



## **FINAL PROJECT:**

BY

**SIR FURQAN HUSSAIN ESSANI**

## **PROJECT NAME:**

**FILE ZIPPER USING HUFFMAN CODING.**

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# **Report on Project: File Zipper Using Huffman Coding.**

## **1. Introduction:**

This code is an implementation of file zipping technique using Huffman coding algorithm in C++. The program covers vector, priority queue, heap memory and Tree. It efficiently manages data structures, file I/O, and dynamic memory allocation to achieve its goal while maintaining clarity and modularity.

## **2. Project Description:**

The project implements Huffman coding for file compression and decompression. Huffman coding is a variable-length prefix coding algorithm used for lossless data compression. The program reads a file, constructs a Huffman tree based on character frequencies, generates Huffman codes, and then compresses or decompresses the input file accordingly. The Huffman tree and encoded data are stored in a binary file during compression and used during decompression. The priority queue is employed to efficiently build the Huffman tree based on character frequencies.

## **3. Functionalities:**

The provided C++ code implements Huffman coding for file compression and decompression. Here are the main functionalities provided by the code.

### **1. Compression Functionality:**

- **Reading Input File:** The program reads the input file specified in the command-line arguments.
- **Frequency Counting:** It counts the frequency of each character in the input file.
- **Min Heap Creation:** Constructs a Min Heap (priority queue) of nodes based on character frequencies.
- **Huffman Tree Construction:** Builds a Huffman tree using the Min Heap.
- **Huffman Code Generation:** Traverses the Huffman tree to generate Huffman codes for each character.

- **Saving Metadata (Huffman Tree):** Saves metadata of the Huffman tree (character data and codes) in the compressed file.
- **Encoding Characters:** Encodes each character in the input file using the generated Huffman codes.
- **Saving Encoded File:** Saves the encoded file, including the Huffman tree metadata and encoded characters.

## 2. De-compression Functionalities:

- **Reading Input File:** Reads the compressed input file specified in the command-line arguments.
- **Reconstructing Huffman Tree:** Reconstructs the Huffman tree based on the metadata stored in the compressed file.
- **Decoding Characters:** Decodes the Huffman-coded characters in the compressed file using the reconstructed Huffman tree.
- **Saving Decoded File:** Saves the decoded file, obtaining the original content from the Huffman-coded characters.

## 3. Additional Functionalities:

- **Binary-to-Decimal and Decimal-to-Binary Conversion:** Provides functions for converting binary strings to decimal values and vice versa.
- **Error Handling:** Checks if the correct number of command-line arguments is provided. Outputs an error message if the required files are not detected.

## Overall:

The code provides a complete implementation of Huffman coding, including the construction of Huffman trees, generation of Huffman codes, and encoding/decoding of files.

The functionalities are encapsulated within the huffman class, promoting modularity and code organization.

The error handling ensures that the program gracefully handles incorrect usage and missing files.

The code aims to achieve efficient and lossless compression and decompression of files using Huffman coding.

## **4. Data Structures Used in the Code:**

### **1. Vector:**

- **Purpose:** Used to store a collection of nodes representing characters' ASCII values, each initialized with zero frequencies.
- **Reason:** Provides a dynamic array-like structure to easily access and manipulate individual nodes for frequency counting.

### **2. Priority Queue:**

- **Purpose:** Used to maintain a Min Heap of nodes based on their frequencies during Huffman tree construction.
- **Reason:** Ensures that the node with the lowest frequency is always at the top of the heap, facilitating efficient extraction of nodes with the lowest frequencies.

### **3. Heap Memory:**

- **Purpose:** Dynamically allocates memory for Node objects.
- **Reason:** Allows the creation and manipulation of nodes dynamically during the construction of the Huffman tree. Dynamic memory allocation is essential for managing nodes with varying frequencies efficiently.

### **4. Huffman Tree:**

- **Purpose:** Used to construct a tree which later helps in assigning codes for each node.
- **Reason:** The primary purpose of the Huffman tree is to represent the encoding scheme for characters in the input data, where characters with higher frequencies are assigned shorter binary codes, and characters with lower frequencies are assigned longer binary codes.

The chosen data structures in the code are selected to efficiently manage and manipulate the information required for Huffman coding, including character frequencies, Huffman tree nodes, and input/output files. The use of these data structures contributes to the clarity, modularity, and efficiency of the implementation.

## **5. Contributions:**

### **1. Ayesha Yousuf:**

- Present the main idea.
- Implement the compression logic.
- Helped in debugging.
- Create a filling logic.
- Presented the idea of conditional compilation and worked on it.
- Project report.

### **2. Maryam Khan:**

- Implement the de-compression logic.
- Designed a logic for Huffman class.
- Focus on maintaining the other functionalities.
- Idea for the features.
- Project planning.
- Debugging.
- Contributed in Error Handling.

### **3. Ghufraan Raza:**

- Idea for the features.
- Participated in overall implementation.
- Including necessary libraries.
- Testing of the code.
- Documentation and comments.

## 6. Code:

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BST.cpp Depth_firstSearch.cpp LAB-13_CR-22004.cpp huffman.hpp X graph.cpp
C: > Users > CPT > Desktop > project > huffman.hpp > ...
1 //Header Guards to prevent header files from being included multiple times
2 #ifndef HUFFMAN_HPP
3 #define HUFFMAN_HPP
4 #include <string>
5 #include <vector>
6 #include <queue>
7 #include <fstream>
8 using namespace std;
9
10 //Defining Huffman Tree Node
11 struct Node {
12     char data;
13     unsigned freq;
14     string code;
15     Node *left, *right;
16
17     Node() {
18         left = right = NULL;
19     }
20 };
21
22 class huffman {
23     private:
24         vector <Node*> arr;
25
26         fstream inFile, outFile;
```

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file Edit Selection View Go ... DSAinC++
huffman.hpp X
C: > Users > CPT > Desktop > project > huffman.hpp > huffman
26 fstream inFile, outFile;
27
28 string inFileName, outFileName;
29
30 Node *root;
31
32 class Compare {
33     public:
34         bool operator() (Node* l, Node* r)
35         {
36             return l->freq > r->freq;
37         }
38 };
39
40 priority_queue <Node*, vector<Node*>, Compare> minHeap;
41
42 //Initializing a vector of tree nodes representing character's ascii value and initializing its frequency with
43 void createArr();
44
45 //Traversing the constructed tree to generate huffman codes of each present character
46 void traverse(Node*, string);
47
48 //Function to convert binary string to its equivalent decimal value
49 int binToDec(string);
50
```

```
File Edit Selection View Go ... DSAinC++
huffman.hpp x
C: > Users > CPT > Desktop > project > huffman.hpp > huffman
48 //Function to convert binary string to its equivalent decimal value
49 int binToDec(string);
50
51 //Function to convert a decimal number to its equivalent binary string
52 string decToBin(int);
53
54 //Reconstructing the Huffman tree while Decoding the file
55 void buildTree(char, string&);
56
57 //Creating Min Heap of Nodes by frequency of characters in the input file
58 void createMinHeap();
59
60 //Constructing the Huffman tree
61 void createTree();
62
63 //Generating Huffman codes
64 void createCodes();
65
66 //Saving Huffman Encoded File
67 void saveEncodedFile();
68
69 //Saving Decoded File to obtain the original File
70 void saveDecodedFile();
71
72 //Reading the file to reconstruct the Huffman tree
73 void getTree();
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```

```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp > traverse(Node *, string)
1  #include "huffman.hpp"
2
3  void huffman::createArr() {
4      for (int i = 0; i < 128; i++) {
5          arr.push_back(new Node());
6          arr[i]->data = i;
7          arr[i]->freq = 0;
8      }
9  }
10
11 void huffman::traverse(Node* r, string str) {
12     if (r->left == NULL && r->right == NULL) {
13         r->code = str;
14         return;
15     }
16
17     traverse(r->left, str + '0');
18     traverse(r->right, str + '1');
19 }
20
21 int huffman::binToDec(string inStr) {
22     int res = 0;
23     for (auto c : inStr) {
24         res = res * 2 + c - '0';
25     }
26     return res;
27 }
```

```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp > decToBin(int)
20     return res;
21 }
22
23 string huffman::decToBin(int inNum) {
24     string temp = "", res = "";
25     while (inNum > 0) {
26         temp += (inNum % 2 + '0');
27         inNum /= 2;
28     }
29     res.append(8 - temp.length(), '0');
30     for (int i = temp.length() - 1; i >= 0; i--) {
31         res += temp[i];
32     }
33     return res;
34 }
35
36 void huffman::buildTree(char a_code, string& path) {
37     Node* curr = root;
38     for (int i = 0; i < path.length(); i++) {
39         if (path[i] == '0') {
40             if (curr->left == NULL) {
41                 curr->left = new Node();
42             }
43             curr = curr->left;
44         }
45         else if (path[i] == '1') {
46             if (curr->right == NULL) {
47                 curr->right = new Node();
48             }
49             curr = curr->right;
50         }
51     }
52     curr->data = a_code;
53 }
```



```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp -o createMinHeap()
51     else if (p[curr->right] == NULL) {
52         if (curr->right == NULL) {
53             curr->right = new Node();
54         }
55         curr = curr->right;
56     }
57 }
58 curr->data = a_code;
59 }
60
61 void huffman::createMinHeap() {
62     char id;
63     inFile.open(inFileName, ios::in);
64     inFile.get(id);
65     //Incrementing frequency of characters that appear in the input file
66     while (!inFile.eof()) {
67         arr[id]->freq++;
68         inFile.get(id);
69     }
70     inFile.close();
71     //Pushing the Nodes which appear in the file into the priority queue (Min Heap)
72     for (int i = 0; i < 128; i++) {
73         if (arr[i]->freq > 0) {
74             minHeap.push(arr[i]);
75         }
76     }
77 }
```

```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp -o createCodes()
78
79 void huffman::createTree() {
80     //Creating Huffman Tree with the Min Heap created earlier
81     Node *left, *right;
82     priority_queue<Node*, vector<Node*>, Compare> tempPQ(minHeap);
83     while (tempPQ.size() != 1)
84     {
85         left = tempPQ.top();
86         tempPQ.pop();
87
88         right = tempPQ.top();
89         tempPQ.pop();
90
91         root = new Node();
92         root->freq = left->freq + right->freq;
93
94         root->left = left;
95         root->right = right;
96         tempPQ.push(root);
97     }
98 }
99
100 void huffman::createCodes() {
101     //Traversing the Huffman Tree and assigning specific codes to each character
102     traverse(root, "");
103 }
```

```
File Edit Selection View Go ... DSAinC++
huffman.cpp X
C:\Users\CPT\Desktop\project> huffman.cpp > saveEncodedFile()
105 void huffman::saveEncodedFile() {
106     //Saving encoded (.huf) file
107
108     // Open input and output files
109     inFile.open(inFileName, ios::in);
110     outFile.open(outFileName, ios::out | ios::binary);
111
112     // Initialize strings for encoding
113     string in = "";
114     string s = "";
115     char id;
116
117     //Saving the meta data (huffman tree)
118     in += (char)minHeap.size(); //storing to indicate how many nodes to be created during decoding
119     priority_queue<Node*, vector<Node*>, Compare> tempPQ(minHeap);
120     while (!tempPQ.empty()) {
121         Node* curr = tempPQ.top();
122         in += curr->data;
123         //Saving 16 decimal values representing code of curr->data
124         s.assign(127 - curr->code.length(), '0');
125         s += '1';
126         s += curr->code;
127         //Saving decimal values of every 8-bit binary code
128         in += (char)binToDec(s.substr(0, 8));
129         for (int i = 0; i < 15; i++) {
```

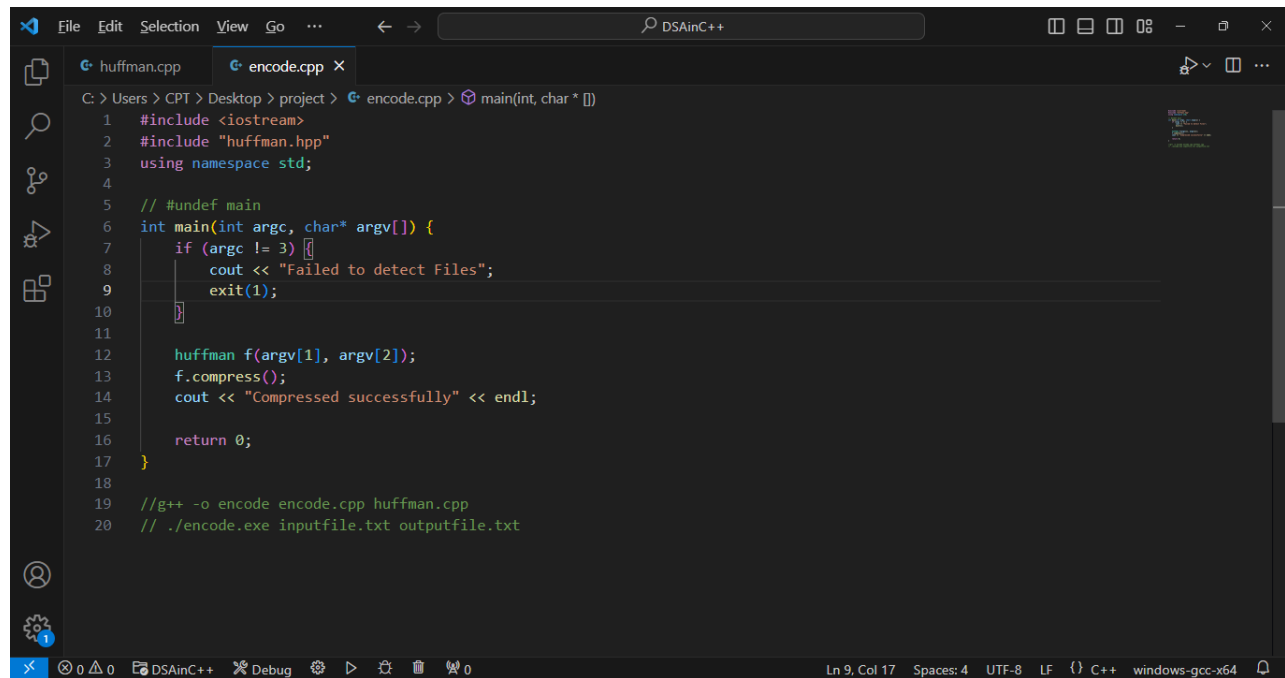
```
File Edit Selection View Go ... DSAinC++
huffman.cpp X
C:\Users\CPT\Desktop\project> huffman.cpp > saveEncodedFile()
129         for (int i = 0; i < 15; i++) {
130             s = s.substr(8);
131             in += (char)binToDec(s.substr(0, 8));
132         }
133         tempPQ.pop();
134     }
135     s.clear();
136
137     //Saving codes of every character appearing in the input file
138     inFile.get(id);
139     while (!inFile.eof()) {
140         s += arr[id]->code;
141         //Saving decimal values of every 8-bit binary code
142         while (s.length() > 8) {
143             in += (char)binToDec(s.substr(0, 8));
144             s = s.substr(8);
145         }
146         inFile.get(id);
147     }
148
149     //Finally if bits remaining are less than 8, append 0's (padding)
150     int count = 8 - s.length();
151     if (s.length() < 8) {
152         s.append(count, '0');
153     }
154     in += (char)binToDec(s);
```

```
huffman.cpp
C:\Users\CPT\Desktop\project> huffman.cpp > saveEncodedFile()
153     }
154     in += (char)binToDec(s);
155     //append count of appended 0's
156     in += (char)count;
157
158     //write the in string to the output file
159     outFile.write(in.c_str(), in.size());
160     inFile.close();
161     outFile.close();
162 }
163
164 void huffman::saveDecodedFile() {
165     inFile.open(inFileName, ios::in | ios::binary);
166     outFile.open(outFileName, ios::out);
167     unsigned char size;
168     inFile.read(reinterpret_cast<char*>(&size), 1);
169     //Reading count at the end of the file which is number of bits appended to make final value 8-bit
170     inFile.seekg(-1, ios::end);
171     char count0;
172     inFile.read(&count0, 1);
173     //Ignoring the meta data (huffman tree) (1 + 17 * size) and reading remaining file
174     inFile.seekg(1 + 17 * size, ios::beg);
175
176     vector<unsigned char> text;
177     unsigned char textseg;
178     inFile.read(reinterpret_cast<char*>(&textseg), 1);
179     while (!inFile.eof()) {
180         text.push_back(textseg);
181         inFile.read(reinterpret_cast<char*>(&textseg), 1);
182     }
183
184     Node *curr = root;
185     string path;
186     for (int i = 0; i < text.size() - 1; i++) {
187         //Converting decimal number to its equivalent 8-bit binary code
188         path = decToBin(text[i]);
189         if (i == text.size() - 2) {
190             path = path.substr(0, 8 - count0);
191         }
192         //Traversing huffman tree and appending resultant data to the file
193         for (int j = 0; j < path.size(); j++) {
194             if (path[j] == '0') {
195                 curr = curr->left;
196             }
197             else {
198                 curr = curr->right;
199             }
200
201             if (curr->left == NULL && curr->right == NULL) {
202                 outFile.put(curr->data);
203                 curr = root;
204             }
205         }
206     }
207 }
```

```
huffman.cpp
C:\Users\CPT\Desktop\project> huffman.cpp > saveDecodedFile()
178     inFile.read(reinterpret_cast<char*>(&textseg), 1);
179     while (!inFile.eof()) {
180         text.push_back(textseg);
181         inFile.read(reinterpret_cast<char*>(&textseg), 1);
182     }
183
184     Node *curr = root;
185     string path;
186     for (int i = 0; i < text.size() - 1; i++) {
187         //Converting decimal number to its equivalent 8-bit binary code
188         path = decToBin(text[i]);
189         if (i == text.size() - 2) {
190             path = path.substr(0, 8 - count0);
191         }
192         //Traversing huffman tree and appending resultant data to the file
193         for (int j = 0; j < path.size(); j++) {
194             if (path[j] == '0') {
195                 curr = curr->left;
196             }
197             else {
198                 curr = curr->right;
199             }
200
201             if (curr->left == NULL && curr->right == NULL) {
202                 outFile.put(curr->data);
203                 curr = root;
204             }
205         }
206     }
207 }
```

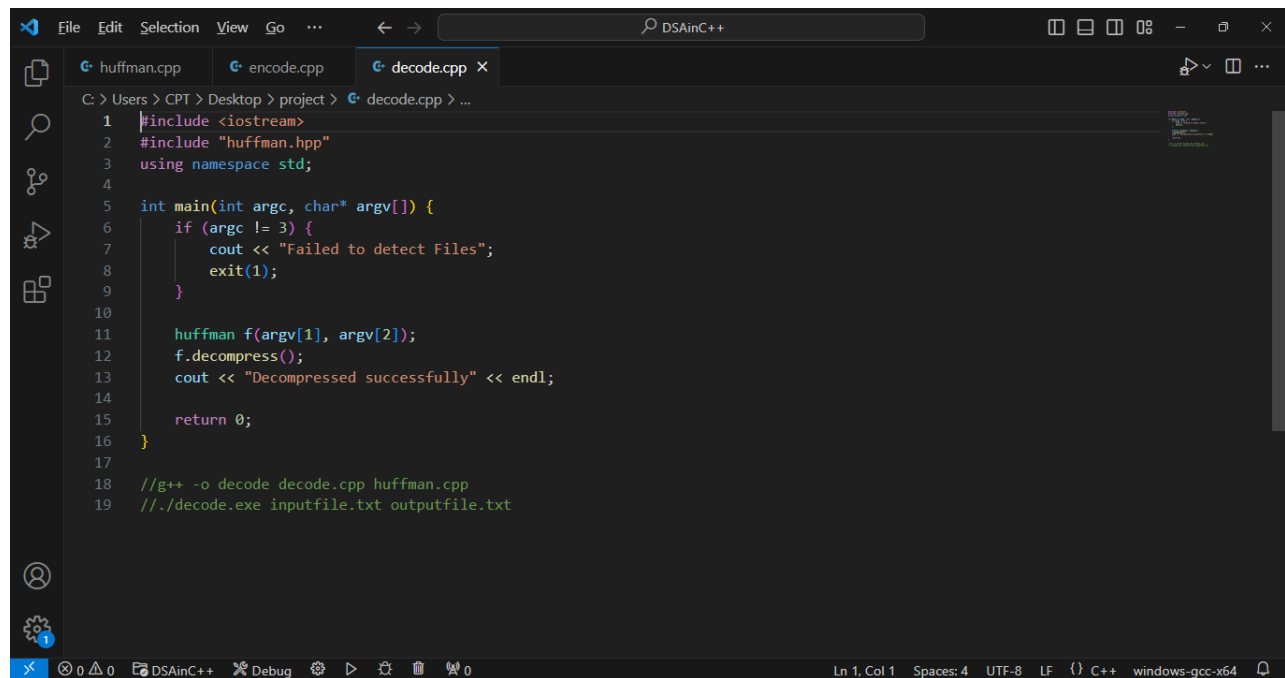
```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp > getTree()
205     }
206 }
207 inFile.close();
208 outFile.close();
209 }
210
211 void huffman::getTree() {
212     inFile.open(inFileName, ios::in | ios::binary);
213     //Reading size of MinHeap
214     unsigned char size;
215     inFile.read(reinterpret_cast<char*>(&size), 1);
216     root = new Node();
217     //next size * (1 + 16) characters contain (char)data and (string)code[in decimal]
218     for(int i = 0; i < size; i++) {
219         char aCode;
220         unsigned char hCodeC[16];
221         inFile.read(&aCode, 1);
222         inFile.read(reinterpret_cast<char*>(hCodeC), 16);
223         //converting decimal characters into their binary equivalent to obtain code
224         string hCodeStr = "";
225         for (int i = 0; i < 16; i++) {
226             hCodeStr += decToBin(hCodeC[i]);
227         }
228         //Removing padding by ignoring first (127 - curr->code.length()) '0's and next '1' character
229         int j = 0;
```

```
huffman.cpp
C:\Users\CPT\Desktop\project> g++ huffman.cpp > ...
228     //Removing padding by ignoring first (127 - curr->code.length()) '0's and next '1' character
229     int j = 0;
230     while (hCodeStr[j] == '0') {
231         j++;
232     }
233     hCodeStr = hCodeStr.substr(j+1);
234     //Adding node with aCode data and hCodeStr string to the huffman tree
235     buildTree(aCode, hCodeStr);
236 }
237 inFile.close();
238 }
239
240 void huffman::compress() {
241     createMinHeap();
242     createTree();
243     createCodes();
244     saveEncodedFile();
245 }
246
247 void huffman::decompress() {
248     getTree();
249     saveDecodedFile();
250 }
251
```



```
C:\Users> CPT\Desktop> project> encode.cpp > main(int, char* [])
1  #include <iostream>
2  #include "huffman.hpp"
3  using namespace std;
4
5  // #undef main
6  int main(int argc, char* argv[]) {
7      if (argc != 3) {
8          cout << "Failed to detect Files";
9          exit(1);
10     }
11
12     huffman f(argv[1], argv[2]);
13     f.compress();
14     cout << "Compressed successfully" << endl;
15
16     return 0;
17 }
18
19 //g++ -o encode encode.cpp huffman.cpp
20 // ./encode.exe inputfile.txt outputfile.txt
```

Ln 9, Col 17 Spaces: 4 UTF-8 LF {} C++ windows-gcc-x64



```
C:\Users> CPT\Desktop> project> decode.cpp > ...
1  #include <iostream>
2  #include "huffman.hpp"
3  using namespace std;
4
5  int main(int argc, char* argv[]) {
6      if (argc != 3) {
7          cout << "Failed to detect Files";
8          exit(1);
9      }
10
11     huffman f(argv[1], argv[2]);
12     f.decompress();
13     cout << "Decompressed successfully" << endl;
14
15     return 0;
16 }
17
18 //g++ -o decode decode.cpp huffman.cpp
19 // ./decode.exe inputfile.txt outputfile.txt
```

Ln 1, Col 1 Spaces: 4 UTF-8 LF {} C++ windows-gcc-x64