Counting Sort – Data Structures and Algorithms Tutorials

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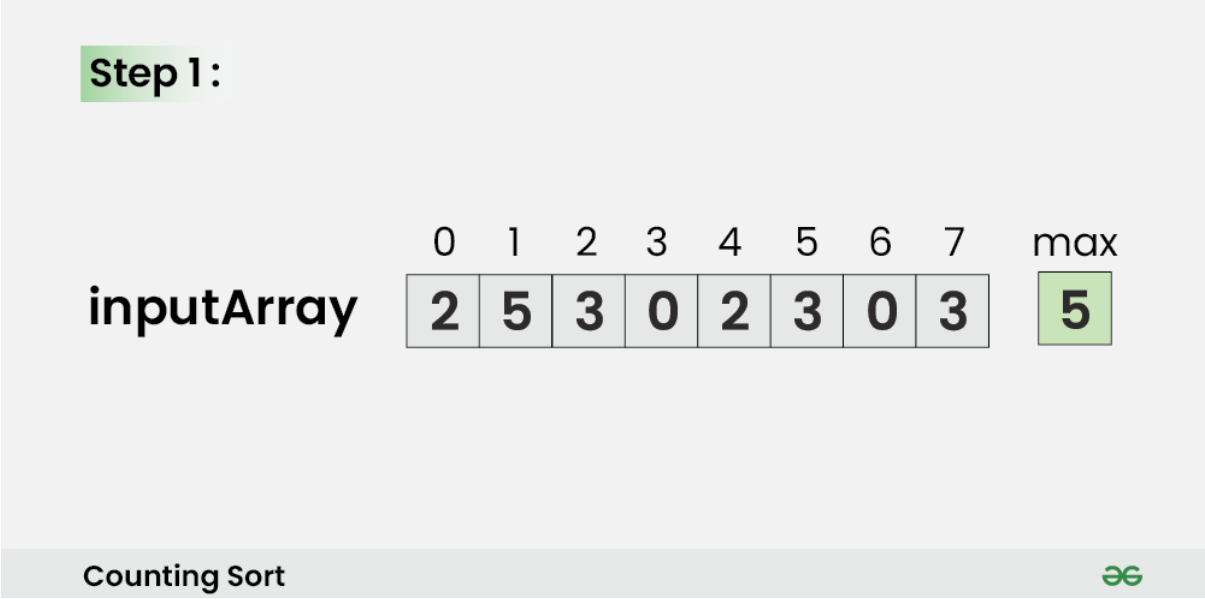
What is Counting Sort?

> **Counting Sort** is a **non-comparison-based** sorting algorithm that works well when there is limited range of input values. It is particularly efficient when the range of input values is small compared to the number of elements to be sorted. The basic idea behind **Counting Sort** is to count the **frequency** of each distinct element in the input array and use that information to place the elements in their correct sorted positions.

How does Counting Sort Algorithm work?

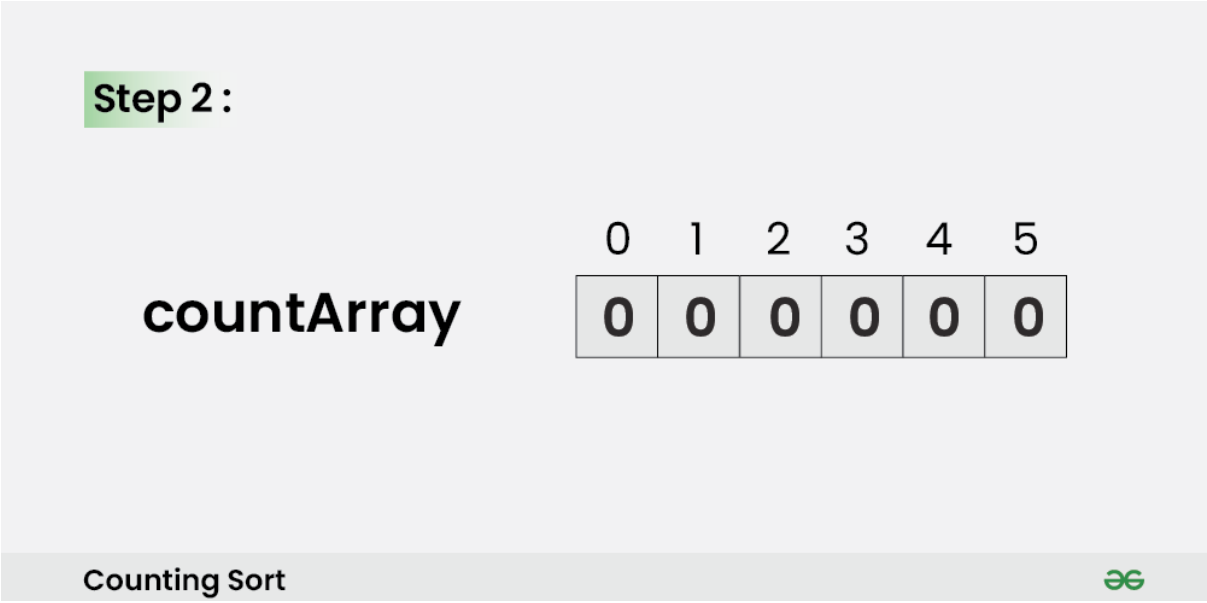
Step1 :

Find out the **maximum** element from the given array.



Step 2:

Initialize a **countArray[]** of length **max+1** with all elements as **0**. This array will be used for storing the occurrences of the elements of the input array.



Step 3:

- In the **countArray[]**, store the count of each unique element of the input array at their respective indices.
- **For Example:** The count of element **2** in the input array is **2.** So, store **2** at index **2** in the **countArray[]**. Similarly, the count of element **5** in the input array is **1**, hence store **1** at index **5** in the **countArray[]**.

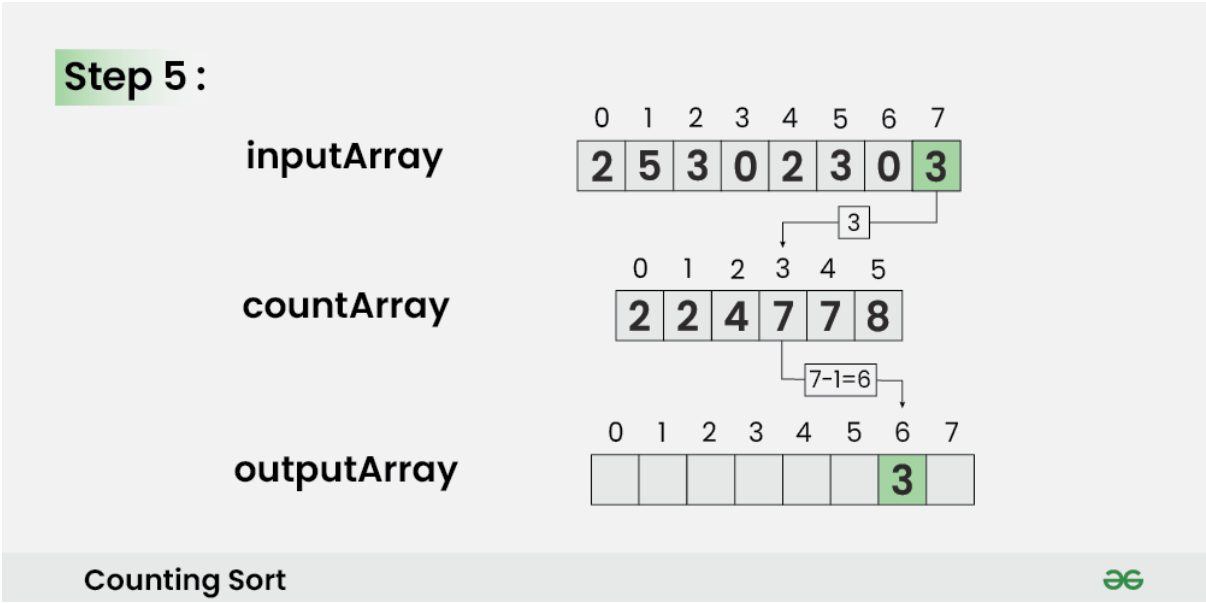
Step 4:

Store the **cumulative sum** or **prefix sum** of the elements of the **countArray[]** by doing **countArray[i] = countArray[i – 1] + countArray[i].** This will help in placing the elements of the input array at the correct index in the output array.

Step 5:

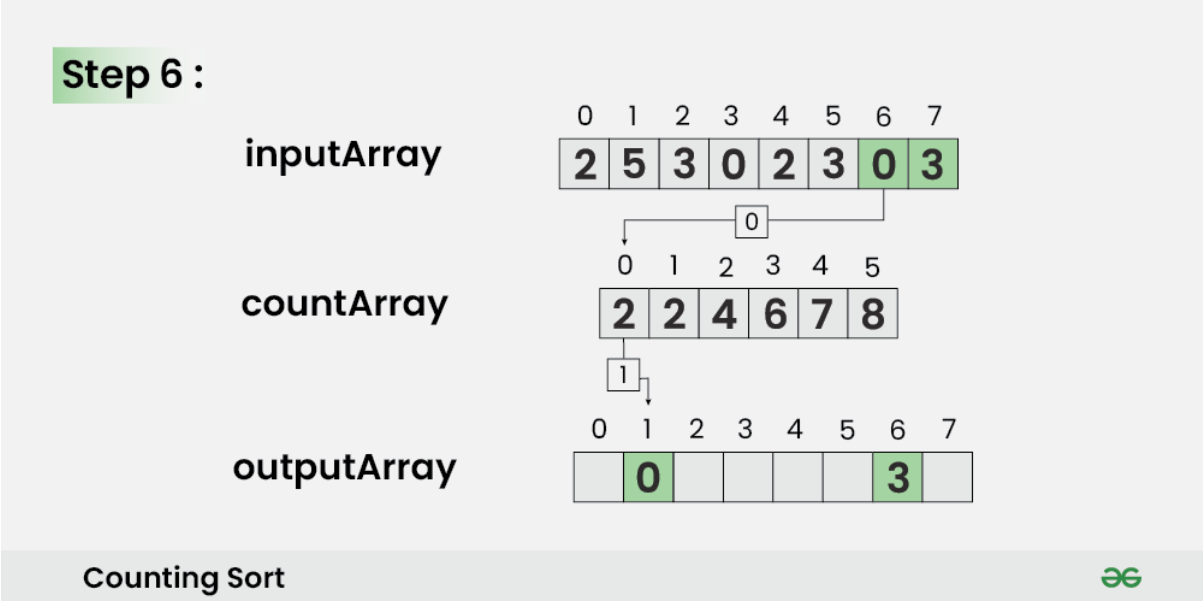
Iterate from end of the input array and because traversing input array from end preserves the order of equal elements, which eventually makes this sorting algorithm **stable**.

- Update **outputArray[countArray[inputArray[i]] – 1] = inputArray[i]**.
- Also, update **countArray[inputArray[i]] = countArray[inputArray[i]]**– -.



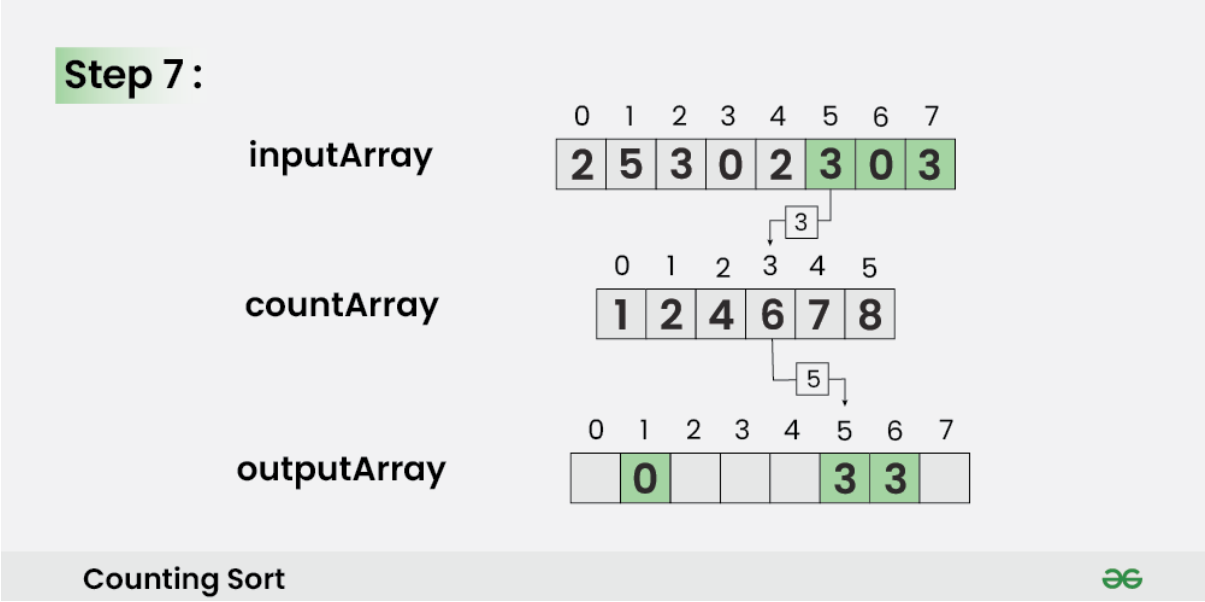
Step 6: **For i = 6**,

Update **outputArray[countArray[inputArray[6]] – 1] = inputArray[6]**
Also, update **countArray[inputArray[6]] = countArray[inputArray[6]]- –**



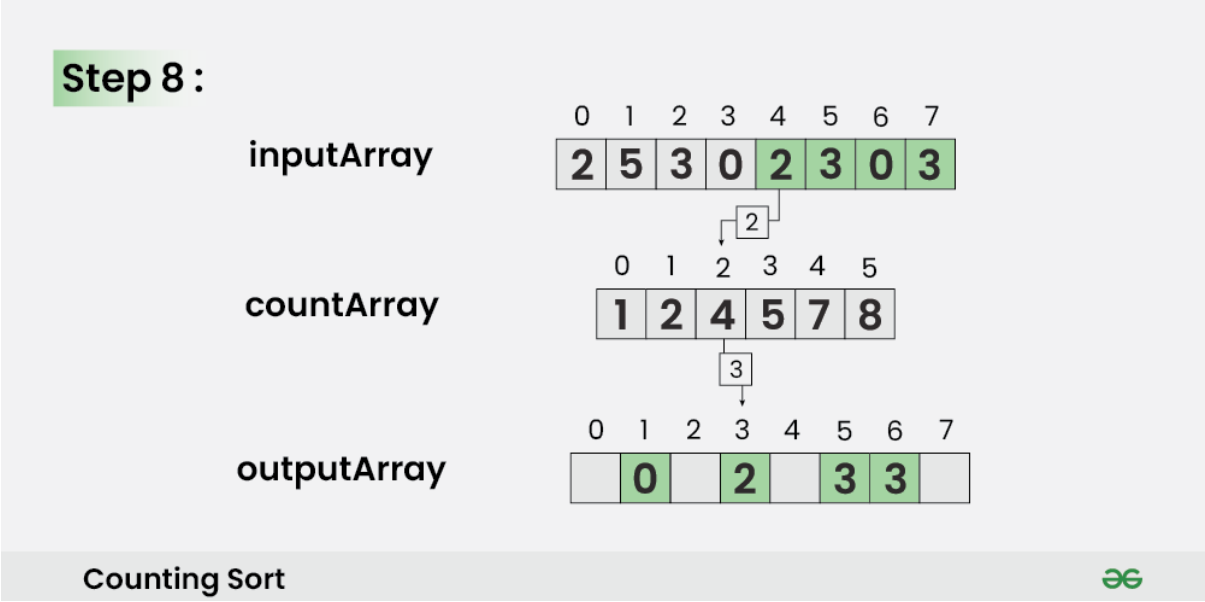
Step 7: For i = 5,

> Update **outputArray[countArray[inputArray[5]] – 1] = inputArray[5]**
> Also, update **countArray[inputArray[5]] = countArray[inputArray[5]]- –**



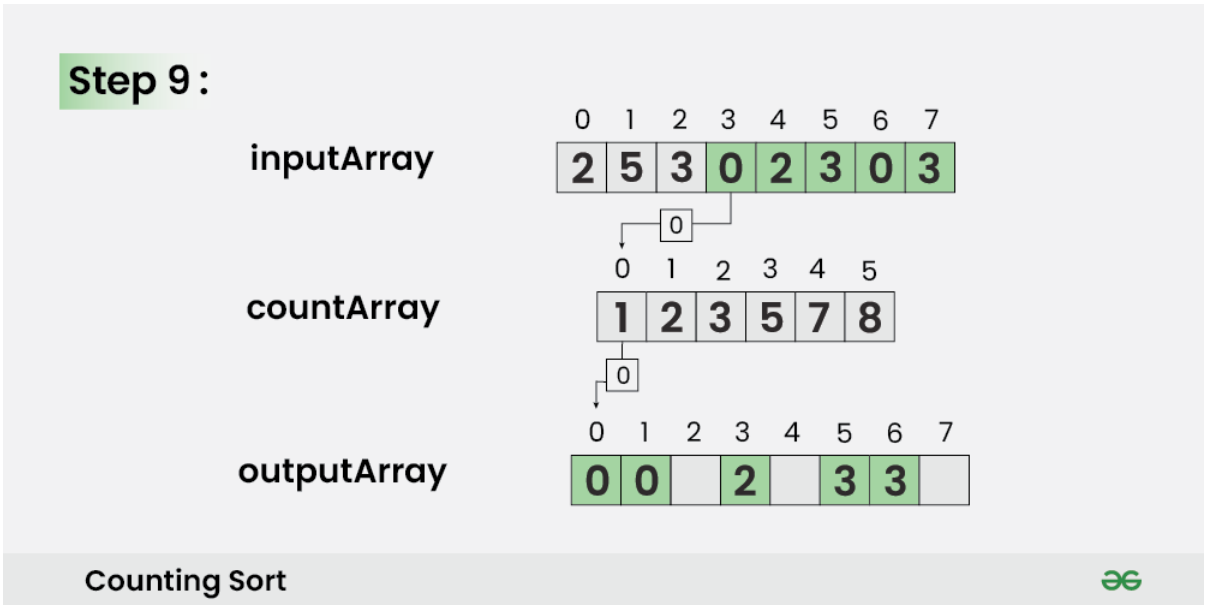
Step 8: For i = 4,

> Update **outputArray[countArray[inputArray[4]] – 1] = inputArray[4]**
> Also, update **countArray[inputArray[4]] = countArray[inputArray[4]]- –**



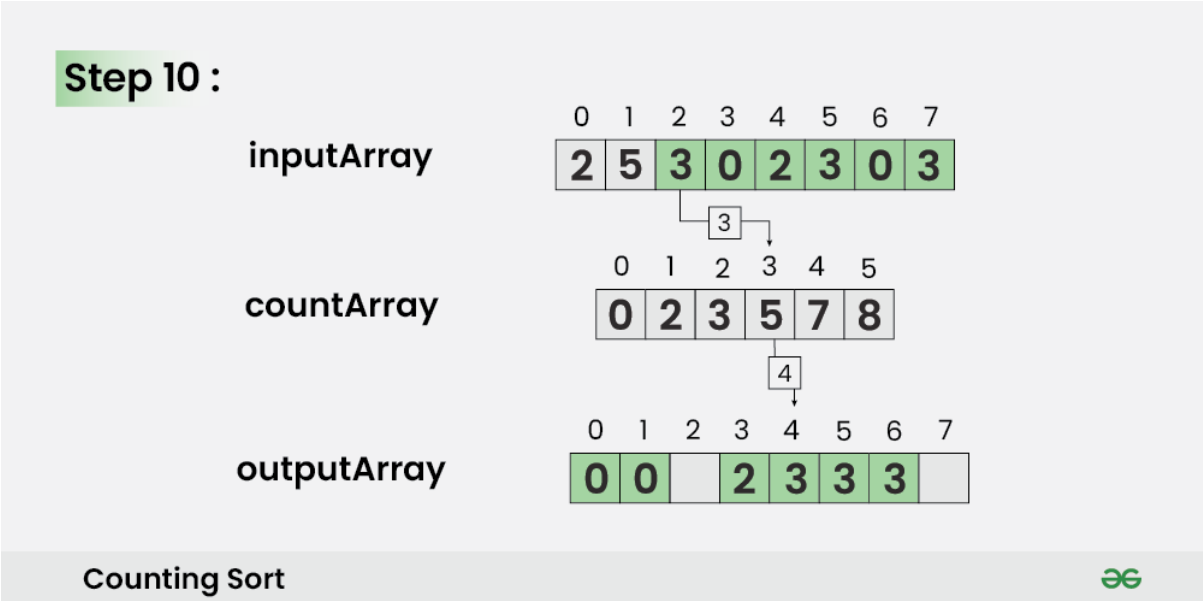
Step 9: For i = 3,

> Update **outputArray[countArray[inputArray[3]] – 1] = inputArray[3]**
> Also, update **countArray[inputArray[3]] = countArray[inputArray[3]]- –**



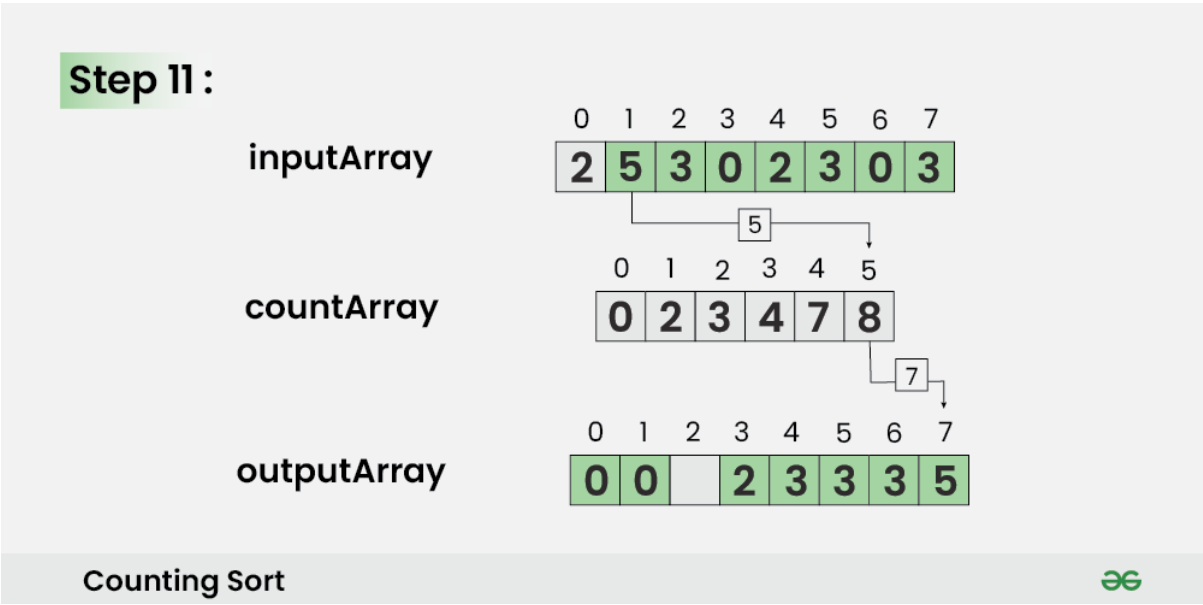
Step 10: For i = 2,

> Update **outputArray[countArray[inputArray[2]] – 1] = inputArray[2]**
> Also, update **countArray[inputArray[2]] = countArray[inputArray[2]]- –**



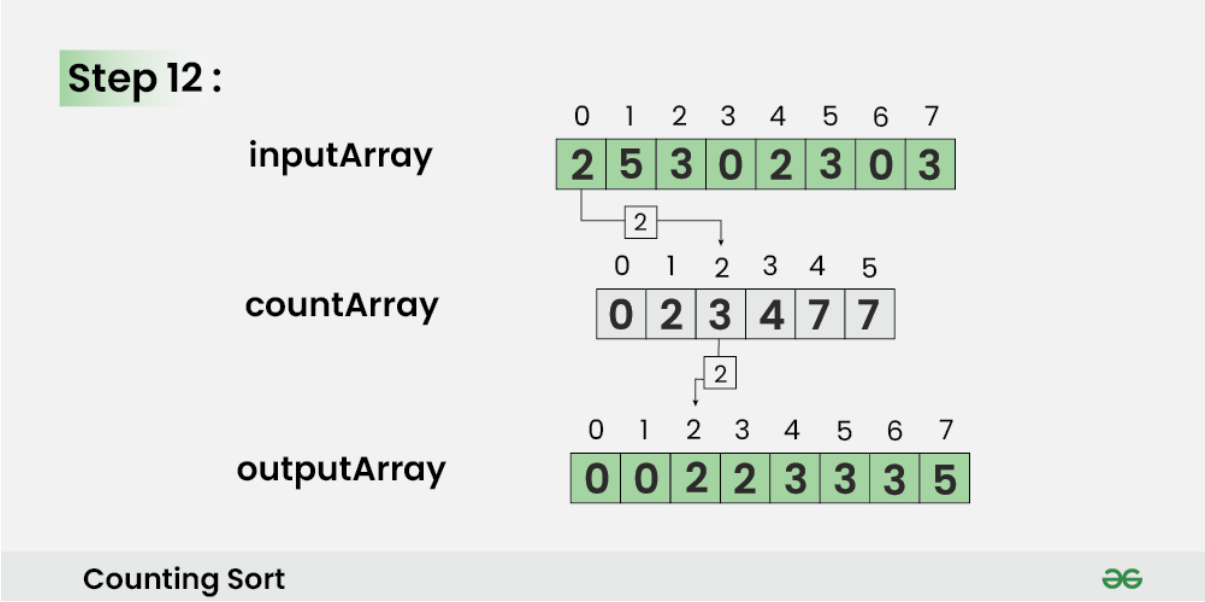
Step 11: **For i = 1**,

> Update **outputArray[countArray[inputArray[1]] – 1] = inputArray[1]**
> Also, update **countArray[inputArray[1]] = countArray[inputArray[1]]- –**



Step 12: **For i = 0,**

> Update **outputArray[countArray[inputArray[0]] – 1] = inputArray[0]**
> Also, update **countArray[inputArray[0]] = countArray[inputArray[0]]- –**



Counting Sort Algorithm:

- Declare an auxiliary array **countArray[]** of size **max(inputArray[])+1** and initialize it with **0**.
- Traverse array **inputArray[]** and map each element of **inputArray[]** as an index of **countArray[]** array, i.e., execute **countArray[inputArray[i]]++** for **0 <= i < N**.
- Calculate the prefix sum at every index of array **inputArray**[].
- Create an array **outputArray[]** of size **N**.
- Traverse array **inputArray[]** from end and update **outputArray[countArray[inputArray[i]] – 1] = inputArray[i]**. Also, update **countArray[inputArray[i]] = countArray[inputArray[i]]- –** .

Below is the implementation of the above algorithm:

Java

```
import java.util.Arrays;

public class CountSort {

public static int[] countSort(int[] inputArray) {

int N = inputArray.length;

int M = 0;

for (int i = 0; i < N; i++) {

M = Math.max(M, inputArray[i]);

}
```

```
int[] countArray = new int[M + 1];
for (int i = 0; i < N; i++) {
countArray[inputArray[i]]++;
}
for (int i = 1; i <= M; i++) {
countArray[i] += countArray[i - 1];
}
int[] outputArray = new int[N];
for (int i = N - 1; i >= 0; i--) {
outputArray[countArray[inputArray[i]] - 1] = inputArray[i];
countArray[inputArray[i]]--;
}
return outputArray;
}
public static void main(String[] args) {
int[] inputArray = {4, 3, 12, 1, 5, 5, 3, 9};
int[] outputArray = countSort(inputArray);
for (int i = 0; i < inputArray.length; i++) {
System.out.print(outputArray[i] + " ");
}
}
}
```

C#

```
using System;
using System.Collections.Generic;
class GFG
{
```

```
static List<int> CountSort(List<int> inputArray)
{
int N = inputArray.Count;
// Finding the maximum element of the array inputArray[].
int M = 0;
for (int i = 0; i < N; i++)
M = Math.Max(M, inputArray[i]);
// Initializing countArray[] with 0
List<int> countArray = new List<int>(new int[M + 1]);
// Mapping each element of inputArray[] as an index
// of countArray[] array
for (int i = 0; i < N; i++)
countArray[inputArray[i]]++;
// Calculating prefix sum at every index
// of array countArray[]
for (int i = 1; i <= M; i++)
countArray[i] += countArray[i - 1];
// Creating outputArray[] from the countArray[] array
List<int> outputArray = new List<int>(new int[N]);
for (int i = N - 1; i >= 0; i--)
{
outputArray[countArray[inputArray[i]] - 1] = inputArray[i];
countArray[inputArray[i]]--;
}
return outputArray;
}
// Driver code
static void Main()
{
```

```
// Input array
List<int> inputArray = new List<int> { 4, 3, 12, 1, 5, 5, 3, 9 };
// Output array
List<int> outputArray = CountSort(inputArray);
for (int i = 0; i < inputArray.Count; i++)
Console.Write(outputArray[i] + " ");
Console.WriteLine();
}
}
```

Javascript

```
function countSort(inputArray) {
const N = inputArray.length;
// Finding the maximum element of inputArray
let M = 0;
for (let i = 0; i < N; i++) {
M = Math.max(M, inputArray[i]);
}
// Initializing countArray with 0
const countArray = new Array(M + 1).fill(0);
// Mapping each element of inputArray as an index of countArray
for (let i = 0; i < N; i++) {
countArray[inputArray[i]]++;
}
// Calculating prefix sum at every index of countArray
for (let i = 1; i <= M; i++) {
countArray[i] += countArray[i - 1];
}
```

```
// Creating outputArray from countArray
const outputArray = new Array(N);
for (let i = N - 1; i >= 0; i--) {
outputArray[countArray[inputArray[i]] - 1] = inputArray[i];
countArray[inputArray[i]]--;
}
return outputArray;
}
// Driver code
const inputArray = [4, 3, 12, 1, 5, 5, 3, 9];
// Sorting the input array
const outputArray = countSort(inputArray);
// Printing the sorted array
console.log(outputArray.join(' '));
//This code is contributed by Utkarsh
```

C++14

```
#include <bits/stdc++.h>
using namespace std;
vector<int> countSort(vector<int>& inputArray)
{
int N = inputArray.size();
// Finding the maximum element of array inputArray[].
int M = 0;
for (int i = 0; i < N; i++)
M = max(M, inputArray[i]);
// Initializing countArray[] with 0
vector<int> countArray(M + 1, 0);
```

```
// Mapping each element of inputArray[] as an index
// of countArray[] array
for (int i = 0; i < N; i++)
countArray[inputArray[i]]++;
// Calculating prefix sum at every index
// of array countArray[]
for (int i = 1; i <= M; i++)
countArray[i] += countArray[i - 1];
// Creating outputArray[] from countArray[] array
vector<int> outputArray(N);
for (int i = N - 1; i >= 0; i--)
{
outputArray[countArray[inputArray[i]] - 1]
= inputArray[i];
countArray[inputArray[i]]--;
}
return outputArray;
}
// Driver code
int main()
{
// Input array
vector<int> inputArray = { 4, 3, 12, 1, 5, 5, 3, 9 };
// Output array
vector<int> outputArray = countSort(inputArray);
for (int i = 0; i < inputArray.size(); i++)
cout << outputArray[i] << " ";
return 0;
}
```

Python3

```
def count_sort(input_array):
# Finding the maximum element of input_array.
M = max(input_array)
# Initializing count_array with 0
count_array = [0] * (M + 1)
# Mapping each element of input_array as an index of count_array
for num in input_array:
count_array[num] += 1
# Calculating prefix sum at every index of count_array
for i in range(1, M + 1):
count_array[i] += count_array[i - 1]
# Creating output_array from count_array
output_array = [0] * len(input_array)
for i in range(len(input_array) - 1, -1, -1):
output_array[count_array[input_array[i]] - 1] = input_array[i]
count_array[input_array[i]] -= 1
return output_array
# Driver code
if __name__ == "__main__":
# Input array
input_array = [4, 3, 12, 1, 5, 5, 3, 9]
# Output array
output_array = count_sort(input_array)
for num in output_array:
print(num, end=" ")
```

Output

```
1 3 3 4 5 5 9 12
```

Complexity Analysis of Counting Sort:

- **Time Complexity**: O(N+M), where **N** and **M** are the size of **inputArray[]** and **countArray[]** respectively.
  - Worst-case: O(N+M).
  - Average-case: O(N+M).
  - Best-case: O(N+M).
- **Auxiliary Space:** O(N+M), where **N** and **M** are the space taken by **outputArray[]** and **countArray[]** respectively.

Advantage of Counting Sort:

- Counting sort generally performs faster than all comparison-based sorting algorithms, such as merge sort and quicksort, if the range of input is of the order of the number of input.
- Counting sort is easy to code
- Counting sort is a **stable algorithm**.

Disadvantage of Counting Sort:

- Counting sort doesn’t work on decimal values.
- Counting sort is inefficient if the range of values to be sorted is very large.
- Counting sort is not an **In-place sorting** algorithm, It uses extra space for sorting the array elements.

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