690. Employee Importance

Medium | Depth-First Search | Breadth-First Search | Hash Table | Leetcode Link

Problem Description

The problem revolves around calculating a collective importance score for an employee and their entire reporting hierarchy within a company. There is a data structure for employee information where each employee has a unique ID, a numeric value representing their importance, and a list of IDs for their direct subordinates. Our goal is to find the total importance value for a single employee specified by their ID, along with the importance of their direct and indirect subordinates. Essentially, we are tasked with performing a sum of importance values that spans across multiple levels of the employee reporting chain.

Intuition

To solve this problem, we need a way to traverse through an employee's subordinates and all of their subsequent subordinates recursively until there are none left. We should think of each employee as a node in a tree, where the given employee is the root, and their direct and indirect subordinates form the branches and leaves.

The first step is to map all the employees by their IDs for quick access. This is because we're provided with a list, and checking each employee's ID to find their subordinates would take a lot of time especially if there are many employees.

With this mapping in place, we'll use recursion, which is a natural fit for this tree-like structure. The idea of the recursive depth-first search (DFS) is to start with the given employee ID, find the employee's importance, and then call the function recursively for each of its subordinates. This process will sum up all the importance values from the bottom of the hierarchy (the leaf nodes with no subordinates) all the way to the top (the employee whose ID was provided).

An alternative approach could also be using breadth-first search (BFS), where we process all direct subordinates first before moving on to the next level down in the hierarchy. However, the provided solution uses DFS, which is more intuitive for such hierarchical structures, often yielding simpler and more concise code.

Solution Approach

The solution employs a depth-first search (DFS) algorithm which is a common technique used to traverse tree or graph data structures. Here's a step-by-step explanation of the implementation:

1. **Hash Table Creation:** We start by creating a hash table (in Python, a dictionary) to map each employee's ID to the corresponding employee object. This mapping allows for quick access to any employee's details when given their ID, which is essential for efficient traversal. The hash table creation is represented by the line `e = {emp.id: emp for emp in employees}` in the code.
2. **Recursive DFS Function:** A recursive function named `dfs` is defined inside the `Solution` class. This function takes an employee's ID as an input and returns the total importance value of that employee, plus the importance of all their subordinates, both direct and indirect. This is implemented as follows:
   - Retrieve the `Employee` object corresponding to the given ID from the hash table.
   - Initialize a sum `s` with the importance of the employee.
   - Loop through the list of subordinates of the employee. For each subordinate ID, call the `dfs` function and add the returned importance to the sum `s`.
   - Return the total sum `s` after traversing all subordinates.
3. **Initiating the DFS Call:** The `getImportance` function is the entry point for the solution. It calls the DFS `dfs` function starting with the employee ID provided as an input to the problem and returns the importance value obtained from this call.

The importance of recursion here is that it naturally follows the hierarchy structure by diving deep into each branch (subordinate chain) and unwinding the importance values as the call stack returns. This DFS approach ensures that all employees in the hierarchy are accounted for and their importances are added up correctly to yield the final answer.

The code snippet `return dfs(id)` initiates the process by starting the recursive traversal, passing the ID of the employee whose total importance is to be calculated.

The key algorithm and data structure pattern used here is a combination of a DFS algorithm for traversal and a hash table for efficient data access.

Example Walkthrough

Let's consider a small set of employee data:

- Employee 1: Importance = 5, Subordinates = [2, 3]
- Employee 2: Importance = 3, Subordinates = []
- Employee 3: Importance = 6, Subordinates = [4]
- Employee 4: Importance = 2, Subordinates = []

We are asked to calculate the total importance score for Employee 1.

Hash Table Creation:

First, we create a hash table mapping employee IDs to their respective Employee objects for quick access:

```
1 m = {1: Employee(1, 5, [2, 3]), 2: Employee(2, 3, []), 3: Employee(3, 6, [4]), 4: Employee(4, 2, [])}
```

Recursive DFS Function:

The `dfs` function operates as follows when we call `dfs(1)`:

1. Look up Employee 1 in the hash table 'm' and find its importance and subordinates.
2. Start with a sum `s = 5`, the importance value of Employee 1.
3. Loop over Employee 1's subordinates (Employee 2 and 3):
   - For Employee 2: no subordinates, so just add 3 to the sum `s` (now `s = 8`).
   - For Employee 3: Call `dfs` for Employee 3.
     - Look up Employee 3 in hash table, get importance (6), and its subordinate (Employee 4).
     - Sum the importance for Employee 3 (`s = 6`).
     - Employee 3 has a subordinate, Employee 4, call `dfs` on Employee 4.
       - Add Employee 4's importance to the sum `s` (now `s = 8`).
     - No more subordinates, return `s` (8). Add this to our main sum `s` which is now `s = 16`.
4. After traversing all subordinates of Employee 1, the total sum `s` is 16.

Initiating the DFS Call:

The `getImportance` function initiates the DFS call with `return dfs(1)` and would return the total importance value of 16 for Employee 1 and their entire reporting hierarchy.

Python Solution

```python
# Definition for Employee class.
class Employee:
    def __init__(self, id: int, importance: int, subordinates: list[int]):
        self.id = id
        self.importance = importance
        self.subordinates = subordinates


class Solution:
    def getImportance(self, employees: list['Employee'], id: int) -> int:
        # Create a dictionary where the key is the employee ID and the value is the employee object.
        # This allows for quick access to any employee object.
        employee_map = {employee.id: employee for employee in employees}

        # Recursive function to calculate the total importance value starting from the given employee ID.
        def calculate_importance(employee_id: int) -> int:
            # Retrieve the employee object using the employee ID.
            employee = employee_map[employee_id]
            # Start with the employee's importance.
            total_importance = employee.importance
            # For each of the employee's subordinates, add their importance recursively.
            for subordinate_id in employee.subordinates:
                total_importance += calculate_importance(subordinate_id)
            # Return the total importance accumulated.
            return total_importance

        # Call the recursive function starting from the given ID.
        return calculate_importance(id)
```

Java Solution

```java
import java.util.HashMap;
import java.util.List;
import java.util.Map;

// Definition for Employee class provided.
class Employee {
    public int id;
    public int importance;
    public List<Integer> subordinates;
}

class Solution {

    // A hashmap to store employee id and corresponding Employee object for quick access.
    private final Map<Integer, Employee> employeeMap = new HashMap<>();

    // Calculates the total importance value of an employee and all their subordinates.
    public int getImportance(List<Employee> employees, int id) {
        // Populate the employeeMap with the given list of employees.
        for (Employee employee : employees) {
            employeeMap.put(employee.id, employee);
        }
        // Start the Depth-First Search (DFS) from the given employee id.
        return dfs(id);
    }

    // Helper method to perform DFS on the employee hierarchy and accumulate importance.
    private int dfs(int employeeId) {
        // Retrieve the current Employee object using its id.
        Employee employee = employeeMap.get(employeeId);
        // Start with the importance of the current employee.
        int totalImportance = employee.importance;
        // Recursively accumulate the importance of each subordinate.
        for (Integer subordinateId : employee.subordinates) {
            totalImportance += dfs(subordinateId);
        }
        // Return the total importance accumulated.
        return totalImportance;
    }
}
```

C++ Solution

```cpp
#include <vector>
#include <unordered_map>

// C++ struct definition for Employee.
struct Employee {
    int id;
    int importance;
    std::vector<int> subordinates;
};

/**
 * Calculates the total importance value of an employee and their subordinates.
 *
 * @param employees - Vector of Employee pointers.
 * @param employeeId - The id of the employee whose importance value needs to be calculated.
 * @return The total importance value of the employee and their subordinates.
 */
int getImportance(std::vector<Employee*> employees, int id) {
    // Unordered map to store employee id as key and employee pointer as value for constant time look-ups.
    std::unordered_map<int, Employee*> employee_map;

    // Fill the map with the employees.
    for (Employee* employee : employees) {
        employee_map[employee->id] = employee;
    }

    // Recursive helper function to calculate importance using depth-first search.
    std::function<int(int)> dfs = [&](int employeeId) -> int {
        // Retrieve the current employee from the map using their id.
        auto it = employee_map.find(employeeId);

        // If the employee is not found in the map, there is no such employee with the employeeId.
        if (it == employee_map.end()) {
            return 0;
        }

        Employee* employee = it->second;

        // Start with the importance of the current employee.
        int total_importance = employee->importance;

        // Include the importance of each subordinate using depth-first search.
        for (int subId : employee->subordinates) {
            total_importance += dfs(subId);
        }

        return total_importance;
    };

    // Kick off the recursive depth-first search process using the provided id.
    return dfs(id);
}

// Usage of the function remains the same as provided by the user.
```

Typescript Solution

```typescript
// TypeScript type definitions for Employee.

type Employee = {
    id: number;
    importance: number;
    subordinates: number[];
};

/**
 * Calculates the total importance value of an employee and their subordinates.
 *
 * @param employees - Array of Employee objects.
 * @param id - The employee id for which the importance value needs to be calculated.
 * @return The total importance value of the employee and their subordinates.
 */
const getImportance = (employees: Employee[], id: number): number => {
    // Map to store employee id as key and employee object as value.
    const employeeMap: Map<number, Employee> = new Map();

    // Fill the map with the employees for constant time look-ups.
    employees.forEach(employee => {
        employeeMap.set(employee.id, employee);
    });

    /**
     * Recursive helper function to calculate importance using depth-first search.
     *
     * @param employeeId - The id of the current employee being processed.
     * @return The total importance including all subordinates' importance.
     */
    const dfs = (employeeId: number): number => {
        // Retrieve the current employee from the map using their id.
        const employee = employeeMap.get(employeeId);

        // If employee is undefined, there is no such employee with the employeeId.
        if (!employee) {
            return 0;
        }

        // Start with the importance of the current employee.
        let totalImportance = employee.importance;

        // Include the importance of each subordinate (depth-first search).
        employee.subordinates.forEach(subId => {
            totalImportance += dfs(subId);
        });

        return totalImportance;
    };

    // Kick off the recursive process using the provided id.
    return dfs(id);
};

// Usage of the function remains the same as provided by the user.
```

Time and Space Complexity

The given code defines a `Solution` class with a method `getImportance` to calculate the total importance value of an employee and all of their subordinates recursively.

Time Complexity

The time complexity of the code is $O(N)$, where N is the total number of employees. This is because the `dfs` function ensures that each employee is processed exactly once. The creation of the dictionary `e` is $O(N)$ since it involves going through all the employees once and inserting them into the `e` mapping, and the recursive `dfs` calls process each employee and their subordinates once.

Space Complexity

The space complexity of the code is also $O(N)$. This involves the space for the dictionary `e` which stores all the employees, corresponding to $O(N)$. Additionally, the space complexity takes into account the recursion call stack, which in the worst case, when the organization chart forms a deep hierarchy, can go as deep as the number of employees N in the path from the top employee to the lowest-level employee.