863. All Nodes Distance K in Binary Tree Medium Tree Binary Tree Depth-First Search Breadth-First Search

Leetcode Link

The problem presents a binary tree and asks us to find all nodes that are a certain distance k from a given target node. It's important

Problem Description

to note that distance here refers to the number of edges we must traverse to reach one node from another. This problem doesn't ask to find nodes only in the subtree of the target node but from the entire tree, so we must consider not only the children of the target node but also its ancestors and siblings. Intuition

they're ancestors, descendants, or neither (siblings or cousins). The approach to finding this solution is divided into several parts: 1. Mapping Parents: We first need a way to traverse the tree not only downwards from the root to the leaves (as is normally the case with tree traversals) but also upwards, from any node to its parent. This is not usually possible in a binary tree because

nodes don't have a reference to their parent. Therefore, we create a map that keeps track of each node's parent.

To solve this problem, we need to find all nodes that are at the specified distance k from the target node, regardless of whether

starting from the target node. As we explore the tree, we keep track of the current distance from the target. When this distance equals k, we add the current node's value to our answer. 3. Avoiding Revisits: To ensure we don't count any nodes twice or enter a loop, we keep a set of visited nodes. Whenever we visit

2. Performing the Search: Once we have the ability to move both up and down the tree, we perform a depth-first search (DFS)

- a node, we add it to the set. If we encounter a node that's already in our set, we skip it. With this approach, we can explore all possible paths - down to the children, up to the parent, and across to siblings and other relatives - to find all nodes that are exactly k distance away from the target.
- Solution Approach The solution is implemented using a depth-first search (DFS) algorithm along with additional data structures to track parent nodes

tree and values are their respective parent nodes. It goes through all the nodes in a pre-order traversal (parent, then left child,

2. Depth-First Search (DFS): The second function, dfs, is the crucial part of the implementation where we perform a depth-first

and visited nodes. Here's a step-by-step breakdown of how the code accomplishes the task: 1. Parent Mapping: The first function, parents, is a recursive function that populates a dictionary p where keys are nodes of the

then right child) and assigns the current node's parent to it in the dictionary.

target node. At the end of the function, we simply return ans.

Step 1: Parent Mapping First, we construct a map of parent pointers:

Step 3: Avoiding Revisits We start with an empty vis set to keep track of visited nodes.

search, starting from the target node. The function takes a node and the distance k as arguments.

3. Visited Set: Inside the DFS function, we first ensure that the current node is not None and hasn't been visited yet, as indicated by checking the vis set. If we have seen the node already, we return early to avoid revisiting it.

- 4. Base Case for Distance: If the distance k is 0, it means we have found a node at the exact distance from the target we are looking for, so we append the value of the current node to the ans list, which will eventually be our output. 5. Recursive Case for Traversal: If k is not 0, we recursively call DFS on the left child, the right child, and the parent of the current
- 6. Execution: Finally, we initialize our data structures: p for parents, ans for answers, and vis for visited nodes. We then populate p using the parents function and execute dfs starting with the target node and the initial distance k. 7. Result: After DFS completes the traversal of the tree, ans will contain all the node values that are k distance away from the

In summary, the algorithm traverses the entire binary tree to build a parent-child relationship map, then it uses DFS to search all

node, each time with k-1 to account for the decrease in distance as we move one step away from the target.

possible paths from the target node to find nodes that are exactly k steps away while avoiding loops and repetitions. Example Walkthrough

Let's walk through a small example to illustrate the solution approach described above. Suppose we have the following binary tree

and we want to find all the nodes that are a distance k = 2 away from the target node with value 5.

Step 2: Performing the Search We then perform a DFS starting from the target node 5. We are looking for nodes that are at a distance k = 2.

4. Thus, the answer is [3, 4].

target in a binary tree.

Python Solution

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The parent of node 2 is 1.

The parent of node 3 is 1.

The parent of node 4 is 2.

The parent of node 5 is 2, and so on.

Starting from node 5, the search goes as follows:

Visit node 5 (distance k = 2), mark it as visited.

Move to node 8 (distance k = 1), mark it as visited.

parent 1). Again, as the distance is 0, add node 3 to the answer.

 Similarly, move to node 9 (distance k = 1), mark it as visited. Since node 9 has no children, return to node 5 and move up to its parent node 2 (distance k = 1), mark it as visited. • Since node 2 is visited for the first time with distance k = 1, move to node 4 (already visited) and node 3 (distance k = 0 via

Step 4: Summary of the Results At the end of the DFS, we find that the nodes at distance 2 from the target node 5 are nodes 3 and

By following the steps in the provided solution approach, we have successfully found all nodes at a specific distance from a given

Move to node 4 (distance k = 0), since the distance is 0 and node 4 hasn't been visited, add it to the answer.

1 # Definition for a binary tree node. 2 class TreeNode:

if node:

return

parent_map = {}

visited = set()

return result

map_parents(root, None)

// Definition for a binary tree node.

private Set<Integer> visited;

private List<Integer> answer;

mapParents(root, null);

return answer;

result = []

visited.add(node.val)

if remaining_distance == 0:

result.append(node.val)

self.val = val self.left = left self.right = right

def __init__(self, val=0, left=None, right=None):

parent_map[node] = parent

map_parents(node.left, node)

if not node or node.val in visited:

Initialize the parent map and result list

Map parents for all nodes in the tree

Start DFS from the target node

find_nodes_at_distance_k(target, k)

private Map<TreeNode, TreeNode> parentMap;

// This method finds all nodes at distance K from the target node.

answer = new ArrayList<>(); // Stores the results.

private void mapParents(TreeNode node, TreeNode parent) {

// Associates each node with its parent.

findNodesAtDistanceK(target, k);

// Maps each node to its parent recursively.

// Perform DFS to find nodes at distance K.

public List<Integer> distanceK(TreeNode root, TreeNode target, int k) {

parentMap = new HashMap<>(); // Used to store parent-child relationships.

visited = new HashSet<>(); // Tracks visited nodes to prevent cycles.

map_parents(node.right, node)

def find_nodes_at_distance_k(node, remaining_distance):

class Solution: def distanceK(self, root: TreeNode, target: TreeNode, k: int) -> List[int]: # Helper function to store parent pointers for each node 11 def map_parents(node, parent): 12

Helper function to perform Depth-First Search (DFS) and find nodes at distance k

25 else: 26 # Visit children and parent 27 find_nodes_at_distance_k(node.left, remaining_distance - 1) 28 find_nodes_at_distance_k(node.right, remaining_distance - 1) 29 find_nodes_at_distance_k(parent_map[node], remaining_distance - 1) 30

class TreeNode { int val; TreeNode left; TreeNode right; TreeNode(int x) { val = x; }

class Solution {

Java Solution

import java.util.*;

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33
           if (node == null) {
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               return;
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37
           parentMap.put(node, parent);
           mapParents(node.left, node); // Parent for left child is 'node'
38
           mapParents(node.right, node); // Parent for right child is 'node'
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       // DFS to find and add all nodes that are K distance from the given node.
43
       private void findNodesAtDistanceK(TreeNode node, int k) {
           if (node == null || visited.contains(node.val)) {
44
               // Base case: if the node is null or already visited, stop the search.
45
46
               return;
47
48
           visited.add(node.val); // Mark this node as visited.
49
50
           if (k == 0) {
51
52
               // If the distance is zero, the current node is K distance from the target.
53
               answer.add(node.val);
54
               return; // Node added to the answer, end this path here.
55
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57
           // Continue searching in the left subtree.
58
            findNodesAtDistanceK(node.left, k - 1);
59
60
           // Continue searching in the right subtree.
            findNodesAtDistanceK(node.right, k - 1);
61
62
           // Also search the sub-tree above using the parent references.
64
           findNodesAtDistanceK(parentMap.get(node), k - 1);
65
66 }
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C++ Solution
    /**
      * Definition for a binary tree node.
      */
    struct TreeNode {
         int val;
        TreeNode *left;
         TreeNode *right;
         TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
    };
  9
 10
 11 class Solution {
 12 public:
         // Maps each node to its parent
 13
 14
         unordered_map<TreeNode*, TreeNode*> parentMap;
 15
 16
         // Keeps track of visited nodes
 17
         unordered_set<int> visited;
 18
         // Stores the results
 19
 20
         vector<int> result;
 21
 22
         // Function that returns all nodes at distance K from the target node
 23
         vector<int> distanceK(TreeNode* root, TreeNode* target, int k) {
 24
             // Find and store all parents of nodes
 25
             storeParents(root, nullptr);
 26
 27
             // Perform search to find all nodes at distance k
 28
             depthFirstSearch(target, k);
 29
```

val: number; left: TreeNode | null; right: TreeNode | null; 6 constructor(val: number) { this.val = val; 8

2 class TreeNode {

Typescript Solution

1 // Definition for a binary tree node.

this.left = null;

this.right = null;

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};

return result;

if (!node) return;

parentMap[node] = parent;

storeParents(node->left, node);

storeParents(node->right, node);

void depthFirstSearch(TreeNode* node, int k) {

// Mark the current node as visited

result.push_back(node->val);

depthFirstSearch(node->left, k - 1);

depthFirstSearch(node->right, k - 1);

visited.insert(node->val);

 $if (k == 0) {$

return;

if (!node || visited.count(node->val)) return;

// Continue the search in left and right subtree

// Also consider the parent node in the search

depthFirstSearch(parentMap[node], k - 1);

// Helper method to relate each node to its parent in the tree

// The DFS method that traverses the tree to find nodes at a distance k

// If the desired distance is reached, add the node's value to the results

// If the node is null or already visited, stop the search

void storeParents(TreeNode* node, TreeNode* parent) {

```
12 }
 13
    // Maps each node to its parent
    const parentMap: Map<TreeNode, TreeNode | null> = new Map();
 16
 17 // Keeps track of visited nodes
 18 const visited: Set<number> = new Set();
 19
 20 // Stores the results
 21 const result: number[] = [];
 22
    // Function that returns all nodes at distance K from the target node
    function distanceK(root: TreeNode | null, target: TreeNode, k: number): number[] {
        // Find and store all parents of nodes
 25
 26
         storeParents(root, null);
 27
 28
         // Perform search to find all nodes at distance k
         depthFirstSearch(target, k);
 29
 30
 31
         return result;
 32 }
 33
     // Helper function to relate each node to its parent in the tree
     function storeParents(node: TreeNode | null, parent: TreeNode | null) {
 36
         if (!node) return;
 37
 38
         parentMap.set(node, parent);
 39
        storeParents(node.left, node);
         storeParents(node.right, node);
 41
 42 }
 43
     // The DFS method that traverses the tree to find nodes at a distance k
     function depthFirstSearch(node: TreeNode | null, k: number) {
 46
        // If the node is null or already visited, stop the search
 47
         if (!node || visited.has(node.val)) return;
 48
 49
        // Mark the current node as visited
         visited.add(node.val);
 50
 51
 52
         // If the desired distance is reached, add the node's value to the results
 53
        if (k === 0) {
 54
             result.push(node.val);
 55
             return;
 56
 57
 58
         // Continue the search in the left and right subtree
 59
         depthFirstSearch(node.left, k - 1);
         depthFirstSearch(node.right, k - 1);
 60
 61
 62
         // Also consider the parent node in the search
 63
         const parentNode = parentMap.get(node) || null;
 64
         depthFirstSearch(parentNode, k - 1);
 65 }
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Time and Space Complexity
The provided Python code defines a function distanceK that finds all nodes at distance k from a target node in a binary tree.
```

2. The function dfs is a recursive depth-first search. In the worst case, it can visit each node once when k equals the height of the tree. Additionally, it might visit each node's parent, resulting in 0(2N) operations, which simplifies to 0(N). Given these steps, the overall time complexity is O(N) since both parents and dfs functions operate linearly with respect to the

0(N).

number of nodes in the tree.

Now, let's consider the space complexity:

Space Complexity:

Time Complexity:

1. The p dictionary holds a pair for each node in the tree, hence O(N) space. 2. The ans list could hold up to N nodes (in the case that the tree is a straight line and k equals N-1), so its space is O(N). 3. The call stack for the DFS function can go up to the height of the tree in the case of a skewed tree, which in the worst case is

To analyze the time complexity, let's break down the procedure into its main steps:

- 4. The vis set contains nodes that are already visited, which in the worst case can be O(N) as well when every node is visited. The space complexity is determined by adding the space required for the p dictionary, the ans list, the call stack, and the vis set, which all contribute linearly to O(N) space.
- Overall, taking into account both the worst-case scenarios for the recursive calls stack and the space needed for auxiliary data

1. The function parents traverses the entire tree to build a dictionary p mapping each node to its parent. This is a depth-first

search (DFS) with a single visit to each node, hence its complexity is O(N), where N is the number of nodes in the tree.

structures, the space complexity is O(N).