CMSC 315 Project #3: Binary Trees

In this project, you'll work with Binary Trees, Complete Binary Trees, Binary Heaps, and Binary Search Trees.

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1. **Binary Tree (General)**

A binary tree is a tree in which each node has at most two children. There are no additional constraints.

Example:

```
     A
    / \
   B   C
      /
     D
```

- Node A has two children (B and C).
- Node C has one child (D).
- No rules about ordering or completeness are followed.

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2. **Complete Binary Tree**

A binary tree where all levels are completely filled except possibly the last, which is filled from **left to right**.

Example:

```
     A
    / \
   B   C
  / \
 D   E
```

- All levels are filled except the last.
- The last level is filled **left to right**.

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3. **Binary Heap**

A complete binary tree where each parent node follows the **heap property**:

- **Max-heap**: Parent ≥ children.
- **Min-heap**: Parent ≤ children.

Example (Max-Heap):

```
        90
       /  \
     70    50
    / \   /
   20 40 10
```

- Every parent is **greater than or equal to** its children.
- It is also a **complete binary tree**.

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4. **Binary Search Tree (BST)**

A binary tree where for every node, all values in the left subtree are strictly less than the node's value, and all values in the right subtree are strictly greater than the node's value. This rule applies recursively to every node in the tree — not just the immediate children.

Example:

```
          60
         /  \
       40    80
      /        \
    30          90
      \        /  \
       35     85   100
                     \
                      102
```

Summary Table:

Tree Type	Structure	Ordering Property
Binary Tree	Any	None
Complete Binary Tree	All levels full, last left-to-right	None
Binary Heap (Max)	Complete	Parent ≥ children
Binary Search Tree	Any	Left < Parent < Right

Starter Code Info

Download project3_starter.zip and extract the files. The zip contains three classes, `Main`, `CompleteBinaryTree`, and `InvalidTreeException`. You should be able to create a new Java project and copy the classes into your project.

The `CompleteBinaryTree` class defines one instance variable named `root`, which is an instance of the nested class `TreeNode`.

The `Main` class contains a `main` method with code to create an instance of `CompleteBinaryTree` from a sample array in integers. The tree is built using the array in level-order, meaning the nodes are filled from left to right, one level at a time. Here's how the positions in the array map to the tree:

If a node is at index i in the array:

- Its left child is at index 2 * i + 1
- Its right child is at index 2 * i + 2

This pattern is used recursively to create the tree. Thus, `Integer[] values = { 90, 70, 50, 20, 40 };` produces the following tree:

```
       90
      /  \
    70    50
   / \
  20 40
```

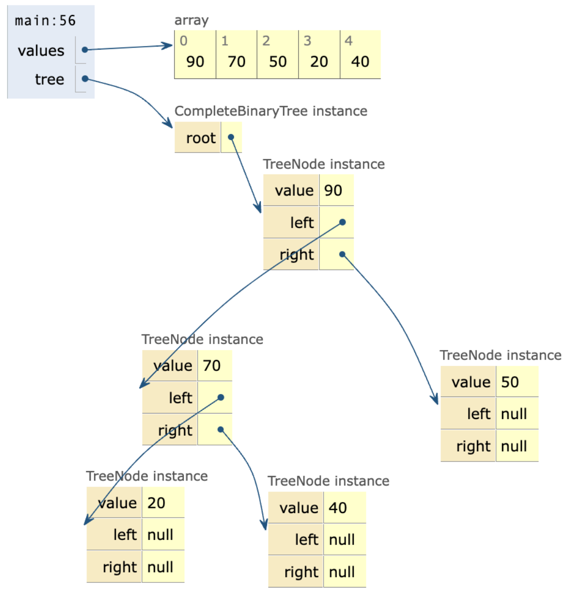
After creating the tree, the `main` method calls the `preorder` method to print the values using a preorder traversal.

Run the `Main` class and confirm the output:

```
90 70 20 40 50
```

It is important to understand the `CompleteBinaryTree` constructor and the recursive help method named `makeNode`. Use your IDE's debugger to step through the creation of the binary tree:

- Set a breakpoint in the constructor and use the debugger to **step into** each call to `makeNode`. Pay special attention to each call to `makeNode` and the value of the index parameter.
- Alternatively, [click this link]() to visualize the code slightly adapted to work in the Python Tutor website. Press the `Next` button to execute each line of code and view the method call stack and object structures in memory.



NOTE: Python tutor only allows one top-level public class. Other classes must either be nested or not public.

Task 1. Evolve the `preorder` methods to indent based on the node's level in the tree.

Expected Output

```
String[] tokens = NLPUtility.splitTextIntoTokens("WOW!?!    That .?#
is  REALLY(reaLLy)  amazing!    ");
System.out.println(Arrays.toString(tokens));
// [WOW, That, is, REALLY, reaLLy, amazing]
```

Task 2. `public static TreeMap<String, Integer> countFilteredWords(String[] words, Set<String> stopWords)`

Counts the frequency of non-stop words in the given array of words, ignoring case. Returns a `TreeMap` sorted alphabetically by key (i.e. word).

Example:

```
String[] words = {"i", "love", "a", "good", "BOOK", "and", "LOVE", "sad",
"BooK", "book"};
Set<String> stopWords = new HashSet<>(
   Arrays.asList("the", "is", "in", "at", "of", "and", "a", "to", "it",
"or", "was", "so"));

System.out.println(NLPUtility.countFilteredWords(words, stopWords));
//{book=3, good=1, i=1, love=2, sad=1}
```

Task 3. `public static LinkedHashMap<String, Integer> sortByValueDescending(Map<String, Integer> map)`

Returns a `LinkedHashMap` sorted by frequency in descending order. For ties, maintains the original order of keys as they appear in the map.

Algorithm:

1. Convert the word map entries to a list for sorting
2. Sort the list of entries in descending order based on value (frequency)
3. Create a LinkedHashMap and insert the sorted entries to maintain their order.

Example:

```java
Map<String, Integer> wordMap = new TreeMap<>();
wordMap.put("book", 3);
wordMap.put("good", 1);
wordMap.put("i", 1);
wordMap.put("love", 2);
wordMap.put("sad", 1);

System.out.println(wordMap); // {book=3, good=1, i=1, love=2, sad=1}

System.out.println(NLPUtility.sortByValueDescending(wordMap)); // {book=3, love=2, good=1, i=1, sad=1}
```

Task 4. `public static String getSentimentFromFrequencies(Map<String, Integer> wordMap, Set<String> positiveWords, Set<String> negativeWords)`

Sums the total frequencies of words in the corresponding positive and negative word sets. Returns a summary string in the format "Positive: X, Negative: Y".

Example:

```java
Map<String, Integer> wordMap2 = new LinkedHashMap<>();
wordMap2.put("book", 3);
wordMap2.put("love", 2); // positive
wordMap2.put("good", 1); // positive
wordMap2.put("i", 1);
wordMap2.put("sad", 1); // negative
System.out.println(wordMap2); // {book=3, love=2, good=1, i=1, sad=1}

Set<String> positiveWords = new HashSet<>(Arrays.asList("good", "great", "happy", "love", "like"));
Set<String> negativeWords = new HashSet<>(Arrays.asList("bad", "terrible", "horrible", "sad", "hate"));
```

```
System.out.println(NLPUtility.getSentiment(wordMap2, positiveWords,
negativeWords));// Positive: 3, Negative: 1
```

Task 5. `public static Map<String, Object> getWordsWithMaxFrequency(Map<String, Integer> wordMap)`

Returns a map containing an alphabetically sorted list of words that appear most frequently in the given word map, along with the corresponding frequency.

Algorithm:

- Finds the maximum frequency value in the input map
- Collect a list of all words that occur with that frequency
- Sorts the list alphabetically
- Returns a new map with two entries having the following keys:
  - "words": a list of most frequent words, sorted alphabetically
  - "frequency": the maximum frequency as an integer

Note: The returned map contains two entries with `String` keys: `"words"` and `"frequency"`.

- The value associated with `"words"` is a `List<String>` containing the most frequently occurring words.
- The value for `"frequency"` is an `Integer` representing the highest frequency found.

Because the values are of different types (`List<String>` and `Integer`), the method returns a map of type `Map<String, Object>`.

Example:

```
Map<String, Integer> wordMap3 = new LinkedHashMap<>();
wordMap3.put("good", 1);
wordMap3.put("i", 1);
wordMap3.put("love", 3);
wordMap3.put("book", 3);
wordMap3.put("sad", 1);
System.out.println(wordMap3); // {good=1, i=1, love=3, book=3, sad=1}

System.out.println(NLPUtility.getWordsWithMaxFrequency(wordMap3)); //
{words=[book, love], frequency=3}
```

Note that the map passed as a parameter may not be sorted by frequency or word. Your method will have to find the maximum frequency, along with all words that are mapped to that frequency.

🧪 Sample Program Flow

```
Enter a paragraph of text:
I really love a good book, and You REALLY love a sad movie.  We both
ReAllY LOVE going for a walk!

Tokenized:
[I, really, love, a, good, book, and, You, REALLY, love, a, sad, movie,
We, both, ReAllY, LOVE, going, for, a, walk]

Word map sorted by key ascending:
book:1
both:1
for:1
going:1
good:1
i:1
love:3
movie:1
really:3
sad:1
walk:1
we:1
you:1

Word map sorted by value descending:
love:3
really:3
book:1
both:1
for:1
going:1
good:1
i:1
movie:1
sad:1
walk:1
we:1
you:1

Sentiment: Positive: 4, Negative: 1

Most frequent word(s): [love, really] (used 3 times)
```

🚫 Example: Empty or Non-Meaningful Input

```
Enter a paragraph of text:
SO is.!  It????

Tokenized:
[SO, is, It]
```

```
No valid words found.
```

Submitting your solution

You are to submit two files.

1. The first is a `.zip` file that contains all the source code for the project. The `.zip` file should contain only source code and nothing else, which means only the `.java` files. If you elect to use a package the `.java` files should be in a folder whose name is the package name. Every outer class should be in a separate `.java` file with the same name as the class name. Each file should include a comment block at the top containing your name, the project name, the date, and a short description of the class contained in that file.

2. The second is a Word document (PDF or RTF is also acceptable) that contains the documentation for the project, which should include the following:

    - A UML class diagram that includes all classes.
    - A test plan that includes test cases that you have created indicating what aspects of the program each one is testing.
        - Conduct unit tests for each method within the `NLPUtility` class. You may want to develop separate test classes (include "Test" in the class name, and/or place in a separate package) to individually call each method in isolation. Include screenshots that capture the result of your unit tests. Ensure your test cases sufficiently demonstrate each method returns a sorted result when sorting is required.
    - A short paragraph on lessons learned from the project.