2022. Convert 1D Array Into 2D Array

Easy Array Matrix Simulation

Problem Description

The given problem presents us with a 1-dimensional array `original` and asks us to create a 2-dimensional array with `m` rows and `n` columns. The new 2D array should be filled with all the elements from `original` in such a way that the first `n` elements of `original` become the first row of the 2D array, the next `n` elements become the second row, and so on, continuing this process until we have `m` rows.

The key condition here is that each row of the newly formed 2D array must be filled with exactly `n` elements. Therefore, a 2D array can only be formed if the total number of elements in `original` is equal to `m * n`. If this condition is not met, it is not possible to form a 2D array that satisfies the criteria, and we should return an empty 2D array.

Intuition

The solution to this problem hinges on a simple mathematical verification followed by a grouping operation. The verification is to check whether the total number of elements in the `original` array is equal to the total number of elements that would be in the resulting 2D array (`m * n`). If they are not equal, it is impossible to construct the requested 2D array, so we return an empty list.

Solution Approach

The implementation of the solution uses basic list comprehension and slicing, which are common Python techniques for manipulating lists.

1. **Verification Step**: The first step in the solution is to verify whether the transformation from a 1D array to a 2D array is possible. This is done by checking if the product of `m` (number of rows) and `n` (number of columns) equals the length of the `original` array. If the condition `m * n != len(original)` is `True`, then it means that the 1D array cannot be perfectly partitioned into a 2D array with the specified dimensions, and the function returns an empty list `[]`.
2. **Transformation Step**: If the verification step is successful, the code proceeds to transform the `original` array into the desired 2D array. This is where list comprehension and slicing come into play. The list comprehension iterates over the `original` list, starting from index 0, all the way to the last element in steps of `n`.
   - The slice `original[i : i + n]` extracts `n` elements from the `original` array starting at index `i`. The slice's end index `i + n` is non-inclusive, meaning that it will extract elements up to but not including index `i + n`.
   - The `range` function in the list comprehension `range(0, m * n, n)` is used to generate the starting indices for each row. The third argument of `range` is the step, which we set to `n` to ensure we skip ahead by one full row each time.
3. **Construction Step**: The slices extracted during the transformation step are each a row of the 2D array. The list comprehension collects all these rows and constructs a list of lists, which is the desired 2D array.

The result is a 2D array that uses all elements of the `original` array to form an array with `m` rows and `n` columns as required by the problem. This algorithm is efficient, running in O(m*n), which is the size of the `original` array since each element is visited once.

Example Walkthrough

Let's walk through a small example to illustrate the solution approach described above:

Suppose we have the following 1-dimensional array `original` and values for `m` and `n`:

```
original = [1, 2, 3, 4, 5, 6]
m = 2
n = 3
```

First, let's verify whether the transformation from a 1D array to a 2D array is possible:

- The length of `original` is 6.
- We want to convert it into a 2D array with `m = 2` rows and `n = 3` columns.
- The total number of elements required to fill this 2D array is `m * n = 2 * 3 = 6`.

Since `len(original)` (which is 6) equals `m * n` (also 6), the transformation is possible.

Now let's transform `original` into the desired 2D array:

1. We start at index 0 of `original`. The first slice we take is `original[0:0 + 3]`, which gives us the first row `[1, 2, 3]`.
2. We then move to the next set of elements by stepping forward `n` places. The next index is 3, so we take the slice `original[3:3 + 3]` which gives us the second row `[4, 5, 6]`.

By putting these rows together, we construct our 2D array as follows:

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

In this case, the resulting 2D array has exactly `m` rows and `n` columns, using all elements of `original`. The approach works perfectly for this example.

Solution Implementation

Python

```python
from typing import List

class Solution:
    def construct2DArray(self, original: List[int], num_rows: int, num_cols: int) -> List[List[int]]:
        # If the total number of elements in the 2D array doesn't match the length of the original array,
        # it is not possible to construct the 2D array; return an empty list in such a case.
        if num_rows * num_cols != len(original):
            return []

        # Construct the 2D array by slicing the original array.
        # Walk through the original array in steps of `num_cols` and slice it into rows of length `num_cols`.
        return [
            original[i : i + num_cols]  # Slice from the current index to the index plus the number of columns.
            for i in range(0, num_rows * num_cols, num_cols)  # Iterate in steps of the number of columns.
        ]
```

Java

```java
class Solution {
    // Method to convert a 1D array into a 2D array with given dimensions m x n
    public int[][] construct2DArray(int[] original, int m, int n) {
        // Check if the total elements of the 2D array (m * n) match the length of the original 1D array
        if (m * n != original.length) {
            // If they don't match, return an empty 2D array
            return new int[0][0];
        }

        // Initialize the 2D array with the given dimensions
        int[][] twoDArray = new int[m][n];

        // Iterate over each row of the 2D array
        for (int row = 0; row < m; ++row) {
            // Iterate over each column of the 2D array
            for (int column = 0; column < n; ++column) {
                // Calculate the corresponding index in the original 1D array
                // and assign the value to the 2D array at [row][column]
                twoDArray[row][column] = original[row * n + column];
            }
        }

        // Return the constructed 2D array
        return twoDArray;
    }
}
```

C++

```cpp
class Solution {
public:
    // Function to construct a 2D array from a 1D array
    vector<vector<int>> construct2DArray(vector<int>& original, int rows, int cols) {
        // Return an empty 2D array if the given dimensions do not match the size of the original 1D array
        if (rows * cols != original.size()) {
            return {};
        }

        // Prepare an output 2D array with the given dimensions
        vector<vector<int>> result(rows, vector<int>(cols));

        // Loop through each element in the output 2D array
        for (int i = 0; i < rows; ++i) {
            for (int j = 0; j < cols; ++j) {
                // Map 1D array index to corresponding 2D array indices
                result[i][j] = original[i * cols + j];
            }
        }

        // Return the constructed 2D array
        return result;
    }
};
```

TypeScript

```typescript
function construct2DArray(original: number[], m: number, n: number): number[][] {
    // If the length of the original array is not equal to the product of dimensions m and n
    // Then it's not possible to construct a 2D array of m x n, return empty array
    if (m * n !== original.length) {
        return [];
    }

    // Initialize an empty array for the 2D array
    const twoDArray: number[][] = [];

    // Loop through the original array with step of size n
    for (let i = 0; i < original.length; i += n) {
        // Push a slice of the original array of length n into twoDArray
        twoDArray.push(original.slice(i, i + n));
    }

    // Return the constructed 2D array
    return twoDArray;
}
```

```python
from typing import List

class Solution:
    def construct2DArray(self, original: List[int], num_rows: int, num_cols: int) -> List[List[int]]:
        # If the total number of elements in the 2D array doesn't match the length of the original array,
        # it is not possible to construct the 2D array; return an empty list in such a case.
        if num_rows * num_cols != len(original):
            return []

        # Construct the 2D array by slicing the original array.
        # Walk through the original array in steps of `num_cols` and slice it into rows of length `num_cols`.
        return [
            original[i : i + num_cols]  # Slice from the current index to the index plus the number of columns.
            for i in range(0, num_rows * num_cols, num_cols)  # Iterate in steps of the number of columns.
        ]
```

Time and Space Complexity

The given code snippet defines a function `construct2DArray` which converts a 1D array to a 2D array with `m` rows and `n` columns.

Time Complexity

To determine the time complexity, we need to consider the operations performed by the code:

1. The function first checks if the total number of elements required for the 2D array (`m * n`) matches the length of the original list. This comparison operation is `O(1)`.
2. Then, a list comprehension is used to generate the 2D array. This will iterate over the original list in steps of size `n`, creating a total of `m` sublists.

Assuming `k` is the length of the original list, the total number of iterations in the list comprehension is `k / n` which simplifies to `m` (since `m * n = k`).

The slicing operation within each iteration can be considered `O(n)` because it involves creating a new sublist of size `n`.

Thus, the time complexity of the list comprehension is `O(m * n)`.

Therefore, the total time complexity of the function is `O(1) + O(m * n)` which simplifies to `O(m * n)`.

Space Complexity

For space complexity, we consider the additional space required by the program:

1. The space needed for the output 2D array which will hold `m * n` elements. Hence, the space complexity for the 2D array is `O(m * n)`.
2. There is no additional space being used that grows with the input size. Hence, other than the space taken by the output, the space complexity remains constant `O(1)` for the code execution.

Therefore, the overall space complexity of the function `construct2DArray` is `O(m * n)` because of the storage space for the final 2D array.

In summary:

- Time Complexity: `O(m * n)`
- Space Complexity: `O(m * n)`