637. Average of Levels in Binary Tree **Binary Tree Depth-First Search Breadth-First Search** Easy Tree

The task is to calculate the average value of all the nodes on each level of a binary tree. A binary tree is a data structure where each

level 2, and so on.

Problem Description

before moving on to the next one.

represents the average value of the nodes at a corresponding level. The problem states that the answer will be considered correct if it's within 10^-5 of the actual average. This means our solution does not need to be exact down to the last decimal place, allowing for a small margin of error, potentially due to floating-point precision issues.

The input will be the root node of a binary tree, and the output should be a list of floating-point numbers, where each number

node has at most two children, referred to as the left and the right child. In this context, a level refers to a set of nodes that are the

same number of steps from the root. For example, the root itself is at level 0, its children are at level 1, the children's children are at

Intuition

To find the average value of nodes at each level, we can use a technique called breadth-first search (BFS). This approach involves

traversing the tree level by level from top to bottom and left to right and computing the average of the nodes' values at each level

2. The queue will help us process all nodes level by level. For each level:

Here's how we can arrive at the solution: 1. We start by initializing a queue data structure and put the root node in it.

We compute the total number of nodes at that level (this is the same as the number of elements currently in the queue).

• We then iterate over these elements, summing up their values and adding their children (if any) to the back of the queue to

After processing all nodes in the current level, we calculate the average value by dividing the sum of the nodes' values by

the total number of nodes. We append this average to our answer list. 3. Once the queue is empty, all levels have been processed, and our answer list contains the average of each level.

be processed in the next round.

- 4. We return the answer list. Using a queue in this manner ensures that we process all nodes at a given level before moving on to the next, enabling us to
- calculate the average per level efficiently.

3. Level Processing: Within the while-loop, we perform these actions:

A note on the implementation: In Python, we use deque from the collections module, as it provides an efficient way to pop elements from the left of the queue and to append elements to the right of the queue with 0(1) time complexity for each operation, which is essential for maintaining the overall efficiency of the BFS algorithm.

1. Queue Initialization: The queue is initialized with q = deque([root]), which will contain all nodes from the current level that we need to process. 2. Level Traversal: We use a while-loop while q: to continue processing nodes level by level until there are no more nodes left to

The implementation follows the BFS pattern, using a queue to track nodes at each level. Here are the steps taken, matched with the

and initialize a sum variable s to collect the sum of the nodes' values.

averages of each level, is returned.

Solution Approach

code provided:

process.

 A for-loop is used to iterate over each node in the current level: for _ in range(n):. For each node, we use q.popleft() to pop the leftmost node from the queue (representing the next node in the current level). 4. Node Processing and Child Enqueueing: Within the for-loop:

 \circ s, n = 0, len(q): We start by storing the current level size n (which represents the number of nodes at the current level)

• We increment the sum with the current node's value: s += root.val. We check for children of the current node and enqueue them:

• If a left child exists: if root.left:, we append it to the queue q.append(root.left).

Similarly, for a right child: if root.right:, we append it to the queue q.append(root.right).

sum s by the number of nodes n: ans.append(s / n). The result is then appended to the answer list ans.

Each iteration of the for-loop processes one node from the current level until all nodes at that level have been handled.

(these would be nodes from the next level that were enqueued during the for-loop). This process repeats until all levels are processed.

7. Returning the Result: After all levels have been iterated over and the while-loop exits, the answer list ans, now containing the

The solution uses a simple but effective linear-time algorithm that processes each node exactly once, giving an overall time

nodes at any level in the input tree (in the worst case, m could be up to n/2 for a full level in a perfectly balanced tree).

complexity of O(n), where n is the number of nodes in the <u>tree</u>. The space complexity is O(m), where m is the maximum number of

5. Average Calculation and Storage: After all nodes of the current level are processed, we calculate the average by dividing the

6. Continuation and Completion: Once the for-loop finishes, the while-loop iterates again if there are any nodes left in the queue

- Example Walkthrough Let's illustrate the solution approach with a concrete example. Consider the following binary tree:
- We want to calculate the average value of all the nodes on each level of this tree. 1. Queue Initialization: Initialize the queue with the root node (which is 3).

2. Level Traversal: The while-loop begins since the queue is not empty. while q:

3. Level Processing: For the first level (level 0 with the root node), we store the current queue size, which is 1, and the sum

s += 3

2 q.append(20)

1 s += 9

2 s += 20

3 q.append(15)

4 q.append(7)

which in this case is just 3 / 1.

ans.append(3.0) \rightarrow ans = [3.0]

s, n = 0, $len(q) \rightarrow s$, n = 0, 2

ans.append(14.5) \rightarrow ans = [3.0, 14.5]

For the third level (level 2), we execute a similar process.

q = deque([3])

variable is initialized to 0.

s, n = 0, $len(q) \rightarrow s$, n = 0, 1

We then enter a for-loop to process this level's nodes.

Since node 3 has two children (9 and 20), we enqueue those children. q.append(9)

5. Average Calculation and Storage: At the end of the level, we calculate the average by dividing the sum by the number of nodes,

6. Continuation and Completion: The queue now contains two nodes for the next level (9 and 20). The while-loop continues for

4. Node Processing and Child Enqueueing: Pop the leftmost node (which is 3) and add its value to the sum.

the next iteration. For the second level (level 1), we again calculate the total nodes and sum.

Calculate and store the average for this level (29 / 2).

7. Returning the Result: Now the queue is empty, and the while-loop exits. We return the list ans, which contains [3.0, 14.5,

Calculate and store the average (22 / 2). ans.append(11.0) \rightarrow ans = [3.0, 14.5, 11.0]

Python Solution

class Solution:

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51 // Example usage:

while (queue.length > 0) {

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from collections import deque

queue = deque([root])

averages = []

while queue:

return averages

this.val = val;

class Solution {

/**

this.left = left;

this.right = right;

* Computes the average of each level of a binary tree.

List<Double> averages = new ArrayList<>(); // Stores the averages of each level

int levelSize = queue.size(); // Number of nodes in the current level

sum += currentNode.val; // Add the node's value to the sum

long sum = 0; // Sum of values of nodes in the current level

// Iterate over all nodes in the current level

// Enqueue child nodes for the next level

queue.offer(currentNode.left);

queue.offer(currentNode.right);

Deque<TreeNode> queue = new ArrayDeque<>(); // Queue for traversing the tree level by level

TreeNode currentNode = queue.pollFirst(); // Get and remove the node from the queue

averages.add((double)sum / levelSize); // Compute and add the average for this level to the result

public List<Double> averageOfLevels(TreeNode root) {

for (int i = 0; i < levelSize; ++i) {</pre>

if (currentNode.left != null) {

if (currentNode.right != null) {

return averages; // Return the list of averages

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) {}

const levelSize: number = queue.length; // The number of nodes at current level.

const currentNode = queue.shift(); // Remove the next node from queue.

// If the current node has a left child, add it to the queue.

// If the current node has a right child, add it to the queue.

averages.push(sum / levelSize); // Compute and add the average to the result array.

// let tree = new TreeNode(3, new TreeNode(9), new TreeNode(20, new TreeNode(15), new <math>TreeNode(7));

sum += currentNode.val; // Add the value of the current node to the level sum.

let sum: number = 0; // Initialize sum of values at current level.

// Loop through nodes of the current level.

for (let i = 0; i < levelSize; i++) {</pre>

if (currentNode.left) {

if (currentNode.right) {

return averages; // Return the array of averages.

queue.push(currentNode.left);

queue.push(currentNode.right);

if (currentNode) {

queue.offer(root); // Start with the root

* @param root Root of the binary tree.

while (!queue.isEmpty()) {

4 // Definition for a binary tree node.

* @return List of averages of each level.

s, n = 0, $len(q) \rightarrow s$, n = 0, 2

class TreeNode: # Definition for a binary tree node. def __init__(self, val=0, left=None, right=None): self.val = val self.left = left self.right = right

Initialize a queue for breadth-first traversal with the root node

Initialize the sum and get the number of nodes at the current level

def averageOfLevels(self, root: TreeNode) -> List[float]:

List to store the averages of each level

Loop while there are nodes in the queue

for _ in range(num_nodes):

if node.left:

node = queue.popleft()

level_sum += node.val

level_sum, num_nodes = 0, len(queue)

Iterate over all nodes at the current level

Pop the first node from the queue

Add its value to the level sum

No more children are enqueued at this level because neither 15 nor 7 have children.

Pop each node, add its value, and enqueue any children (15 and 7 are enqueued).

The queue now contains the nodes for the next level (15 and 7), so the while-loop iterates again.

11.0]. This list represents the average value of the nodes at each level of the given binary tree.

29 queue.append(node.left) 30 # If there is a right child, add it to the queue 31 if node.right: 32 queue.append(node.right) 33 # Calculate the average for the level and add it to the result list averages.append(level_sum / num_nodes) 34

If there is a left child, add it to the queue

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Java Solution
 1 /**
    * Definition for a binary tree node.
    */
   class TreeNode {
       int val;
       TreeNode left;
       TreeNode right;
       TreeNode() {}
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       TreeNode(int val) {
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           this.val = val;
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       TreeNode(int val, TreeNode left, TreeNode right) {
```

C++ Solution 1 #include <vector> 2 #include <queue>

5 struct TreeNode {

int val;

TreeNode *left;

TreeNode *right;

```
14 class Solution {
 15 public:
 16
         vector<double> averageOfLevels(TreeNode* root) {
             queue<TreeNode*> nodesQueue; // Queue to hold the nodes at the current level.
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 18
             nodesQueue.push(root); // Start with the root node.
             vector<double> averages; // Vector to store the average values of each level.
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             while (!nodesQueue.empty()) {
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                 int levelSize = nodesQueue.size(); // Number of nodes at the current level.
                 long long levelSum = 0; // Sum of the values of nodes at the current level. Use long long to avoid integer overflow.
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                 // Iterate over all nodes at the current level.
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                 for (int i = 0; i < levelSize; ++i) {</pre>
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                     TreeNode* currentNode = nodesQueue.front(); // Retrieve the front node in the queue.
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                     nodesQueue.pop(); // Remove the node from the queue.
                     levelSum += currentNode->val; // Add the node value to the level sum.
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                     // If the left child exists, add it to the queue for the next level.
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                     if (currentNode->left) {
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                         nodesQueue.push(currentNode->left);
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 35
                     // If the right child exists, add it to the queue for the next level.
                     if (currentNode->right) {
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                         nodesQueue.push(currentNode->right);
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                 // Calculate the average for the current level and add it to the result vector.
                 // Casting levelSum to double to get floating point division.
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                 averages.push_back(static_cast<double>(levelSum) / levelSize);
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             return averages; // Return the vector containing averages of each level.
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 48 };
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Typescript Solution
1 // Definition for a binary tree node.
   class TreeNode {
       val: number;
       left: TreeNode | null;
       right: TreeNode | null;
       constructor(val: number = 0, left: TreeNode | null = null, right: TreeNode | null = null) {
           this.val = val;
           this.left = left;
           this.right = right;
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12 }
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   /**
    * Computes the average of the node values at each level of a binary tree.
    * @param {TreeNode | null} root - The root of the binary tree.
    * @return {number[]} - An array of averages, one for each level of the tree.
18
   function averageOfLevels(root: TreeNode | null): number[] {
       let queue: Array<TreeNode | null> = [root]; // Initialize the queue with the root node.
20
       let averages: number[] = []; // Initialize the array to hold averages of each level.
21
22
```

Time Complexity

// let result = averageOfLevels(tree);

Time and Space Complexity

// console.log(result); // Output: [3, 14.5, 11]

children are potentially added to the queue.

Space Complexity The space complexity of the code can be considered as O(W), where W is the maximum width of the tree or the maximum number of

The time complexity of the given code is O(N), where N is the number of nodes in the binary tree. This is because the algorithm uses

a queue to traverse each node exactly once. During the traversal, each node's value is accessed and added to a sum, and its

nodes at any level of the tree. This occurs because the queue stores a level of the tree at most, which, in the worst case, can be all the leaf nodes of a full binary tree at the last level.