

Trees - Part 2

- Karun Karthik

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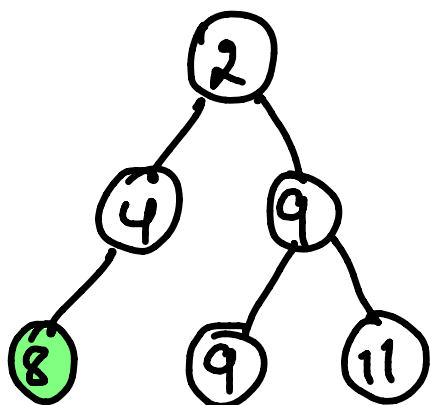
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D7

(21)

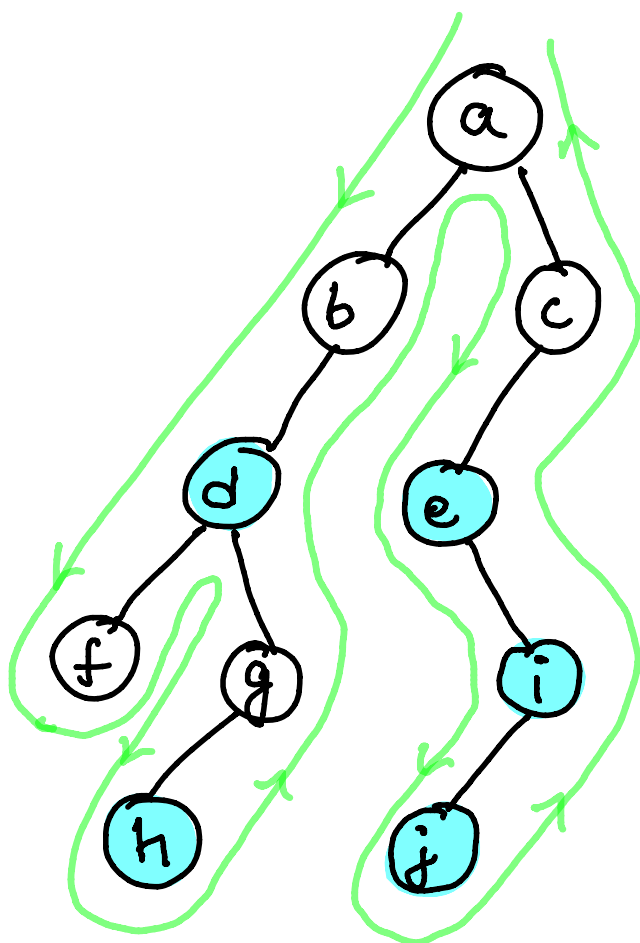
Print all nodes that do not have any siblings

✓
457



Result ↗

Sibling → same level, same parent



$T_c \rightarrow O(n)$

$S_c \rightarrow O(n)$

At every node, check if

both branches exist → then call both of them recursively

only left branch exist → then call left branch recursively

only right branch exist → then call right branch recursively

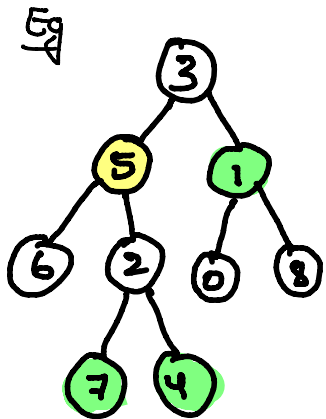
code →

```
1 void findNode(Node* root, vector<int>&res){
2
3     if(root==NULL) return;
4     if(root->left == NULL && root->right==NULL) return;
5
6     // both branches present then call recursively
7     if(root->left!=NULL && root->right!=NULL)
8     {
9         findNode(root->left, res);
10        findNode(root->right, res);
11    }
12    else if(root->left!=NULL) // right branch absent
13    {
14        res.push_back(root->left->data);
15        findNode(root->left, res);
16
17    } else if(root->right!=NULL) // left branch absent
18    {
19        res.push_back(root->right->data);
20        findNode(root->right, res);
21    }
22    return;
23 }
24
25 vector<int> noSibling(Node* node)
26 {
27     vector<int> res;
28     findNode(node, res);
29     if(res.size()==0) res.push_back(-1);
30     sort(res.begin(), res.end());
31     return res;
32 }
33
```

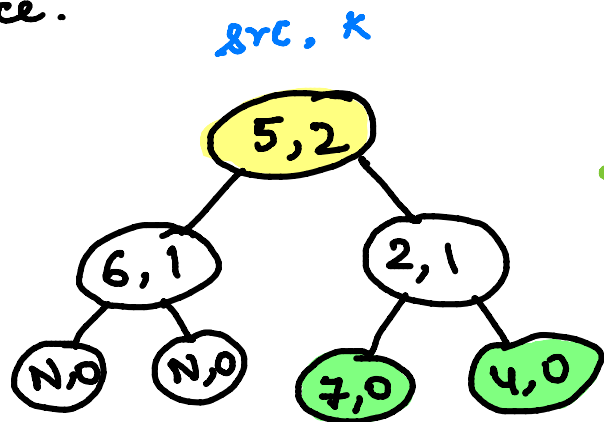
D8 (22) All nodes distance k in Binary Tree

given a source node, find all the nodes that are at a distance of k units.

① consider nodes in downward direction of source.



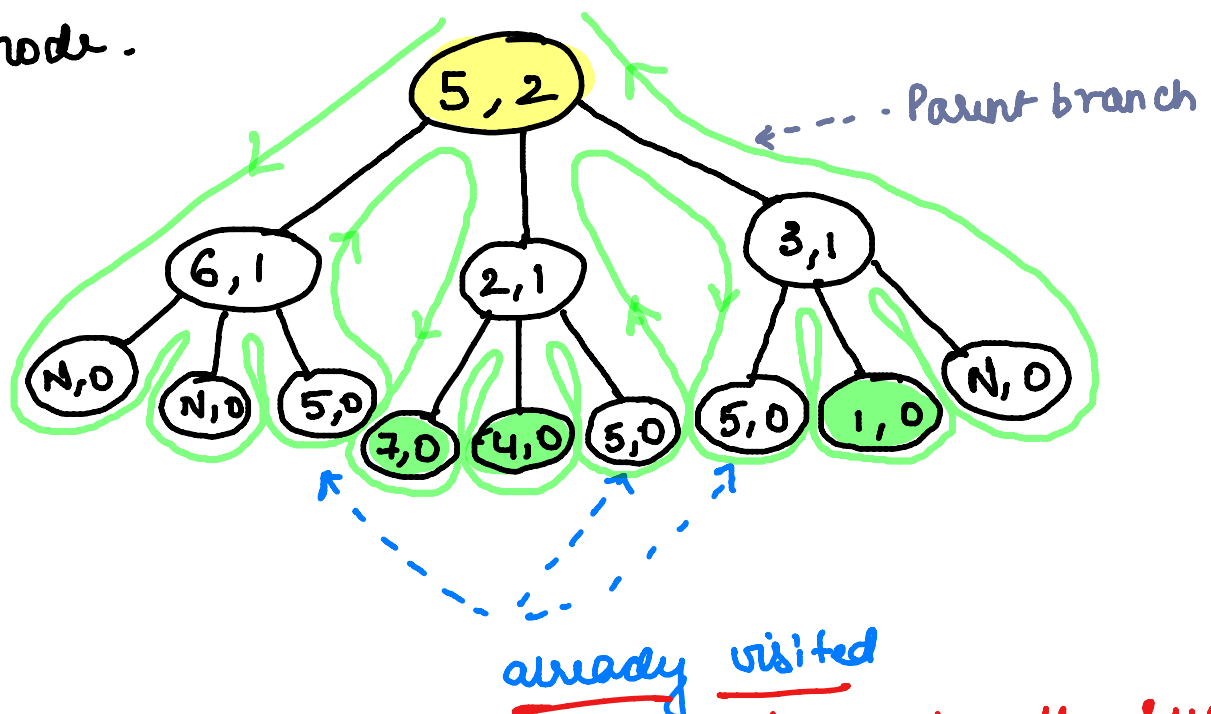
Source = 5
k = 2



• Store in result if $k=0$
Return if $k < 0$

② To solve for the upward direction we can use hashing to store the parent node.

Node	Parent
3	NULL
5	3
1	3
6	5
2	5
0	1
8	1
7	2
4	2



* If $k=0$
& the node value is valid (not null) then add to result array

↳ to handle such cases we use a set.

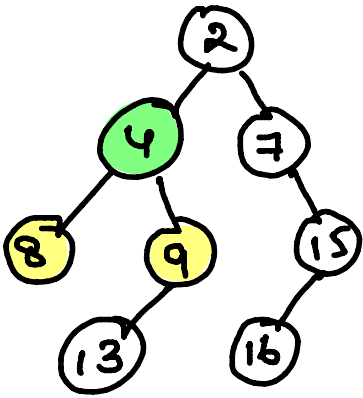
populating traversal
Tc $\rightarrow O(n) + O(n)$
Sc $\rightarrow O(n) + O(n) + O(1)$
result

Code.

```
1  class Solution {
2  public:
3      // to create hashtable
4      void populateMap(TreeNode* currnode, TreeNode* currparent,
5                          unordered_map<TreeNode*,TreeNode*>&parentmap){
6          if(currnode == NULL) return;
7          parentmap[currnode] = currparent;
8          populateMap(currnode->left,currnode,parentmap);
9          populateMap(currnode->right,currnode,parentmap);
10         return;
11     }
12
13     // finding all the nodes at distance K
14     void printKdistance(TreeNode* currnode, int k,set<TreeNode*>&s,
15                         unordered_map<TreeNode*,TreeNode*>&parentmap,vector<int>&ans)
16     {
17         if(currnode == NULL || s.find(currnode)!=s.end() || k<0)
18             return;
19
20         s.insert(currnode);
21
22         if(k==0)
23         {
24             ans.push_back(currnode->val);
25             return;
26         }
27
28         printKdistance(currnode->left,k-1,s,parentmap,ans); // call left child
29         printKdistance(currnode->right,k-1,s,parentmap,ans); // call right child
30         printKdistance(parentmap[currnode],k-1,s,parentmap,ans); // call the parent
31         return;
32     }
33
34     vector<int> distanceK(TreeNode* root, TreeNode* target, int k) {
35         vector<int>ans;
36         set<TreeNode*>s;
37         unordered_map<TreeNode*,TreeNode*>parentmap;
38         populateMap(root,NULL,parentmap);
39         printKdistance(target,k,s,parentmap,ans);
40         return ans;
41     }
42 };
```

(23) Lowest Common Ancestor

Eg



node to root paths
↓
 $n_1 = 8, n_2 = 9$ then $\bar{n}_1 = [8, 4, 2]$
 $\bar{n}_2 = [9, 4, 2]$ } → 4

$n_1 = 9, n_2 = 13$ then $\bar{n}_1 = [9, 4, 2]$
 $\bar{n}_2 = [13, 9, 4, 2]$ } → 9

→ for every node, check if it matches n_1 or n_2 .

if found return node

else call recursively in both branches.

if both return non-null value $\Rightarrow$ root is LCA

else return the branch value that is non-null.

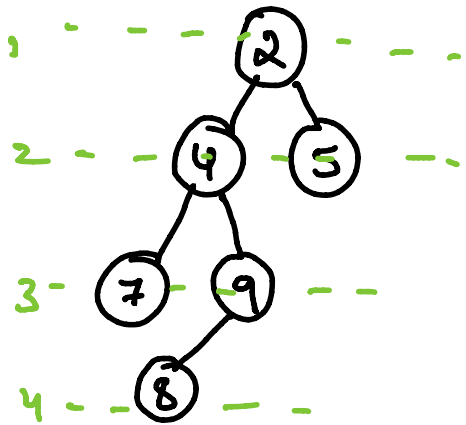
code

```
class Solution {
public:
    TreeNode* lowestCommonAncestor(TreeNode* root, TreeNode* p, TreeNode* q) {
        if(root==NULL) return NULL;
        if(root->val == p->val || root->val == q->val) return root;
        TreeNode* leftSubTree = lowestCommonAncestor(root->left, p, q);
        TreeNode* rightSubTree = lowestCommonAncestor(root->right, p, q);
        if(leftSubTree!=NULL && rightSubTree!=NULL) return root;
        if(leftSubTree!=NULL) return leftSubTree;
        if(rightSubTree!=NULL) return rightSubTree;
        return NULL;
    }
};
```

D9 (24) Level order traversal Binary Tree

↳ given root node, find level order traversal.

Eg.



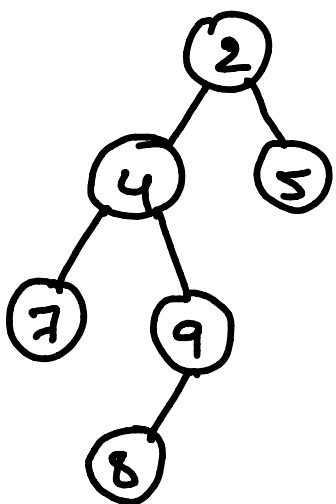
⇒ $[[2], [4, 5], [7, 9], [8]]$

$Tc \rightarrow O(n)$

$Sc \rightarrow O(n)$

→ To find level order traversal use queue. ↪ FIFO data structure
Inserting → Rear
Removing → Front

→ Before removing from queue, add the children to the queue (BFS)



Queue

2

4, 5

5, 7, 9

7, 9

9

8

empty →

Result

$[]$

$[2]$

$[2, 4]$

$[2, 4, 5]$

$[2, 4, 5, 7]$

$[2, 4, 5, 7, 9]$

Answer → $[2, 4, 5, 7, 9, 8]$

Code →

```
1  class Solution {
2  public:
3      vector<vector<int>> levelOrder(TreeNode* root) {
4          vector<vector<int>> res;
5          queue<TreeNode*> q;
6
7          if(root==NULL) return res;
8          q.push(root);
9
10         while(!q.empty()){
11
12             int currsz = q.size();
13             vector<int> currLevel;
14
15             while(currsz>0)
16             {
17                 TreeNode* currnode = q.front();
18                 q.pop();
19                 currLevel.push_back(currnode->val);
20                 currsz--;
21
22                 if(currnode->left!=NULL)
23                     q.push(currnode->left);
24
25                 if(currnode->right!=NULL)
26                     q.push(currnode->right);
27             }
28             res.push_back(currLevel);
29         }
30         return res;
31     }
32 };
```


②5 Level order traversal N-ary Tree

→ Everything is same as previous problem, intuition & complexity

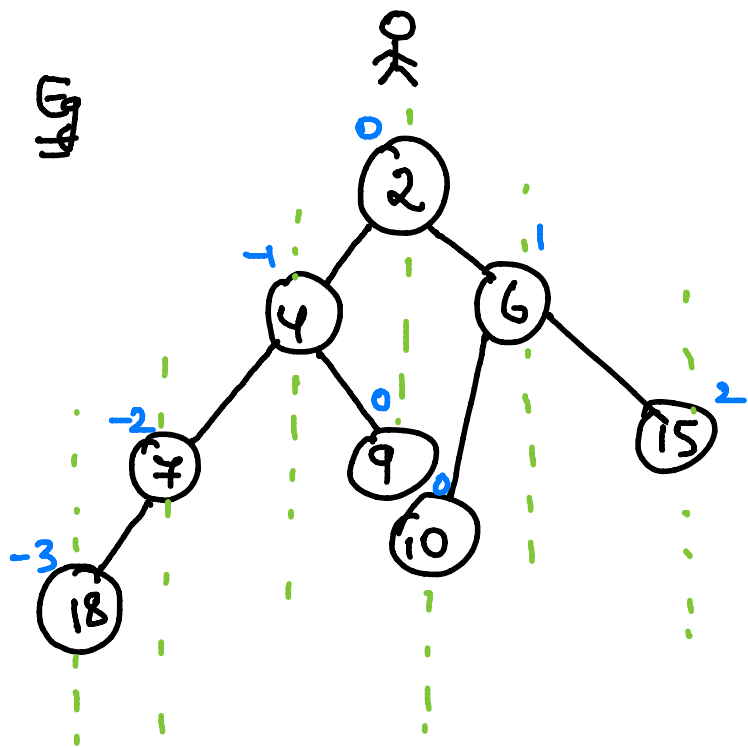
$T_c \rightarrow O(n)$

$S_c \rightarrow O(n)$

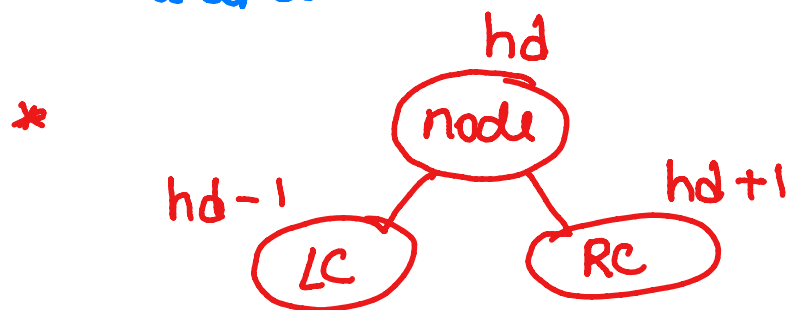
code →

```
1  class Solution {
2  public:
3      vector<vector<int>> levelOrder(Node* root) {
4          vector<vector<int>> res;
5          queue<Node*> q;
6
7          if(root == NULL) return res;
8          q.push(root);
9
10         while(!q.empty())
11         {
12             int currsz = q.size();
13             vector<int> currLevel;
14             while(currsz > 0)
15             {
16                 Node* currnode = q.front();
17                 q.pop();
18                 currLevel.push_back(currnode->val);
19                 currsz--;
20
21                 // enqueue all the children
22                 for(auto child: currnode->children)
23                     q.push(child);
24             }
25             res.push_back(currLevel);
26         }
27         return res;
28     }
29 };
```

26 Top View of Binary Tree



* For top view or bottom view we use concept of horizontal distance.



* hd of root = 0

* make a pair with node & its hd .
& perform bfs.

$\langle node, hd \rangle$

	①	②	③	④	⑤	⑥	⑦	⑧
$\hookrightarrow$	(2, 0)	(4, -1)	(6, 1)	(7, -2)	(9, 0)	(10, 0)	(15, 2)	(18, -3)

use a hashmap to store result.

HD	NODE
0	2
-1	4
1	6
-2	7
2	15
-3	18

- ① As $hd = 0$ is not present in map add 2 to map.
- ② As $hd = -1$ is not present in map add 4 to map.
- ③ As $hd = 1$ is not present in map add 6 to map.
- ④ As $hd = -2$ is not present in map add 7 to map.
- ⑤ $hd = 0$ is already present.
- ⑥ $hd = 0$ is already present.
- ⑦ As $hd = 2$ is not present in map add 15 to map.
- ⑧ As $hd = -3$ is not present in map add 18 to map.

$\rightarrow$ convert into array & return as result

code

```
1  class Solution
2  {
3      public:
4      vector<int> topView(Node *root)
5      {
6          vector<int> res;
7          if(root==NULL) return res;
8
9          map<int,int> mp;
10         queue<pair<Node*,int>> q;
11
12         q.push({root,0});
13
14         while(!q.empty()){
15
16             auto it = q.front();
17             q.pop();
18
19             Node* node = it.first;
20             int hd = it.second;
21
22             if(mp.find(hd) == mp.end())
23                 mp[hd] = node->data;
24
25             if(node->left!=NULL)
26                 q.push({node->left,hd-1});
27
28
29             if(node->right!=NULL)
30                 q.push({node->right,hd+1});
31         }
32
33         // store in vector or array
34         for(auto it:mp)
35             res.push_back(it.second);
36
37         return res;
38     }
39 };
40
```

$\log n \rightarrow \text{map}$.

$T_c \rightarrow O(n \log n)$

$Sc \rightarrow O(n)$

27) Bottom View of Binary Tree

→ Similar to top view, but replace entries in hashmap so you'll get last possible element with particular hd.

Code →

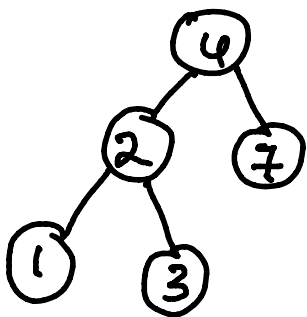
```
1  class Solution {
2      public:
3          vector<int> bottomView(Node *root) {
4              vector<int> res;
5              if(root==NULL) return res;
6
7              map<int, int> mp;
8              queue<pair<Node*, int>> q;
9
10             q.push({root, 0});
11             while(!q.empty()){
12                 auto it = q.front();
13                 q.pop();
14
15                 Node* node = it.first;
16                 int hd = it.second;
17
18                 mp[hd] = node->data;
19
20                 if(node->left!=NULL)
21                     q.push({node->left, hd-1});
22
23                 if(node->right!=NULL)
24                     q.push({node->right, hd+1});
25             }
26
27             for(auto it:mp)
28                 res.push_back(it.second);
29
30             return res;
31         }
32     };
```

D10 Binary Search Tree

- every node is $>$ than previous node & $<$ than next node.
- If duplicates, then it'll be mentioned that it'll be included in LC or RC

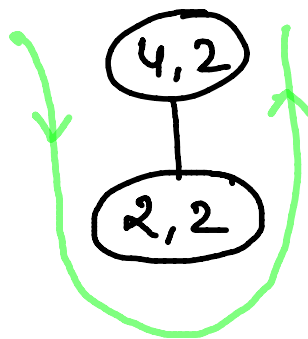
- ① $LC < node < RC$
- ② $LC \leq node < RC$
- ③ $LC < node \leq RC$

②8 Search in a BST



val = 2

⇒ return the subtree with given value.



• as $2 < 4$, search in LST.

• as $2 == 2$ return node.

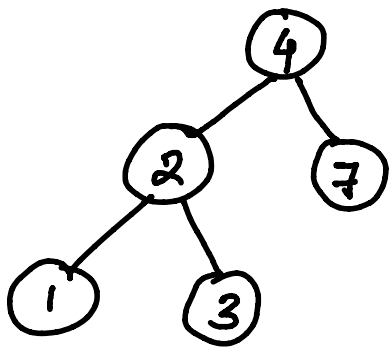
TC $\rightarrow O(\log_2 n)$, $O(n)$
 avg worst

SC $\rightarrow O(n)$

code

```
class Solution {
public:
    TreeNode* searchBST(TreeNode* root, int val) {
        if(root==NULL) return NULL;
        if(root->val == val) return root;
        if(root->val < val) return searchBST(root->right, val);
        return searchBST(root->left, val);
    }
};
```

29) Insert into BST



val = 5.

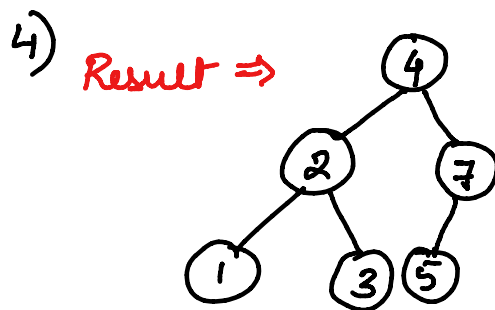
TC $\rightarrow O(\log_2 n)$ / $O(n)$
 avg worst

SC $\rightarrow O(1)$

code $\rightarrow$

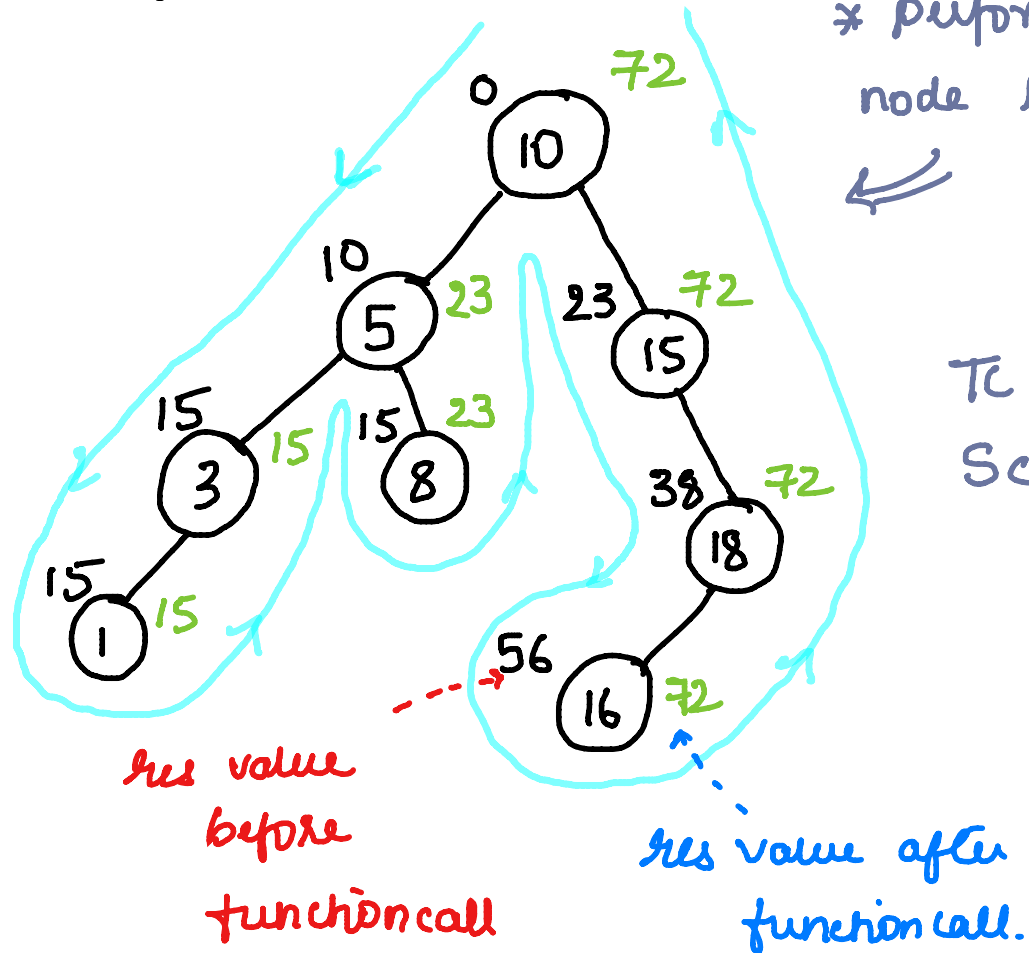
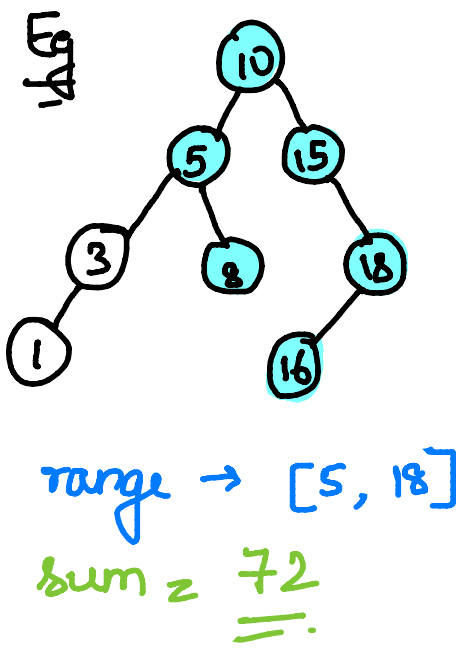
```
class Solution {
public:
    TreeNode* insertIntoBST(TreeNode* node, int val) {
        if(node==NULL){
            return new TreeNode(val);
        }
        if (val < node->val) {
            node->left = insertIntoBST(node->left, val);
        }
        else {
            node->right = insertIntoBST(node->right, val);
        }
        return node;
    }
};
```

- 1) ^{root} 4 5 As $5 > 4$, go to RST
- 2) 4 5 7 As $5 < 7$, go to LST
- 3) • As LST of 7 is null, create node with value = 5. 5
• Link 5 as LST of 7.



30) Range sum of BST

Given a root node & interval $[x, y]$, find sum of all nodes that lies in $[x, y]$.

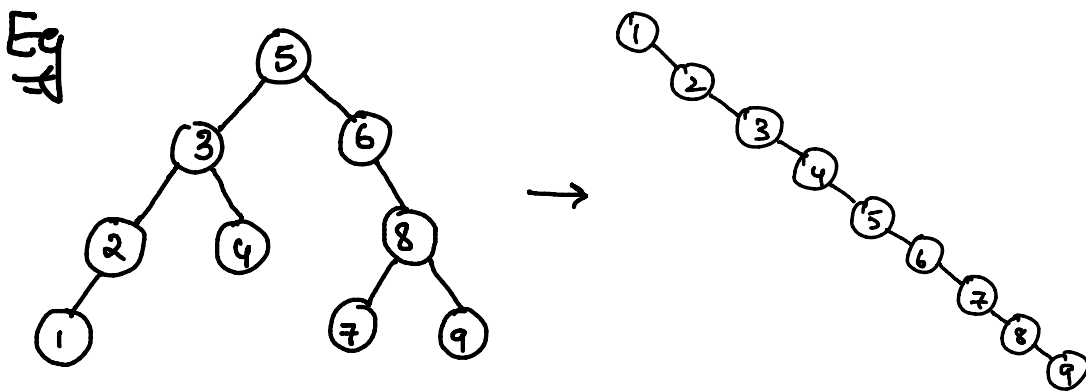


Code $\rightarrow$

```
1 class Solution {
2 public:
3     void sumUtil(TreeNode* root, int low, int high, int &res){
4         if(root==NULL) return;
5         if(root->val <= high && root->val >= low){
6             res += root->val;
7         }
8         sumUtil(root->left, low, high, res);
9         sumUtil(root->right, low, high, res);
10    }
11
12    int rangeSumBST(TreeNode* root, int low, int high) {
13        int res = 0;
14        sumUtil(root, low, high, res);
15        return res;
16    }
17 };
```


31) Increasing order search tree

Given a BST, create an increasing order search tree.



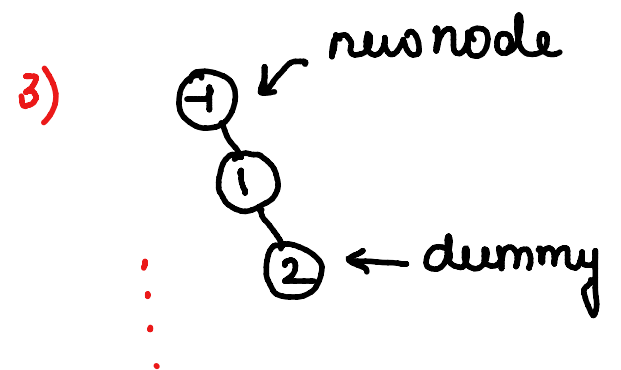
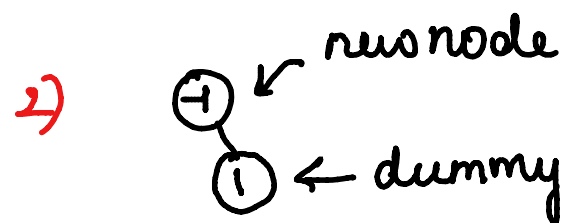
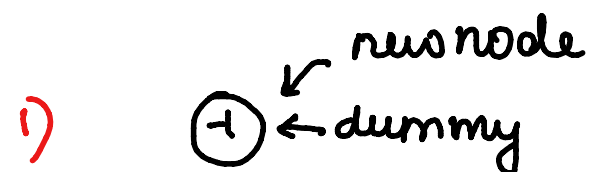
① Perform inorder traversal.

② create a skewed tree using elements in inorder traversal.

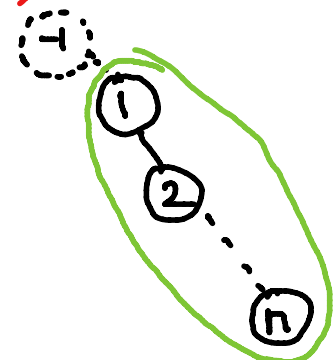
Code

```
1 class Solution {
2 public:
3     void inorder(TreeNode* root, vector<int> &res){
4         if(root==NULL) return;
5         inorder(root->left, res);
6         res.push_back(root->val);
7         inorder(root->right, res);
8     }
9     TreeNode* increasingBST(TreeNode* root) {
10         vector<int> res;
11         inorder(root, res);
12
13         // create right skewed tree
14         TreeNode* dummy = new TreeNode(-1);
15         TreeNode* newNode = dummy;
16         for(auto it: res){
17             dummy->right = new TreeNode(it);
18             dummy = dummy->right;
19         }
20         return newNode->right;
21     }
22 };
```

Lines 16-20



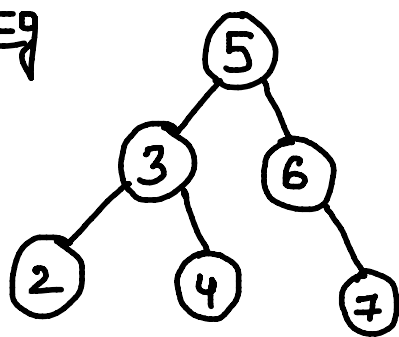
last) return newNode->right



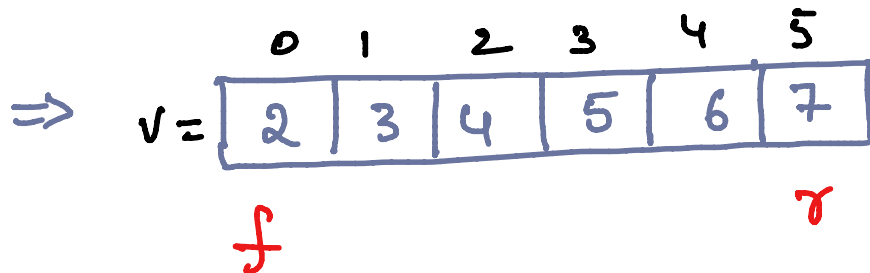
32) Two sum IV - Input is a BST

↳ return true if sum of any 2 values == k

Eg



k = 9



as $v[f] + v[r] == k$, return true, else $f++$ or $r--$ as per sum & k.

code →

```
class Solution {
public:
    void inorder(TreeNode* root, vector<int> &res){
        if(root==NULL) return;
        inorder(root->left, res);
        res.push_back(root->val);
        inorder(root->right, res);
    }
    bool findTarget(TreeNode* root, int k) {
        vector<int> res;
        inorder(root, res);
        int front = 0;
        int rear = res.size()-1;
        while(front < rear){
            if(res[front]+res[rear]==k) return true;
            if(res[front]+res[rear]>k) rear--;
            else front++;
        }
        return false;
    }
};
```

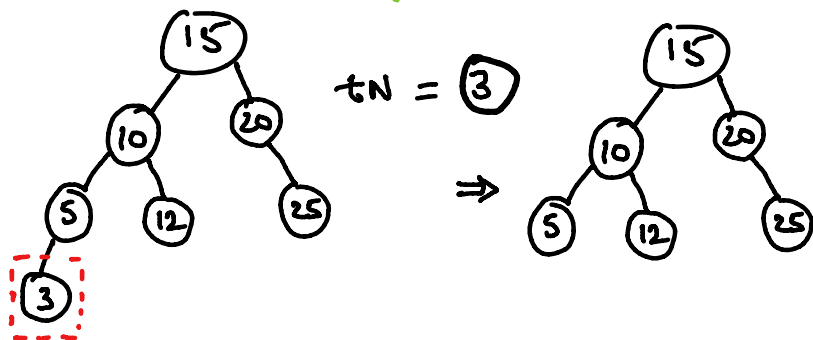
Tc → $O(n) + O(n)$
Sc → $O(n)$

D11 (33) Delete Node in BST

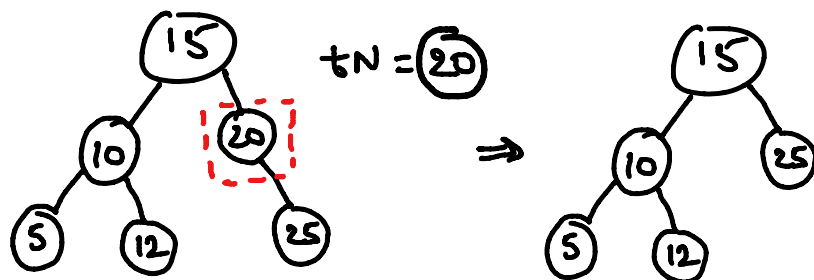
Given root of BST & a target node, delete the target node & return the tree.

Cases →

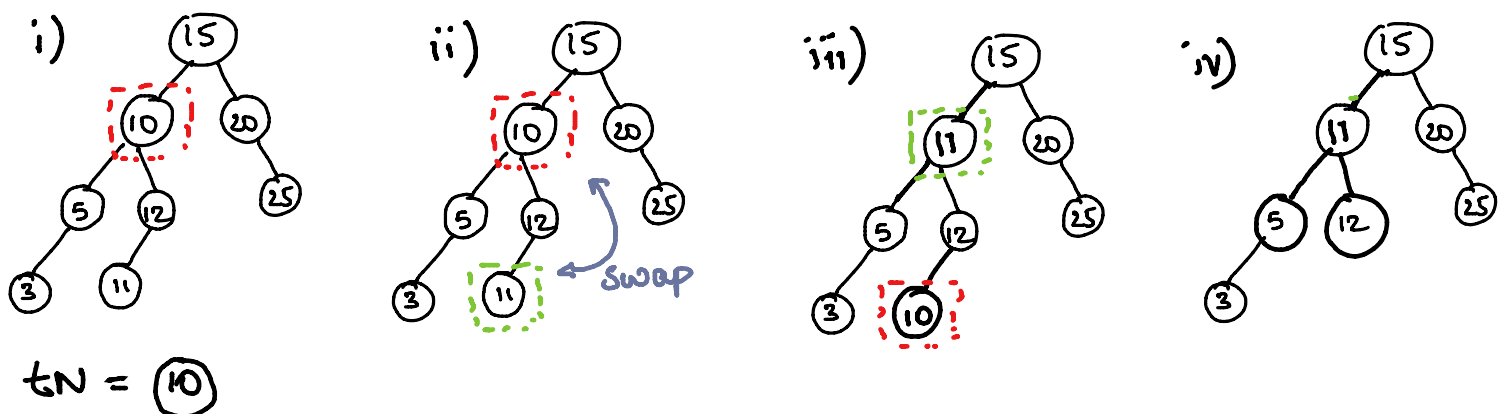
- ① If target node is leaf →
then simply delete it



- ② If target node has 1 child →
then remove node & return the subtree



- ③ If target node has 2 children →
then go to right child's left subtree & swap its value with target node & then delete it.



Tc →

Avg $\Rightarrow O(\log n)$

Worst $\Rightarrow O(n)$

SC $\Rightarrow O(h)$

Code

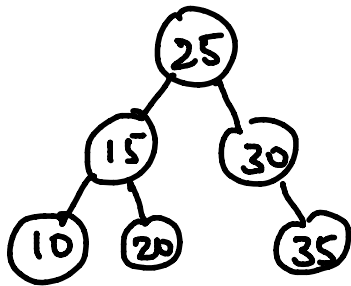
```
1  class Solution {
2  public:
3      TreeNode* findleftmostNode(TreeNode* root){
4          while(root->left!=NULL)
5              root = root->left;
6          return root;
7      }
8
9      TreeNode* deleteNode(TreeNode* root, int key) {
10
11         if(root==NULL) return NULL;
12
13         if(root->val > key)
14             root->left = deleteNode(root->left, key);
15
16         else if(root->val < key)
17             root->right = deleteNode(root->right, key);
18
19         else { // root->val == key
20             if(root->left == NULL && root->right == NULL){
21                 root = NULL;
22                 return root;
23             }
24             if(root->left != NULL && root->right == NULL){
25                 root = root->left;
26                 return root;
27             }
28             if(root->right != NULL && root->left == NULL){
29                 root = root->right;
30                 return root;
31             }
32
33             // finding left most node in right subtree
34             TreeNode* temp = findleftmostNode(root->right);
35
36             //swapping root's value with left most node's val
37             int tempVal = root->val;
38             root->val = temp->val;
39             temp->val = tempVal;
40
41             // performing delete in right subtree
42             root->right = deleteNode(root->right, key);
43             return root;
44         }
45         return root;
46     }
47 };
```

(34) Inorder successor of BST

Given root, find inorder successor of given node

↳ the element just after the node in inorder traversal.

Ex



n = 15 o/p → 20

n = 35 o/p → null.

Code →

```
class Solution{
public:

    void inorder(Node *root, vector<Node*> &res){
        if(root==NULL) return;
        inorder(root->left, res);
        res.push_back(root);
        inorder(root->right, res);
    }

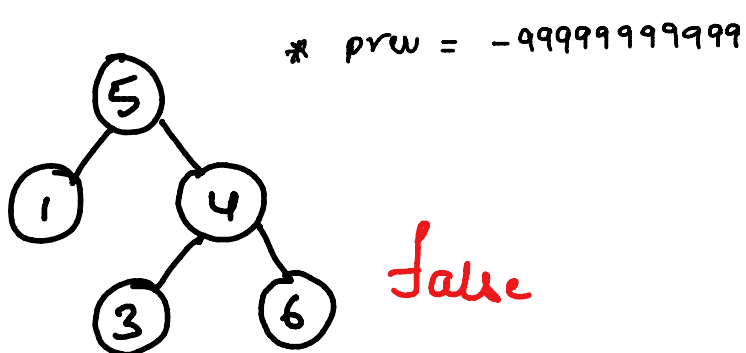
    Node * inOrderSuccessor(Node *root, Node *x)
    {
        vector<Node*> res;
        inorder(root, res);
        for(int i=0; i<res.size(); i++){
            if(res[i]==x && i<res.size()-1){
                return res[i+1];
            }
        }
        return NULL;
    }
};
```


D12

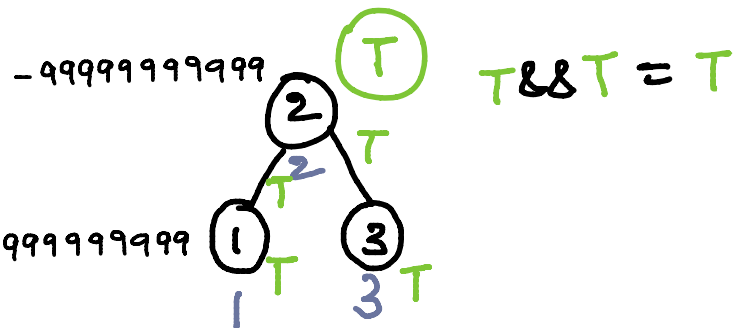
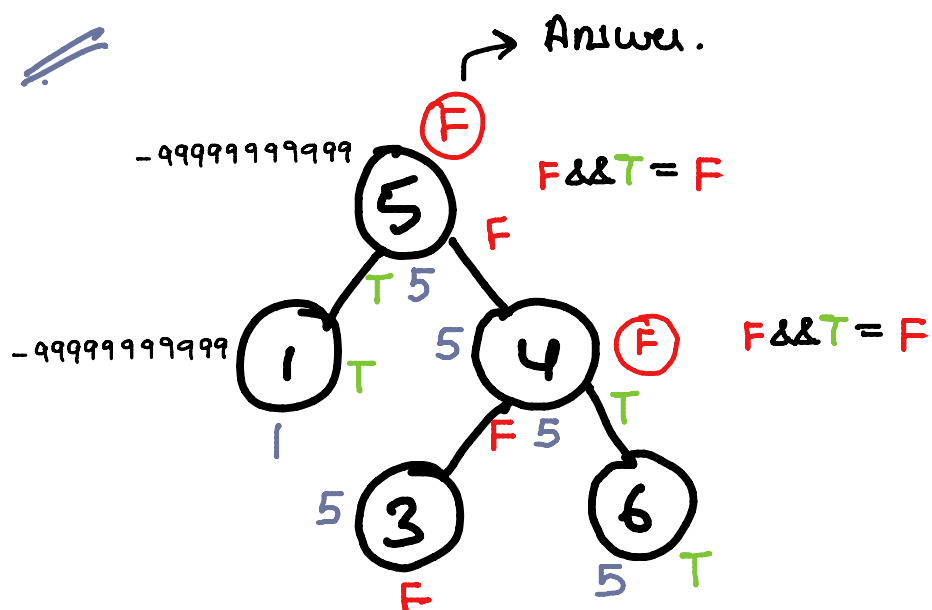
(35) Validate BST given a root node, return true if it is valid BST

* Every value should be less than previous one in Inorder traversal

Eg



Answer.



- Return True on NULL nodes
- Check for left subtree
- previous value gets updated before checking Right subtree & after checking left subtree
- if $currVal \leq prev$ then return false
- return true if both LST & RST are BST

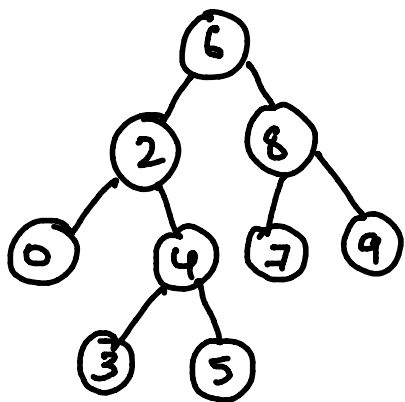
code

```
class Solution {
public:
    bool isBST(TreeNode* root, long int &prev){
        if(root==NULL) return true;
        bool isLeftBalanced = isBST(root->left, prev);
        if(root->val <= prev) return false;
        prev = root->val;
        bool isRightBalanced = isBST(root->right, prev);
        return isLeftBalanced && isRightBalanced;
    }

    bool isValidBST(TreeNode* root) {
        long int prev = -999999999999;
        return isBST(root, prev);
    }
};
```

36 LCA of BST →

Eg.



$P=2, Q=8$

if $currNode > \text{both } P \ \& \ Q$
then LCA lies in LST

if $currNode < \text{both } P \ \& \ Q$
then LCA lies in RST

in every other case the $currNode$ is
LCA as $P \ \& \ Q$ will be on

	worst	Avg
Tc →	$O(n)$	$O(\log n)$
Sc →	$O(n)$	

code

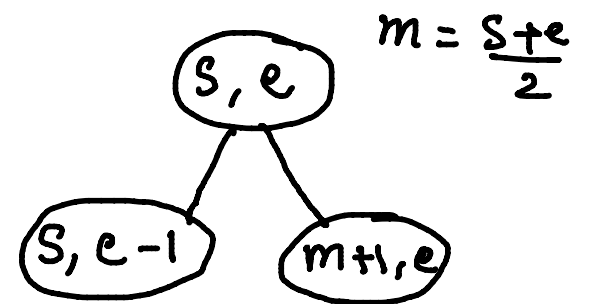
```
class Solution {
public:
    TreeNode* lowestCommonAncestor(TreeNode* root, TreeNode* p, TreeNode* q) {
        if(root==NULL) return NULL;

        if(root->val < p->val && root->val < q->val){
            return lowestCommonAncestor(root->right, p, q);
        }
        else if(root->val > p->val && root->val > q->val){
            return lowestCommonAncestor(root->left, p, q);
        }
        else {
            return root;
        }
    }
};
```

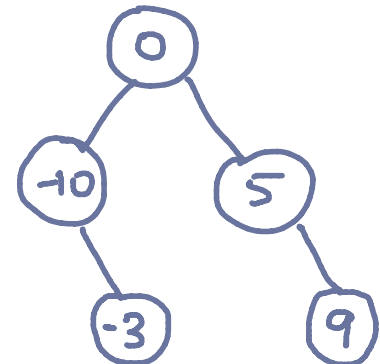
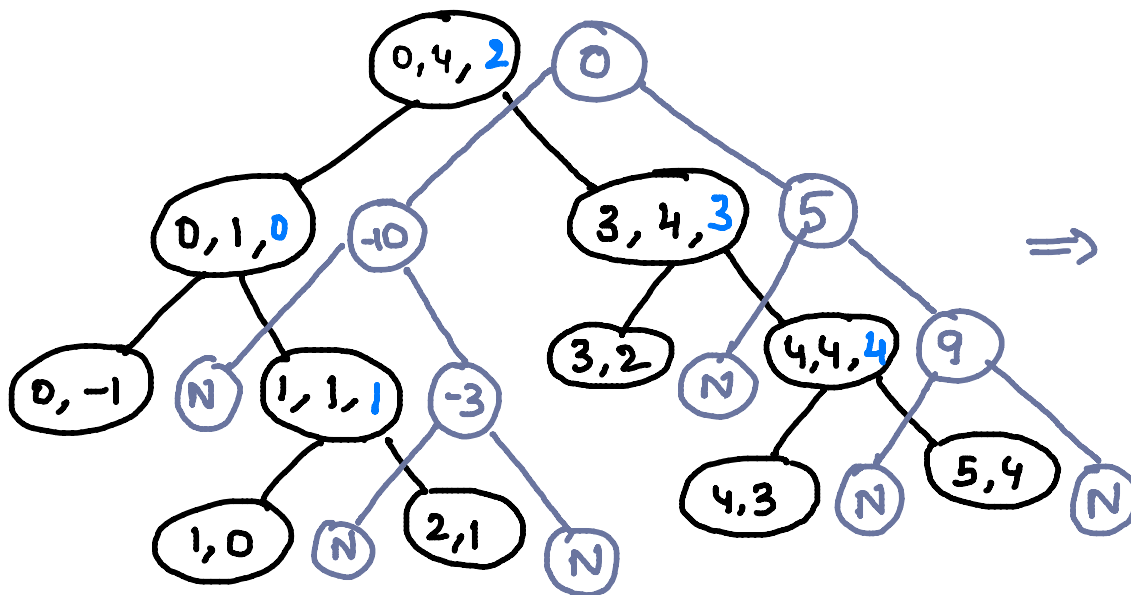
37) Convert Sorted Array to BST

Given sorted array, create a BST

Eg $[-10, -3, 0, 5, 9]$
0 1 2 3 4



start, end, mid



code →

```
class Solution {
public:
    TreeNode* createBST(vector<int>&nums, int start, int end){
        if(start>end) return NULL;

        int mid = (start + end)/2;
        TreeNode* root = new TreeNode(nums[mid]);

        root->left = createBST(nums, start, mid-1);
        root->right = createBST(nums, mid+1, end);
        return root;
    }

    TreeNode* sortedArrayToBST(vector<int>& nums) {
        return createBST(nums, 0, nums.size()-1);
    }
};
```

DI3 (38) Construct Binary Tree from Pre & Inorder Traversal

Ex: $pre = [3, 9, 20, 15, 7]$
 $in = [9, 3, 15, 20, 7]$

TC $\rightarrow O(n^2)$

SC $\rightarrow O(n)$

* for every node in Pre, the corresponding LST & RST are in In

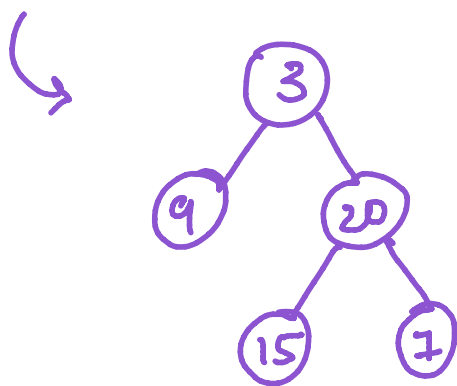
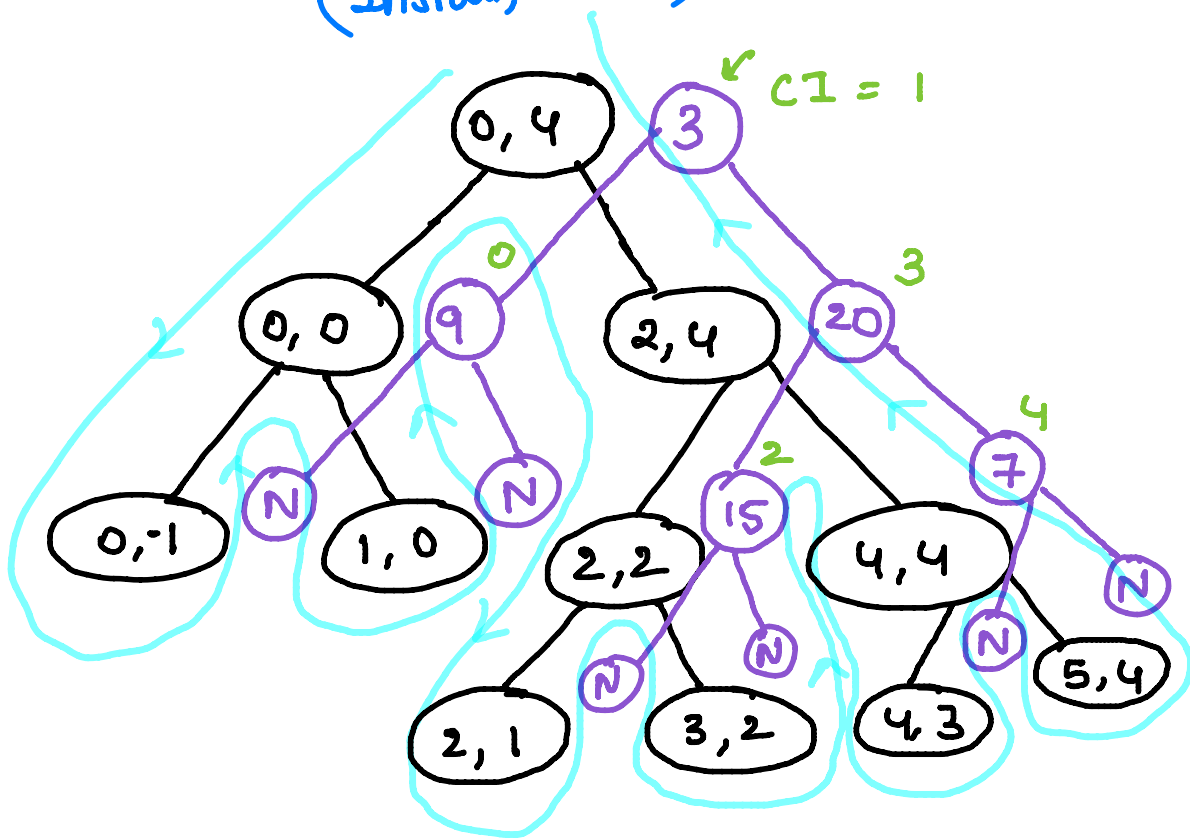
ie $3 \rightarrow [9, 3, 15, 20, 7]$
 LST: $[9]$ CI: 1 RST: $[15, 20, 7]$

$pre = [3, 9, 20, 15, 7]$
 $in = [9, 3, 15, 20, 7]$

LST = (instart, CI-1)
 RST = (CI+1, inend)

CI = index of pre[0] in In

(Instart, Inend)



- for preorder index = 0, inorder boundary = [0, 4]
- find root value in Inorder array & its index is CurrIndex
- if instart > CI-1 or CI+1 < inend return NULL

To reduce TC we can use

hash table to find indexing

TC $\rightarrow O(n)$

SC $\rightarrow O(n) + O(n)$

code →

```
1  class Solution {
2  public:
3      TreeNode* constructTree(vector<int>& preorder, unordered_map<int, int> &mp,
4      int start, int end, int &preIdx ){
5
6          if(start>end)    return NULL;
7          TreeNode* root = new TreeNode(preorder[preIdx]);
8
9          // find currIndex as per inorder array
10         int currIdx = mp[preorder[preIdx]];
11         // increment preIdx to find next root
12         preIdx++;
13
14         // recursively call LST & RST
15         root->left = constructTree(preorder, mp, start, currIdx-1, preIdx);
16         root->right = constructTree(preorder, mp, currIdx+1, end, preIdx);
17         return root;
18     }
19
20     unordered_map<int,int> populate(vector<int>&inorder){
21         unordered_map<int,int> mp;
22         for(int i=0; i<inorder.size(); i++){
23             mp[inorder[i]] = i;
24         }
25         return mp;
26     }
27
28     TreeNode* buildTree(vector<int>& preorder, vector<int>& inorder) {
29         unordered_map<int,int> mp = populate(inorder);
30         int preIdx = 0;
31         return constructTree(preorder, mp, 0, inorder.size()-1, preIdx);
32     }
33 };
34
```


39) Construct BinaryTree from In & Postorder traversal

Intuition is same as previous program, only changes are

- traverse from last element in postorder array
- process RST & then go for LST

code →

```
1  class Solution {
2  public:
3
4      TreeNode* constructTree(vector<int>& postorder, unordered_map<int, int> &mp,
5      int start, int end, int &postIdx ){
6
7          if(start>end)    return NULL;
8          TreeNode* root = new TreeNode(postorder[postIdx]);
9
10         // find currIndex as per inorder array
11         int currIdx = mp[postorder[postIdx]];
12         postIdx--;
13
14         // recursively call RST & LST
15         root->right = constructTree(postorder, mp, currIdx+1, end, postIdx);
16         root->left = constructTree(postorder, mp, start, currIdx-1, postIdx);
17         return root;
18     }
19
20     unordered_map<int,int> populate(vector<int>&inorder){
21         unordered_map<int,int> mp;
22         for(int i=0; i<inorder.size(); i++){
23             mp[inorder[i]] = i;
24         }
25         return mp;
26     }
27
28     TreeNode* buildTree(vector<int>& inorder, vector<int>& postorder) {
29         unordered_map<int,int> mp = populate(inorder);
30         int postIdx = postorder.size()-1;
31         return constructTree(postorder, mp, 0, inorder.size()-1, postIdx);
32     }
33 };
```

40 Construct BST from Preorder traversal

$$[8, 5, 1, 7, 10, 12]$$

← $T_c \rightarrow O(n \log n)$ (due to sorting)

Approach 1 $\rightarrow$ Sort given Preorder to get Inorder, now similar to problem (28).

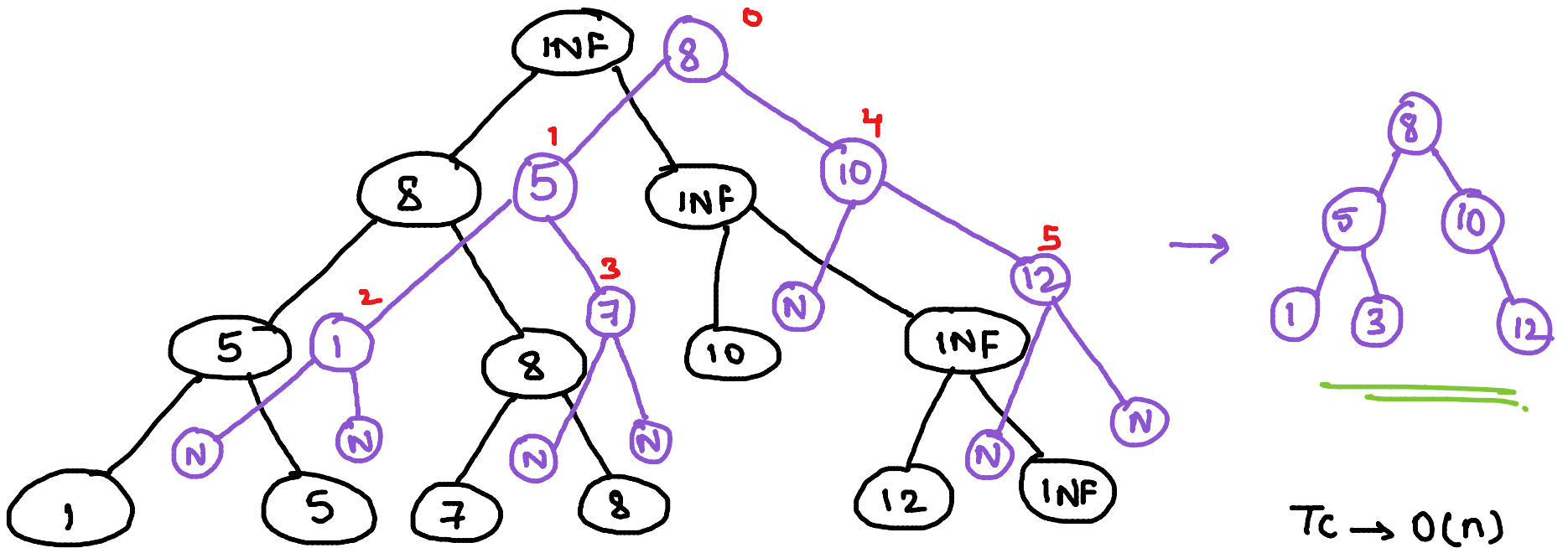
Approach 2 $\rightarrow$

$[8, 5, 1, 7, 10, 2]$

0 1 2 3 4 5

Boundary of LST $\rightarrow$ Val
RET $\rightarrow$ bo

$RST \rightarrow \text{boundVal}$ initially (INF)


$$\begin{aligned} T_c &\rightarrow O(n) \\ S_c &\rightarrow O(n) \end{aligned}$$

code →

```

1  class Solution {
2  public:
3      TreeNode* buildTree(vector<int>& preorder, int &preIdx, int boundary){
4          if(preIdx >= preorder.size() || preorder[preIdx] >= boundary)
5              return NULL;
6
7          // create root using preIdx
8          TreeNode* root = new TreeNode(preorder[preIdx]);
9          preIdx++;
10
11         // recursively call LST & RST
12         root->left = buildTree(preorder, preIdx, root->val);
13         root->right = buildTree(preorder, preIdx, boundary);
14         return root;
15     }
16
17     TreeNode* bstFromPreorder(vector<int>& preorder) {
18         int preIdx = 0;
19         return buildTree(preorder, preIdx, 1001);
20     }
21 };
22

```

Find the rest on

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