HUFFMAN CODING C++ IMPLEMENTATION

Disclaimer: This Huffman Coding Program I created is just a simplified version developed for educational purposes, based on the logic discussed in our class. It may NOT be optimized for performance or efficiency and should not be used as a reference for general Huffman Coding algorithms. The code is still under development and may contain limitations or bugs. Use at your own discretion. Thank you.

Huffman Coding is an algorithm that was developed by David Huffman that is for data compression on a file without losing any of its information. It is generally useful to compress the data in which there are frequently occurring characters. This is my implementation.

Program Functionalities

- **Frequency Scanning (Table)**
- **Queuing Process**
- **Building of Huffman Tree**
- **Character Traversal (Bit Generator)**
- **Summation of Bits**

Frequency Scanning (Table)

First of all, we need to read the inputted string and then record the frequencies of each character and then store it into some table. In this case, I used a map of string and integer. Why did I use a string instead of a character for this? In the building process, if the program encounters duplicate frequencies or tree root nodes that have the same frequencies, the program must sort it alphabetically. After combining two characters we need to add their values and concatenate their texts into a tree node. But before that, let's discuss the frequency table first.

When we read the inputted string we use a loop and then store the character into a map. As we read through the loop, we increment the character's pair since the map is a map of string and integer. Thus, this is our code:

```
map<string, int> getFrequencies(string text)
{
     map<string, int> table;
     for (char character : text)
     {
          string str;
          str += character;
          table[str]++;
     }
     return table;
}
```

Queuing Process

After we have obtained the frequency table, we can now start our queuing process by passing our frequency table into our queuing process function. We first initialize a vector of nodes that we name it as *minHeap.* We will loop through the passed map and then create a node for each character and frequency. For every creation of nodes, we will push them into our vector. After this we can start building the tree by instantiating a new node and then calling our *buildHuffmanTree* function and then assigning it into our newly instantiated node. This is the code for the queuing process:

```
Node *queuingProcess(map<string, int> &frequencyTable, char
buildSteps)
{
     vector<Node*> minHeap;
     for (auto entry: frequencyTable)
     {
          Node    *character    =    new    Node(entry.first,
entry.second);
          minHeap.push_back(character);
     }

     Node *tree = buildHuffmanTree(minHeap, buildSteps);

     return tree;
}
```

Building of Huffman Tree

This is the heart of our program, as it is the step-by-step building of the huffman tree with a specific order. First of all, we will declare a new node as the root of our huffman tree. From time to time, our root will be changed until the final computation. I have also included a step-by-step printing of the building of the tree to display how it is constructed. This is going to be our algorithm for that:

Huffman Tree Building

Procedure: HuffmanTreeBuilding(minHeap[])
Let z be our root node
while minHeap's size > 1 **do**
n ← minHeap's size
sort(minHeap, comparator) in descending order based on the frequencies and as well as alphabetically descending if some frequencies are the same using the comparator.

Let x ← minHeap[n - 1]
Let y ← minHeap[n - 2]

z ← buildTree(x, y)

minHeap.pop_back()
minHeap.pop_back()
minHeap.push_back(z)
end while
return z
end procedure

- This is our main huffman tree builder that loops throughout *minHeap* until only one element is left, which in that case, the root of the tree, meaning it is fully constructed.

Tree Building

Procedure: TreeBuilding(x, y)
Let root ← new Node(x_{text} + y_{text}, $x_{frequency}$, + $y_{frequency}$)
$root_{left}$ ← x
$root_{right}$ ← y
return root
end procedure

- This is the helper tree builder which builds a tree every time a merging of two least frequency characters occur.

Comparator

Procedure: Compare(x, y)

if $x_{frequency}, = y_{frequency}$ **do**
return $x_{text} > y_{text}$
end if
return $x_{frequency}, > y_{frequency}$
end procedure

- We pass this in our sorting function which is built-in in C++. This sorts the *minHeap* based on the frequencies, and if it contains duplicate frequencies, it is sorted alphabetically.

Overall Code of the Algorithms above

Huffman Tree Building

```
     Node *buildHuffmanTree(vector<Node*> &minHeap, char
buildSteps)
{
     Node *z;
     if (buildSteps == 'y') cout << "Tree Building Steps: "
<< endl;
     while (!minHeap.empty() && minHeap.size() > 1)
     {
          int n = minHeap.size();
          sort(minHeap.begin(), minHeap.end(), compare);

          if (buildSteps == 'y')
treeBuildingSteps(minHeap);

          Node *x = minHeap[n - 1];
          Node *y = minHeap[n - 2];

          z = buildTree(x, y);
          minHeap.pop_back();
          minHeap.pop_back();

          minHeap.push_back(z);
     }
     return z;
}
```

Tree Building

```
Node *buildTree(Node *x, Node* y)
```

```
{
     Node *root = new Node(x->text + y->text, x->frequency
+ y->frequency);
     root->left = x;
     root->right = y;
     return root;
}
```

Comparator

```
bool compare(const Node *a, const Node *b)
{
     if (a->frequency == b->frequency)
     {
          return a->text > b->text;
     }
     return a->frequency > b->frequency;
}
```

Character Traversal (Bits Generator)

This functionality traverses each character from the table to generate its bits. This is the algorithm for that:

Procedure: GenerateBits(root, character, binaryCode)
  if root = nullptr **do**
    return false
  end if

  if $root_{text}$ = character **do**
    return true
  end if

  if GenerateBits($root_{left}$, character, binaryCode) **do**
    binaryCode.push_back(0)
    return true
  end if

  if GenerateBits($root_{right}$, character, binaryCode) **do**
    binaryCode.push_back(1)
    return true
  end if

  if binaryCode is empty **do**
    binaryCode.pop_back()
  end if

  return false

end procedure

Code of the Algorithm

```
     bool codeHelper(Node *root, string character, 
vector<bool> &binaryCode)
{
     if (!root) return false;

     if (root->text == character) return true;

     if (codeHelper(root->left, character, binaryCode))
     {
          binaryCode.push_back(0);
          return true;
     }

     if (codeHelper(root->right, character, binaryCode))
     {
          binaryCode.push_back(1);
          return true;
     }

     if (!binaryCode.empty()) binaryCode.pop_back();
     return false;
}
```

Summation of Bits

After all the building and queuing process, we acquire a table consisting of characters, frequencies, and bits. We calculate the frequency of the character and size of its bits and then summate them. For this functionality, I have already embedded the calculation function within my display table function. This is the code:

```
void presentStatistics(map<string, int> &frequencyTable, 
Node* huffmanTree)
{
     map<string, pair<int, pair<vector<bool>, int>>> 
characterCodes;

     for (auto entry : frequencyTable)
     {
          vector<bool> binaryCode;
          codeHelper(huffmanTree, entry.first, binaryCode);
```

```
            characterCodes[entry.first]    =    {entry.second,
{binaryCode, binaryCode.size() * entry.second}};
        }

        int overallBits = 0;

        cout << "Table: " << endl;
        cout                                                  <<
"+----------+---------+---------+----------+" << endl;
        cout << "| Character| frequency|    code    | weighted
|" << endl;
        cout                                                  <<
"+----------+---------+---------+----------+" << endl;
        for (auto entry : characterCodes)
        {
            cout << "|      " << entry.first << "    |    " <<
entry.second.first << "     |   ";
            for  (int  i  =  entry.second.second.first.size()  -
1; i >= 0; i--)
            {
                cout << entry.second.second.first[i];
            }
            cout   <<   "               |               "   <<
entry.second.second.second << "   |" << endl;
            cout                                              <<
"+----------+---------+---------+----------+" << endl;
            overallBits += entry.second.second.second;
        }

        cout  <<  "Your  Huffman  Compression  has  overall  "  <<
overallBits << " bits." << endl;
}
```

Overall

Combining the functions together, we can now simulate the huffman coding algorithm by inputting texts on it.

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