CS 3100 – *Data Structures and Algorithms*

Project #4 – Indexing with AVL Trees

Learning Objectives

- Demonstrate effective use of memory management techniques in C++
- Implement a data structure to meet given specifications
- Design, implement, and use an AVL tree data structure
- Analyze operations for time complexity

Overview

Your task for this assignment is to implement an AVL tree that serves as a *map* data type (sometimes also called a *dictionary*. A map allows you to store and retrieve key/value pairs. For this project, the key will be an integer and the value will be a string.

The AVLTree Class

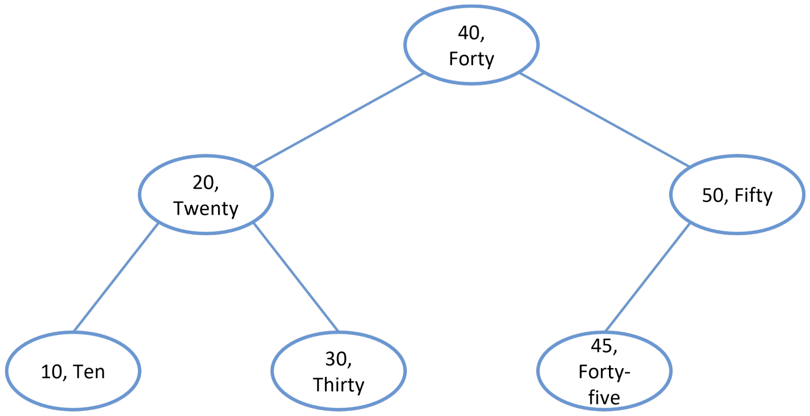
The map will be implemented as an AVL tree. For this project, you must write your own AVL tree - not using code from outside sources. Your AVL tree should remain balanced by implementing single and double rotations when inserting new data. Your tree must support the following operations:

- **`bool AVLTree::insert(int key, string value)`** – Insert a new key/value pair into the tree. For this assignment the duplicate keys are not allowed. This function should return **true** if the key/value pair is successfully inserted into the map, and **false** if the pair could not be inserted (for example, due to a duplicate key already found in the map). The time complexity for insert should be O($\log_2 n$).

- **`int AVLTree::getHeight()`** – return the height of the AVL tree. The time complexity for getHeight should be O(1).

- **`int AVLTree::getSize()`** – return the total number of nodes (key/value pairs) in the AVL tree. The time complexity for getSize should be O(1).

- **`friend ostream& operator<<(ostream& os, const AVLTree& me)`** - print the tree using the << operator. You should overload the << operator to print the AVL tree "sideways" using indentation to show the structure of the tree. For example, consider the following AVL tree (each node contains a key, value pair):



This tree would be printed as follows:

```
        50, Fifty
              45, Forty-five
```

```
40, Forty
                30, Thirty
        20, Twenty
                10, Ten
```

(*Note: If you turn your head sideways, you can see how this represents the tree.*)
(*Also note: This style of printout can be directly implemented as a right-child-first inorder traversal of the tree.*)

- **`bool AVLTree::find(int key, string& value)`** – if the given key is found in the AVL tree, this function should return **true** and place the corresponding value in **value**. Otherwise this function should return **false** (and the value in **value** can be anything). The time complexity for find should be O($\log_2 n$).

- **`vector<string> AVLTree::findRange(int lowkey, int highkey)`** – this function should return a C++ vector of strings containing all of the values in the tree with keys ≥ lowkey and ≤ highkey. For each key found in the given range, there will be one value in the vector. If no matching key/value pairs are found, the function should return an empty vector.

  Example: Suppose the call **`resultVector = myTree.findRange(30, 47)`** were called on the tree pictured above. The findRange function would then return a vector containing the strings: {"Thirty", "Fourty", "Forty five"}.

Turn in and Grading

- The AVLTree class should use a seperate AVLTree.h and AVLTree.cpp file.
- Please zip your entire project directory into a single file called project4.zip and upload to the dropbox in Pilot.

This project is worth 50 points, distributed as follows:

Task	**Points**
`AVLTree::insert` stores key/value pairs in the correct locations in the AVLTree, and correctly rejects duplicate keys	3
`AVLTree::getHeight()` correctly returns the height of the tree	3
`AVLTree::getSize()` correctly returns the number of key/value pairs in the tree	3
The tree maintains correct balance, regardless of the order in which keys are inserted	10
`operator<<` prints the tree in a neat and readable manner, using indentation or some other appropriate mechanism to clearly show the structure of the tree	4
`AVLTree::find` correctly finds and returns key/value pairs in the tree in Θ(log n) time, and returns **false** when no matching key is found	4
`AVLTree::findRange` correctly returns a C++ vector of strings matching keys in the specified range	6
`AVLTree::operator=` correctly creates an independent copy of an AVL tree	4
Copy constructor correctly creates an independent copy of an AVL tree	4
Code has no memory leaks	4
Code is well organized, well documented, and properly formatted. Variable names are clear, and readable. Your AVLTree class is declared and implemented in separate (.cpp and .h) files.	5