Assignment 5

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Aim:

Experiment task-1: Consider a XYZ courier company. They receive different goods to transport to different cities. Company needs to ship thegoods based on their life and value. Goods having less shelf life and high cost shall be shipped earlier. Consider list of 100 such items and capacity of transport vehical is 200 tones. Implement Algorithm for fractional knapsack problem.

Experiment task-2: Download books from the website in html, text, doc, and pdf format. Compress these books using Hoffman coding technique. Find the compression ratio.

Algorithm for Experiment task-1:

```
STRUCT item
 int value
 int weight
Double ratio

Function Compare (item a , item b)   RETURNS BOOL
  RETURN   a.ratio > b.ratio.

FUNTION fractional knapsack(INT capacity, List of item items)
      RETURNS Double
For Each item in items Do
  item.ratio = (Double) item.value/item.weight
  ENDFOR

SORT items USING Compare Function

 Double total value = 0.0

For EACH item in items Do

 if item.weight <= capacity Then
   total value + = item.value
   capacity - = item.weight

ELSE

  total value + = item.ratio * capacity
  Break          // Knapsack is full
END if
END For
```

```
Return total value

Function main()

List of item items = { {60, 10}, {100, 20}, {120, 30}}

 int capacity = 50

Double max value = fractional Knapsack (capacity , items)

Print "Total value in Knapsack :" + max value

END FUNCTION
```

Algorithm for Experiment task-2:

```
STRUCT Node
  Char character
  int frequency
  Node * left
  Node * right

Function compare (Node * left, Node * right) RETURNS BOOL
  RETURN left.frequency > right.frequency

Function generate codes(Node * root, STRING code, HASH_MAP
                         < char, STRING > &huffman code)
if root is Null then
  RETURN

if root.left is Null AND root.right is Null Then
  huffmancodes [root.character] = code

CALL generate codes (root.left, code + "0", huffmancodes)
CALL generate codes (root.right, code + "1", huffman codes)

Function huffmanCoding (STRING data) RETURNS PAIR <string, Double>
  if data is EMPTY THEN
  RETURN {"", 0.0}

HASH_MAP < char, INT > frequency
FOR EACH CHAR ch in data DO
  frequency [ch] ++
```

```
PRIORITY_QUEUE <Node*> Pq
FOR EACH PAIR <char, INT> Pair in frequency Do
  Pq.Push (New Node (Pair.first, Pair.second))

WHILE Pq.size() > 1 Do
  Node* left = Pq.top()
   Pq.pop()
  Node * right = Pq.top()
   Pq.pop()
 Node* merged = NEW Node ('\0', left.frequency + right.frequency)
  merged.left = left
  merged.right = right
   Pq.push (merged)

Node * root = Pq.top()

HASH_MAP <char, string> huffmanCodes
CALL generate code (root, "", huffmanCodes)

STRING compressed DATA.
For EACH CHAR ch in data Do
  compressed Data + = huffmancodes [ch]

Double original size = data.size() * 8     // Assuming 1 Char = 8 bits
Double compressed size = compressed Data.size()
Double Compression ratio = (original size - compressed size)/original size

RETURN {Compressed Data, Compression Ratio}
```

```
Function main()

VECTOR<string> teststrings = {"aabcc", "helloworld"}

FOR EACH string test in teststrings Do
Pair <string, Double> result = huffman coding(test)
PRINT "Input:" + test
PRINT "compressed:" + result.first + "(compressed Ratio:" +
                                   result.second + ")"
END FUNCTION
```

Test cases for Experiment 1:

Sample input & output

Positive Test Cases:-

	items	capacity	output
1	(60, 10), (100, 20), (120, 30)	50	240
2	(40, 5), (30, 10), (50, 15)	25	90
3	(20, 4), (40, 6), (60, 10)	20	100
4	(10, 1), (15, 2), (40, 3)	6	65
5	(50, 10), (30, 5)	20	90

Negative Test Cases:-

	items	Capacity	output
1	(10, 5)	4	0
2	(0, 0)	10	0
3	[20, 10)	0	0
4	(30, 10), (50, 20)]	0	0
5	(10, 10)	10	10

Test cases for Experiment 2:

Sample input & output:-

Positive Test Cases :-

	input	Compressed	Compression ratio
1	"aabcc"	00 01 10	0.4
2	"hello world"	10 110 111 0 01 1111	0.5
3	"aa aaaaa"	0	1.0
4	"abcde"	000 001 010 011 100	0.6
5	"mississippi"	0000 00 010 011 100	0.5

Negative Test Cases :-

input	compressed	Compression ratio
"" (Empty string)	No data	0
"a" (Single character)	"0"	1.0
"abcdefg" (All unique char)	"000 001 010 011 100 101 110"	0.3
" " (Single space)	"0"	1.0
"aaaaaa bbb" (few unique)	"00 01"	0.5

Time Complexity for Experiment 1:

Time Complexity

A) Brute force Algorithm

$O(2^n)$:- where n is the no. of items, due to checking all possible combinations.

B) Greedy Algorithm:-

$O(n \log n)$:- for sorting the items based on their value to weight ratio.

Time Complexity for Experiment 2:

Time Complexity

A) Brute Force Algorithm:

$O(n!)$ – This would apply if we checked every possible coding combination, which is infeasible.

B) Greedy Algorithm:- $O(n \log n)$:- due to the operations involving the priority queue for sorting and combining nodes.

Code for Experiment 1:

```
#include <iostream>

#include <vector>

#include <algorithm>


using namespace std;


struct Item {

    int value;

    int weight;

    double ratio;

};


// Function to compare items based on their value-to-weight ratio

bool compare(Item a, Item b) {

    return a.ratio > b.ratio; // Sort in descending order

}


// Function to calculate the maximum value that can be carried

double fractionalKnapsack(int capacity, vector<Item>& items) {

    for (auto& item : items) {

        item.ratio = (double)item.value / item.weight;

    }

    sort(items.begin(), items.end(), compare);


    double totalValue = 0.0;


    for (const auto& item : items) {

        if (item.weight <= capacity) {

            totalValue += item.value;

            capacity -= item.weight;

        } else {
```

```
        totalValue += item.ratio * capacity; // Take the fraction of the item
        break; // Knapsack is full
      }
    }

    return totalValue;
}

int main() {
    // Positive Test Cases
    vector<Item> testCasesPositive[] = {
      { {60, 10}, {100, 20}, {120, 30} }, // Case 1
      { {40, 5}, {30, 10}, {50, 15} },   // Case 2
      { {20, 4}, {40, 6}, {60, 10} },    // Case 3
      { {10, 1}, {15, 2}, {40, 3} },     // Case 4
      { {50, 10}, {30, 5} }              // Case 5
    };
    int capacitiesPositive[] = {50, 25, 20, 6, 20};

    // Negative Test Cases
    vector<Item> testCasesNegative[] = {
      { {10, 5} },                 // Case 1
      { {0, 0} },                  // Case 2
      { {20, 10} },                // Case 3
      { {30, 10}, {50, 20} },      // Case 4
      { {10, 10} }                 // Case 5
    };
    int capacitiesNegative[] = {4, 10, 0, 0, 10};

    // Run Positive Test Cases
    cout << "Positive Test Cases:\n";
```

```
    for (int i = 0; i < 5; ++i) {
        double result = fractionalKnapsack(capacitiesPositive[i], testCasesPositive[i]);
        cout << "Test Case " << (i + 1) << ": Capacity = " << capacitiesPositive[i] << ", Total Value = " << result << endl;
    }

    // Run Negative Test Cases
    cout << "\nNegative Test Cases:\n";
    for (int i = 0; i < 5; ++i) {
        double result = fractionalKnapsack(capacitiesNegative[i], testCasesNegative[i]);
        cout << "Test Case " << (i + 1) << ": Capacity = " << capacitiesNegative[i] << ", Total Value = " << result << endl;
    }

    return 0;
}
```

Code for Experiment 2:

```
#include <iostream>
#include <queue>
#include <unordered_map>
#include <vector>
#include <string>

using namespace std;

// Node structure for Huffman Tree
struct Node {
    char character;
    int frequency;
    Node* left;
```

```
    Node* right;

    Node(char ch, int freq) : character(ch), frequency(freq), left(nullptr), right(nullptr) {}
};

// Comparator for priority queue
struct compare {
    bool operator()(Node* left, Node* right) {
        return left->frequency > right->frequency;
    }
};

// Function to generate codes for characters
void generateCodes(Node* root, const string& code, unordered_map<char, string>& huffmanCodes) {
    if (!root) return;

    if (root->left == nullptr && root->right == nullptr) {
        huffmanCodes[root->character] = code;
    }

    generateCodes(root->left, code + "0", huffmanCodes);
    generateCodes(root->right, code + "1", huffmanCodes);
}

// Function to perform Huffman coding
pair<string, double> huffmanCoding(const string& data) {
    if (data.empty()) return {"", 0.0};

    // Frequency map
    unordered_map<char, int> frequency;
```

```
for (char ch : data) {
    frequency[ch]++;
}

// Priority queue (min-heap)
priority_queue<Node*, vector<Node*>, compare> pq;
for (const auto& pair : frequency) {
    pq.push(new Node(pair.first, pair.second));
}

// Build Huffman Tree
while (pq.size() > 1) {
    Node* left = pq.top(); pq.pop();
    Node* right = pq.top(); pq.pop();
    Node* merged = new Node('\0', left->frequency + right->frequency);
    merged->left = left;
    merged->right = right;
    pq.push(merged);
}

Node* root = pq.top();

// Generate Huffman codes
unordered_map<char, string> huffmanCodes;
generateCodes(root, "", huffmanCodes);

// Create compressed data
string compressedData;
for (char ch : data) {
    compressedData += huffmanCodes[ch];
```

```
    }

    // Calculate compression ratio
    double originalSize = data.size() * 8;  // Assuming 1 char = 8 bits
    double compressedSize = compressedData.size();
    double compressionRatio = (originalSize - compressedSize) / originalSize;

    return {compressedData, compressionRatio};
}

int main() {
    // Test cases: 5 positive and 5 negative
    vector<string> testStrings = {
        "aabcc",        // Positive Test Case 1
        "hello world",   // Positive Test Case 2
        "aaaaaaa",      // Positive Test Case 3
        "abcde",        // Positive Test Case 4
        "mississippi",   // Positive Test Case 5
        "",            // Negative Test Case 1 (Empty string)
        "a",           // Negative Test Case 2 (Single character)
        "abcdefg",      // Negative Test Case 3 (All unique characters)
        " ",           // Negative Test Case 4 (Single space)
        "aaaaaa bbb"     // Negative Test Case 5 (Few unique characters)
    };

    // Run test cases
    for (const string& test : testStrings) {
        auto [compressed, ratio] = huffmanCoding(test);
        cout << "Input: '" << test << "'" << endl;
        cout << "Compressed: '" << compressed << "' (Compression Ratio: " << ratio << ")" << endl << endl;
```

```
  }

  return 0;
}
```

Output for Experiment 1:

```
/tmp/Kto6BGRpSR.o
Positive Test Cases:
Test Case 1: Capacity = 50, Total Value = 240
Test Case 2: Capacity = 25, Total Value = 105
Test Case 3: Capacity = 20, Total Value = 120
Test Case 4: Capacity = 6, Total Value = 65
Test Case 5: Capacity = 20, Total Value = 80

Negative Test Cases:
Test Case 1: Capacity = 4, Total Value = 8
Test Case 2: Capacity = 10, Total Value = 0
Test Case 3: Capacity = 0, Total Value = 0
Test Case 4: Capacity = 0, Total Value = 0
Test Case 5: Capacity = 10, Total Value = 10


=== Code Execution Successful ===
```

Output for Experiment 2:

```
/tmp/Jv7kDwjupG.o
Input: 'aabcc'
Compressed: '00101111' (Compression Ratio: 0.8)

Input: 'hello world'
Compressed: '01100010101101111010110001101110' (Compression Ratio: 0.636364)

Input: 'aaaaaaa'
Compressed: '' (Compression Ratio: 1)

Input: 'abcde'
Compressed: '000111110110' (Compression Ratio: 0.7)

Input: 'mississippi'
Compressed: '100110011001110110111' (Compression Ratio: 0.761364)

Input: ''
Compressed: '' (Compression Ratio: 0)

Input: 'a'
Compressed: '' (Compression Ratio: 1)

Input: 'abcdefg'
Compressed: '10110000111011110010' (Compression Ratio: 0.642857)

Input: ' '
Compressed: '' (Compression Ratio: 1)

Input: 'aaaaaa bbb'
Compressed: '11111100010101' (Compression Ratio: 0.825)



=== Code Execution Successful ===
```

Conclusion:

In Experiment Task 1, we implemented the Fractional Knapsack Problem using greedy and brute force algorithms. The greedy approach, which prioritizes items based on their value-to-weight ratio, demonstrated efficiency with a time complexity of O(nlogn), making it suitable for larger datasets. The test cases highlighted the algorithm's effectiveness in optimizing the total value within a constrained capacity.

In Experiment Task 2, we implemented Huffman Coding for lossless data compression. This algorithm efficiently generated prefix codes based on character frequencies, achieving significant compression ratios, especially for repetitive data. With a time complexity of O(nlogn), Huffman coding proved effective in various scenarios, as evidenced by both positive and negative test cases.

Overall, both experiments showcased the power of greedy algorithms in solving optimization problems and their practical applications in data processing.