CSCE 221 Cover Page
Programming Assignment #6
Due **April 29** by midnight to eCampus

First Name Last Name UIN

User Name E-mail address

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Type of sources			
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Your Name Date

Programming Assignment #6

Due ***April 29*** to submit to eCampus

In this project you will be implementing a map data structure. A map is a way to store data with a key and a value. Whenever we store something in the map, we say I would like to store some data, with a key, and when we want to retrieve something from the map, we say that we have a key, and we ask the map for the value that is linked to that key. We can think of a vector as a specific map that has an integer key and a templated value. So, any time you use v[1], you're asking v to return the value mapped to 1. This property makes maps very useful when we want to index data by other types than just integers.

The examples STL map functionalities:

- Declaration of the map object, `std_map`:
  ```
  map<string,double> std_map;
  ```
- Adding a new entry, key and value, to the map:
  ```
  std_map["PA5" ]= 5.5;
  ```
- Searching for a `value` using a given `key` in a map
  ```
  double val= std_map["PA5"];
  ```
  However, if a `key` does not exit the default `value 0.0` will be returned, e.g. `double val= std_map["PA4"]`
- Updating a value using for a given `key` in a map
  ```
  std_map["PA5" ]= 100;
  ```
- When we want to display a map it should appear as a sorted sequence of pairs: `key value`:

  ‘‘a’’ 123

  ‘‘b’’ 22

  ‘‘c’’ 4343

  ‘‘eff’’ 123123123123

  ‘‘PA5’’ 191991
- When you create a map from an input file that the file that the file should contains pairs, usually unsorted:

  ‘‘PA5’’ 191991

  ‘‘a’’ 123

  ‘‘eff’’ 123123123123

  ‘‘b’’ 22

  ‘‘c’’ 4343
- A map data structure implementation:

  To create a map, we have three options: we can either use a Hash table, a Tree, or a sorted vector. In the hash table version, you use a hash of the key as an index. In the tree version we use a regular tree but we insert in key_value objects. These objects just store pairs, a key and a value and have comparison operators that only care about the keys. In the vector implementation you still use the key_value pairs, but you just insert them in sorted order, with respect to key, into your map.

  When you open up your skeleton code you should see *my_map.h* and *key_value.h*. *key_value* is a wrapper around a key and a value that has comparison operators, you shouldn't need to mess with this file. The next is *my_map*. In my_map you will need use the binary tree you made in PA 4, or the STL vector to create the map. The most important thing in *my_map* is the brackets operator. When you implement your brackets operator make sure it works exactly the same as the std map, which is

described above. You will also need to make a constructor, copy constructor, move constructor, output operator, and input operator.

If you use the your own Binary tree you will be given a small bonus (10 points), because several parts of the assignment become harder with a binary tree.

- **Iterators**

  For a map we don't have a good way to go through each element (for example trying to print out your map), so we will have to create iterators for our map. When you make your iterators make sure they go through the tree in an **inorder traversal**, or in your vector printing out in sorted order.

  A good reference for iterators is the textbook on page 368. A better reference is your 121 book by Stroustrup, on page 720, and 1139.

- **Iterator Refresher**

  You probably haven't noticed iterators since 121, but that's fine, here we'll go through the basics again.

  On all data structures we have a beginning and an ending to our data and some way to step through it. So, we create iterators as a nice way to do that no matter what data structure were in. So in our code we have a `begin()`, `end()`, and in the iterator class itself we have an `operator++` function. When we combine all three of these functions we have an effective way of going through every element in a list one item at a time. Note, sometimes the `operator-` function is implemented in iterators, this just goes backwards, and we're not doing that for this project. The `begin` and `end` functions return iterator objects (in our case the iterator class is called `map_iter`) so the begin should give us an iterator to the start of our data structure and the end should return one past the end of our data structure (think of it how in a for loop we see if our loop variable has gone one past the end rather than being on the end itself). The `operator++` should step through our data structure one element at a time.

  For example, if we made an array iterator. Inside of our iterator class we would store a pointer, which is where we are inside of the array. The begin() function would return a pointer to the first element of the array. The operator++ function would increment the pointer to the next element in the array. Finally the end() function would return one past the end of the array.

  Once we have created an iterator for our data structure we can do cool things like this

  ```
  for(auto i=dataStructure.begin(); i!=dataStructure.end(); i++ )
  ```

  This for loop will go through any data structure as long as it has implemented iterators. With iterators you can also do other useful things like finding and summing elements without thinking about the underlying structure of the object. You might have noticed that I used `auto` for the type of the iterator, this is because iterator types are gross and really long, so this is one of the few times is recommended using auto instead of just writing out the type.

  So if you do

  ```
  Vector<int> v;
  v.push_back(1);
  v.push_back(2);
  v.push_back(3);
  ```

  and then

  ```
  for(auto i=v.begin(); i!=v.end(); i++)
  cout << *i << endl;
  ```

  The operator `*` "dereferences" the iterator. In this case it just returns what is stored at that location. You should see:

  ```
  1
  2
  3
  ```

- **The map_iter**
- *Vector Version*

  The vector implementation for iterators should be very similar to the array example above. Although I would not use pointers directly, instead just keep and integer index for where the iterator is currently in the array. the `begin()`function should just return an iterator to the first element in the vector, and then the `end()`should return one past the end of the vector (just set the index to vec.size()). the `operator++` function should just increment index.

- *Tree Version*

  So, in our map we will need to be creating an iterator. For this portion if you choose to use the tree from PA4 you will need to make a whole new iterator from scratch (using the skeleton code we give you). The first thing you will need to do is find the beginning. Notice that since we are doing an inorder traversal the root is not the first element. The most left node is. To get this you will need to traverse down the tree to find the most left node and set that as your starting point whenever the `begin()` function is called.

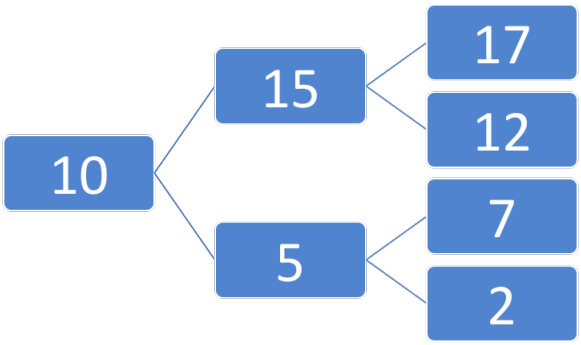
  The next part is finding the end. For this you should notice that the end is the element after the real end of the tree. You might want to look at what an inorder traversal looks like to see what node should come after the last real node (it should just be `nullptr`).

  The final part is the `operator++` function. For this you must do the inorder traversal iteratively. You should definitely do a couple inorder traversals by hand to get the hang of it. In general, though you should notice that in an inorder traversal you always go to the left most element in your subtree and one by one work your way up to a branch you haven't visited yet, and then if there is a right branch take it and start over.

  We have included a couple helper functions that haven't been completed yet, don't feel like you have to implement and use these functions, but we did use them in our solution.

- **Example**

  Let our map have an underlying tree that looks like



  We iterator over it using this code (the values being displayed are the key values for our map)

```
for(auto i=map.begin(); i!=map.end(); i++)
   cout << *i << endl;
```

  We will get

```
2
5
7
10
12
15
17
```

- **Text Frequency**

  For the next part you are going to do some text frequency analysis. You should create an object `textFrequencies`:

  ```
  my_map<string,double>textFrequencies;
  ```

- **Reading File**

  You should complete the `read_file function`, which just reads the whole file into one string. Next remove all of the punctuation from the file using the `remove_punctuation` function (this is already done for you).

- **Counting**

  Complete the function `create_freq_map` which takes the string that you generated previously and create the map from each word in the text. First it would be useful to use a string stream for parsing that big string of text. This will create a string stream for you to use.

  ```
  stringstream ss(text) ;
  ```

  Once you have that string stream you can use it just like a file stream (or `cin`)

  ```
  ss >> word;
  ```

  To do this you should use the brackets operator you implemented earlier. The first step of this will pass over each word in the text and count how many times you see that word, it would be helpful to use.

  ```
  map["word"]++ ;
  ```

  Now after you have counted everything you need to divide each word count by the total count of words in the text. First you need to find every word in your map. To do this we will use iterators. If you implemented your begin, end, and `++ operators` on your iterator properly you should be able to use this for loop.

  ```
  for(auto word:  freq_map);
  ```

  That for loop will find every word in your map, and then you just use this calculation to generate the frequency.

  ```
  map[word] /=total_cnt;
  ```

- **Output**

  Complete the `vectorize_map` function, which translates your map into a vector. This should use your `my_map` iterators. Next finish the `print_top_20_freqs` function which should print the 20 most frequent words.

- **Filter**

  You should notice that you see a lot of meaningless words (the, and, of, for ...) in your top 20 words. To fix this, make a list of words that you would want to filter out and remove them from your frequency vector.

- **Analysis**

  Now print out your filtered output and create a table of words and their frequencies. Finally make a plot of words on the x axis and their frequencies on the y axis.

- **Hints**

  All operations in your map should rely on operations from your binary tree/vector, so for example don't try to rewrite the insert function, because you already did it. Also if you look at the start of your `my_map`, you have a `BTree<key_value<T,E>>`, which is the main data structure for your map, don't try to change its type.

- **Report**

1. Explain how your brackets operator works.
   (a) What is the running time expressed in terms of big-Oh asymptotic notation of your brackets operator?
   (b) How could you improve the running time? Here don't think about micro optimizations, think about changing data structures or major algorithm changes.
2. Explain what the advantages and disadvantages of implementing map with the following data structures
   (a) A vector of key_values b.
   (b) A tree of key_values.
      i. Regular binary
      ii. Red Black
      iii. AVL
      iv. 2-4
   (c) A Hash Table of key_values
3. Explain one real life use case for a map, you should say specifically why it would benefit from using a map over a simpler data structure like a vector. This doesn't have to be something that exists currently, it's just an idea for how you could use a map. Example (don't use this one) storing word frequencies for a large document.
4. Grading

   When we grade this, we will not be using your main file, we will be using our own. Because of this do not change the file name that holds the main function, also make sure you use a make file. When we grade we will be making sure that you map does not crash/throw exceptions under any circumstances. We will be taking some input from file and storing them into your map, performing some operations using the brackets operator, then printing the map out, your map should print in sorted order. We will provide a `main` function that will test all of the same operators, but with different inputs.

Points distribution	
Using PA4 Tree	15
Input/output operators	10
Constructors	5
Brackets adding	5
Brackets searching	5
Brackets search miss	5
Brackets update	5
Iterator `begin()/end()`	10
Iterator `operator++`	10
Report	30
Total	100