1968. Array With Elements Not Equal to Average of Neighbors

Medium Greedy Array Sorting Leetcode Link

Problem Description

You are provided with an array `nums` which consists of unique integers. The goal is to rearrange the elements in the array in such a way that no element is equal to the average of its immediate neighbors. To clarify, for every index `i` of the rearranged array (`1 <= i < nums.length - 1`), the value at `nums[i]` should not be equal to `(nums[i-1] + nums[i+1]) / 2`. The task is to return any version of the `nums` array that satisfies this condition.

Intuition

The key observation to arrive at the solution is that if we arrange the numbers in a sorted manner and then alternate between the smaller and larger halves of the sorted array, we can ensure that no element will be the average of its neighbors. This is because the numbers are distinct and sorted, so a number from the smaller half will always be less than the average of its neighbors, and a number from the larger half will always be greater than the average of its neighbors.

Therefore, first, we sort `nums`. Then, we divide the sorted array into two halves - the first half containing the smaller elements and the second half containing the larger elements. We then interleave these two halves such that we first take an element from the first half, followed by an element from the second half, and so on until we run out of elements.

Here's how the thought process breaks down:

1. Sort the array to easily identify the smaller and larger halves.
2. Identify the middle index to divide the sorted array into two halves.
3. Create an empty array `ans` to store the final rearranged sequence.
4. Iterate through each of the elements in the first half and alternate by adding an element from the second half.
5. Return the rearranged array which should now meet the requirements of the problem.

Solution Approach

The solution is pretty straightforward once we understand the intuition behind the problem. The approach makes use of the sorting algorithm, which is a very common and powerful technique in many different problems to create order from disorder.

Here's a step-by-step explanation of the implementation with reference to the provided solution code:

1. We start by sorting the array `nums`. Sorting is done in-place and can use the TimSort algorithm (Python's default sorting algorithm), which has a time complexity of O(n log n), where n is the number of elements in the array.

   ```
   nums.sort()
   ```

2. Calculate the middle index `m` of the array. It represents the starting index of the second half of the sorted array. If the array is of odd length, the middle index will include one more element in the first half.

   ```
   m = (n + 1) >> 1
   ```

   The `>>` operator is a right bitwise shift, which is equivalent to dividing by two, but since we are dealing with arrays that are zero-indexed, `(n + 1)` ensures that the first half includes the middle element when `n` is odd. For even `n`, this does not change the result.

3. An empty list `ans` is initialized to store the final rearranged sequence of `nums`.

   ```
   ans = []
   ```

4. Use a for-loop to iterate over the indices of the first half of `nums`, which runs from `0` to `m - 1` inclusive. For each `i`, add `nums[i]` to `ans`. Then, check if the corresponding index in the second half `i + m` is within bounds (`i + m < n`), and if so, add `nums[i + m]` to `ans`. This ensures that elements are alternated from both halves.

   ```
   for i in range(m):
       ans.append(nums[i])
       if i + m < n:
           ans.append(nums[i + m])
   ```

5. The completed `ans` list is now a rearranged version of `nums` that satisfies the problem conditions and is returned as the result.

   ```
   return ans
   ```

By implementing this solution, we ensure that elements from the lower half and the upper half of the sorted array alternate in the final arrangement, which prevents any element from being the average of its neighbors due to the distinct and sorted nature of `nums`.

Example Walkthrough

Let's walk through a small example to illustrate the solution approach described above using an array `nums`. Suppose our input array is:

```
nums = [1, 3, 2, 5, 4, 6]
```

Following the steps in the approach:

1. We start by sorting the array `nums`, which gives us:

   ```
   nums.sort() => [1, 2, 3, 4, 5, 6]
   ```

2. Calculate the middle index `m`. There are 6 elements (`n = 6`), so the middle index will be:

   ```
   m = (6 + 1) >> 1 => 3
   ```

   This means that the first half is `[1, 2, 3]` and the second half is `[4, 5, 6]`.

3. An empty list `ans` is initialized to store the final rearranged sequence of `nums`.

   ```
   ans = []
   ```

4. Use a for-loop to iterate over the indices of the first half of `nums`. We take an element from the first half, then an element from the second half, and repeat:

   ```
   for i in range(3):  # range(m)
       ans.append(nums[i])     # Add from the first half
       if i + 3 < 6:           # Check if the second half index is within bounds
           ans.append(nums[i + 3])  # Add from the second half
   ```

   When we iterate through, the `ans` array gets filled as follows:

   - `i = 0`: Append `nums[0]` which is `1` and then `nums[0 + 3]` which is `4`, so `ans = [1, 4]`.
   - `i = 1`: Append `nums[1]` which is `2` and then `nums[1 + 3]` which is `5`, so `ans = [1, 4, 2, 5]`.
   - `i = 2`: Append `nums[2]` which is `3` and then `nums[2 + 3]` which is `6`, so `ans = [1, 4, 2, 5, 3, 6]`.

5. The reordered list `ans` is now `[1, 4, 2, 5, 3, 6]` and satisfies the problem condition where no element is equal to the average of its immediate neighbors, and this is returned as the result.

The final output for the initial `nums` array is:

```
return ans => [1, 4, 2, 5, 3, 6]
```

The process effectively rearranges the original array preventing any value from being the average of its neighbors by interleaving the first and second halves of the sorted list.

Python Solution

```python
class Solution:
    def rearrangeArray(self, nums: List[int]) -> List[int]:
        # Sort the list of numbers in ascending order
        nums.sort()
        # Get the length of the nums list
        n = len(nums)
        # Find the middle index, rounded up to account for odd lengths
        # Equivalent to ceil function: m = ceil(n / 2)
        m = (n + 1) // 2
        # Initialize an empty list to store the answer
        ans = []
        # Iterate over the first half of the sorted list
        for i in range(m):
            # Add the current element from the first half to the answer list
            ans.append(nums[i])
            # Check if there is a corresponding element in the second half
            if i + m < n:
                # Add the corresponding element from the second half to the answer list
                ans.append(nums[i + m])
        # Return the rearranged list
        return ans

# Demonstrating the use of Solution class:
# Assuming 'List' has already been imported from 'typing' module otherwise, add the following line:
# from typing import List

# Initialize the class instance
solution_instance = Solution()

# Example input list of numbers
input_nums = [6,2,0,9,7]

# Get the rearranged list from the rearrangeArray method
rearranged_nums = solution_instance.rearrangeArray(input_nums)

# Print the rearranged list
print(rearranged_nums)

```

Java Solution

```java
class Solution {
    public int[] rearrangeArray(int[] nums) {
        // Sort the array to arrange elements in ascending order
        Arrays.sort(nums);

        // Find the length of the array
        int length = nums.length;

        // Compute the mid-index accounting for both even and odd length arrays
        int midIndex = (length + 1) >> 1;

        // Initialize a new array to store the rearranged elements
        int[] rearranged = new int[length];

        // Loop to interleave elements from the two halves of the sorted array
        for (int i = 0, j = 0; i < length; i += 2, j++) {
            // Place the j-th element from the first half into the i-th position of the rearranged array
            rearranged[i] = nums[j];

            // Check if there's an element to pair from the second half and place it next to the element from the first half
            if (j + midIndex < length) {
                rearranged[i + 1] = nums[j + midIndex];
            }
        }

        // Return the rearranged array
        return rearranged;
    }
}

```

C++ Solution

```cpp
#include <vector>
#include <algorithm>

class Solution {
public:
    // Method to rearrange the elements of the array such that each positive integer
    // is followed by a negative integer and vice-versa.
    vector<int> rearrangeArray(vector<int>& nums) {
        // First, sort the elements of the nums array in non-decreasing order.
        sort(nums.begin(), nums.end());

        // Declare a vector to store the rearranged elements.
        vector<int> rearranged;

        // Calculate the middle index based on the size of nums to divide
        // the array into two halves.
        int mid = (nums.size() + 1) >> 1; // Equivalent to (n+1)/2

        // Loop through the first half of the sorted array.
        for (int i = 0; i < mid; ++i) {
            // Add the current element from the first half to the rearranged vector.
            rearranged.push_back(nums[i]);

            // If the symmetric position in the second half exists, add it to the rearranged vector.
            if (i + mid < nums.size()) rearranged.push_back(nums[i + mid]);
        }

        // Return the vector with rearranged elements.
        return rearranged;
    }
};

```

Typescript Solution

```typescript
function rearrangeArray(nums: number[]): number[] {
    // Sort the elements of the nums array in non-decreasing order.
    nums.sort((a, b) => a - b);

    // Declare an array to store the rearranged elements.
    const rearranged: number[] = [];

    // Calculate the middle index based on the size of nums to divide
    // the array into two halves. Equivalent to (n+1)/2
    const mid = Math.floor((nums.length + 1) / 2);

    // Loop through the first half of the sorted array.
    for (let i = 0; i < mid; ++i) {
        // Add the current element from the first half to the rearranged array.
        rearranged.push(nums[i]);

        // Check if the symmetric position in the second half exists,
        // if so, add it to the rearranged array.
        const secondHalfIndex = i + mid;
        if (secondHalfIndex < nums.length) {
            rearranged.push(nums[secondHalfIndex]);
        }
    }

    // Return the array with rearranged elements.
    return rearranged;
}

```

Time and Space Complexity

Time Complexity

The time complexity of the code consists of the sort operation and the loop that rearranges the elements.

1. Sorting the `nums` array takes `O(n log n)` time, where `n` is the number of elements in `nums`.
2. The for loop runs for `m = (n + 1) >> 1` iterations, which is essentially `n/2` iterations for large `n`. Each iteration executes constant time operations, making this part `O(n/2)` which simplifies to `O(n)`.

Hence, the overall time complexity is dominated by the sort operation: `O(n log n)`.

Space Complexity

The space complexity is determined by the additional space used besides the input `nums` array.

1. The `ans` list, which contains `n` elements, requires `O(n)` space.
2. There are also constant-size extra variables like `n`, `m`, and `i` which use `O(1)` space.

Thus, the total space complexity is `O(n)` for the `ans` list.