor with a helpful message for users; yours should do the same.

   Note: Unlike ZipParseException's constructor, yours will take only one parameter.

2. Write a SquareRoot class with the following method:

   /** Takes the positive square root of an integer.
   * @param n The integer to be rooted
   * @return The square root of the parameter
   * @throws SquareRootException when the parameter has no integral square root
   */
   public static int squareRoot(int n) throws SquareRootException

   You will find the sqrt method in the Math class in the java.lang package helpful; look it up in the Java online documentation. Note that sqrt works with doubles, so you will have to do some work to make it work with ints.

3. Write a main method that allows you to interact with your squareRoot method. It should print a helpful message to the user if their number does not have a square root. Do not add a throws clause to your main method.

4. Create a JUnit test class SquareRootTest to test your method:

   a. One test method should test successful uses of squareRoot (by taking, say, the square root of numbers like 9 and 16). This test should fail if squareRoot throws an exception.
b. One test method should test what happens when you call \texttt{squareRoot} on a positive number that has no integral square root. It should succeed if \texttt{squareRoot} throws a \texttt{SquareRootException} and fail otherwise.

c. One test method should test what happens when you call \texttt{squareRoot} on a negative number. It should succeed if \texttt{squareRoot} throws a \texttt{SquareRootException} and fail otherwise.

d. One test method should test what happens when you call \texttt{squareRoot} on 0. By reading the specification above, you should figure out what the correct behavior should be.

\textbf{Part II: Equality}

This short interlude refreshes us on the difference between \texttt{==} and \texttt{equals} in Java.

5. Download the \texttt{Fraction} class posted next to yesterday's class and put it in your project.

6. In a new class \texttt{Equals}, write this main method:

\begin{verbatim}
public static void main(String[] args) {
    Fraction f1 = new Fraction(3,4);
    Fraction f2 = new Fraction(3,4);
    Fraction f3 = new Fraction(6,8);
    Fraction f4 = f1;

    System.out.println("f1 == f2: "+ (f1 == f2));
    System.out.println("f1 == f3: "+ (f1 == f3));
    System.out.println("f1 == f4: "+ (f1 == f4));
    System.out.println("f1.equals(f2): "+ f1.equals(f2));
    System.out.println("f1.equals(f3): "+ f1.equals(f3));
    System.out.println("f1.equals(f4): "+ f1.equals(f4));
}
\end{verbatim}

7. What behavior do you observe while running this program? Why do you think this happens? Write your answer in comments in the file. Test your hypotheses by writing more experiments.

\textbf{Part II: Using ArrayList}

8. Make a new class \texttt{ArrayListPractice}. Write this method in it:

\begin{verbatim}
/**
 * Gets the prime factors of a number, without duplicates.
 * @param n The number to factor
 * @return An ArrayList of the prime factors. If the number
 *        has no prime factors (because it is less than 2),
 */
\end{verbatim}
* this returns an empty (but non-null) ArrayList.
*/

public static ArrayList<Integer> primeFactors(int n)

You should adapt the code you wrote for the first assignment to complete this. Yes, it's perfectly allowed to show this code to your partner, given that the first assignment is in the distant past.

Our book, sections 2.1-2.2, contains examples of using an ArrayList. It's also introduced on many blog posts, etc. One such post is at http://javarevisited.blogspot.com/2011/05/example-of-arraylist-in-java-tutorial.html. The writing isn't the best, but the Java is accurate.

Note that the return value is an ArrayList<Integer>, not an ArrayList<int>. There is a difference between these (for example, the latter is illegal in Java), as we'll discuss in class, but this difference does not matter in implementing this method. You can pretend that the elements in the ArrayList are all plain old ints, and everything should work.

9. Write a JUnit test class ArrayListTest that tests your method until you're confident that it works.

10. Lookup the documentation for ArrayList on the Java API web site. ArrayList is in the java.util package. Answer the following questions in comments in your ArrayListPractice.java file:

   a. One of the ArrayList constructors takes an int parameter. What does this constructor do? If I say
      
      ArrayList<String> list = new ArrayList<>((5);
      
      what will list.size() be? (Test your answer!)
      
   b. What exception is thrown if you try to get an element that's not in the ArrayList? (Test your answer!)
      
   c. One method on an ArrayList searches through the ArrayList for a specific value, returning true if the value is present and false otherwise. Which method is it?

11. The ArrayList method indexOf searches through an ArrayList for a value and returns the index of that value, or -1 if the value is not present. (This is not the answer to question (c) above.) How does it work to compare objects? Specifically, we've seen that the Java operator == and the method equals work differently. Which one does indexOf use? While the documentation answers this question (read it!), design an experiment (a main method in ArrayListPractice similar to the one in step 6) that demonstrates this choice. Include comments explaining how to interpret the results of your experiment. You may find it useful to have an ArrayList of Fractions.
Part IV: Implementing ArrayList

12. Download the KWArrayList.java and KWArrayListRaw.java files from the syllabus page. These files are taken from the code written in section 2.3 of our textbook. The KWArrayList.java files includes an implementation of a generic list structure. Generic types have a type parameter (in this case, $E$) that allows the type to be specialized when you use it. When reading the code, treat $E$ as an unknown reference type to be determined later. The book has more information about this, and we will discuss it in class.

13. Read through the code. In a new class KWALExercises, answer the following questions in comments:
   
   a. Why does the second add method have a loop?
   b. Why does that loop count backwards? Is it possible to rewrite this so that it counts up, instead of down?
   c. Why does the remove method have a loop?
   d. Why does that loop count up? Is it possible to rewrite this so that it counts down, instead of up?

14. The KWArrayListRaw.java file contains a non-generic list structure, which may feel more familiar. In it, $E$ is replaced with Object. Otherwise, the files are the same. It has a reallocate method that makes the theData array double in size, using the method copyOf, a static method in the java.util.Arrays class. Rewrite reallocate not to call copyOf but instead to grow the array manually. Note that there is no way of directly growing an array. Instead, you will make a new array (with new Object[...]) and copy all the elements from the old array into the new one, using a loop. (This is exactly what copyOf does under the hood.)

15. Test your implementation, either using a JUnit test class or with a main method.

16. Submit your project on Gradescope.