113. Path Sum II Medium Tree **Depth-First Search** Backtracking **Binary Tree Leetcode Link**

In this problem, we are given a binary tree and an integer targetSum. Our task is to find all the different paths from the root of the

Problem Description

binary tree to any of its leaves such that the sum of node values along each path is equal to targetSum. A root-to-leaf path is defined as a path that begins at the root node and ends at a leaf node, where a leaf node is a node that does not have any children. The solution should return all such paths as lists of node values. Intuition

recursively visit each node's children until we reach the leaf nodes. As we traverse the tree, we can keep track of the sum of the values of the nodes along the path and the nodes themselves in a list. When we reach a leaf node (a node with no children), we check if the sum of the path is equal to targetSum. If it is, we found a valid

path and add a copy of the current path list to an answer array that we maintain to store all valid paths. If the sum is not equal to

The intuition behind the solution is to traverse the tree in a depth-first search (DFS) manner. We can start from the root and

targetSum, we simply backtrack and continue exploring other nodes and paths. The key aspects of the solution are: Starting from the root, perform DFS to explore all paths to leaf nodes.

 Keep a temporary list to track the node values for the current path. If a leaf node is reached where the running sum is equal to targetSum, add the current path to the solution list.

After processing a node, backtrack by popping the last node value from the temporary path list before returning to the parent

Keep a running sum of node values for the current path being explored.

- node. This approach allows us to systematically explore all potential paths in the tree and collect the ones that satisfy the condition
- without missing any.
- The solution uses a recursive depth-first search (DFS) strategy to explore all possible root-to-leaf paths in the binary tree. Let's walk through the key components of the implementation:

visited.

targetSum.

given criteria.

Solution Approach

 The root of the current subtree that we are exploring. A running sum s that starts at 0 and accumulates the sum of node values from the root to the current node.

A list t is used to maintain the current path, representing the sequence of node values from the root to the current node being

The dfs function is a helper function that we define within the pathSum method. It takes two arguments:

A list ans is maintained to store all successful paths that sum up to targetSum.

predecessors as we return to the parent node.

- The dfs function works as follows: 1. If the current node root is None, we have hit a dead-end and need to terminate this branch of recursion.
 - 2. We add the current node's value to the running sum s and append this value to t to track the path.
 - successful path. We make a shallow copy of t using t[:] and append this copy to ans to record the successful path. 4. We recursively call dfs on the left and right children of the current node, with the updated running sum s.

5. After exploring both children, we backtrack by popping the last element from t, ensuring that t reflects the path for its

By calling dfs(root, 0) initially, we begin the search from the root of the entire tree with an initial sum of 0. We keep exploring

This approach effectively employs DFS traversal and backtracking to explore the tree's paths and return only those that meet the

3. If the current node is a leaf (neither left nor right child exists), and the running sum s equals targetSum, we have found a

The return value of the pathSum function is ans, which contains lists of node values for all the root-to-leaf paths that add up to

recursively as described above until all possible paths have been checked for the condition.

Let's consider a binary tree and a targetSum of 22 for our example:

will track both the current sum of the path and the path of node values itself as we progress. Here's how it would work, step-by-

4. We move to node 7, and now the path becomes [5, 4, 11, 7] and s is 27. Since this is a leaf, we check if s is equal to targetSum

5. We then visit the right child of 11, which is node 2, making the path [5, 4, 11, 2] and s is now 22. This is a leaf node and the

We'll use the DFS approach to navigate through this tree and look for such paths. Using the solution approach described earlier, we

(22). It is not, so we backtrack to 11.

is now [5, 8] and s becomes 13.

step:

Example Walkthrough

sum matches targetSum, so this path is added to our answer list. 6. After checking both children of node 11, we backtrack to node 4 and then to node 5, and proceed to its right child (8). Our path

The result of the search using our example tree and targetSum is the following list of paths:

Here we define a TreeNode class for the binary tree nodes.

Helper method to perform depth-first search.

nonlocal targetSum, paths, current_path

paths.append(current_path[:])

dfs(node.current_left, current_sum)

dfs(node.current_right, current_sum)

Add the current node's value to the running sum.

Continue the search on the left and right subtrees.

This will hold all the paths that sum to the target.

* Finds all paths from root to leaves that sum to targetSum.

* @param targetSum The sum that each path needs to add up to.

public List<List<Integer>> pathSum(TreeNode root, int targetSum) {

* Performs a depth-first search to find all paths with the target sum.

* @param remainingSum The remaining sum after subtracting the node's value.

// Subtract the node's value from the remaining sum and add the node's value to the current path

// Check if it's a leaf node and the remaining sum is zero, which means we've found a valid path

* @return A list of all paths that sum to targetSum.

* @param node The current node in the recursion.

private void dfs(TreeNode node, int remainingSum) {

// If we've reached a null node, just return.

* @param root The root of the tree.

dfs(root, targetSum);

if (node == null) {

remainingSum -= node.val;

currentPath.add(node.val);

return;

return paths;

Temp list to hold the current path being checked.

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

3. Continuing deeper, we reach node 11 and our path is [5, 4, 11], with s updating to 20.

2. We move to the left child (4), include it in our path. So, our path is now [5, 4] and s becomes 9.

We want to find all root-to-leaf paths where the sum of the node values is equal to targetSum.

1. We start with the root node (5), add it to our path and running sum s is now 5.

7. Node 8 has two children, so we explore the left child first (node 13). Although now s becomes 26, since 13 has no children, we quickly backtrack to 8 without changing our path list. 8. Moving to the right child of node 8 (node 4), the path and sum update to [5, 8, 4] and s of 17, respectively. 9. Node 4 has one child, which is a leaf (node 5). We visit it, and the path becomes [5, 8, 4, 5] and s sums up to 22, which is equal to targetSum. We add this path to the list of valid paths.

[5, 8, 4, 5] The DFS approach has successfully identified all the paths whose node values sum up to the targetSum.

self.current_left = left self.current_right = right

if node.current_left is None and node.current_right is None and current_sum == targetSum:

We've finished exploring from this node, so backtrack and remove the node value from the current path.

def pathSum(self, root: Optional[TreeNode], targetSum: int) -> List[List[int]]:

If so, add a copy of the current path to the list of paths.

10. All nodes are visited, and we've now found all the required paths. We populate these into our answers list.

```
17
               current_sum += node.val
               # Add the current node's value to the current path being evaluated.
18
19
               current_path.append(node.val)
20
               # Check if we're at a leaf node and the running sum equals the target sum.
21
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*/

/**

[5, 4, 11, 2],

Python Solution

self.val = val

def dfs(node, current_sum):

if node is None:

current_path.pop()

paths = []

return

class TreeNode:

class Solution:

```
36
           current_path = []
           # Initialize the DFS from the root node with a sum of 0.
37
38
           dfs(root, 0)
39
           return paths
40
Java Solution
    * Definition for a binary tree node.
    * This class defines the structure of the tree node which includes
    * a value, and references to the left and right child nodes.
6 class TreeNode {
       int val;
       TreeNode left;
8
       TreeNode right;
9
10
11
       TreeNode() {}
12
13
       TreeNode(int val) {
14
           this.val = val;
15
16
17
       TreeNode(int val, TreeNode left, TreeNode right) {
           this.val = val;
18
           this.left = left;
19
           this.right = right;
20
22 }
23
24
   /**
    * Solution class where we define the method to find all root-to-leaf paths
    * that add up to a given target sum.
27
    */
   class Solution {
       // A list to store all the paths that sum to the target
29
       private List<List<Integer>> paths = new ArrayList<>();
30
       // A temporary list to keep track of the current path
31
32
       private List<Integer> currentPath = new ArrayList<>();
33
34
       /**
```

```
if (node.left == null && node.right == null && remainingSum == 0) {
61
62
               // If so, add a copy of the current path to the list of valid paths
63
               paths.add(new ArrayList<>(currentPath));
64
65
66
           // Recurse deeper into the tree
           dfs(node.left, remainingSum); // Go left
67
           dfs(node.right, remainingSum); // Go right
68
69
           // After exploring both sides, remove the current node's value before going back up the tree
70
           currentPath.remove(currentPath.size() - 1);
71
72
73 }
74
C++ Solution
  1 /**
     * Definition for a binary tree node.
     */
  4 struct TreeNode {
         int val;
         TreeNode *left;
         TreeNode *right;
         TreeNode() : val(0), left(nullptr), right(nullptr) {}
  8
         TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
  9
         TreeNode(int x, TreeNode *left, TreeNode *right) : val(x), left(left), right(right) {}
 10
 11 };
 12
 13 class Solution {
    public:
 15
        // Main function to find all paths that sum to the target.
 16
         vector<vector<int>> pathSum(TreeNode* root, int targetSum) {
 17
             vector<vector<int>> allPaths; // Stores all paths that sum to targetSum.
             vector<int> currentPath; // Holds the current path being evaluated.
 18
 19
 20
             // Helper function to perform DFS on the tree
 21
             function<void(TreeNode*, int)> depthFirstSearch = [&](TreeNode* node, int remainingSum) {
 22
                 if (!node) // Base case: If the node is null, return.
 23
                     return;
 24
 25
                 remainingSum -= node->val; // Subtract the node's value from the remaining sum.
 26
                 currentPath.emplace_back(node->val); // Add the current node's value to the path.
 27
 28
                 // Check if it's a leaf node and the remaining sum is 0; if so, store the path.
 29
                 if (!node->left && !node->right && remainingSum == 0) {
                     allPaths.emplace_back(currentPath);
 30
 31
 32
 33
                 // Continue searching in the left and right subtrees.
 34
                 depthFirstSearch(node->left, remainingSum);
 35
                 depthFirstSearch(node->right, remainingSum);
 36
 37
                 // Backtrack: remove the last element before returning to the previous caller.
 38
                 currentPath.pop_back();
 39
             };
 40
 41
             // Start the depth-first search with the original root and target sum.
 42
             depthFirstSearch(root, targetSum);
 43
 44
             // Return all found paths after the search is complete.
 45
             return allPaths;
 46
 47 };
 48
Typescript Solution
  // Definition for a binary tree node
  class TreeNode {
       val: number;
```

```
/**
14
    * Main function to find all paths that sum to the target value
    * @param root The root of the binary tree
    * @param targetSum The sum to find in the binary tree
    * @return An array of arrays, where each array represents a path that sums to targetSum
19
    */
   const pathSum = (root: TreeNode | null, targetSum: number): number[][] => {
       const allPaths: number[][] = []; // To store all the valid paths.
21
22
       const currentPath: number[] = []; // To keep track of the current path.
24
       // Helper function to perform DFS (Depth First Search) on the binary tree
25
       const dfs = (node: TreeNode | null, remainingSum: number) => {
           if (!node) return; // Base case: if the current node is null, do nothing.
26
27
28
           remainingSum -= node.val; // Subtract the current node value from the remaining sum.
           currentPath.push(node.val); // Insert the current node value into the current path.
30
31
           // Check if it's a leaf node and the remaining sum is 0, which means we've found a valid path.
32
           if (!node.left && !node.right && remainingSum === 0) {
33
               allPaths.push([...currentPath]); // Add a copy of the current path to allPaths.
34
35
           dfs(node.left, remainingSum); // Continue DFS on the left subtree.
           dfs(node.right, remainingSum); // Continue DFS on the right subtree.
38
           currentPath.pop(); // Backtrack: remove the last node value from the current path.
39
       };
40
41
       dfs(root, targetSum); // Start DFS with the root node and the initial targetSum.
43
       return allPaths; // Return all the valid paths.
44
45 };
   export { TreeNode, pathSum }; // Exporting the TreeNode class and pathSum function for other modules to use.
Time and Space Complexity
Time Complexity
The time complexity of the provided code is O(n), where n is the number of nodes in the tree. This is because in the worst case, the
algorithm will visit each node exactly once while performing depth-first search (DFS).
```

constructor(val: number = 0, left: TreeNode | null = null, right: TreeNode | null = null) {

Space Complexity The space complexity is more complex to analyze due to the space taken by the recursion stack and the space required to store the

left: TreeNode | null;

right: TreeNode | null;

this.val = val;

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11

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12 }

this.left = left;

this.right = right;

paths. 1. Recursion Stack: The space taken by the recursion stack is proportional to the height of the tree. In the worst case for a skewed tree, the height can be n leading to O(n) complexity. In the best case for a balanced tree, the height will be log(n), leading to

O(log(n)) complexity. 2. Path Storage: For every leaf node, we potentially have a path equal in size to the tree's height. In the worst case (all paths are saved), this results in O(n * h) space, where h is the height of the tree. However, since the height can range from log(n) for a

Considering these aspects, the total space complexity of the code can be 0(n * h) where h is the height of the tree. The exact bound depends on the shape of the tree. In the case of a balanced tree, the space complexity would be 0(n * log(n)), while for a completely unbalanced tree, it would be closer to 0(n^2).

balanced tree to n for a skewed tree, the space complexity for storing paths ranges from 0(n * log(n)) to $0(n^2)$.