



二、二叉树的遍历

1. 广度优先搜索(BFS)

- 从根结点开始，先访问所有结点的左子结点，再访问所有结点的右子结点。
- 二叉树的广度优先搜索算法实现。

```
void bfs(Node *root) //广度优先搜索
{
    head = tail = 0;
    Queue[tail++] = root;
    while(head<tail)
    {
        Node *node = Queue[head];
        cout << node->key << endl;
        if(node->lchild) Queue[tail++] = node->lchild;
        if(node->rchild) Queue[tail++] = node->rchild;
        head++;
    }
    return;
}
```

2. 深度优先搜索(DFS)

- 从根结点开始，先访问所有结点的左子结点，再访问所有结点的右子结点。
- 二叉树的深度优先搜索算法实现。

```
void dfs(Node *root) //深度优先搜索
{
    if(root == NULL) return;
    int start,end;
    tot += 1;
    start = tot;
    if(root->lchild) dfs(root->lchild); //访问左子结点
    if(root->rchild) dfs(root->rchild); //访问右子结点
    tot += 1;                                //访问当前结点
    end = tot;
    cout << root->key << endl;
    return;
}
```

3. 其他遍历方法

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 - 2^*i+1

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```
#include<bits/stdc++.h>
using namespace std;
void build_inorder_thread(Node *root)
{
    if(root == NULL) return ;
    if(root->ltag == 0) build_inorder_thread(root->lchild);
    if(inorder_root == NULL) inorder_root = root; //root
    //prenode->lchild = inorder_root
    if(root->lchild == NULL) //||
    {
        root->lchild = prenode;
        root->ltag = 1;
    }
    if(prenode && prenode->rchild == NULL) //||
    {
        prenode->rchild = root;
        prenode->rtag = 1;
    }
    prenode = root; //prenode->lchild = root
    //||
    if(root->rtag == 0) build_inorder_thread(root->rchild);
    return;
}

void __build_inorder_thread(Node *root)
{
    build_inorder_thread(root);
    prenode->rchild = NULL; //prenode->rchild = NULL
    prenode->rtag = 1;
}
```

```

        return;
    }

Node *getnext(Node *root)
{
if(root->rtag == 1) return root->rchild; //右子树根
    root = root->rchild;           //右子树根为root
    while(root->ltag == 0 && root->lchild) //若root->tag
        root = root->lchild; //左子树根
    {
        root = root->lchild;
    }
    return root;
}
int main()
{
    Node *node = inorder_root; //中序遍历根
    while(node)
    {
        cout << node->key << " ";
        node = getnext(node);
    }
    clear(root);
    return 0;
}

```

中序遍历二叉树，输出二叉树的中序遍历结果

输出结果

输出结果

```

#include<bits/stdc++.h>
using namespace std;
#define KEY(n) (n ? n->key : -1) //键值

typedef struct Node
{
    int key;
    struct Node *lchild,*rchild;
}Node;

Node *getnewnode(int key)
{
    Node *p = new Node;
    p->key = key;
    p->lchild = p->rchild = NULL;
    return p;
}

```

```

}

void clear(Node *root)
{
    if(root == NULL)  return ;
    clear(root->lchild);
    clear(root->rchild);
    delete root;
    return ;
}

Node *insert(Node *root,int key)
{
    if(root == NULL) return getnewnode(key);
    if(rand()%2) root->lchild = insert(root->lchild,key);
    else root->rchild = insert(root->rchild,key);
    return root;
}

Node *getranderbinarytree(int n)
{
    Node *root =NULL;
    for(int i = 0;i < n;i++)
    {
        root = insert(root,rand() % 100);
    }
    return root;
}

char buff[1000];
int len = 0; //����������

void __serialize(Node *root) //������������
{
    if(root == NULL) return;
    len += sprintf(buff + len ,"%d",root->key); //sprintf������������
    if(root->lchild == NULL && root->rchild == NULL) return;
    len += sprintf(buff + len , "(");
    __serialize(root->lchild);
    if(root->rchild)
    {
        len += sprintf(buff + len , ",");
        __serialize(root->rchild);
    }
    len += sprintf(buff + len , ")");
    return ;
}

void serialize(Node *root)
{
    memset(buff,0,sizeof(buff));
    len = 0;
}

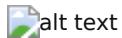
```

```
__serialize(root);
return;
}

void print(Node *node)
{
    printf("%d(%d,%d)\n",KEY(node),KEY(node->lchild),KEY(node->rchild));
    return ;
}

void output(Node *root)
{
    if(root == NULL) return;
    print(root);
    output(root->lchild);
    output(root->rchild);
    return;
}
int main()
{
    srand((unsigned)time(NULL));
#define n 10
    Node *root = getranderbinarytree(n);
    serialize(root);
    output(root);
    cout << buff << " " <<"\u25a0\u25a0\u25a0";
    clear(root);
    return 0;
}
```

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 - 亂数生成

```
#include<bits/stdc++.h>
using namespace std;
#define KEY(n) (n ? n->key : -1) //键值

typedef struct Node
{
    int key;
    struct Node *lchild,*rchild;
}Node;
```

```

Node *getnewnode(int key)
{
    Node *p = new Node;
    p->key = key;
    p->lchild = p->rchild = NULL;
    return p;
}

void clear(Node *root)
{
    if(root == NULL)  return ;
    clear(root->lchild);
    clear(root->rchild);
    delete root;
    return ;
}

Node *insert(Node *root,int key)
{
    if(root == NULL) return getnewnode(key);
    if(rand()%2) root->lchild = insert(root->lchild,key);
    else root->rchild = insert(root->rchild,key);
    return root;
}

Node *getranderbinarytree(int n)
{
    Node *root =NULL;
    for(int i = 0;i < n;i++)
    {
        root = insert(root,rand() % 100);
    }
    return root;
}
char buff[1000];
int len = 0; //����������

void __serialize(Node *root) //������������
{
    if(root == NULL) return;
    len += sprintf(buff + len ,"%d",root->key); //sprintf������������
    if(root->lchild == NULL && root->rchild == NULL) return;
    len += sprintf(buff + len , "(");
    __serialize(root->lchild);
    if(root->rchild)
    {
        len += sprintf(buff + len , ",");
        __serialize(root->rchild);
    }
    len += sprintf(buff + len , ")");
    return ;
}

```

```

}

void serialize(Node *root)
{
    memset(buff,0,sizeof(buff));
    len = 0;
    __serialize(root);
    return;
}

Node *deserialize(char *buff,int n)
{
    Node **s = (Node **)malloc(sizeof(Node *) * 100);
    int top = -1,flag = 0,scode = 0; //scode:0=数字,1=左括号,2=右括号,3=逗号,4=空格
    Node *p = NULL , *root =NULL;
    for(int i = 0 ; buff[i];i++)
    {
        switch(scode)
        {
            case 0:
                {
                    if(buff[i] >= '0' && buff[i] <= '9') scode = 1;
                    else if(buff[i] == '(') scode = 2;
                    else if(buff[i] == ',') scode = 3;
                    else scode = 4;
                    i -= 1;
                }
                break;
            case 1:
                {
                    int num = 0;
                    while(buff[i] <= '9' && buff[i] >= '0')
                    {
                        num = num * 10 +(buff[i] - '0');
                        i += 1;
                    }
                    p = getnewnode(num);
                    if(top >= 0 && flag == 0) s[top]->lchild = p;
                    if(top >= 0 && flag == 1) s[top]->rchild = p;
                    i -= 1; //num[i]到num[i+1]的长度为i+1-i=1
                    scode = 0;
                }
                break;
            case 2:
                {
                    s[++top] = p;
                    flag = 0;
                    scode = 0;
                }
        }
    }
}

```

```

        break;
    case 3:
    {
        flag = 1;
        scode = 0;
    }
    break;
    case 4:
    {
        root = s[top--];
        scode = 0;
    }
    break;
}
return root;
}

void print(Node *node)
{
    printf("%d(%d,%d)\n",KEY(node),KEY(node->lchild),KEY(node->rchild));
    return ;
}

void output(Node *root)
{
    if(root == NULL) return;
    print(root);
    output(root->lchild);
    output(root->rchild);
    return;
}
int main()
{
    srand((unsigned)time(NULL));
#define n 10
    Node *root = getranderbinarytree(n);
    serialize(root);
    output(root);
    cout << buff << " " <<"\0\0\0";
    Node *new_root = deserialize(buff,len);
    output(new_root);
    clear(root);
    return 0;
}

```

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```

#include<bits/stdc++.h>
using namespace std;
typedef struct Node
{
    int freq;
    char ch;
    struct Node *lchild,*rchild;
}Node;

Node *getnewnode(int freq,char ch)
{
    Node *p = new Node;
    p->ch = ch;
    p->freq = freq;
    p->lchild = p->rchild = NULL;
    return p;
}

void swap_node(Node **node_arr,int i,int j)
{
    Node *temp = node_arr[i];
    node_arr[i] = node_arr[j];
    node_arr[j] = temp;
    return;
}

int find_min_node(Node **node_arr,int n)
{
    int ind = 0;
    for(int j = 1;j <= n;j++)
    {
        if(node_arr[ind]->freq > node_arr[j]->freq) ind = j;
    }
    return ind;
}
//████████████████████
Node *buildhaffmantree(Node **node_arr,int n)
{
    for(int i = 1;i < n;i++)
    {
        int ind1 = find_min_node(node_arr,n - i);
        swap_node(node_arr,ind1,n-i); //████████████████████
        int ind2 = find_min_node(node_arr,n - i - 1);
        swap_node(node_arr ,ind2,n - i - 1);
        int freq = node_arr[n - i]->freq + node_arr[n - i - 1]->freq;
        Node *node = getnewnode(freq , 0);
        node->lchild = node_arr[n - i];
        node->rchild = node_arr[n- i - 1];
        node_arr[n - i - 1] = node;
    }
}

```

```

        return node_arr[0];
    }

void extracthaffmancode(Node *root ,char buff[],int k)
{
    buff[k] = 0;
    if(root->lchild == NULL && root->rchild == NULL)
    {
        cout << root->ch << buff << endl;
        return ;
    }
    buff[k] = '0';
    extracthaffmancode(root->lchild,buff,k+1);
    buff[k] = '1';
    extracthaffmancode(root->rchild,buff,k+1);
    return ;
}
void clear(Node *root)
{
    if(root = NULL) return ;
    clear(root->lchild);
    clear(root->rchild);
    delete root;
    return ;
}

int main()
{
    int n,freq;
    char s[10];
    cin >> n;
    Node **node_arr = new Node *[n];
    for(int i = 0;i < n;i++)
    {
        cin >> s >> freq;
        node_arr[i] = getnewnode(freq,s[0]);
    }
    Node *root = buildhaffmantree(node_arr,n);
    char buff[1000];
    extracthaffmancode(root,buff,0);
    clear(root);
    return 0;
}

```

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/* // Definition for a Node. class Node { public: int val; vector<Node*> children;

```

Node() {}

Node(int _val) {
    val = _val;
}

Node(int _val, vector<Node*> _children) {
    val = _val;
    children = _children;
}

};

*/

```

class Solution {

public:

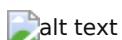
```

vector<int> preorder(Node* root) {
    if(root == NULL) return vector<int>();
    vector<int> ans;
    ans.push_back(root->val);
    for(auto x: root->children)
    {
        vector<int> temp = preorder(x);
        for(auto y : temp) ans.push_back(y);
    }
    return ans;
}

```

};

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```

class Solution {
public:
    TreeNode* buildTree(vector<int>& preorder, vector<int>& inorder) {
        if(preorder.size() == 0) return NULL;
        int pos = 0;
        while(inorder[pos] != preorder[0]) pos += 1;
        TreeNode *root = new TreeNode(preorder[0]);
        vector<int> pre , in;
        for(int i = 1;i <= pos;i++) pre.push_back(preorder[i]);
        for(int i = 0;i <= pos - 1;i++) in.push_back(inorder[i]);
        root->left = buildTree(pre,in);
        pre.clear();
        in.clear();
    }
};

```

```

        for(int i = pos + 1;i < preorder.size();i++)
    {
        pre.push_back(preorder[i]);
        in.push_back(inorder[i]);
    }
    root->right = buildTree(pre,in);
    return root;
}
};

```

二叉树的遍历

alt text

二叉树

```

class Solution {
public:
    vector<vector<int>> levelOrder(TreeNode* root) {
        if(root == NULL) return vector<vector<int>>();
        TreeNode *node;
        queue<TreeNode *> q;
        q.push(root);
        vector<vector<int>> ans;
        while(!q.empty())
        {
            int cnt = q.size();
            vector<int> temp;
            for(int i = 0;i < cnt;i++)
            {
                node = q.front();
                temp.push_back(node->val);
                if(node->left) q.push(node->left);
                if(node->right) q.push(node->right);
                q.pop();
            }
            ans.push_back(temp);
        }
        return ans;
    }
};

```

二叉树

- 二叉树的遍历
- 二叉树的层次遍历

```

class Solution {
    void dfs(TreeNode *root,int k,vector<vector<int>> &ans)
    {
        if(root == NULL) return ;

```

```
        if(k == ans.size()) ans.push_back(vector<int>());
        ans[k].push_back(root->val);
        dfs(root->left,k+1,ans);
        dfs(root->right,k+1,ans);
    return ;
}
public:
vector<vector<int>> levelOrder(TreeNode* root) {
vector<vector<int>> ans;
dfs(root,0,ans);
return ans;
}
};
```

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-   
 -  C++  swap 

```
class Solution {
public:
    TreeNode* invertTree(TreeNode* root) {
        if(root == NULL) return NULL;
        swap(root->right,root->left);
        invertTree(root->left);
        invertTree(root->right);
        return root;
    }
};
```

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```
class Solution {
public:
    void dfs(TreeNode *root,int k,vector<vector<int>> &ans)
    {
        if(root == NULL) return;
        if(k == ans.size()) ans.push_back(vector<int>());
        ans[k].push_back(root->val);
        dfs(root->left,k+1,ans);
        dfs(root->right,k+1,ans);
        return ;
    }
    vector<vector<int>> levelOrderBottom(TreeNode* root){
        vector<vector<int>> ans;
        dfs(root,0,ans);
        reverse(ans.begin(),ans.end());
        return ans;
    }
};
```

```
        for(int i = 0,j = ans.size()-1;i < j;i++,j--)  
        {  
            swap(ans[i],ans[j]);  
        }  
    return ans;  
}  
};
```

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```
class Solution {
public:
    void dfs(TreeNode *root,int k,vector<vector<int>> &ans)
    {
        if(root == NULL) return;
        if(k == ans.size()) ans.push_back(vector<int>());
        ans[k].push_back(root->val);
        dfs(root->left,k+1,ans);
        dfs(root->right,k+1,ans);
        return ;
    }
    vector<vector<int>> zigzagLevelOrder(TreeNode* root){
        vector<vector<int>> ans;
        dfs(root,0,ans);
        for(int k = 1;k < ans.size();k+=2)
        {
            for(int i = 0,j = ans[k].size()-1;i < j;i++,j--)
                swap(ans[k][i],ans[k][j]);
        }
        return ans;
    }
};
```

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alt text



- `pair`
 - `set`
 - `set<pair>`
 - `n-1`

```
#include<bits/stdc++.h> //\u4e0e\u4e89 \u4e0eoj287
using namespace std;
typedef pair<int,int> PII;
int main()
```

```

{
    int n;
    set<PII> s;
    cin >> n;
    for(int i = 0,a;i < n;i++)
    {
        cin >> a;
        s.insert(PII(a,i));
    }
    int ans = 0;
    for(int i = 1;i < n;i++)
    {
        int a = s.begin()->first;
        s.erase(s.begin());
        int b = s.begin()->first;
        s.erase(s.begin());
        ans += a+b;
        s.insert(PII(a + b,n + i));
    }
    cout << ans;
    return 0;
}

```

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$P(X \leq x) - P(X < x) = Q - P$, $P(X > x) - P(X \geq x) = P - Q$

```
#include<bits/stdc++.h> //oj245 1000
using namespace std;
int main()
{
    int n;
    vector<int> arr;
    cin >> n;
    for(int i = 0,a;i < n;i++)
    {
        cin >> a;
        arr.push_back(a);
    }
    sort(arr.begin(),arr.end());
    int p = arr[n/2],ans = 0;//n/2
    for(int i = 0;i < n;i++)
    {
        ans += abs(arr[i] - p);
    }
    cout << ans;
}
```

```
    return 0;  
}
```