All Paths for a Sum (medium)

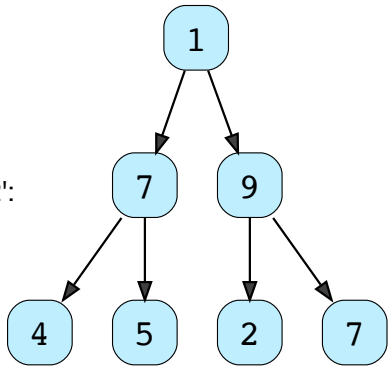
We'll cover the following

Problem Statement#

Given a binary tree and a number ‘S’, find all paths from root-to-leaf such that the sum of all the node values of each path equals ‘S’.

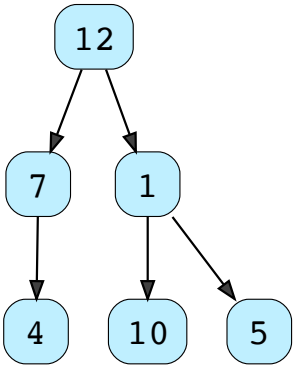
Example 1:

S: 12
Output: [[1, 7, 4], [1, 9, 2]]
Explanation: Here are the two paths with sum '12':
1 -> 7 -> 4 and 1 -> 9 -> 2



Example 2:

S: 23
Output: [[12, 7, 4], [12, 1, 10]]
Explanation: Here are the two paths with sum '23':
12 -> 7 -> 4 and 12 -> 1 -> 10



Try it yourself#

Try solving this question here:

Java | Python3 | JS | C++

```
class TreeNode {
  constructor(value) {
    this.value = value;
    this.left = null;
    this.right = null;
```

```
  }
};


const find_paths = function(root, sum) {
  allPaths = [];
  // TODO: Write your code here
  return allPaths;
};


var root = new TreeNode(12)
root.left = new TreeNode(7)
root.right = new TreeNode(1)
root.left.left = new TreeNode(4)
root.right.left = new TreeNode(10)
root.right.right = new TreeNode(5)
sum = 23
console.log(`Tree paths with sum: ${sum}: ${find_paths(root, sum)}`)

```

Run Save Reset

Solution#

This problem follows the Binary Tree Path Sum (https://www.educative.io/collection/page/5668639101419520/5671464854355968/5642684278505472/) pattern. We can follow the same **DFS** approach. There will be two differences:

1. Every time we find a root-to-leaf path, we will store it in a list.
2. We will traverse all paths and will not stop processing after finding

the first path.

Code#

Here is what our algorithm will look like:

Java | Python3 | C++ | JS

```
const Deque = require('./collections/deque'); //http://www.collectionsjs.com

class TreeNode {
  constructor(val, left = null, right = null) {
    this.val = val;
    this.left = left;
    this.right = right;
  }
}


function find_paths(root, sum) {
  allPaths = [];
  find_paths_recursive(root, sum, new Deque(), allPaths);
  return allPaths;
}


function find_paths_recursive(currentNode, sum, currentPath, allPaths) {
  if (currentNode === null) {
    return;
  }

  // add the current node to the path
  currentPath.push(currentNode.val);

  // if the current node is a leaf and its value is equal to sum, save the curre
  if (currentNode.val === sum && currentNode.left === null && currentNode.right =
    allPaths.push(currentPath.toArray());
  } else {
    // traverse the left sub-tree
    find_paths_recursive(currentNode.left, sum - currentNode.val, currentPath, a
    // traverse the right sub-tree
```

```
    find_paths_recursive(currentNode.right, sum - currentNode.val, currentPath, a
  }
  // remove the current node from the path to backtrack,
  // we need to remove the current node while we are going up the recursive call
  currentPath.pop();
}


const root = new TreeNode(12);
root.left = new TreeNode(7);
root.right = new TreeNode(1);
root.left.left = new TreeNode(4);
root.right.left = new TreeNode(10);
root.right.right = new TreeNode(5);
let sum = 23,
  result = find_paths(root, sum);

process.stdout.write(`Tree paths with sum ${sum}: `);
for (i = 0; i < result.length; i++) {
  process.stdout.write(`[${result[i]}] `);
}
```

Run Save Reset

Time complexity#

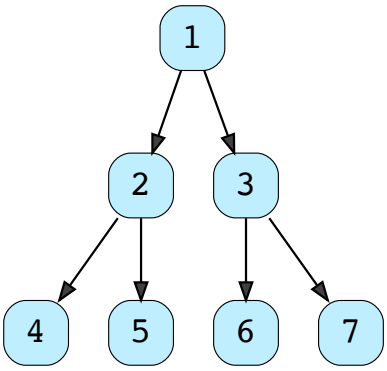
The time complexity of the above algorithm is $O(N^2)$, where 'N' is the total number of nodes in the tree. This is due to the fact that we traverse each node once (which will take $O(N)$), and for every leaf node, we might have to store its path (by making a copy of the current path) which will take $O(N)$.

We can calculate a tighter time complexity of $O(NlogN)$ from the space complexity discussion below.

Space complexity#

If we ignore the space required for the `allPaths` list, the space complexity of the above algorithm will be $O(N)$ in the worst case. This space will be used to store the recursion stack. The worst-case will happen when the given tree is a linked list (i.e., every node has only one child).

How can we estimate the space used for the `allPaths` array? Take the example of the following balanced tree:



Here we have seven nodes (i.e., `N = 7`). Since, for binary trees, there exists only one path to reach any leaf node, we can easily say that total root-to-leaf paths in a binary tree can't be more than the number of leaves. As we know that there can't be more than $(N + 1)/2$ leaves in a binary tree, therefore the maximum number of elements in `allPaths` will be $O((N + 1)/2) = O(N)$. Now, each of these paths can have many nodes in them. For a balanced binary tree (like above), each leaf node will be at maximum depth. As we know that the depth (or height) of a balanced binary tree is $O(logN)$ we can say that, at the most, each path

can have $logN$ nodes in it. This means that the total size of the allPaths list will be $O(N * logN)$. If the tree is not balanced, we will still have the same worst-case space complexity.

From the above discussion, we can conclude that our algorithm's overall space complexity is $O(N * logN)$.

Also, from the above discussion, since for each leaf node, in the worst case, we have to copy $log(N)$ nodes to store its path; therefore, the time complexity of our algorithm will also be $O(N * logN)$.

Similar Problems#

Problem 1: Given a binary tree, return all root-to-leaf paths.

Solution: We can follow a similar approach. We just need to remove the "check for the path sum."

Problem 2: Given a binary tree, find the root-to-leaf path with the maximum sum.

Solution: We need to find the path with the maximum sum. As we traverse all paths, we can keep track of the path with the maximum sum.

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Binary Tree Path Sum (easy)

Sum of Path Numbers (medium)

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