1798. Maximum Number of Consecutive Values You Can Make

Medium Greedy Array [Leetcode Link]

Problem Description

The problem presents us with an array `coins`, each element representing the value of a coin that we have in our possession. The goal is to determine the maximum number of consecutive integer values that we can create by combining these coins, starting from and including the value `0`. It is also mentioned that it's possible to have multiple coins of the same value.

The task can be visualized as a game where we are trying to create a continuous sequence of values starting from zero by selecting coins from the array. The challenge is to find out how long this sequence can be before we encounter a gap that cannot be filled with the available coins.

Intuition

The solution to the problem lies in sorting the array and then iteratively adding the value of coins to a running sum, maintaining the maximum consecutive sequence that can be produced.

We start with an answer `ans` initialized to `1`, which represents the smallest sum we aim to create. Intuitively, if we include value `0` which doesn't require any coins, we can surely create at least `1` as the next consecutive integer value using our coins.

The sorted array allows us to approach the problem in an incremental manner. We iterate through each coin, and for each coin, we check if its value is greater than the current sum `ans`.

- If the coin's value is less than or equal to `ans`, we can add this coin to the previous sum to extend our consecutive sequence up to the new sum.
- If the coin's value is more than `ans`, this indicates that there's a gap we cannot fill using our coins as all smaller coins have already been processed. So, we break the loop.

After processing each coin or upon encountering a gap, the current value of `ans` represents the maximum number of consecutive integer values attainable.

The reason this approach works is that once coins are sorted, combining them from the smallest to the largest ensures that we are filling in the smallest possible gaps first, thus extending the consecutive sequence without missing any possible value.

Solution Approach

The implementation follows a greedy approach using simple control structures and a sorting algorithm.

First, we sort the array. This is essential for the greedy algorithm to work because we want to consider coins in ascending order to build up the consecutive sequence without any gaps.

```python
for v in sorted(coins):
```

Once the coins are sorted, we use a for-loop to iterate through each coin. The variable `ans` is initialized to `1`, which acts as both the accumulator and the tracker for the consecutive numbers that can be made with the coins seen so far.

```python
ans = 1
```

We iterate through each coin's value in the sorted list. For each value `v`, we check if `v` is larger than `ans`. If it is not, we add the value of `v` to `ans`. This addition is the act of creating a new consecutive number by adding the value of the coin to the sum of values that we could already create.

```python
if v > ans:
    break
ans += v
```

The above conditional is used to check for the presence of a gap. If the value of the current coin is greater than the current `ans` value, there is a break in our consecutive numbers, and we cannot extend our sequence further with the current coin. In this case, we break out of the loop and return the maximum consecutive number that we can make until now (since further numbers cannot be made consecutively with what we have).

The `break` statement ends the loop when a gap is found. If all coins are processed without encountering a gap, the loop concludes naturally.

Finally, we return `ans`, which now indicates the maximum sum we could reach consecutively with the given coins.

```python
return ans
```

This algorithm is efficient because the costly operation is the initial sorting which typically has a time complexity of O(n log n), where `n` is the number of coins. The subsequent iteration is an O(n) operation, making the total complexity O(n log n). The space complexity is O(1) since we are not using any additional data structures proportional to the input size.

Example Walkthrough

Let's apply the solution approach to a small set of coins to see how it works. Suppose we have the following coins: `coins = [1,2,3,4]`. Our task is to determine the maximum number of consecutive integer values we can create starting from `0`. Let's walk through the steps specified in the solution approach:

1. First, we sort the coins, but since they are already in ascending order (`1, 2, 3, 4`), we don't need to do anything.
2. We initialize `ans` to `1`. This represents the smallest sum we aim to create, understanding that a sum of `0` can always be created without using any coins.
3. We iterate through each coin in the array. The sorted array is `coins = [1,2,3,4]`.
   - For the first coin (`v = 1`), since `v <= ans` (1 <= 1), we add `v` to `ans`. Now, `ans = ans + v = 2`. We can now create all sums up to and including `2`.
   - The next coin is `v = 2`. Since `v <= ans` (2 <= 2), we can add `v` to `ans`, making `ans = 4`. Now we can create all sums up to and including `4`.
   - We move to the next coin (`v = 3`). Again, `v <= ans` (3 <= 4), so we add `v` to `ans`, which becomes `ans = 7`. We can create all sums up to and including `7`.
   - Lastly, we have the coin `v = 4`. It is also less than or equal to `ans` (4 <= 7), so we add `v` to `ans` to get `ans = 11`. We can create sums up to and including `11`.
   - Since we did not encounter any coin `v` such that `v > ans` throughout the entire iteration, we do not hit the break statement in our loop.
4. After processing all the coins, the current value of `ans` is `11`, which means we can create every consecutive integer value from `0` to `11` with the given coins.
5. We return `ans` which is `11` in this case, indicating the maximum number we can reach consecutively.

In conclusion, with the given array of `coins = [1,2,3,4]`, we can create all consecutive integer values from `0` up to `11`. The greedy algorithm efficiently allows us to determine this by adding coins in ascending order and checking for any possible gaps.

Python Solution

```python
class Solution:
    def getMaximumConsecutive(self, coins: List[int]) -> int:
        # The variable `max_consecutive` is used to track the highest consecutive
        # amount that can be obtained with the current set of coins.
        max_consecutive = 1

        # Loop through the coins sorted in ascending order
        for coin in sorted(coins):
            # If the current coin value is greater than the highest consecutive
            # amount that can be formed, we cannot create the next consecutive
            # number, so we break the loop.
            if coin > max_consecutive:
                break

            # Otherwise, we add the value of the current coin to the highest
            # consecutive amount to increase the range of consecutive amounts
            # that can be formed.
            max_consecutive += coin

        # After processing all the coins we can, return the highest consecutive
        # amount that we were able to reach.
        return max_consecutive

```

Java Solution

```java
import java.util.Arrays; // Import Arrays utility for sorting

class Solution {
    // Method to find the maximum consecutive integer that cannot be created using a given set of coins
    public int getMaximumConsecutive(int[] coins) {
        // Sort the coins array to consider coins in increasing order
        Arrays.sort(coins);

        // Initialize the answer to 1, since we start checking from the first positive integer
        int maxConsecutive = 1;

        // Iterate through the sorted coins
        for (int coin : coins) {
            // If the current coin's value is greater than the current maximum consecutive integer,
            // we cannot extend the consecutive sequence any further
            if (coin > maxConsecutive) {
                break;
            }
            // Otherwise, increase the maximum consecutive integer by the value of the current coin
            // This is because we can create all values from 1 to current maxConsecutive with the coins seen so far
            // and adding the current coin allows us to extend this sequence further
            maxConsecutive += coin;
        }

        // Return the maximum consecutive integer that cannot be formed
        return maxConsecutive;
    }
}

```

C++ Solution

```cpp
#include <vector>   // Include necessary header for vector
#include <algorithm> // Include necessary header for sort function

class Solution {
public:
    // Function to find the maximum consecutive value that cannot be obtained with a given set of coins
    int getMaximumConsecutive(std::vector<int>& coins) {
        // Sort the coins in non-decreasing order
        std::sort(coins.begin(), coins.end());

        // Initialize the answer to 1 (the smallest positive integer)
        int maxConsecutive = 1;

        // Iterate through the sorted vector of coins
        for (int coin : coins) {
            // If the current coin value is greater than the current possible consecutive value, break the loop
            if (coin > maxConsecutive) break;

            // Otherwise, add the value of the coin to the maxConsecutive to extend the range of possible consecutive values
            maxConsecutive += coin;
        }

        // Return the first maximum consecutive value that cannot be obtained
        return maxConsecutive;
    }
};

```

Typescript Solution

```typescript
// Import necessary functionalities
import { sort } from 'algorithm'; // TypeScript does not have these, assuming they exist.

// Declare the function to find the maximum consecutive value that cannot be obtained with a given set of coins
function getMaximumConsecutive(coins: number[]): number {
    // Sort the coins in non-decreasing order
    coins.sort((a, b) => a - b);

    // Initialize the answer to 1(the smallest positive integer)
    let maxConsecutive = 1;

    // Iterate through the sorted array of coins
    for (let coin of coins) {
        // If the current coin value is greater than the current possible consecutive value, break the loop
        if (coin > maxConsecutive) break;

        // Otherwise, add the value of the coin to maxConsecutive to extend the range of possible consecutive values
        maxConsecutive += coin;
    }

    // Return the first maximum consecutive value that cannot be obtained
    return maxConsecutive;
}

```

Time and Space Complexity

Time Complexity

The provided code snippet has a time complexity of `O(n log n)` due to the sorting operation, where `n` is the number of elements in the `coins` list. The `sorted` function in Python uses the Timsort algorithm, which has this time complexity on average and in the worst case. Following the sorting, the code iterates through the sorted coins once, which has a time complexity of `O(n)`. However, since sorting is the dominant operation, the overall time complexity of the code remains `O(n log n)`.

Space Complexity

The space complexity of the code is `O(n)`. This is because the `sorted` function returns a new list containing the sorted elements, therefore it requires additional space proportional to the size of the input list. The other variables used in the function (`ans` and `v`) use constant space and do not depend on the size of the input, so they do not affect the overall space complexity.