ITC Tutorial - 09 Home Assignment

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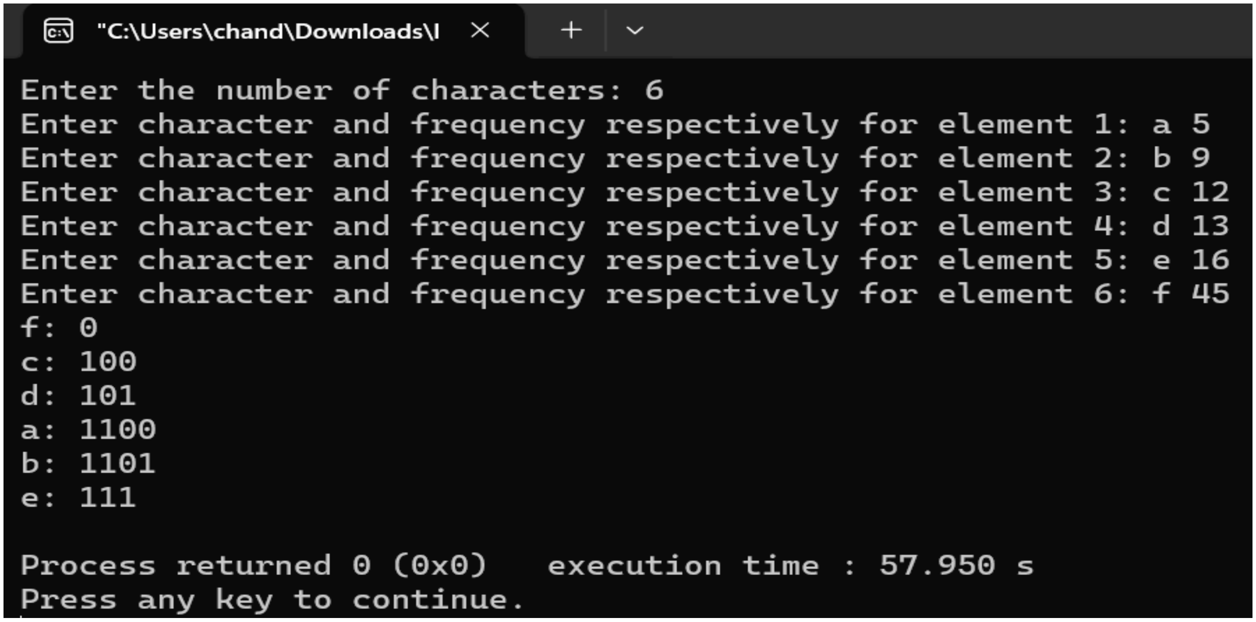
Concept chosen from syllabus: Module - 2 : Huffman Coding

Program:

```
#include <stdio.h>
#include <stdlib.h>

// A Huffman tree node
struct MinHeapNode {
    char data; // One of the input characters
    unsigned freq; // Frequency of the character
    struct MinHeapNode *left, *right; // Left and right child
};

// A Min Heap: Collection of min-heap (or Huffman tree) nodes
struct MinHeap {
    unsigned size; // Current size of min heap
    unsigned capacity; // Capacity of min heap
    struct MinHeapNode** array; // Array of minheap node pointers
};

// A utility function to create a new min heap node
struct MinHeapNode* newNode(char data, unsigned freq) {
    struct MinHeapNode* temp = (struct MinHeapNode*)malloc(sizeof(struct MinHeapNode));
    temp->left = temp->right = NULL;
    temp->data = data;
    temp->freq = freq;
    return temp;
}

// A utility function to create a min heap of given capacity
struct MinHeap* createMinHeap(unsigned capacity) {
    struct MinHeap* minHeap = (struct MinHeap*)malloc(sizeof(struct MinHeap));
    minHeap->size = 0;  // current size is 0
    minHeap->capacity = capacity;
    minHeap->array = (struct MinHeapNode**)malloc(minHeap->capacity * sizeof(struct
MinHeapNode*));
    return minHeap;
}
```

```
// A utility function to swap two min heap nodes
void swapMinHeapNode(struct MinHeapNode** a, struct MinHeapNode** b) {
   struct MinHeapNode* t = *a;
   *a = *b;
   *b = t;
}

// The standard minHeapify function.
void minHeapify(struct MinHeap* minHeap, int idx) {
   int smallest = idx;
   int left = 2 * idx + 1;
   int right = 2 * idx + 2;

   if (left < minHeap->size && minHeap->array[left]->freq < minHeap->array[smallest]->freq)
      smallest = left;

   if (right < minHeap->size && minHeap->array[right]->freq <
minHeap->array[smallest]->freq)
      smallest = right;

   if (smallest != idx) {
      swapMinHeapNode(&minHeap->array[smallest], &minHeap->array[idx]);
      minHeapify(minHeap, smallest);
   }
}

// A utility function to check if size of heap is 1 or not
int isSizeOne(struct MinHeap* minHeap) {
   return (minHeap->size == 1);
}

// A standard function to extract minimum value node from heap
struct MinHeapNode* extractMin(struct MinHeap* minHeap) {
   struct MinHeapNode* temp = minHeap->array[0];
   minHeap->array[0] = minHeap->array[minHeap->size - 1];
   --minHeap->size;
   minHeapify(minHeap, 0);
   return temp;
}

// A utility function to insert a new node to Min Heap
void insertMinHeap(struct MinHeap* minHeap, struct MinHeapNode* minHeapNode) {
   ++minHeap->size;
   int i = minHeap->size - 1;
   while (i && minHeapNode->freq < minHeap->array[(i - 1) / 2]->freq) {
        minHeap->array[i] = minHeap->array[(i - 1) / 2];
        i = (i - 1) / 2;
    }
    minHeap->array[i] = minHeapNode;
}

// A standard function to build min heap
void buildMinHeap(struct MinHeap* minHeap) {
    int n = minHeap->size - 1;
    int i;
    for (i = (n - 1) / 2; i >= 0; --i)
        minHeapify(minHeap, i);
}

// A utility function to print an array of size n
void printArr(int arr[], int n) {
    int i;
    for (i = 0; i < n; ++i)
        printf("%d", arr[i]);
    printf("\n");
}

// Utility function to check if this node is leaf
int isLeaf(struct MinHeapNode* root) {
    return !(root->left) && !(root->right);
}

// Creates a min heap of capacity equal to size and inserts all character of data[] in min heap.
Initially size of min heap is equal to capacity
struct MinHeap* createAndBuildMinHeap(char data[], int freq[], int size) {
    struct MinHeap* minHeap = createMinHeap(size);
    for (int i = 0; i < size; ++i)
        minHeap->array[i] = newNode(data[i], freq[i]);
    minHeap->size = size;
    buildMinHeap(minHeap);
    return minHeap;
}

// The main function that builds Huffman tree
struct MinHeapNode* buildHuffmanTree(char data[], int freq[], int size) {
    struct MinHeapNode *left, *right, *top;

    // Step 1: Create a min heap of capacity equal to size. Initially, there are modes equal to size.
    struct MinHeap* minHeap = createAndBuildMinHeap(data, freq, size);

    // Iterate while size of heap doesn't become 1
    while (!isSizeOne(minHeap)) {
        // Step 2: Extract the two minimum freq items from min heap
        left = extractMin(minHeap);
        right = extractMin(minHeap);

        // Step 3: Create a new internal node with frequency equal to the sum of the two nodes
frequencies. Make the two extracted node as left and right children of this new node. Add this
node to the min heap
        // '$' is a special value for internal nodes, not used
        top = newNode('$', left->freq + right->freq);
        top->left = left;
        top->right = right;

        insertMinHeap(minHeap, top);
    }

    // Step 4: The remaining node is the root node and the tree is complete.
    return extractMin(minHeap);
}

// Prints Huffman codes using the Huffman tree built above
void printCodes(struct MinHeapNode* root, int arr[], int top) {
    // Assign 0 to left edge and recur
    if (root->left) {
        arr[top] = 0;
        printCodes(root->left, arr, top + 1);
    }

    // Assign 1 to right edge and recur
    if (root->right) {
        arr[top] = 1;
        printCodes(root->right, arr, top + 1);
    }

    // If this is a leaf node, then print the character and its code from arr[]
    if (isLeaf(root)) {
        printf("%c: ", root->data);
        printArr(arr, top);
    }
}

// The main function that builds a Huffman Tree and print codes by traversing the built Huffman
Tree
int main() {
    int size;
    printf("Enter the number of characters: ");
    scanf("%d", &size);

    char arr[size];
    int freq[size];

    // Taking input from user
    for (int i = 0; i < size; ++i) {
        printf("Enter character and frequency respectively for element %d: ", i + 1);
        scanf(" %c %d", &arr[i], &freq[i]);
    }

    struct MinHeapNode* root = buildHuffmanTree(arr, freq, size);

    int codes[size], top = 0;
    printCodes(root, codes, top);
    return 0;
}
```

Output:



```
Enter the number of characters: 6
Enter character and frequency respectively for element 1: a 5
Enter character and frequency respectively for element 2: b 9
Enter character and frequency respectively for element 3: c 12
Enter character and frequency respectively for element 4: d 13
Enter character and frequency respectively for element 5: e 16
Enter character and frequency respectively for element 6: f 45
f: 0
c: 100
d: 101
a: 1100
b: 1101
e: 111

Process returned 0 (0x0)   execution time : 57.950 s
Press any key to continue.
```