Project 4

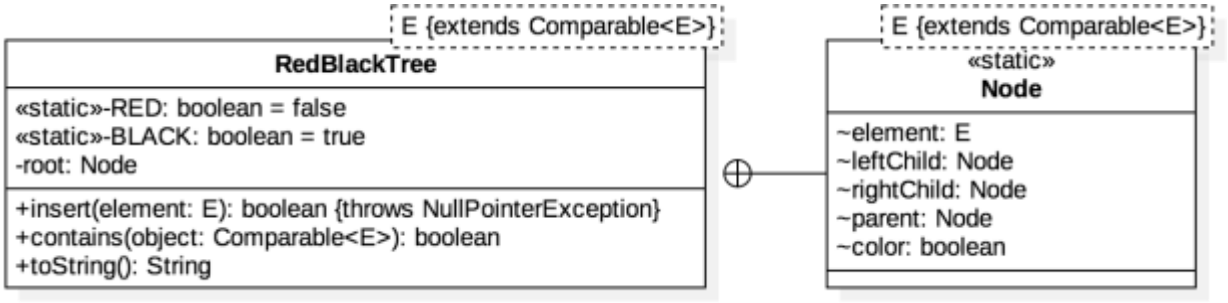
Simplified Red-Black Trees

The task of this project is to implement in Java a red-black tree data structure. However, the tree will be simplified – you only need to support insertion, not deletion.

Specification

The project must implement the following specification exactly, including all identifier names, method signatures, the presence or absence of exceptional behavior, etc. That being said, anything not clearly indicated by the UML diagram(s) or explicitly stated in the description is left up to your discretion. You may also add private helper methods or additional fields as necessary.

Structure



Note that a box with a dashed border over the top right of a class entity denotes a generic type parameter. In this case, the red-black tree class has a generic type named `E` that extends `Comparable<E>` – you may choose whether or not to make `Node` generic as well. The `Comparable<T>` interface is located in the `java.lang` package, so it is not necessary to import it. Finally, for this project you should locate your code in the default package.

Behavior

`insert` should insert the given element into the tree at the correct position, and then rebalance the tree if necessary. The correct position is defined by the properties of a binary search tree, and the rebalancing procedure should enforce the properties of a red-black tree. Regarding input validation, `insert` should immediately throw a `NullPointerException` with a descriptive message if the given element is null. Alternatively, if the given element is a duplicate of an element already in the tree, then `insert` should not insert the given element. The return value should indicate whether the given element was inserted into the tree or not.

Two elements are considered duplicates iff (if and only if) they compare equal to each other using the `compareTo` method. Likewise, the ordering of any two elements for the purposes of insertion and rebalancing is given by the same method.

`contains` should return whether the tree contains any element that compares equal to the given object using the `compareTo` method of the object. This means that you should always do `object.compareTo(element)` but never do `element.compareTo(object)`.

However, if the given object is null, then `contains` should not throw an exception but rather should return false.

`toString` should override the eponymous method of `Object` and return a string representing the in-order traversal of this tree. The returned string should be the ordered concatenation of invoking the `toString` method of each element in the traversal, where every two adjacent elements should be separated by a single tab character (`"\t"`). If an element is located in a **red** node, then it should be preceded by a single asterisk character (`"*"`) in the output string. Otherwise, an element located in a **black** node should not be preceded by an asterisk. An example of the output is as follows (assuming that the elements are of type `Integer`):

```
2    *5    30    47    *60
```

It is entirely optional, but it may make your life easier to use a `StringJoiner` and/or to implement `Node#toString()` as well.

The `color` field of the node class should be assigned and evaluated using the `RED` and `BLACK` constants of the enclosing tree class. This means that you should always do `color = BLACK` or `if(color == RED)` but never do `color = true` or `if(!color)`.

Submission

Submit the following items on eLearning before **11:59PM on Sunday, October 22nd, 2017**:

1. **README.txt**
   This should identify who you are (name, NetID, etc.), which project you are submitting, what files comprise your project, how you developed and compiled your project (e.g. what IDE or text editor, which version of Java, what compiler options, etc.), and any other information you believe the grader should know or you want the grader to know.
2. **RedBlackTree.java**
   This should be the only source code file that you submit. It should not include a `main` method, since it is intended to be used like library code. (that is also how it will be tested) The source code should include an appropriate Javadoc for every public method and class.

Both items should be submitted as a single zipped file named with your lowercase NetID. The file structure should resemble the following example:

```
*-- abc123789.zip
    |-- README.txt
    |-- RedBlackTree.java
```

Evaluation

This project will be evaluated primarily according to the correctness of your implementation of the red-black tree insertion and rebalancing algorithm, and secondarily according to the stability of your implementation and its faithfulness to the specification. It is of utmost importance that you exactly adhere to the structural specifications since your code must be compatible with a standardized test suite. Finally, bonus points may be awarded for exceptional code quality, which

comprises engineering and design (e.g. modularity), documentation and comments (e.g. Javadoc), and style and layout (e.g. visually grouping lines into logical “paragraphs”).

The rubric is as follows:

Category	Weight
`insert`	70%
`contains`	20%
`toString`	10%

Your source code should include a suitable Javadoc for every public method and class.

Commentary

The specification for this project emulates several conventions used in the actual Java standard library (with appropriate simplifications). For example, the `TreeSet` class is a red-black tree that uses `RED` and `BLACK` boolean constants exactly as specified here in order to more efficiently simulate a binary enum without sacrificing the expressive power of an enum.