

Trees - Part 1

- Karun Karthik

Contents

0. Introduction
1. Max depth of Binary tree
2. Max depth of N-ary tree
3. Preorder of binary tree
4. Preorder of N-ary tree
5. Postorder of binary tree
6. Postorder of N-ary tree
7. Inorder of Binary tree
8. Merge two binary trees
9. Sum of root to leaf paths
10. Uni-valued Binary tree
11. Leaf similar trees
12. Binary tree paths
13. Sum of Left leaves
14. Path sum
15. Left view of Binary tree
16. Right view of Binary tree
17. Same tree
18. Invert Binary tree
19. Symmetric tree
20. Cousins of Binary tree

Trees

why trees?

Tree - collection of tree-nodes

① class Treenode

```

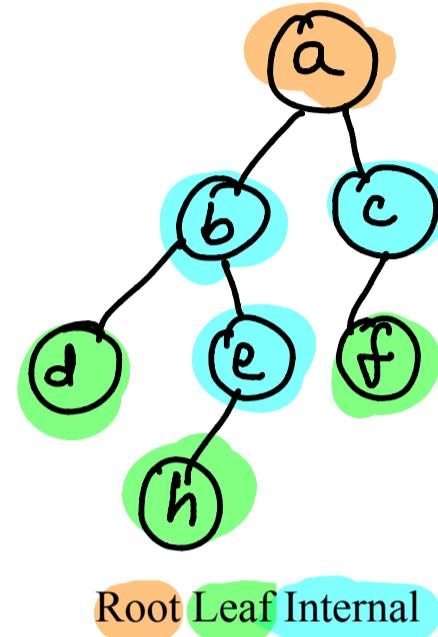
    ↴ data
    ↴ list<Treenode> children
  
```

② Binary Tree → almost 2 children (0,1,2)

```

    ↴ data
    ↴ leftchild
    ↴ rightchild
  
```

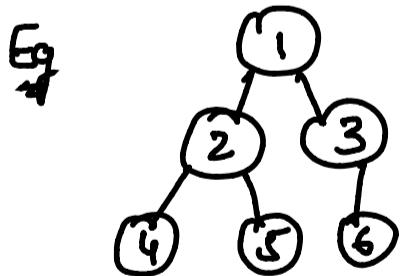
1. Hierarchy
2. Computer system (UNIX)



③ Types →

A) Complete Binary Tree

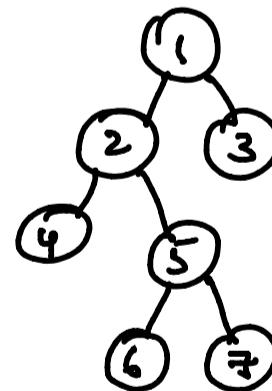
↳ all levels are completely filled except last one



C) Full Binary tree

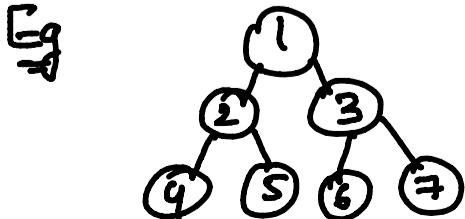
↳ if every node has 0 or 2 children

Eg



B) Perfect Binary Tree

↳ every internal node has exactly 2 children

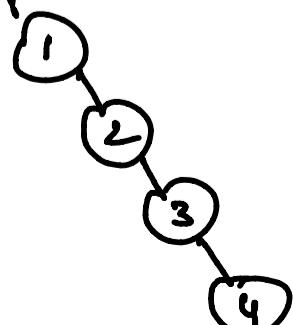


D) Skewed Binary Tree

(* used for finding complexity)

↳ all nodes have either one or no child.

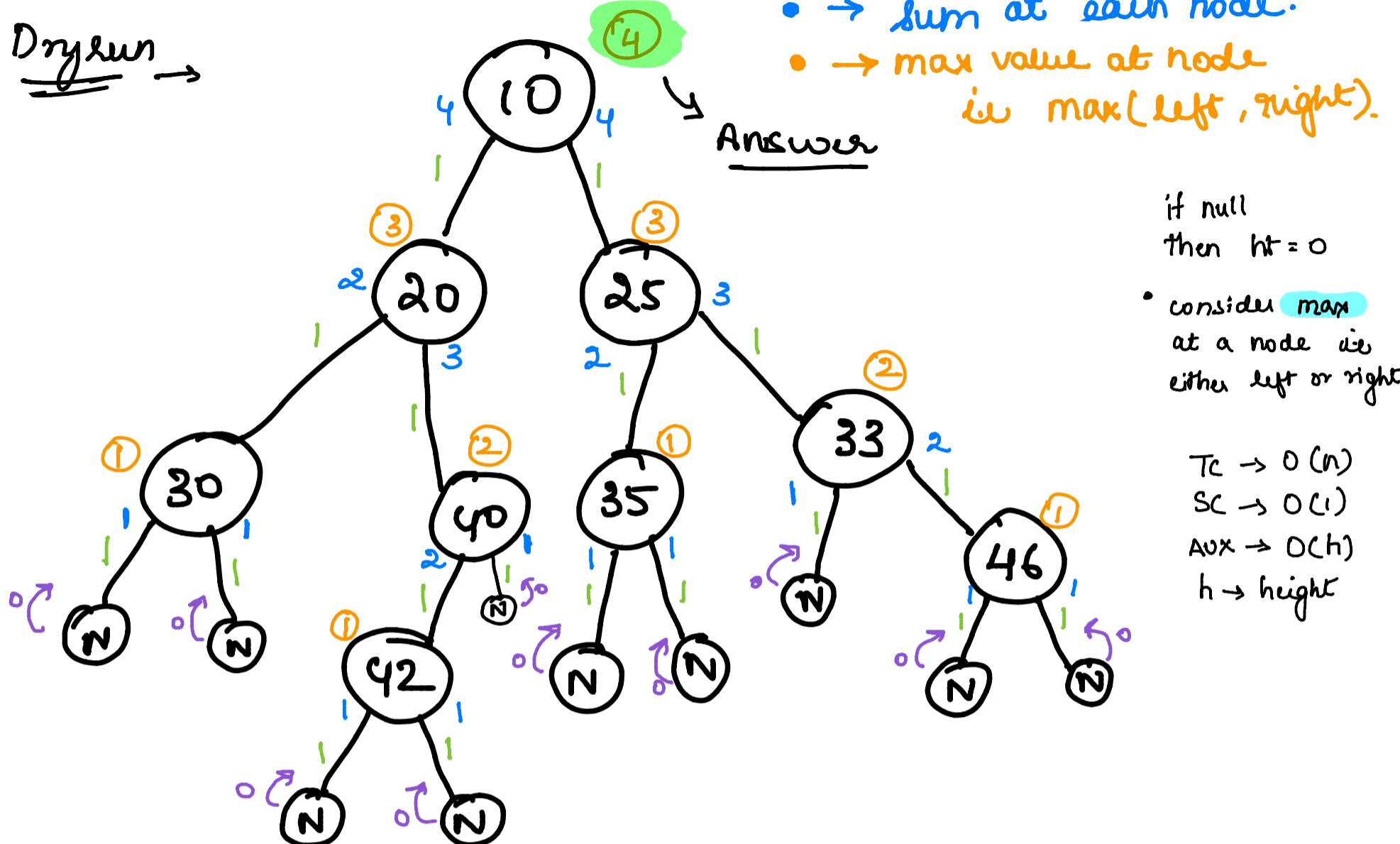
Eg



D1

① Depth of a binary tree (Max depth)

Dry run →



- 1 added while returning.
- sum at each node.
- max value at node is $\max(\text{left}, \text{right})$.

if null
then ht = 0

- consider max
at a node is
either left or right

Tc → O(n)

Sc → O(1)

Aux → O(h)

h → height

Code →

```
C++ v
/*
 * Definition for a binary tree node.
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode() : val(0), left(nullptr), right(nullptr) {}
 *     TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
 *     TreeNode(int x, TreeNode *left, TreeNode *right) : val(x), left(left), right(right) {}
 * };
 */
class Solution {
public:
    int maxDepth(TreeNode* root) {
        if(root == NULL) return 0;

        int lefth= 1+ maxDepth(root->left);
        int righth = 1+maxDepth(root->right);
        return max(lefth,righth);
    }
};
```

2

Maximum depth of n-ary tree

Idea is same as previous problem, only implementation changes

Code →

```
C++ ▾

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

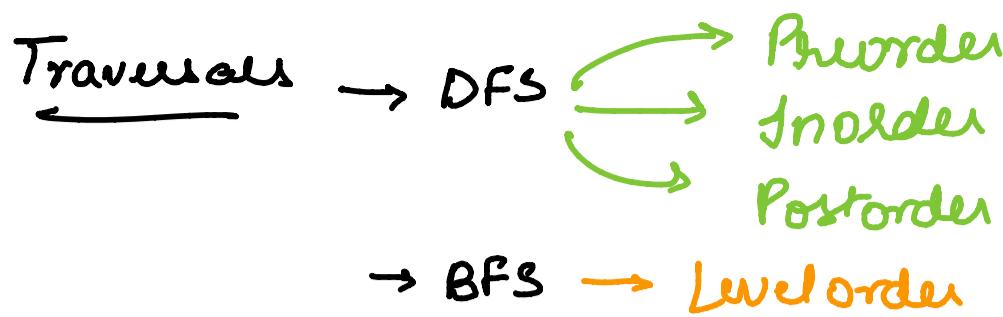
    Node() {}

    Node(int _val) {
        val = _val;
    }

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

class Solution {
public:
    int maxDepth(Node* root) {
        if(root==NULL) return 0;
        int ans=0;
        for(int i=0;i<root->children.size();i++)
        {
            int tempans = maxDepth(root->children[i]);
            ans = max(ans,tempans);
        }
        return ans+1;
    }
};
```

D2



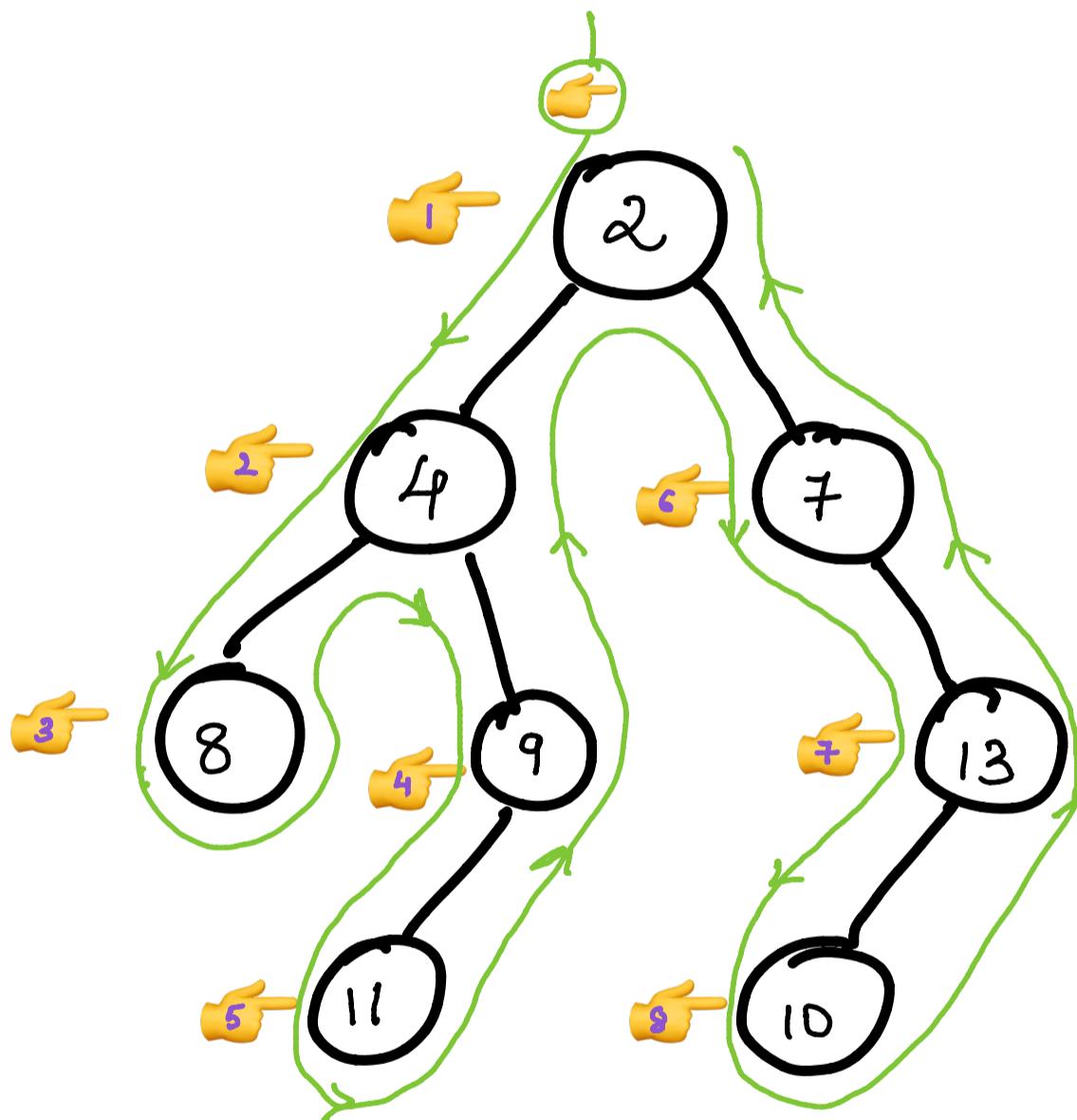
Q4

Preorder →

processing order

node
left child
right child

Eg



* Point fingers as shown
and traverse the
tree starting from Root

* Order of visiting is the
preorder traversal.

Tc → O(n)

Sc → O(n)

~~[2, 4, 8, 9, 11, 6, 13, 10]~~

Recursive Stack space → O(h) h → height.

③ Pre-order traversal of Binary tree

```
class Solution {
public:
    vector<int> preorderTraversal(TreeNode* root) {
        vector<int>ans;
        Preorder(root,ans);
        return ans;
    }
    void Preorder(TreeNode* root,vector<int>&ans)
    {
        if(root == NULL) return;
        ans.push_back(root->val);
        Preorder(root->left,ans);
        Preorder(root->right,ans);
        return;
    }
};
```

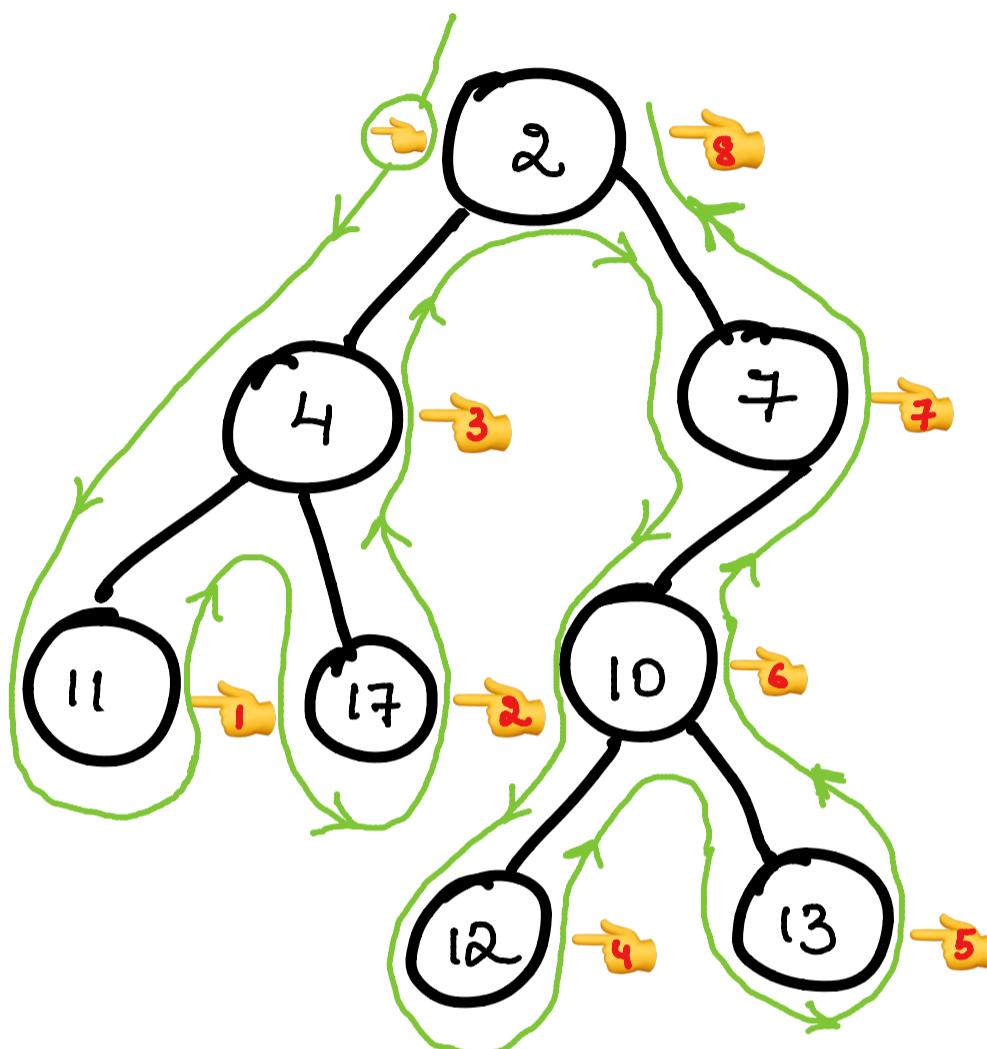
④ Pre-order traversal of n-ary tree

```
class Solution {
public:
    vector<int> preorder(Node* root) {
        vector<int>ans;
        Preorder(root,ans);
        return ans;
    }
    void Preorder(Node* root, vector<int>&ans)
    {
        if(root==NULL) return;
        ans.push_back(root->val);
        for(int i=0;i<root->children.size();i++)
        {
            Preorder(root->children[i],ans);
        }
        return;
    }
};
```

(B) Postorder →
processing order

left child
right child
node

Eg



* Point finger as shown
and traverse the
tree starting from Root

* Order of visiting is the
postorder traversal.

Tc → O(n)

SC → O(n)

~~[11, 17, 4, 12, 13, 10, 7, 2]~~

Recursive Stack space → O(h) h → height .

⑤ Postorder traversal of Binary tree

```
class Solution {
public:
    vector<int> postorderTraversal(TreeNode* root) {
        vector<int>ans;
        Postorder(root,ans);
        return ans;
    }
    void Postorder(TreeNode* root, vector<int>&ans)
    {
        if(root == NULL) return;

        Postorder(root->left,ans);
        Postorder(root->right,ans);
        ans.push_back(root->val);
        return;
    }
};
```

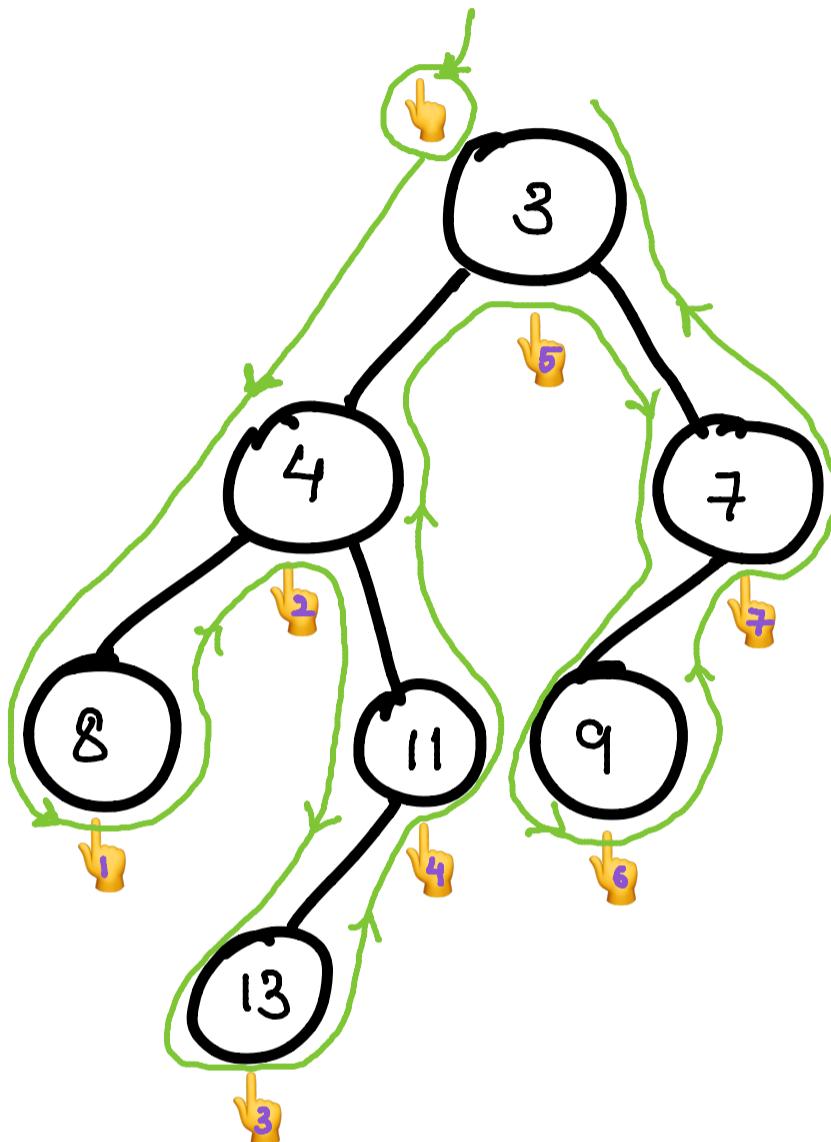
⑥ Postorder traversal of nary tree

```
class Solution {
public:
    vector<int> postorder(Node* root) {
        vector<int>ans;
        Postorder(root,ans);
        return ans;
    }
    void Postorder(Node* root, vector<int>&ans)
    {
        if(root == NULL) return;
        for(int i=0;i<root->children.size();i++)
        {
            Postorder(root->children[i],ans);
        }
        ans.push_back(root->val);
        return;
    }
};
```

(c) Inorder →

processing order →
 left child
 node
 right child

Eg



* Point fingers as shown
 and traverse the
 tree starting from Root

* Order of visiting is the
 Inorder traversal.

↙ [8, 4, 13, 11, 3, 9, 7]

Tc → O(n)

Sc → O(n)

Recursive Stack space → O(h) h → height .

7

In-order traversal of Binary tree

```
class Solution {
public:
    vector<int> inorderTraversal(TreeNode* root) {
        vector<int> ans;
        Inorder(root, ans);
        return ans;
    }
    void Inorder(TreeNode* root, vector<int>& ans)
    {
        if (root == NULL) return;
        Inorder(root->left, ans);
        ans.push_back(root->val);
        Inorder(root->right, ans);
        return;
    }
};
```

In-order traversal of n-ary tree

Approach:

The inorder traversal of an N-ary tree is defined as visiting all the children except the last then the root and finally the last child recursively.

- Recursively visit the first child.
- Recursively visit the second child.
-
- Recursively visit the second last child.
- Print the data in the node.
- Recursively visit the last child.
- Repeat the above steps till all the nodes are visited.

```
void inorder(Node *node)
{
    if (node == NULL)
        return;

    // Total children count
    int total = node->length;

    // All the children except the last
    for (int i = 0; i < total - 1; i++)
        inorder(node->children[i]);

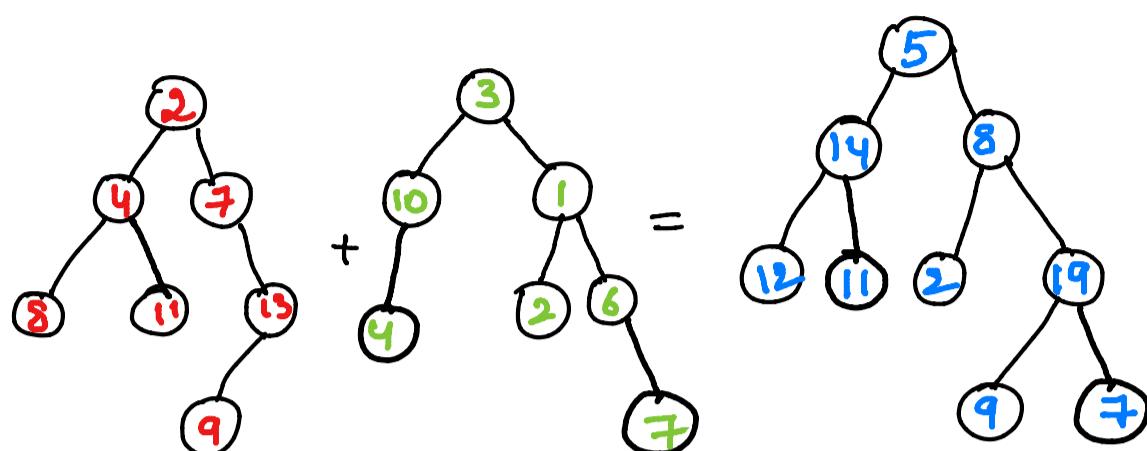
    // Print the current node's data
    cout << node->data << " ";

    // Last child
    inorder(node->children[total - 1]);
}
```

D3 (8) Merge two Binary trees →

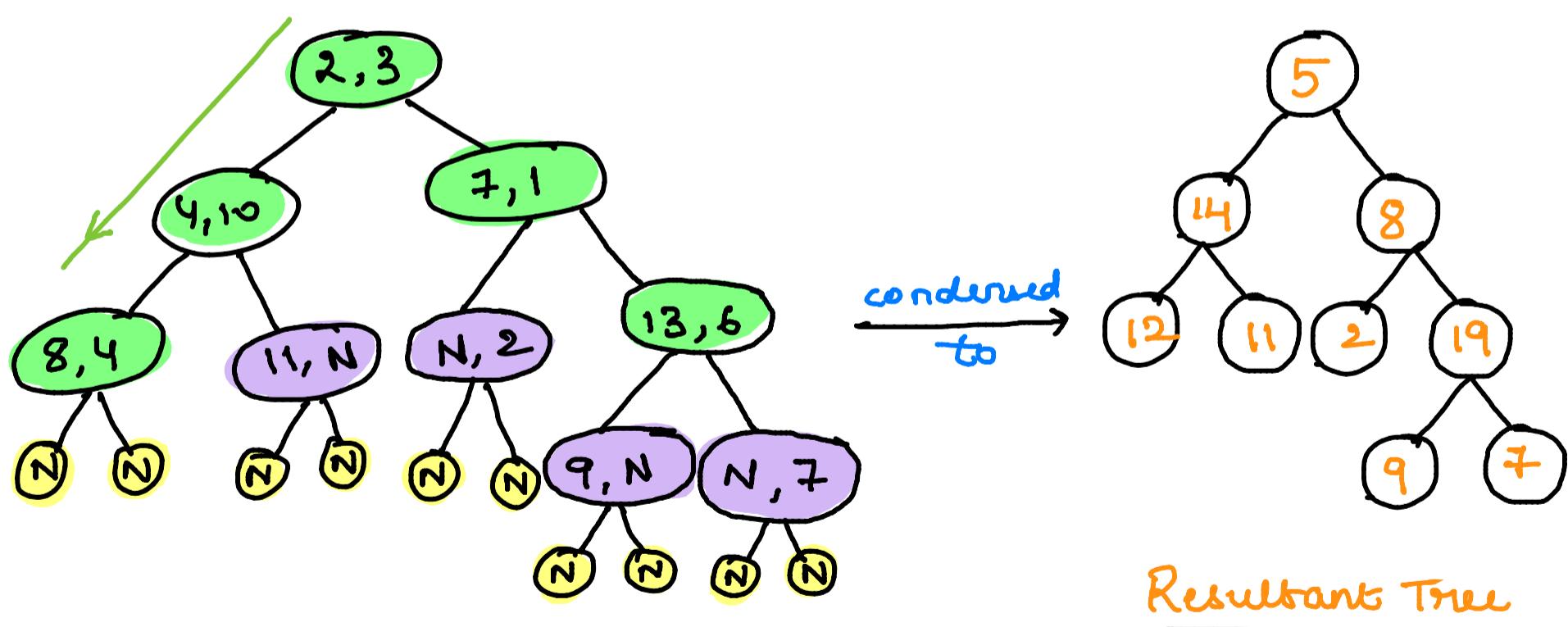
Given root nodes of 2 binary trees, return root of the sum tree

Eg



we will perform preorder traversal on the binary tree because the node/root needs to be processed first.

The recursive tree structure would be like :



Resultant Tree

- NULL & NULL
- Node & NULL
- Node & Node

TC → O(n+m)

SC → O(max(n,m))

Recursive stack → O(max(h₁, h₂))

Code →

```
class Solution {
public:
    TreeNode* merge(TreeNode* root1, TreeNode* root2){

        if(root1==NULL && root2==NULL)  return NULL;
        if(root1==NULL) return root2;
        if(root2==NULL) return root1;

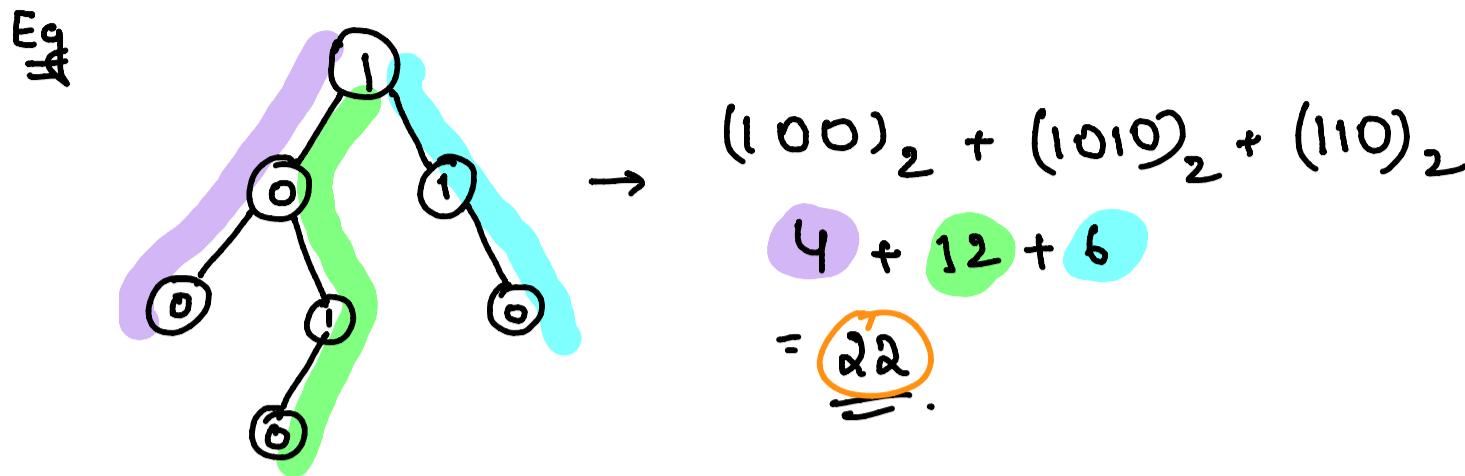
        // Create new node to store sum
        TreeNode *newNode = new TreeNode(root1->val+root2->val);

        // Recursively call the left sub-trees and right sub-trees
        newNode->left = merge(root1->left, root2->left);
        newNode->right = merge(root1->right, root2->right);

        // return the new node
        return newNode;
    }

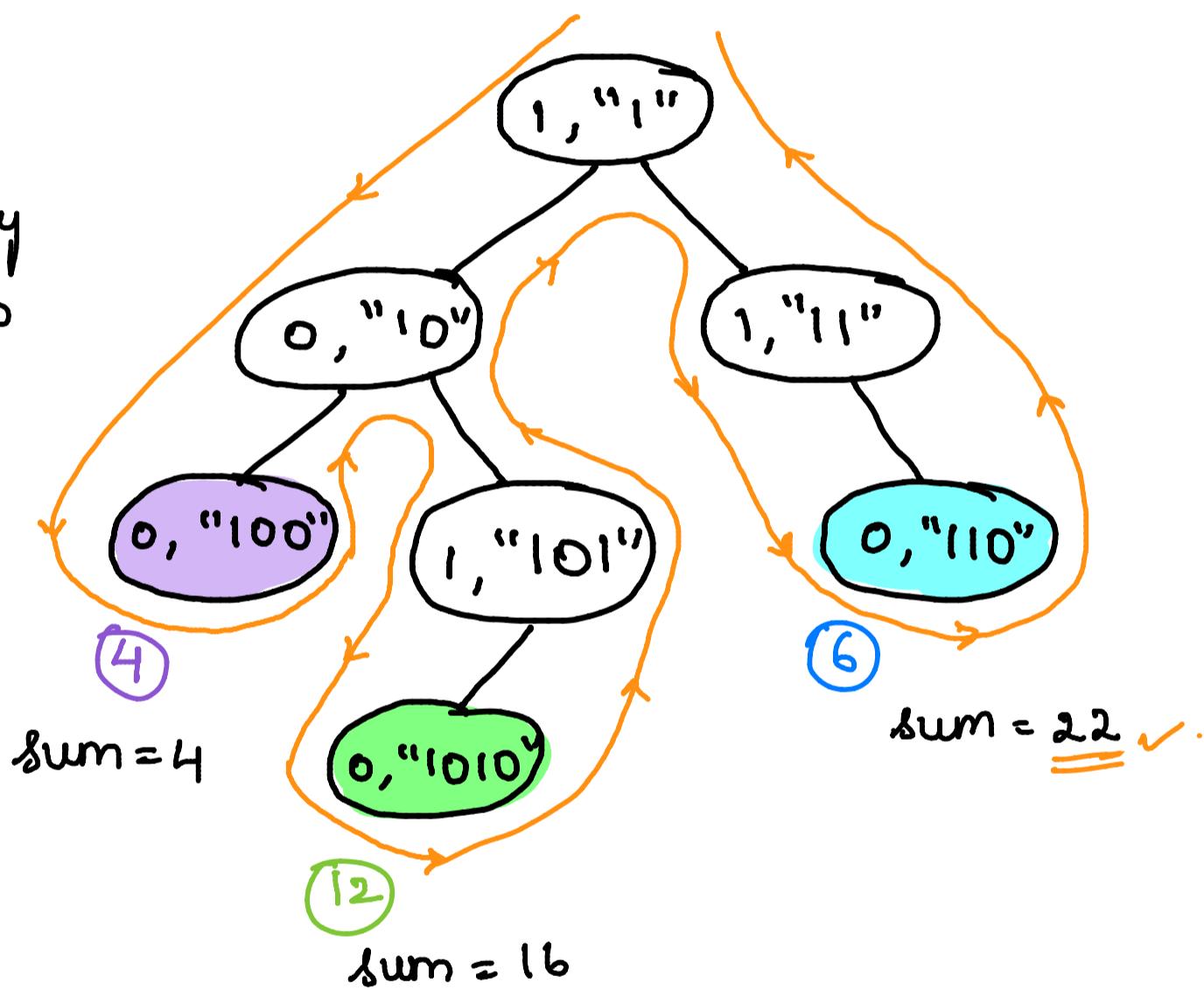
    TreeNode* mergeTrees(TreeNode* root1, TreeNode* root2) {
        return merge(root1, root2);
    }
};
```

Q) Sum of root to leaf paths →



=

Initially
 $\text{sum} = 0$



* If root becomes null convert string to integer & add to sum.

Time → O(n)

Space → O(n)

Recursive stack → O(h)

Code

```
class Solution {
public:
    void rootToLeaf(TreeNode* root, string currentString,int* ans)
    {
        if(root->left== NULL && root->right==NULL)
        {
            currentString+=to_string(root->val);
            ans[0]+=stoi(currentString,0,2);
            return;
        }
        string curr=to_string(root->val);
        if(root->left!=NULL)
            rootToLeaf(root->left,currentString+curr,ans);
        if(root->right!=NULL)
            rootToLeaf(root->right,currentString+curr,ans);

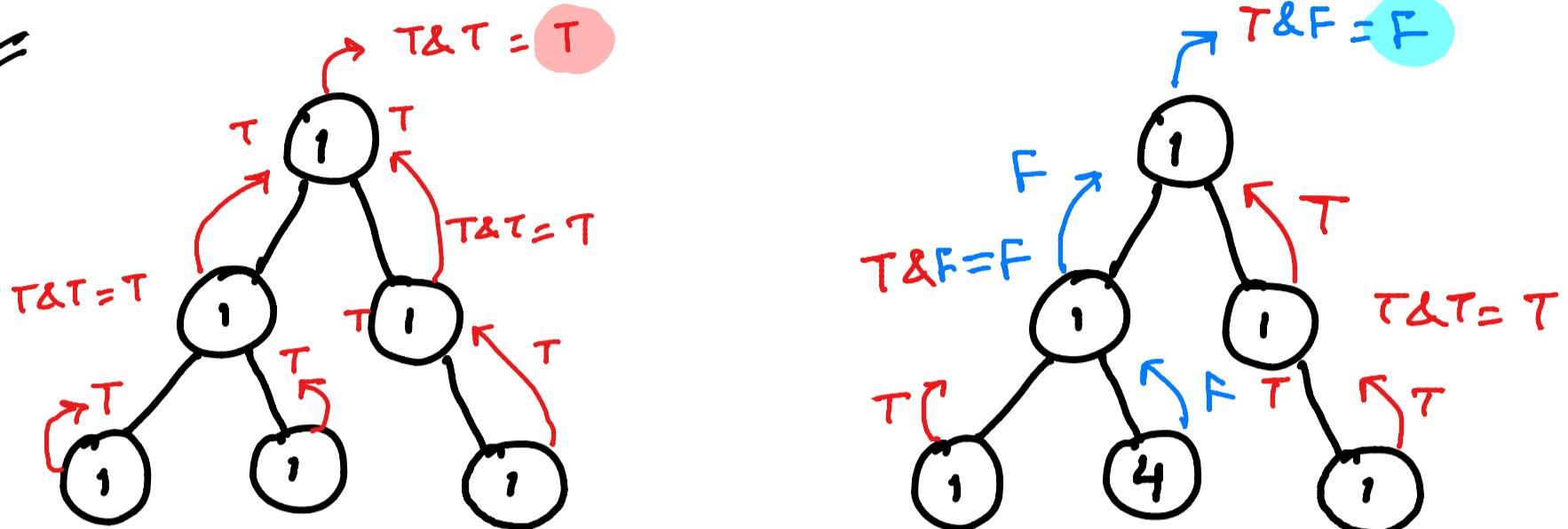
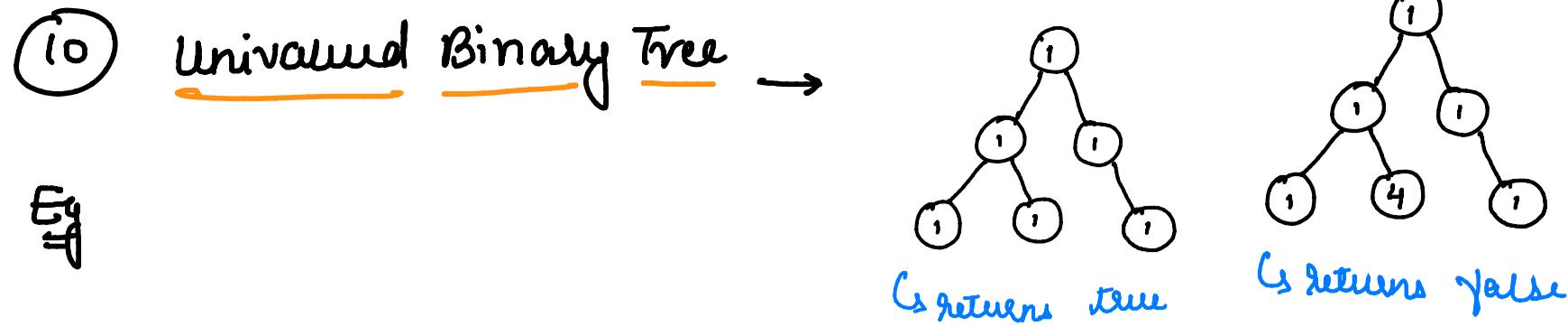
    }
    int sumRootToLeaf(TreeNode* root) {
        int* ans=new int[1];
        ans[0]=0;
        rootToLeaf(root,"",ans);
        return ans[0];
    }
};
```

Note →

stoi() can take upto three parameters, the second parameter is for starting index and third parameter is for base of input number.



[to convert from binary to decimal we give it as 2.]



Code

```
class Solution {
public:
    bool isSame(TreeNode* root, int val){
        if(root==NULL) return true;
        if(root->val!=val) return false;

        bool left = isSame(root->left, val);
        bool right = isSame(root->right, val);

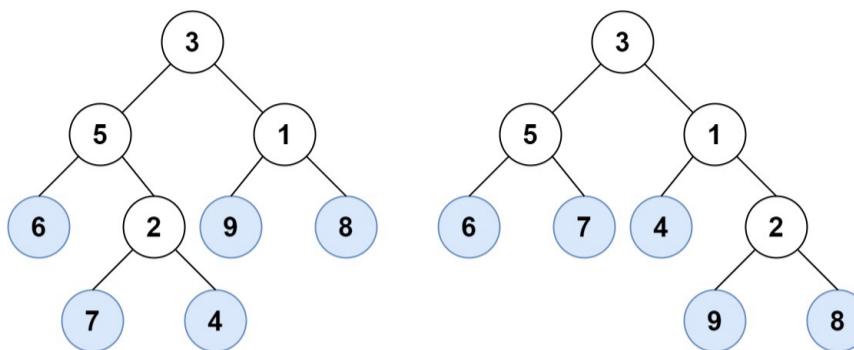
        return left && right;
    }

    bool isUnivalTree(TreeNode* root) {
        return isSame(root, root->val);
    }
};
```

⑪ Leaf Similar trees

→ return true if all leaves are in same order for both trees.

Eg



$$V_1 = 6, 7, 4, 9, 8 \quad \Rightarrow \quad V_1 = V_2$$

$$V_2 = 6, 7, 4, 9, 8 \quad \text{↳ returns true else false.}$$

Code →

```
class Solution {
public:
    void traversal(TreeNode* root, vector<int>&v){
        if(root==NULL)
            return;

        if(root->left==NULL && root->right==NULL)
            v.push_back(root->val);

        if(root->left!=NULL)
            traversal(root->left, v);

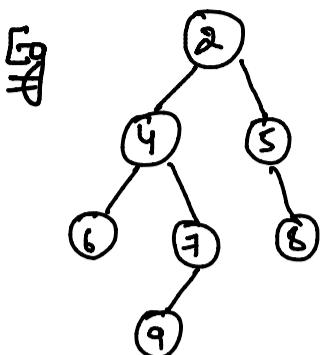
        if(root->right!=NULL)
            traversal(root->right, v);
    }

    bool leafSimilar(TreeNode* root1, TreeNode* root2) {
        vector<int> a;
        vector<int> b;
        traversal(root1,a);
        traversal(root2,b);
        return a==b;
    }
};
```

DS

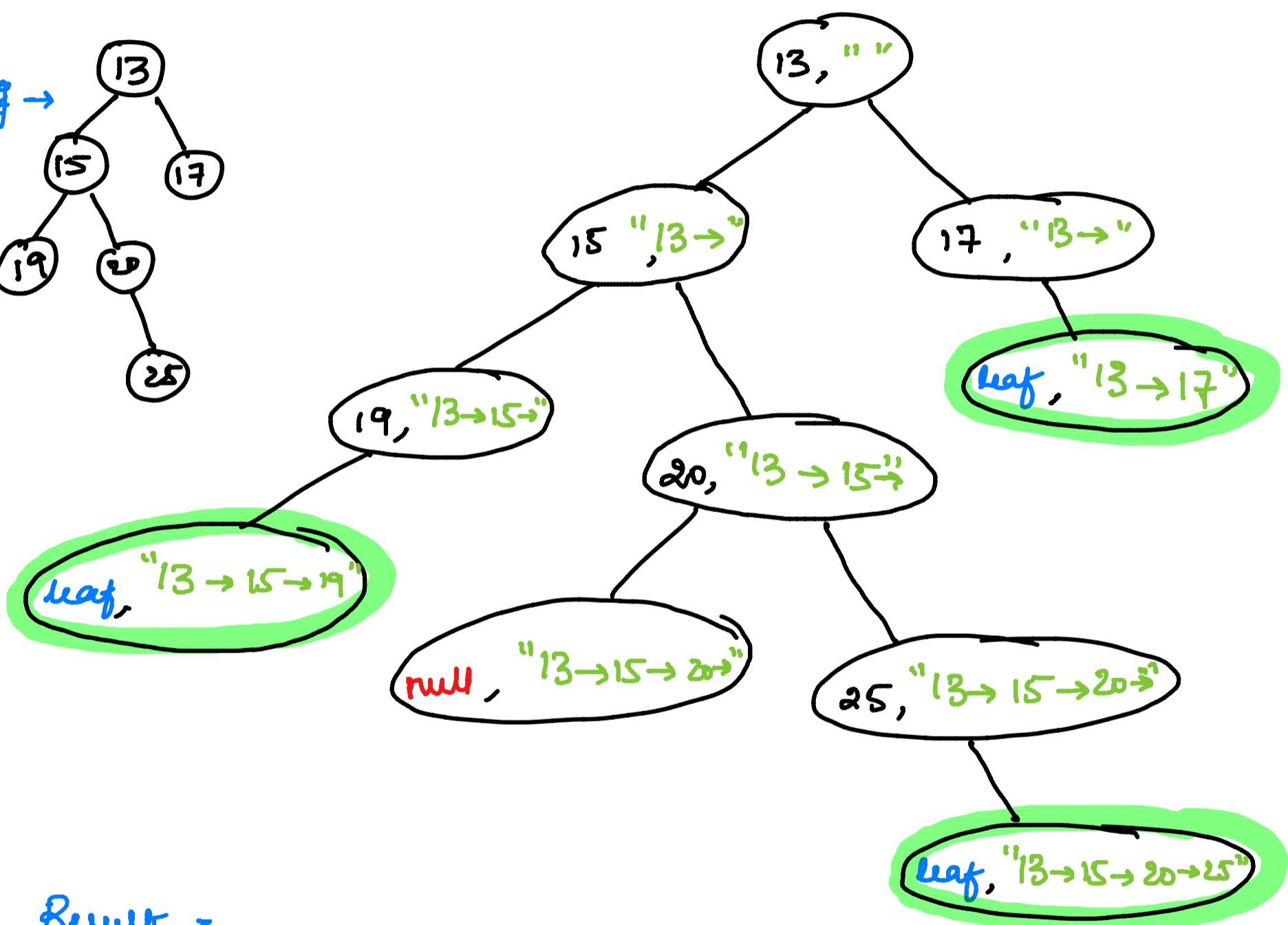
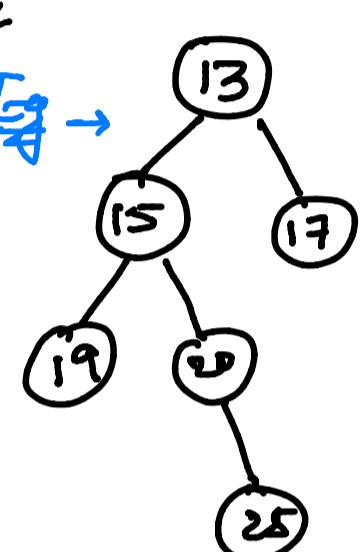
12 Binary tree paths

Given root print all the paths from root to leaf



$\Rightarrow ["2 \rightarrow 4 \rightarrow 6", "2 \rightarrow 4 \rightarrow 7 \rightarrow 9", "2 \rightarrow 5 \rightarrow 8"]$

==



Result =

$["13 \rightarrow 15 \rightarrow 19", "13 \rightarrow 15 \rightarrow 20 \rightarrow 25", "13 \rightarrow 17"]$

Time complexity = $O(n)$

Space complexity = $O(\alpha) + O(h)$ → recursive stack.
 ↴ Answer array

Code →

```
class Solution {
public:
    void pathFinder(TreeNode *root, vector<string> &res, string currPath){

        if(root==NULL)  return;

        // if leaf then add it's value to currentPath
        if(root->left == NULL && root->right==NULL){
            currPath += to_string(root->val);
            res.push_back(currPath);
            return;
        }

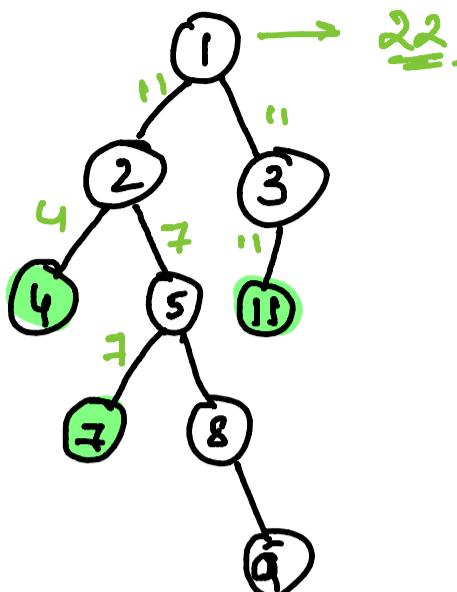
        // else add the node's value to path
        currPath += to_string(root->val)+"->";

        if(root->left)  pathFinder(root->left, res, currPath);
        if(root->right) pathFinder(root->right, res, currPath);
    }

    vector<string> binaryTreePaths(TreeNode* root) {
        vector<string> res;
        pathFinder(root, res, "");
        return res;
    }
};
```

(13) sum of left leaves →

Eg

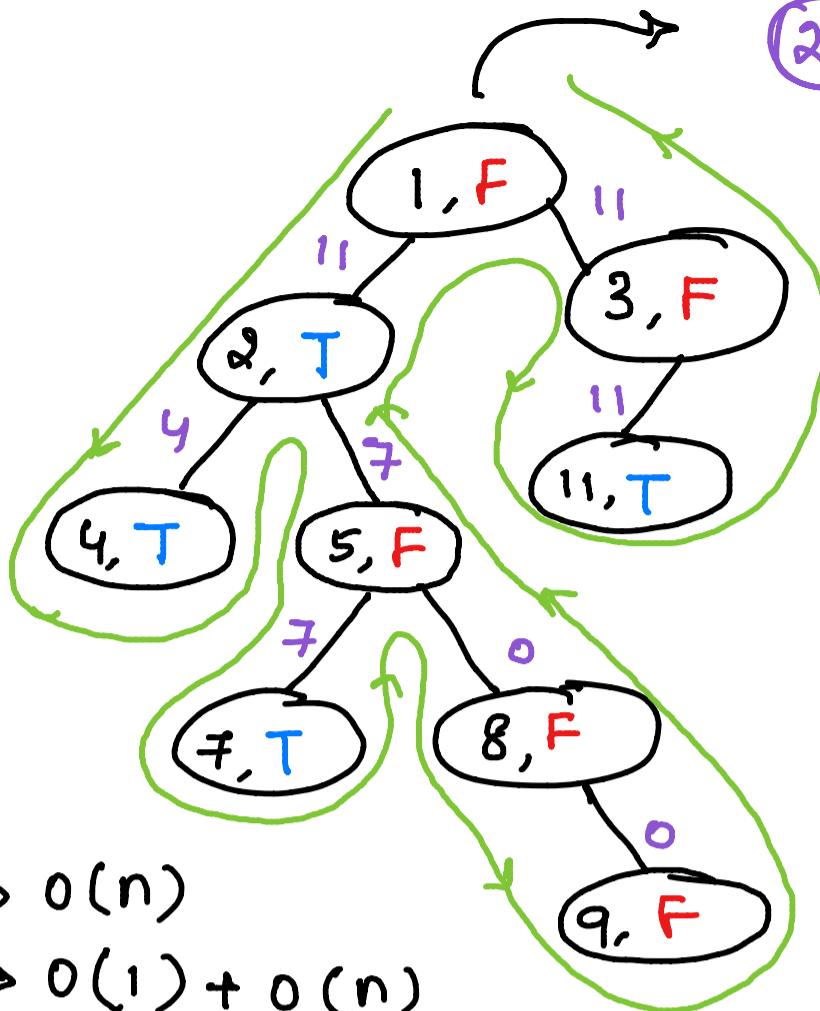


$$\text{Result} = 4 + 7 + 11 \\ = \underline{\underline{22}}.$$

$$Tc \rightarrow O(n) \\ Sc \rightarrow O(1) + O(n)$$

L → Stack

(22)



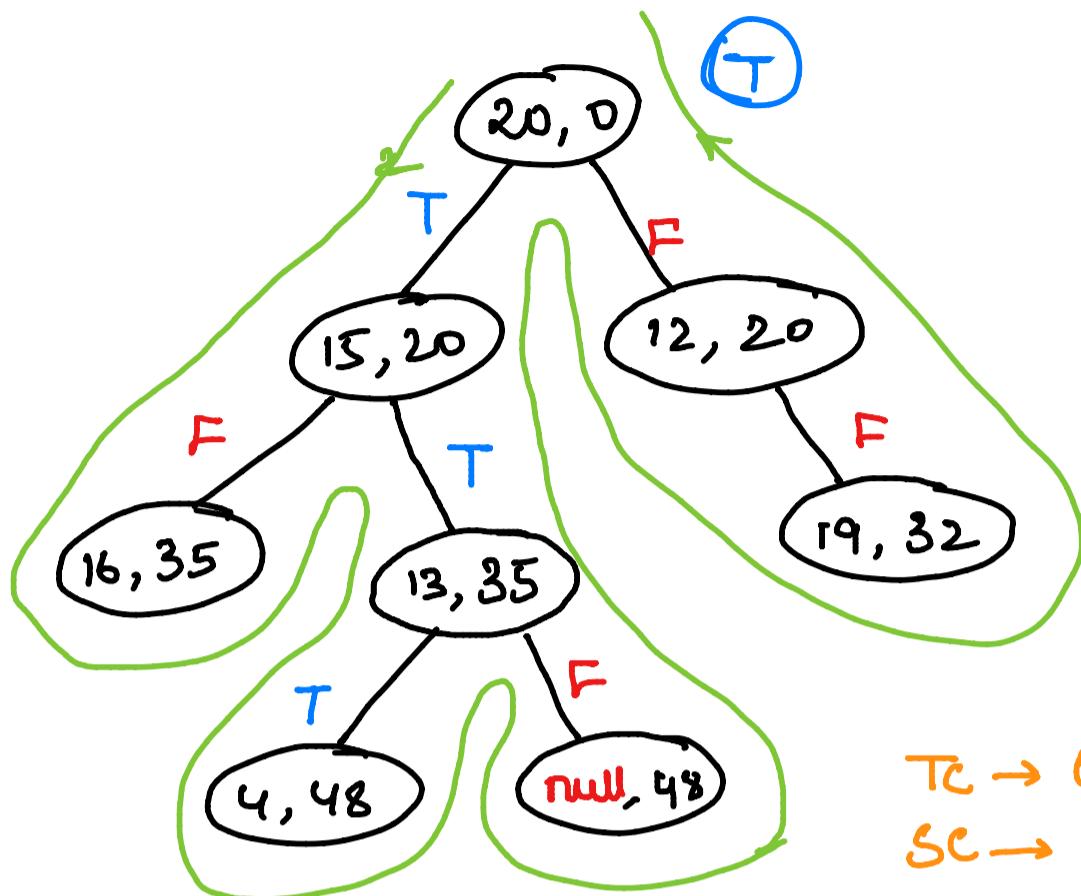
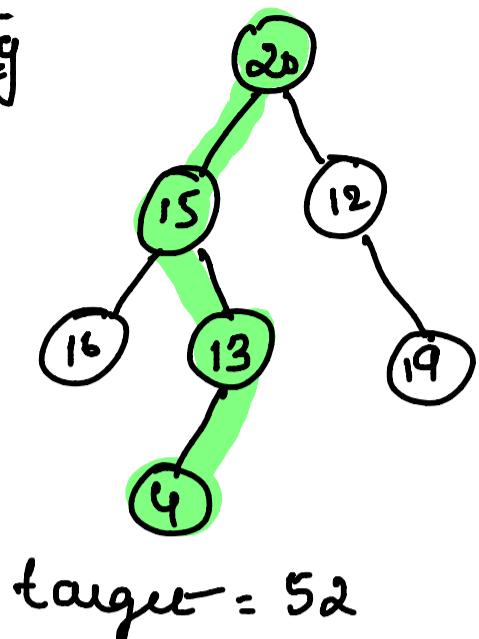
Code →

```
class Solution {
public:
    int leftLeafSum(TreeNode *root, bool leaf){
        if(root==NULL){
            return 0;
        }
        if(root->left==NULL && root->right==NULL && leaf){
            return root->val;
        }
        int ls = leftLeafSum(root->left, true);
        int rs = leftLeafSum(root->right, false);
        return ls+rs;
    }

    int sumOfLeftLeaves(TreeNode* root) {
        return leftLeafSum(root, false);
    }
};
```

14 Path sum → sum of all nodes from root to leaf is equal to target sum → then T else F.

Ex



TC → O(n)

SC → O(1)

Recursive → O(h)
Stack

Code

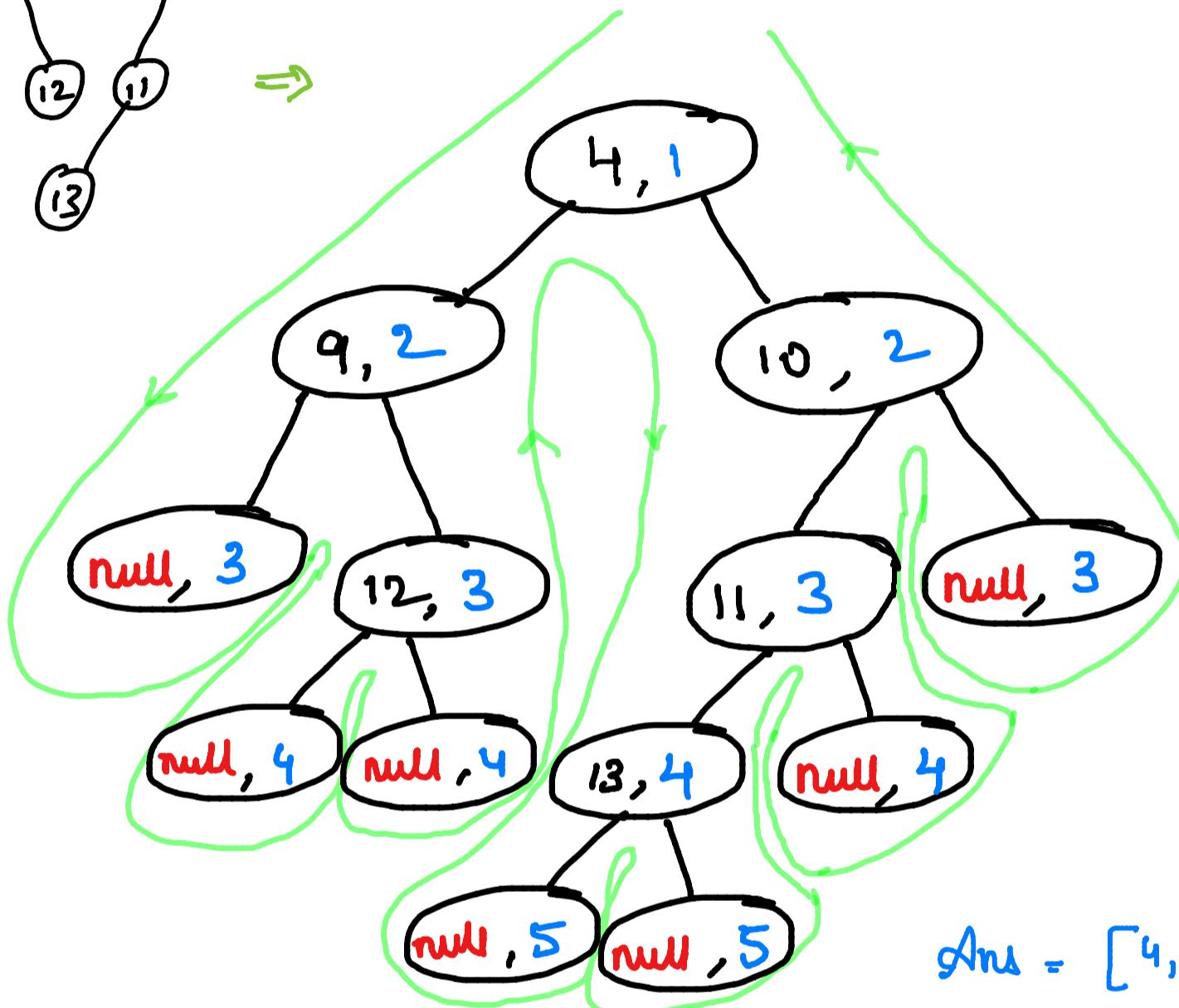
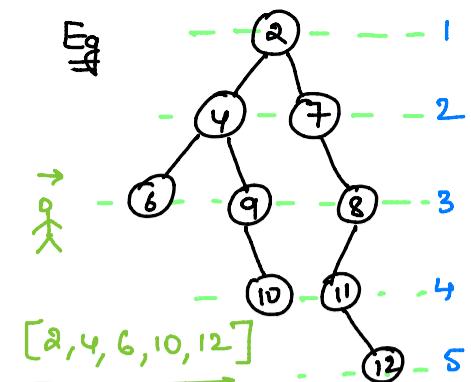
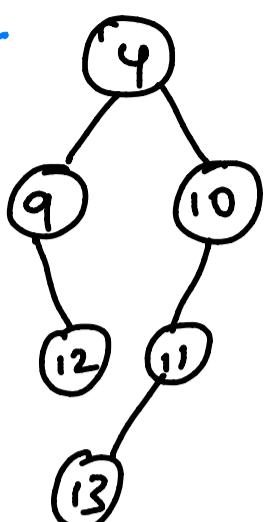
```
class Solution {
public:
    bool pathSumUtil(TreeNode* root, int currSum, int targetSum){
        if(root==NULL)
            return false;

        if(root->left==NULL && root->right==NULL){
            return (currSum+root->val)==targetSum;
        }

        return pathSumUtil(root->left, currSum+root->val, targetSum)
            ||pathSumUtil(root->right, currSum+root->val, targetSum);
    }

    bool hasPathSum(TreeNode* root, int targetSum) {
        return pathSumUtil(root, 0, targetSum);
    }
};
```

DL

(15) Left view of a Binary Tree

→ For every level traversed,
check if it already exist in the set,

if already exist then continue,
else add the root's value
to array q into the set

$T_C \rightarrow O(n)$

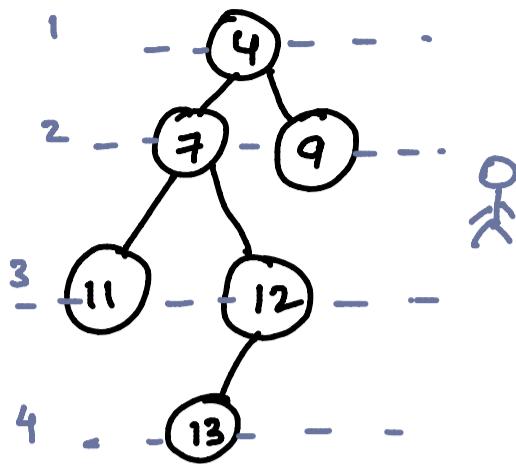
$S_C \rightarrow O(n) + O(n) + O(h)$

↓
result

Code →

```
void viewGenerator(Node *root, vector<int> &res, set<int> &s, int currLevel){  
    if(root==NULL) return;  
    // if level is not reached, then add to result and the set  
    if(s.find(currLevel)==s.end()){  
        s.insert(currLevel);  
        res.push_back(root->data);  
    }  
    // traverse the remaining branches  
    viewGenerator(root->left, res, s, currLevel+1);  
    viewGenerator(root->right, res, s, currLevel+1);  
    return;  
}  
  
vector<int> leftView(Node *root)  
{  
    vector<int> res;  
    set<int> s;  
    viewGenerator(root, res, s, 0);  
    return res;  
}
```

16 Right view of Binary Tree →



Result = [4, 9, 12, 13].

- The entire approach to solve the problem is same as the left view of binary tree. Even the time complexities.
- Only order of calling the branches change.
 - ① right
 - ② left

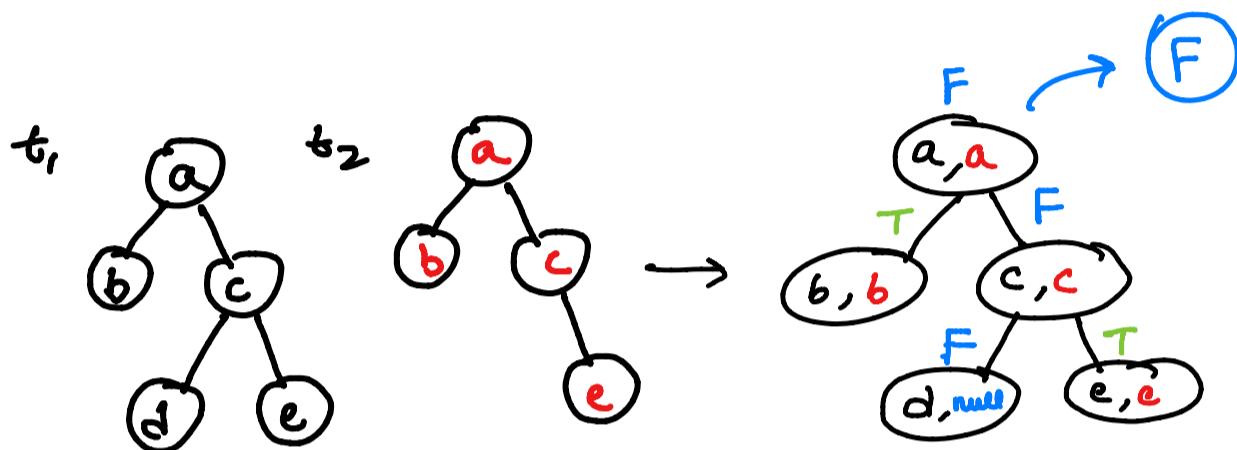
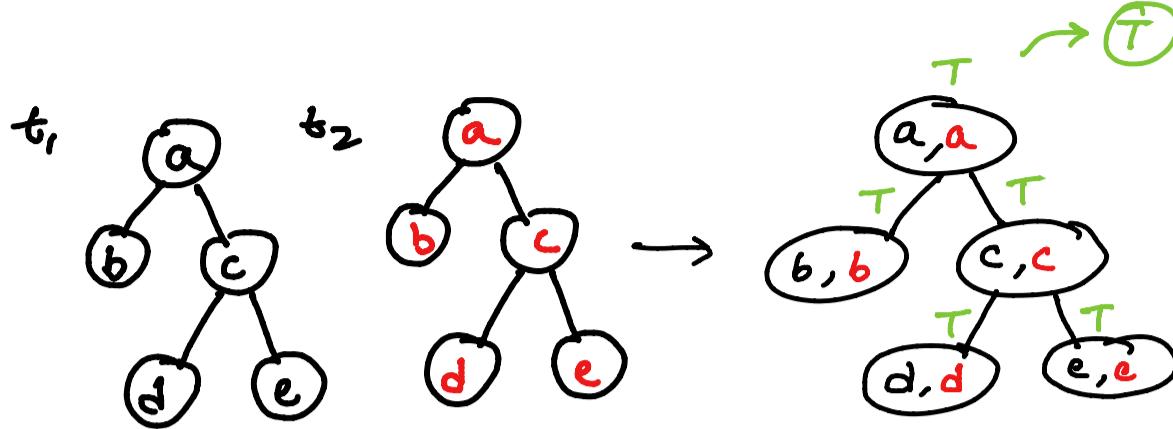
Code

```

class Solution {
public:
    void viewGenerator (TreeNode* root, vector<int> &res, set<int> &s, int currLevel){
        if(root==NULL) return;
        // if level is not reached, then add to result and the set
        if(s.find(currLevel)==s.end()){
            s.insert(currLevel);
            res.push_back(root->val);
        }
        // traverse the remaining branch
        viewGenerator(root->right, res, s, currLevel+1);
        viewGenerator(root->left, res, s, currLevel+1);
        return;
    }
    vector<int> rightSideView(TreeNode* root) {
        vector<int> res;
        set<int> s;
        viewGenerator(root, res, s, 0);
        return res;
    }
};
  
```

$T_C \rightarrow O(n)$
 $S_C \rightarrow O(n) + O(n) + O(h)$
 ↴
 result

17) same tree → return true if both trees are same
else false



$$TC \rightarrow O(\min(m, n))$$

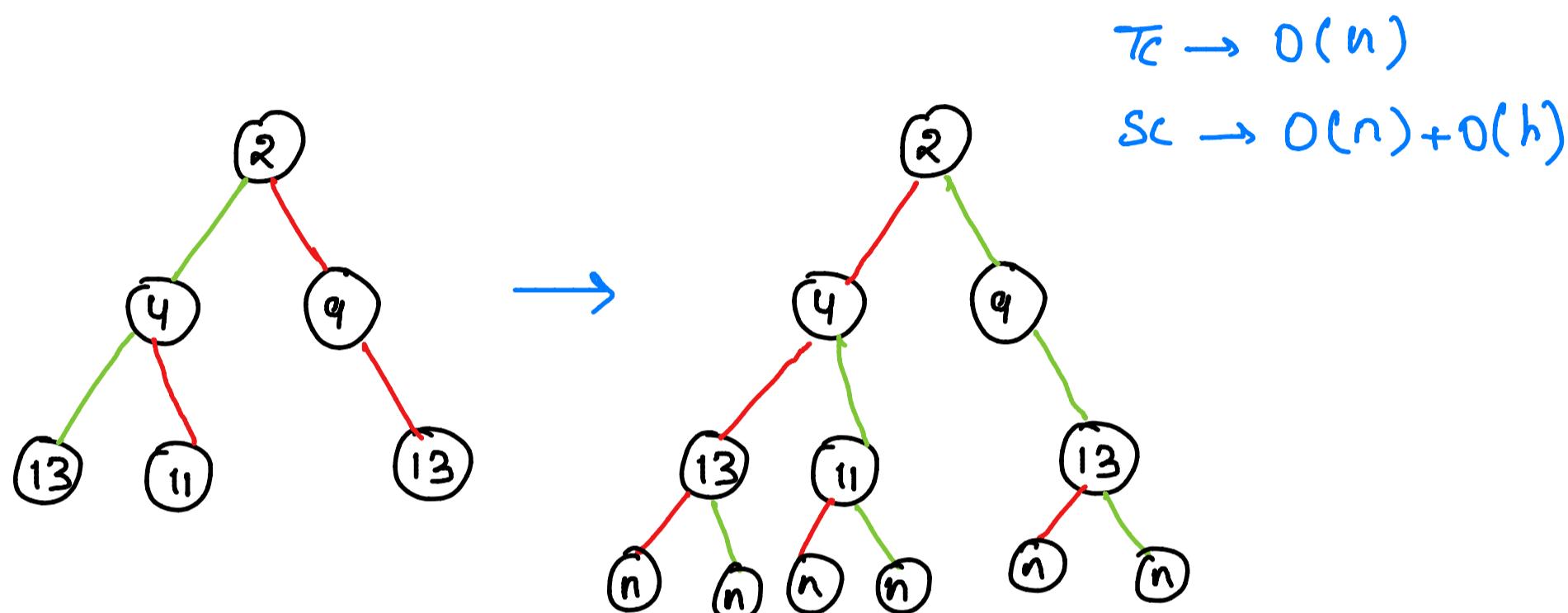
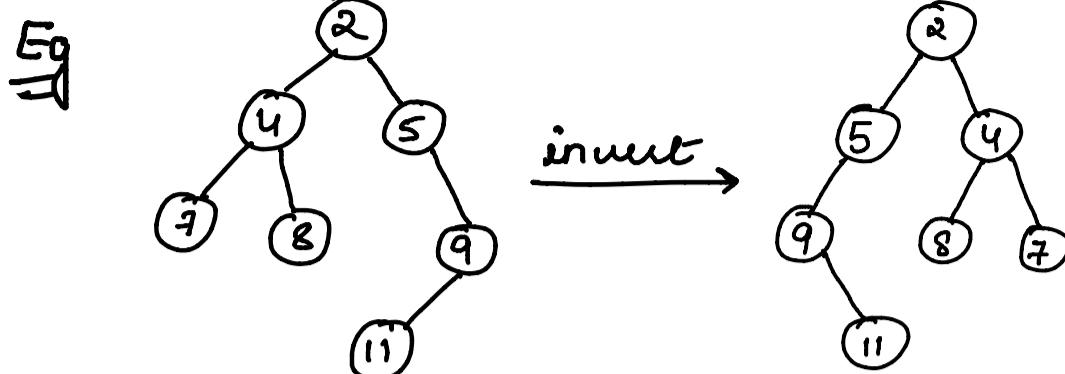
$$SC \rightarrow O(1) + O(\min(h_1, h_2))$$

code →

```
class Solution {
public:

    bool isSameTree(TreeNode* p, TreeNode* q) {
        if(p==NULL && q==NULL) return true;
        if(p==NULL || q==NULL || p->val != q->val) return false;
        return isSameTree(p->left, q->left) && isSameTree(p->right, q->right);
    }
};
```

(18) Invert Binary Tree → given the root of BT, find its mirror img.



Code →

```
class Solution {
public:
    TreeNode* invertTree(TreeNode* root) {
        if(root==NULL) return root;

        /* invert the left and right sub-trees and store
           them separately */
        TreeNode *leftSub = invertTree(root->right);
        TreeNode *rightSub = invertTree(root->left);

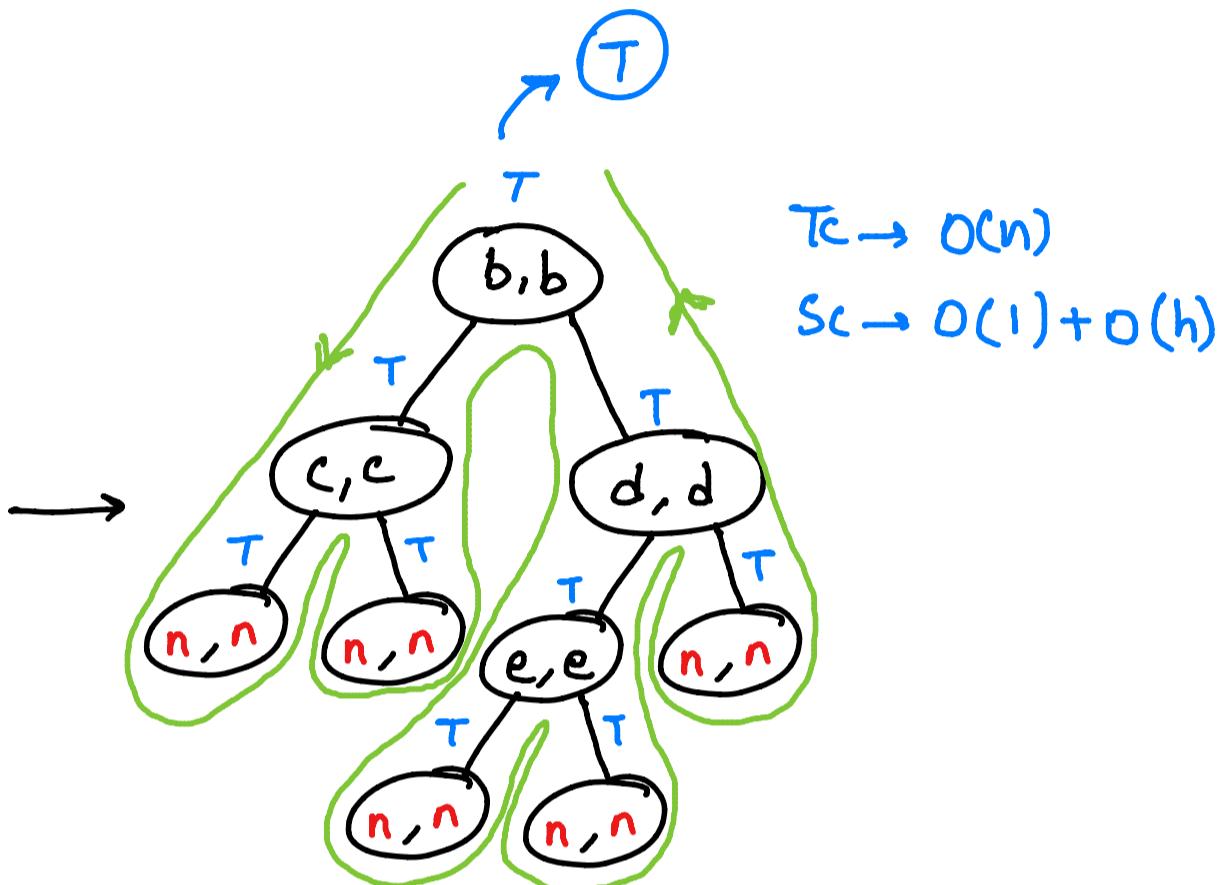
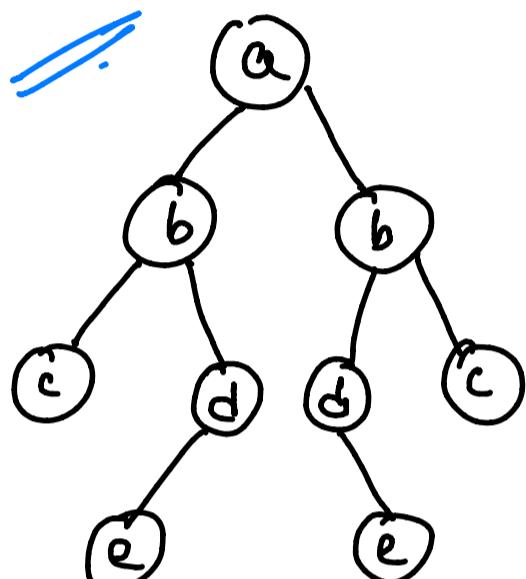
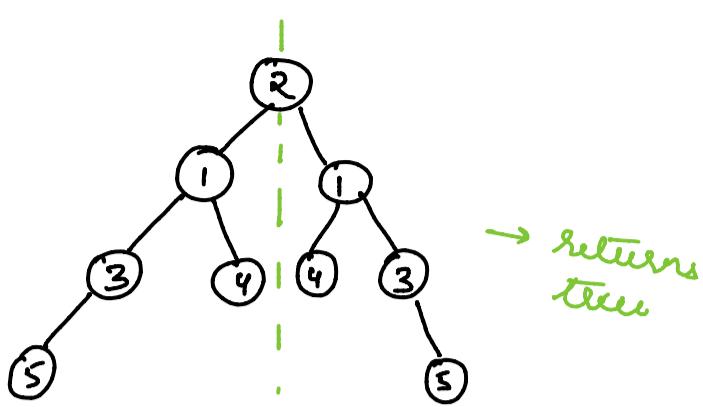
        // attach the branches to root
        root->left = leftSub;
        root->right = rightSub;

        return root;
    }
};
```

D7

19 Symmetric Tree

return true if left subtree
is equal to right subtree,
else return false



Code →

```

class Solution {
public:
    bool isMirror(TreeNode* l, TreeNode* r){

        if(l== NULL && r==NULL)
            return true;
        else if(l==NULL || r==NULL)
            return false;
        else if(l->val != r->val)
            return false;

        return isMirror(l->left,r->right) && isMirror(l->right, r->left);
    }
    bool isSymmetric(TreeNode* root) {
        if(root==NULL) return true;
        return isMirror(root->left, root->right);
    }
};

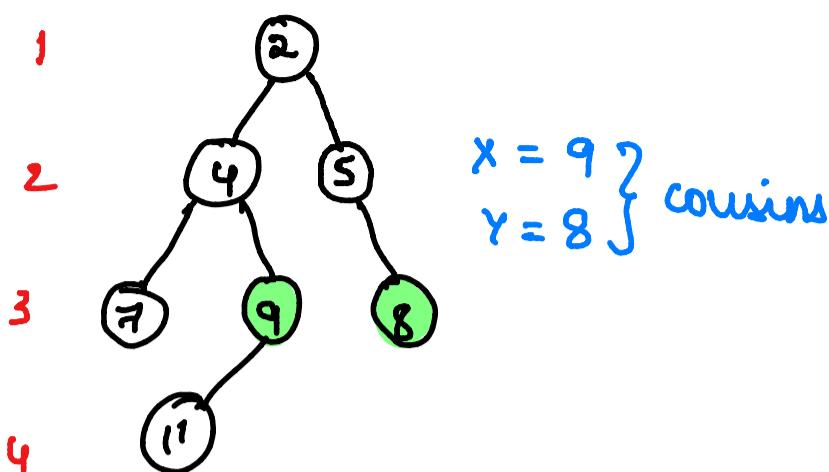
```

20

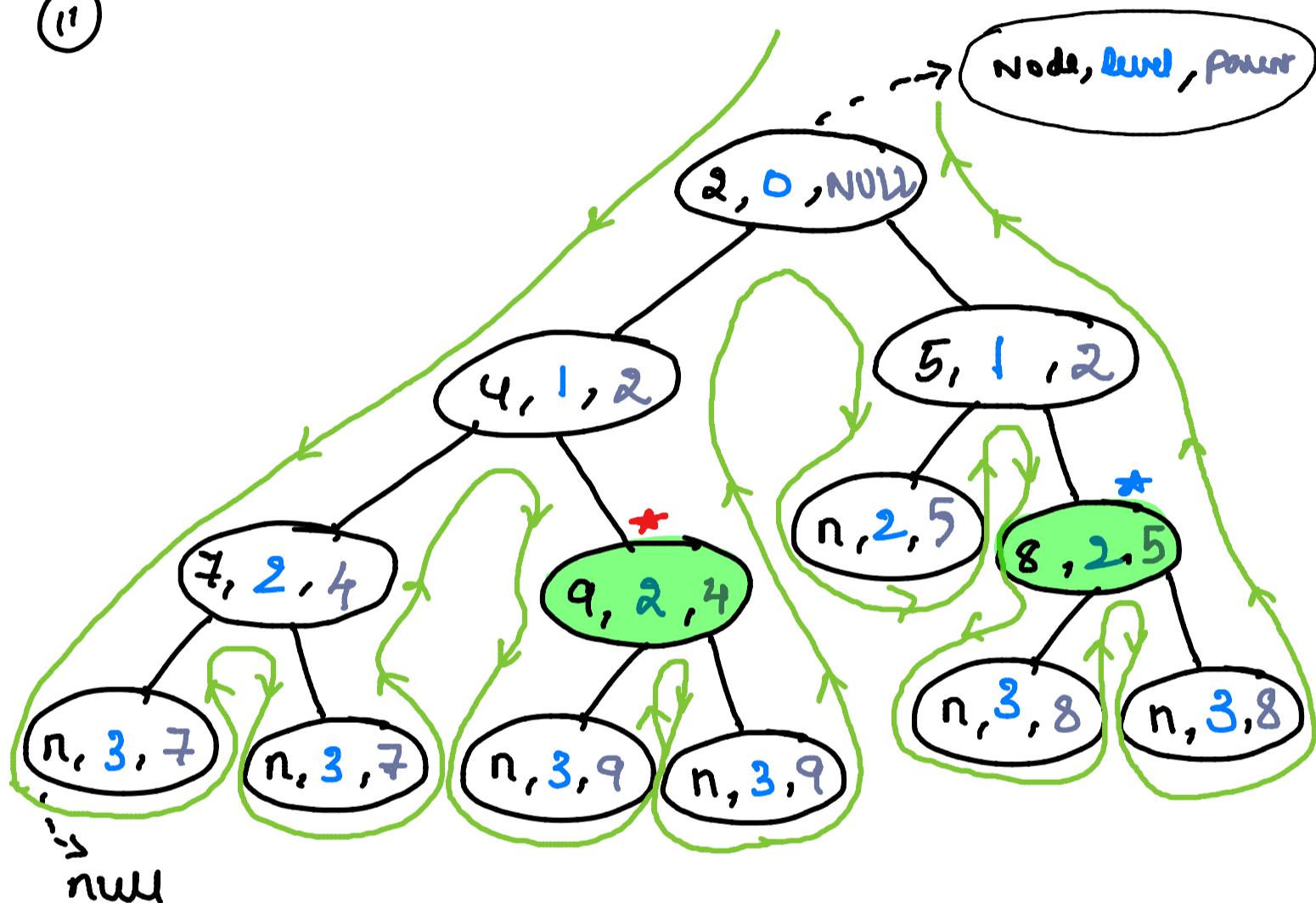
Cousins of a Binary Tree

→ given two nodes, find if they are cousins of each other.

Ex:



same level but diff parents.



- * at this step as value = 9 is found store it's parent & level in separate variables
- * later compare its value with other occurrence in Y such that

- 1) x.parent != y.parent
- 2) x.level == y.level.

TC $\rightarrow O(n)$

SC $\rightarrow O(1)$

Recursive stack $\rightarrow O(n)$

Code

```
class Solution {
public:
    void findNodes(TreeNode* root, int x, int y,int level[2],int parents[2],int currlevel,TreeNode* currparent)
    {
        if(root==NULL) return;
        if(root->val == x)
        {
            level[0]=currlevel;
            parents[0]=currparent->val;
        }
        if(root->val == y)
        {
            level[1]=currlevel;
            parents[1]=currparent->val;
        }
        findNodes(root->left, x, y, level, parents, currlevel+1, root);
        findNodes(root->right, x, y, level, parents, currlevel+1, root);
    }
    bool isCousins(TreeNode* root, int x, int y) {
        int level [2] = {-1,-1};
        int parents[2] = {-1,-1};
        findNodes(root, x, y, level, parents, 0, new TreeNode(-1));
        if(level[0]==level[1] && parents[0]!=parents[1])
            return true;
        return false;
    }
};
```