2191. Sort the Jumbled Numbers

Medium Array Sorting

Problem Description

The problem presents a scenario where we have a custom mapping for digits from 0 to 9, implying a shuffled decimal system. This mapping is given as an array where `mapping[i] = j` means the digit `i` should be mapped to digit `j`. For example, if `mapping[1] = 3`, every `1` in any number will be treated as `3`. The task is to transform a list of integers (`nums`) according to this new digit mapping, and then sort the list based on the new "mapped" values.

After the transformation, the sorted list should maintain the order of numbers that have the same mapped value as they appear in the original `nums` list. It is important to note that while the sorting is done based on the mapped values, the final sorted list should contain the original numbers, not their mapped counterparts.

Intuition

The intuition behind the implemented solution is to simulate this new decimal system by creating a corresponding mapped value for each number in the given list `nums`. The first step is to convert each number to its mapped value according to the provided `mapping`. This means replacing each digit of the number with its correspondent in the `mapping`.

While creating these mapped values, we have to handle them carefully to retain the original order of numbers. Hence, for each number in `nums`, we pair it with its index in the array; that way, after sorting the numbers by their mapped values, we can still return the original numbers in their new sorted order.

The next step is to sort these pairs (which contain the mapped value and the original index) by the mapped value. If this results in ties (i.e., two numbers having the same mapped value), the relative order of their indices will resolve which should come first, achieving "stable sorting."

Finally, we reconstruct the sorted list of original numbers by taking the second element from each sorted pair, which is the original index of that number in the `nums` array.

Note that the way the mapped values are computed respects the magnitude of each digit in the original number (i.e., the tens place is still the tens place after mapping, the hundreds place is still the hundreds place, and so forth). This means we have to multiply the mapped digit by its place value (`10`) as we form the new number `y`. The `k` value is started at `1` and is multiplied by `10` for each digit we move to the left.

After all mapped values and their original indices are sorted, we can then create and return a list of the original numbers from `nums` by their order determined by the mapped values.

Solution Approach

The solution provided follows a mapping and sorting approach to achieve the final sorted array based on custom mapped values.

Firstly, the solution leverages a list called `arr` to store tuples. Each tuple contains two values: the mapped value of the number and the original index of the number in the `nums` array.

Here is a step-by-step breakdown of the algorithm:

1. Iterate through each number in the `nums` array with its index. For each number `x` and its index `i`:
   - Initialize a variable `y` to be the mapped value of `x`. This variable will accumulate the final mapped number. Note that if `x` is zero, we set `y` to `mapping[0]` as its mapped value.
   - Initialize a variable `k` which represents the current digit's place value (e.g., 1 for units, 10 for tens, etc.).
2. For each digit `v` in the number `x` (obtained by repeatedly using `divmod` to split off the last digit):
   - Calculate the mapped digit by using the given mapping (i.e., `mapping[v]`).
   - Multiply the mapped digit by its current place value `k` and add it to `y`, building up the new mapped number digit by digit.
   - Multiply `k` by `10` to update the place value for the next digit to the left.
3. After finishing the mapping for a number, append a tuple `(y, i)` to the list `arr`, where `y` is the mapped value obtained and `i` is the index of the number in `nums`.
4. Sort the list `arr` by the first tuple element, which is the mapped value. Python's default sorting algorithm is stable, which guarantees that `arr` will be sorted by `y` but maintain the relative order of elements that have the same `y` value.
5. Create the final sorted list by extracting and appending the original numbers from `nums` using the sorted indices found in `arr`: `[nums[i] for _, i in arr]`.

The overall time complexity of the solution is dominated by the sorting step, which is O(n log n), where `n` is the length of the `nums` array. The space complexity is O(n) due to the additional list `arr` used for sorting purposes.

This solution pattern effectively applies a custom sort key defined by a map, which is a common way to sort elements in a non-standard manner while maintaining stability in sorting.

Example Walkthrough

Let's consider an example to walk through the solution approach. Suppose we have a mapping array and a list of numbers as follows:

- `mapping = [2, 1, 4, 3, 6, 5, 8, 7, 9, 9]`
- `nums = [990, 332, 981]`

Based on the mapping, each digit in the numbers from `nums` should be converted as follows:

- '0' maps to '2'
- '1' maps to '1'
- '2' maps to '4'
- '3' maps to '3'
- '4' maps to '6'
- '5' maps to '5'
- '6' maps to '8'
- '7' maps to '7'
- '8' maps to '0'
- '9' maps to '9'

1. We'll initiate the list `arr` to store tuples of the mapped value and the original index.
2. We start iterating through `nums`. For `990`, its index `i` is `0`:
   - Mapping '9' to '9' and '0' to '2', the mapped value of `990` is `992`.
   - Append to `arr` the tuple `(992, 0)`.
3. Next, for `332`, its index `i` is `1`:
   - Mapping '3' to '3' and '2' to '4', the mapped value of `332` is `334`.
   - Append to `arr` the tuple `(334, 1)`.
4. Lastly, for `981`, its index `i` is `2`:
   - Mapping '9' to '9', '8' to '0', and '1' to '1', the mapped value of `981` is `901`.
   - Append to `arr` the tuple `(901, 2)`.

Now `arr` looks like this: `[(992, 0), (334, 1), (901, 2)]`.

5. We sort `arr` using the first element of the tuples, so the list becomes `[(901, 2), (334, 1), (992, 0)]`.
6. After sorting, we create the final sorted list based on the original indices: `[nums[i] for _, i in arr]`. Using the sorted indices, we get `nums[2], nums[1], nums[0]`, which correspond to the numbers `[981, 332, 990]`.

So, the transformed and sorted list is `[981, 332, 990]` based on the new "mapped" values, yet the numbers themselves retain their original form.

Solution Implementation

Python

```python
class Solution:
    def sortJumbled(self, mapping: List[int], nums: List[int]) -> List[int]:
        # List to hold tuples of the mapped value and its original index
        mapped_with_index = []

        # Iterate over the input numbers' list
        for index, num in enumerate(nums):
            # If the number is 0, get the mapped value for 0, else start with 0
            mapped_num = mapping[0] if num == 0 else 0
            power_of_ten = 1  # To keep track of the decimal place

            # Decompose the number into digits and map using the provided mapping
            while num:
                num, digit = divmod(num, 10)
                # Map the digit, adjust decimal place and add to the mapped number
                mapped_num = mapping[digit] * power_of_ten + mapped_num
                power_of_ten *= 10  # Increase the decimal place

            # Append the tuple of mapped number and original index to the list
            mapped_with_index.append((mapped_num, index))

        # Sort the list according to the mapped numbers, stable for identical values
        mapped_with_index.sort()

        # Reconstruct the sorted list using the original indices
        return [nums[i] for _, i in mapped_with_index]
```

Java

```java
import java.util.Arrays;

class Solution {

    // Method to sort the array nums based on a custom mapping.
    public int[] sortJumbled(int[] mapping, int[] nums) {
        // Get the length of the nums array.
        int n = nums.length;

        // Create a 2D array to store the mapped number and the original index.
        int[][] mappedWithIndex = new int[n][2];

        // Iterate over the array of numbers.
        for (int i = 0; i < n; ++i) {
            int originalNum = nums[i];  // Original number from nums.
            int mappedNum = originalNum == 0 ? mapping[0] : 0; // Map the number based on mapping rules.
            int placeValue = 1;  // To reconstruct the mapped number based on individual digits.

            // Map each digit of the original number based on the 'mapping' array.
            while (originalNum > 0) {
                int digit = originalNum % 10;  // Retrieve the last digit.
                mappedNum += placeValue * mapping[digit];  // Map the digit and add to mappedNum considering the place value.
                placeValue *= 10;  // Move to the next place value (tens, hundreds, etc.).
                originalNum /= 10;  // Drop the last digit.
            }

            // Store the mapped number and the original index in the array.
            mappedWithIndex[i] = new int[] {mappedNum, i};
        }

        // Sort the array 'mappedWithIndex' based on the mapped numbers and indices.
        Arrays.sort(mappedWithIndex, (a, b) ->
            a[0] == b[0] ? a[1] - b[1] : a[0] - b[0]);  // If mapped numbers are equal, compare index.

        // Prepare the final sorted array based on the mapped values.
        int[] sortedArray = new int[n];
        for (int i = 0; i < n; ++i) {
            sortedArray[i] = nums[mappedWithIndex[i][1]];
        }

        // Return the sorted array.
        return sortedArray;
    }
}
```

C++

```cpp
class Solution {
public:
    vector<int> sortJumbled(vector<int>& mapping, vector<int>& nums) {
        int numsSize = nums.size(); // Number of elements in nums
        vector<pair<int, int>> mappedAndIndexPairs(numsSize); // Pair to store the mapped value and original index

        // Transform each number as per the mapping and associate it with its original index
        for (int i = 0; i < numsSize; ++i) {
            int originalNum = nums[i];
            int mappedNum = originalNum == 0 ? mapping[0] : 0; // If the number is 0, directly map it
            int placeValue = 1; // Represents the place value in the mapped number

            // Decompose the number into its digits and transform it according to the mapping
            while (originalNum > 0) {
                int digit = originalNum % 10; // Get the last digit
                mappedNum += placeValue * mapping[digit]; // Map the digit and add to the mapped number
                originalNum /= 10; // Remove the last digit from the original number
                placeValue *= 10; // Move to the next place value
            }

            // Save the pair of mapped number and original index
            mappedAndIndexPairs[i] = {mappedNum, i};
        }

        // Sort the pairs. The order is firstly by the mapped number, and then by the original index
        sort(mappedAndIndexPairs.begin(), mappedAndIndexPairs.end());

        // Extract the numbers from the sorted pairs, preserving the new order
        vector<int> sortedNums;
        for (auto& pair : mappedAndIndexPairs) {
            sortedNums.push_back(nums[pair.second]);
        }

        // Return the sorted numbers as per the jumbled mapping order
        return sortedNums;
    }
};
```

TypeScript

```typescript
function sortJumbled(mapping: number[], nums: number[]): number[] {
    const numsLength = nums.length;
    const mappedNums: number[][] = [];

    // Loop through all numbers in the 'nums' array
    for (let i = 0; i < numsLength; ++i) {
        let originalNum = nums[i];
        // Calculate the mapped value of an individual number
        // If the number is zero, map it directly using the mapping array;
        // else initialize it to zero to build upon
        let mappedValue = originalNum === 0 ? mapping[0] : 0;
        let positionMultiplier = 1; // Used to place the digit at the correct position

        // Decompose the number and map its digits using the given mapping
        for (; originalNum > 0; originalNum = Math.floor(originalNum / 10), positionMultiplier *= 10) {
            // Add the mapped digit multiplied by its positional value to 'mappedValue'
            mappedValue += mapping[originalNum % 10] * positionMultiplier;
        }

        // Store the mapped value along with the original index
        mappedNums.push([mappedValue, i]);
    }

    // Sort the 'mappedNums' array based on the mapped values, and if those are equal, by the original indices
    mappedNums.sort((a, b) => (a[0] === b[0] ? a[1] - b[1] : a[0] - b[0]));

    // Map the sorted array back to the original numbers using their stored indices
    return mappedNums.map(mappedPair => nums[mappedPair[1]]);
}
```

```python
class Solution:
    def sortJumbled(self, mapping: List[int], nums: List[int]) -> List[int]:
        # List to hold tuples of the mapped value and its original index
        mapped_with_index = []

        # Iterate over the input numbers' list
        for index, num in enumerate(nums):
            # If the number is 0, get the mapped value for 0, else start with 0
            mapped_num = mapping[0] if num == 0 else 0
            power_of_ten = 1  # To keep track of the decimal place

            # Decompose the number into digits and map using the provided mapping
            while num:
                num, digit = divmod(num, 10)
                # Map the digit, adjust decimal place and add to the mapped number
                mapped_num = mapping[digit] * power_of_ten + mapped_num
                power_of_ten *= 10  # Increase the decimal place

            # Append the tuple of mapped number and original index to the list
            mapped_with_index.append((mapped_num, index))

        # Sort the list according to the mapped numbers, stable for identical values
        mapped_with_index.sort()

        # Reconstruct the sorted list using the original indices
        return [nums[i] for _, i in mapped_with_index]
```

Time and Space Complexity

Time Complexity

The time complexity of the code is determined by a few factors:

1. Iterating over each element in `nums` `O(N)`, where `N` is the number of elements in `nums`.
2. Within the loop, transforming each number based on the `mapping`. In the worst case, the number of digits `D` in a number is proportional to the logarithm of the number (`log10(x)`), resulting in a complexity of `O(D)`. Since `D` is small compared to `N` for a reasonable range of integers, this can be approximated to `O(log(M))`, where `M` is the maximum number in `nums`.
3. Sorting the transformed array, which would take `O(N log N)` time.

Thus, combining these factors, the overall time complexity is `O(N * log(M) + N log N)`. If `N` is much larger than `M`, the dominant term is `O(N log N)`.

Space Complexity

The space complexity of the code involves:

1. The additional array `arr` used to store the transformed tuples, which adds a space complexity of `O(N)`.

There are no other significant uses of additional space, so the total space complexity is `O(N)`.