2023. Number of Pairs of Strings With Concatenation Equal to Target

Medium Array String

Problem Description

The given problem involves finding the total number of unique pairs of indices `(i, j)` from an array of digit strings `nums` such that when `nums[i]` and `nums[j]` are concatenated (joined together in the order `nums[i] + nums[j]`), the result equals the given digit string `target`. The constraint is that `i` and `j` must be different, i.e., you cannot use the same index twice in a pair. The task is to return the count of such pairs.

Intuition

To solve this problem, the insight is to use the properties of strings and hash tables. We know that if the concatenation of two strings, `a` and `b`, produces the `target`, then `a` must be a prefix of `target`, and `b` must be a suffix. Furthermore, `a` and `b` together must cover the entire `target` string without overlap, except when `a` and `b` are equal.

One approach would be to iterate over all possible pairs of strings in `nums` and check if their concatenation equals `target`. However, this approach would have a time complexity of O(n^2 * m), where n is the number of strings in `nums` and m is the length of `target`. We can optimize this by using a hash table (a Counter in Python) to store counts of all the strings in `nums`. This allows us to efficiently look up how many times a specific string occurs without iterating through the array again.

The solution iterates through each possible split point in `target`, effectively dividing the `target` into a prefix `a` and a suffix `b`. For each such pair `(a, b)`, the product of the number of occurrences of `a` and `b` in `nums` is added to the answer. If `a` and `b` are the same, we adjust the count since we cannot use the same index twice; this is done by subtracting one from the count of `a` before multiplying.

Solution Approach

The solution approach can be summarized in the following steps:

1. **Initialize a Counter**: A Counter from Python's collections module is initiated to store the occurrences of each string in `nums`. This data structure allows us to query in constant time whether a string is present in `nums` and, if so, how many times.
2. **Iterate through Target Splits**: The approach then involves iterating through each possible index in the `target` string to split it into two parts, `a` and `b`. The indices chosen range from 1 to the length of the `target` string minus one. This ensures that `a` and `b` are non-empty and cover the whole `target` string when concatenated.
3. **Calculate Pair Combinations**: For a given split `(a, b)`:
   - If `a` is not equal to `b`, the number of valid pairs is the product of the occurrences of `a` and `b` in `nums`, since they can be freely paired.
   - If `a` is equal to `b`, one instance of `a` is subtracted from the total count before multiplication to avoid pairing a number with itself as `i` cannot be equal to `j`.

The final answer, stored in `ans`, accumulates the count of valid pairs through all iterations.

```python
class Solution:
    def numOfPairs(self, nums: List[str], target: str) -> int:
        cnt = Counter(nums)  # Step 1: Initialize a Counter
        ans = 0  # Initialize the count of pairs to zero
        for i in range(1, len(target)):  # Step 2: Iterate through Target Splits
            a, b = target[:i], target[i:]  # Split the `target` into `a` and `b`
            if a != b:  # Step 3: Calculate Pair Combinations
                ans += cnt[a] * cnt[b]  # Multiply the counts if `a` and `b` are not equal
            else:
                ans += cnt[a] * (cnt[a] - 1)  # Adjust if `a` and `b` are the same
        return ans # Return the final count of pairs
```

The current implementation is efficient because it avoids the brute-force checking of all pairs in `nums`, instead taking advantage of the hashing capability of the Counter to look up counts quickly.

Example Walkthrough

Let's consider a small example where `nums = ["1","11","111","011"]` and `target = "1111"`. Here's how the solution approach would be applied to find the count of pairs whose concatenation equals `target`.

1. **Initialize Counter**: The Counter will count occurrences of all strings in `nums`.

   ```
   Counter({'1': 1, '11': 1, '111': 1, '011': 1})
   ```

   This allows for constant-time queries of occurrences.
2. **Iterate through Target Splits**: The target "1111" has several possible splits: "1|111", "11|11", and "111|1".
   - For the split "1|111":
     - `a` is "1", and `b` is "111".
     - The count of "1" in `nums` is 1, and the count of "111" is also 1.
     - Since `a` != `b`, we multiply their counts: 1 * 1 = 1.
   - For the split "11|11":
     - `a` is "11", and `b` is also "11".
     - The count of "11" in `nums` is 1.
     - But `a` == `b`, so we use the adjusted count: 1 * (1 - 1) = 0.
   - For the split "111|1":
     - `a` is "111", and `b` is "1".
     - The count of "111" in `nums` is 1, and the count of "1" is 1.
     - Since `a` != `b`, we multiply their counts: 1 * 1 = 1.
3. **Calculate Pair Combinations**: Adding the results of all splits, we get 1 + 0 + 1 = 2.

So, there are 2 unique pairs of indices in `nums` that can be concatenated to form the `target` "1111".

Solution Implementation

Python

```python
from collections import Counter

class Solution:
    def numOfPairs(self, nums: List[str], target: str) -> int:
        # Create a counter to hold the frequency of each number in nums
        num_counter = Counter(nums)

        # Initialize a variable to count the number of valid pairs
        pair_count = 0

        # Iterate through the target string and split it at different points
        for i in range(1, len(target)):
            prefix, suffix = target[:i], target[i:]  # Split target into prefix and suffix

            # If prefix and suffix are different, multiply their counts directly
            if prefix != suffix:
                pair_count += num_counter[prefix] * num_counter[suffix]
            else:
                # If prefix and suffix are the same, we must avoid counting the pair (num, num) twice
                pair_count += num_counter[prefix] * (num_counter[prefix] - 1)

        # Return the total number of pairs found
        return pair_count
```

Java

```java
class Solution {

    public int numOfPairs(String[] nums, String target) {
        // Create a map to store the frequency of each number (string) in the nums array
        Map<String, Integer> countMap = new HashMap<>();
        for (String num : nums) {
            countMap.put(num, countMap.getOrDefault(num, 0) + 1);
        }

        // Initialize a variable to keep track of the number of valid pairs
        int answer = 0;

        // Loop through the target string, excluding its first and last characters
        for (int i = 1; i < target.length(); ++i) {
            // Split the target into two substrings ("a" and "b") at the current position i
            String a = target.substring(0, i);
            String b = target.substring(i);

            // Retrieve the frequency of each substring from the map
            int countA = countMap.getOrDefault(a, 0);
            int countB = countMap.getOrDefault(b, 0);

            // If "a" and "b" are different, multiply their counts since they can form distinct pairs
            if (!a.equals(b)) {
                answer += countA * countB;
            } else {
                // If "a" and "b" are the same, each instance of "a" could pair with all other instances of "b", but not with itself
                answer += countA * (countB - 1);
            }
        }

        // Return the total number of valid pairs found
        return answer;
    }
}
```

C++

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

class Solution {
public:
    // Function to count the number of pairs of strings in 'nums' that can be concatenated to form the 'target' string.
    int numOfPairs(std::vector<std::string>& nums, std::string target) {
        // Using a hashmap to count the frequency of each string in 'nums'.
        std::unordered_map<std::string, int> frequencyMap;
        for (auto &num : nums) {
            ++frequencyMap[num]; // Increment frequency count for each string.
        }

        int pairCount = 0; // This will store the number of valid pairs found.

        // Iterate over all possible splits of 'target' into two non-empty substrings 'leftPart' and 'rightPart'.
        for (int i = 1; i < target.size(); ++i) {
            std::string leftPart = target.substr(0, i);
            std::string rightPart = target.substr(i);

            int leftCount = frequencyMap[leftPart], rightCount = frequencyMap[rightPart];

            // When 'leftPart' and 'rightPart' are different, multiply their frequencies directly.
            // Otherwise, if they are the same (e.g., 'a' and 'a'), pairs are counted by forming combinations
            // of two different indices from the frequency of that string; hence, the (rightCount - 1).
            if (leftPart != rightPart) {
                pairCount += leftCount * rightCount;
            } else {
                pairCount += leftCount * (rightCount - 1);
            }
        }

        return pairCount; // Return the total number of pairs.
    }
};
```

TypeScript

```typescript
type StringFrequencyMap = Record<string, number>;

// Function to count the number of pairs of strings in the array that can be concatenated to form the target string.
function numOfPairs(nums: string[], target: string): number {
    // Creating a map to keep the frequency of each string in the array.
    const frequencyMap: StringFrequencyMap = nums.reduce((acc: StringFrequencyMap, num: string) => {
        acc[num] = (acc[num] || 0) + 1;
        return acc;
    }, {});

    let pairCount = 0; // This will hold the total number of valid pairs found.

    // Iterate over all possible non-empty prefixes and suffixes of the target string.
    for (let i = 1; i < target.length; i++) {
        const leftPart = target.slice(0, i);
        const rightPart = target.slice(i);

        const leftCount = frequencyMap[leftPart] || 0;
        const rightCount = frequencyMap[rightPart] || 0;

        // If leftPart and rightPart are different, compute the product of their counts.
        // If they are the same, we must choose different elements, hence the product of leftCount and (rightCount - 1).
        if (leftPart !== rightPart) {
            pairCount += leftCount * rightCount;
        } else {
            pairCount += leftCount * (rightCount - 1);
        }
    }

    // Return the computed number of pairs.
    return pairCount;
}
```


```python
from collections import Counter

class Solution:
    def numOfPairs(self, nums: List[str], target: str) -> int:
        # Create a counter to hold the frequency of each number in nums
        num_counter = Counter(nums)

        # Initialize a variable to count the number of valid pairs
        pair_count = 0

        # Iterate through the target string and split it at different points
        for i in range(1, len(target)):
            prefix, suffix = target[:i], target[i:]  # Split target into prefix and suffix

            # If prefix and suffix are different, multiply their counts directly
            if prefix != suffix:
                pair_count += num_counter[prefix] * num_counter[suffix]
            else:
                # If prefix and suffix are the same, we must avoid counting the pair (num, num) twice
                pair_count += num_counter[prefix] * (num_counter[prefix] - 1)

        # Return the total number of pairs found
        return pair_count
```


Time and Space Complexity

Time Complexity

The time complexity of the given code is composed of two parts: the creation of the counter and the loop that goes through the possible splits of the target string.

- Constructing `cnt` as a `Counter` object takes `O(n)` time, where `n` is the number of elements in `nums`, because it needs to iterate over all elements once to count the frequencies.
- For the loop that checks all the possible splits, the number of iterations is proportional to the length of the `target` string because it iterates through every possible split index. This is `O(m)`, where `m` is the length of the target string.
- The operations within the loop take constant time since dictionary access and multiplication are `O(1)` operations.

Therefore, the overall time complexity is `O(n + m)`.

Space Complexity

The space complexity is primarily influenced by the storage requirements of the `Counter` object.

- The `Counter` object `cnt` stores each unique element from `nums`. In the worst case, all elements are unique, so the space required is `O(n)`, where `n` is the number of elements in `nums`.

Thus, the space complexity of the code is `O(n)`.