哈爾濱工業大學 (深圳)

多媒体技术实验报告

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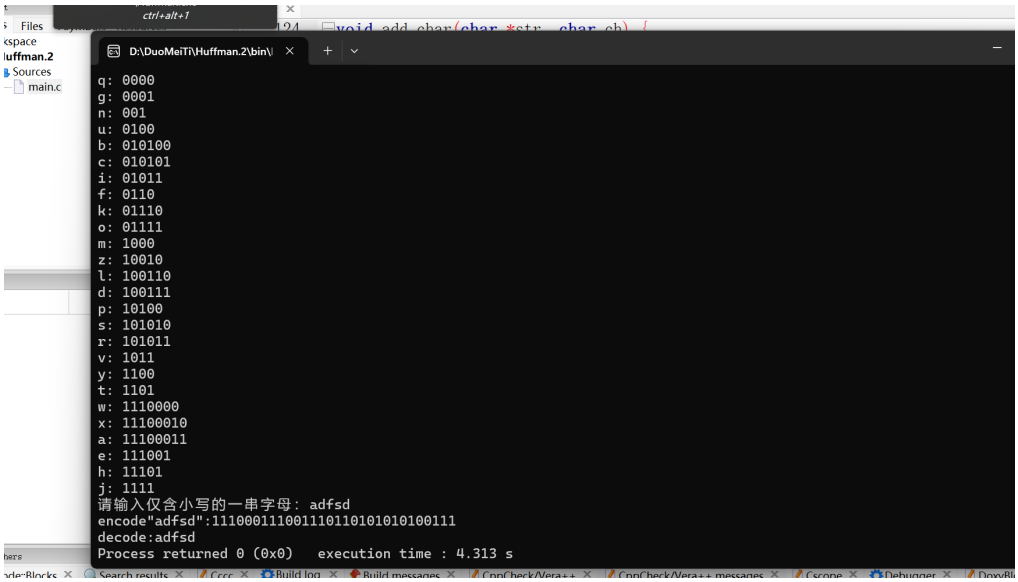
1. 霍夫曼编码

原理：利用二叉树，将带有权重（不同出现频率）的字符编变长码，且各字符的编码的前缀不会与其他字符的编码相同，具有唯一性。

C 语言实现思路：

1. 为各字符创建节点，节点包含字符和权重。
2. 创建最小二叉树。利用二叉树交换函数，将各节点建成如下的二叉树：最高权重的节点在堆顶，子节点（左右）的权重不大于父节点，叶子节点为各字符节点。
3. 为各字符节点编码。利用递归算法遍历二叉树，从堆顶到叶子节点，每往左就编码 0（反之编码 1），使得每个叶子节点都有前缀不同的唯一编码。

实验结果：



代码见文件尾

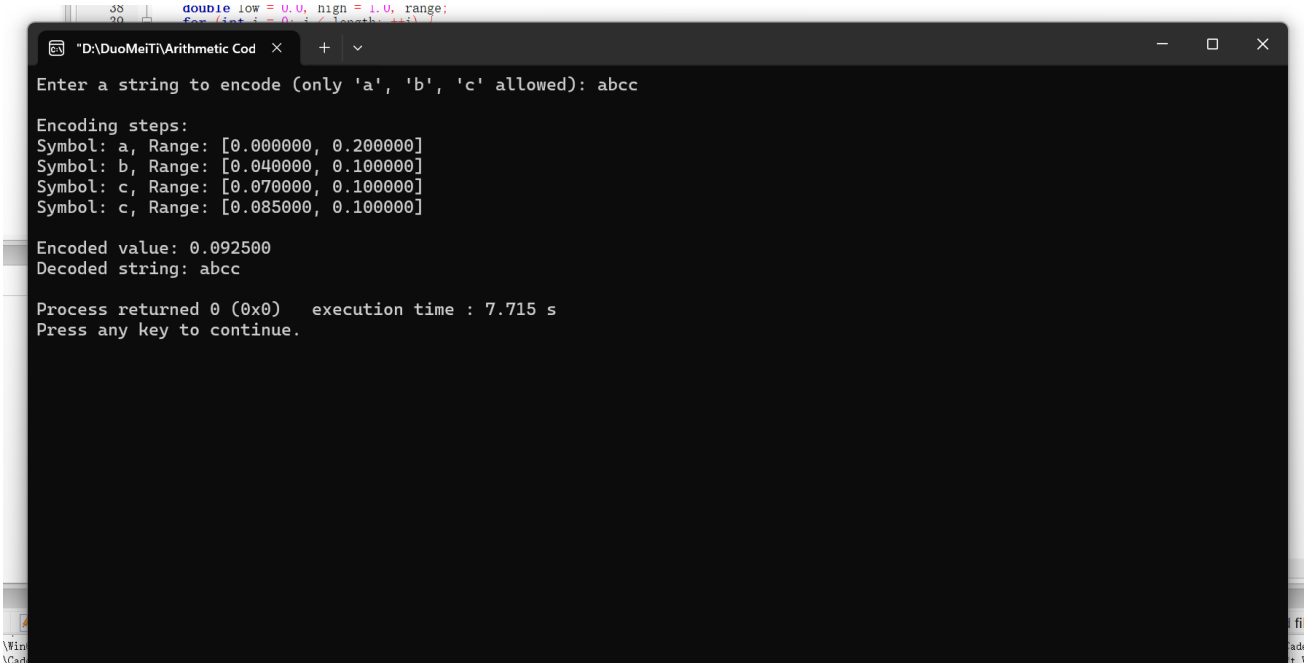
2. 算术编码

实验原理：将不同字符划分在 [0,1] 不同的区间，每编码一个字符都在前一串字符编码区间基础上，划分该字符对应子区间，最终取编码完成的区间的区间中值作为该字符串的编码。

C 语言实现思路：

1. 将各字符根据权重划分到[0,1]的不同区间。
2. 对输入字符串进行循环编码：一步一步取子区间
3. 输出最终子区间中间值作为编码

实验结果：



代码见文件尾

3.代码

霍夫曼编码及译码

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

#define MAX_TREE_NODES 256

typedef struct Code{
    char character;
    char huffcode[MAX_TREE_NODES];
}Code;

typedef struct Node {
    char character;
    int frequency;
    struct Node *left, *right;
} Node;

Node* createNode(char character, int frequency) {
    Node* newNode = (Node*)malloc(sizeof(Node));
    newNode->character = character;
    newNode->frequency = frequency;
    newNode->left = newNode->right = NULL;
    return newNode;
```

```
}

typedef struct {
    char chara[MAX_TREE_NODES];


}Dictionary;
//最小堆，用于存储二叉树成员，size 是最小堆当前的成员数量
typedef struct {
    Node* nodes[MAX_TREE_NODES];
    int size;
} MinHeap;

//功能：插入节点，插入地址是最小堆的末尾
//输入参数：最小堆的指针，待插入节点的指针
void insertHeap(MinHeap* heap, Node* node) {
    heap->nodes[heap->size++] = node;
}

//功能：找出最小堆中“权”最小（即频率最小）的节点，并将堆尾元素替换掉最小权节点，并删除堆尾节点
//输入参数：最小堆指针
//输出参数：返回最小节点
Node* extractMin(MinHeap* heap) {
    int minIndex = 0;
    for (int i = 1; i < heap->size; i++) {
        if (heap->nodes[i]->frequency < heap->nodes[minIndex]->fr
```

```
equency) {
            minIndex = i;
        }
    }
    Node* minNode = heap->nodes[minIndex];
    heap->nodes[minIndex] = heap->nodes[--heap->size]; // Replace
 with last node
    return minNode;
}

//如果是叶子节点，没有子节点，则返回 0
int isLeaf(Node* node) {
    return !(node->left) && !(node->right);
}

void buildHuffmanTree(char characters[], int frequencies[], int s
ize, Node** root) {
    MinHeap heap = { .size = 0 };

    //将所有字符生成一个堆，每个节点没有子节点
    for (int i = 0; i < size; i++) {
        insertHeap(&heap, createNode(characters[i], frequencies[i
]));
    }

    //将最小的两个节点抽出（size-2），作为新节点的子节点，然后将这个新节点放
到最小堆的堆尾(size+1)
```

```
    //重复这个操作，直到堆中只剩一个节点，此时这个节点即为最小堆的堆顶（root）
    while (heap.size > 1) {
        Node* left = extractMin(&heap);
        Node* right = extractMin(&heap);
        Node* newNode = createNode('\0', left->frequency + right->frequency);
        newNode->left = left;
        newNode->right = right;
        insertHeap(&heap, newNode);
    }

    *root = extractMin(&heap);
}

//打印霍夫曼码
//通过 buildHuffmanTree 生成的堆顶节点，利用递归的方法，将最小堆的叶子节点的值及其对应字符打印出来
void printCodes(Node* root, char* code, int top,Code* Huffman) {
    static int index = 0;
    if (root->left) {
        code[top] = '0';
        printCodes(root->left, code, top + 1,Huffman);
    }

    if (root->right) {
        code[top] = '1';
        printCodes(root->right, code, top + 1,Huffman);
```

```
    }

    if (isLeaf(root)) {
        code[top] = '\0';
        printf("%c: %s\n", root->character, code);
        Huffman[index].character = root->character;
        strncpy(Huffman[index++].huffcode, code, sizeof(Huffman[i
ndex++].huffcode) - 1);
        }
}

void encode(Code* Huffman, char* sentence, int size,char* coding_
result)
{
     strcpy(coding_result, ""); // 将 coding_result 重置为空字符串
    int i=0;
//printf("%d",size);
    for(i=0;i<size;i++)
    {
        int j=0;
        for(j=0;j<26;j++)
        {
            if(sentence[i] == Huffman[j].character)
                strcat(coding_result, Huffman[j].huffcode);
        }
    }
    coding_result += '\0';
```

```
}

void add_char(char *str, char ch) {
    size_t len = strlen(str);
    if (len < sizeof(str) - 1) {  // 确保不会超出数组界限
        str[len] = ch;
        str[len + 1] = '\0';  // 确保字符串以 null 字符结尾
    }
}

void decode(char* decode_sentence,Node* root,char* encode_sentens
e)
{
       Node* current = root;
    decode_sentence[0] = '\0'; // 将 decode_sentence 重置为空字符串
    for (int i = 0; encode_sentense[i] != '\0'; i++) {
        if (encode_sentense[i] == '0') {
            current = current->left;
        } else {
            current = current->right;
        }

        // 如果到达叶子节点，打印字符并返回到根节点
        if (current->left == NULL && current->right == NULL) {
            add_char(decode_sentence,current->character);
            current = root; // 返回到根节点
        }
```

```
    }
}
//
int main() {
    char characters[] = { 'a', 'b', 'c', 'd', 'e', 'f' ,'g','h','i','j','k','l','m','n','o','p','q','r','s','t','u','v','w','x','y','z'};
    int frequencies[] = { 5, 9, 12, 13, 16, 45 ,43,33,23,68,23,12,46,82,23,25,34,14,13,64,43,59,8,3,63,25};
    int size = sizeof(characters) / sizeof(characters[0]);
    Code Huffman[size];
     char sentense[MAX_TREE_NODES];
    char encode_sentense[MAX_TREE_NODES] = {};
    char decode_sentense[MAX_TREE_NODES] = {};
    Node* root = NULL;
    buildHuffmanTree(characters, frequencies, size, &root);

    char code[MAX_TREE_NODES];
    printCodes(root, code, 0,Huffman);

    printf("请输入仅含小写的一串字母：");
    scanf("%s",sentense);

    encode(Huffman, sentense, strlen(sentense), encode_sentense);
    printf("encode\"%s\":%s\n", sentense, encode_sentense);

    decode(decode_sentense, root, encode_sentense);
```

```
    printf("decode:%s", decode_sentense);
    return 0;
}
```

算术编码及译码

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

#define MAX_SYMBOLS 256

typedef struct {
    char symbol;
    double probability;
    double cumulativeProbability;
} Symbol;

void calculateCumulativeProbabilities(Symbol symbols[], int count) {
    double cumulative = 0.0;
    for (int i = 0; i < count; ++i) {
        symbols[i].cumulativeProbability = cumulative;
        cumulative += symbols[i].probability;
    }
}

double encode(const char *input, Symbol symbols[], int count) {
    double low = 0.0, high = 1.0, range;
    printf("\nEncoding steps:\n");
```

```
    for (const char *p = input; *p; ++p) {
        for (int i = 0; i < count; ++i) {
            if (symbols[i].symbol == *p) {
                range = high - low;
                high = low + range * (symbols[i].cumulativeProbability
+ symbols[i].probability);
                low = low + range * symbols[i].cumulativeProbability;
                printf("Symbol: %c, Range: [%lf, %lf]\n", *p, low, high
);
                break;
            }
        }
    }
    return (high + low) / 2;
}

void decode(double code, int length, Symbol symbols[], int count, char
*output) {
    double low = 0.0, high = 1.0, range;
    for (int i = 0; i < length; ++i) {
        range = high - low;
        double value = (code - low) / range;
        for (int j = 0; j < count; ++j) {
            if (value >= symbols[j].cumulativeProbability && value < sy
mbols[j].cumulativeProbability + symbols[j].probability) {
                output[i] = symbols[j].symbol;
                high = low + range * (symbols[j].cumulativeProbability
```

```
+ symbols[j].probability);
                low = low + range * symbols[j].cumulativeProbability;
                break;
            }
        }
    }
    output[length] = '\0';
}

int main() {
    Symbol symbols[] = {
        {'a', 0.2}, {'b', 0.3}, {'c', 0.5}
    };
    int count = sizeof(symbols) / sizeof(symbols[0]);

    calculateCumulativeProbabilities(symbols, count);

    char input[100];
    printf("Enter a string to encode (only 'a', 'b', 'c' allowed): ");
    scanf("%s", input);

    double encoded = encode(input, symbols, count);
    printf("\nEncoded value: %lf\n", encoded);

    char decoded[100];
    decode(encoded, strlen(input), symbols, count, decoded);
    printf("Decoded string: %s\n", decoded);
```

```
    return 0;
}
```