

# 1574. Shortest Subarray to be Removed to Make Array Sorted

Medium   Stack   Array   Two Pointers   Binary Search   Monotonic Stack   [Leetcode Link](#)

## Problem Description

The goal is to find the minimum length of a subarray that, when removed from an array `arr`, leaves the remaining elements in a non-decreasing order (i.e., each element is less than or equal to the next). In other words, after removing the subarray, the resulting array should be sorted in non-decreasing order. This problem also includes the possibility of not removing any subarray at all if `arr` is already non-decreasing. The term "subarray" refers to a sequence of elements that are contiguous within the `arr`.

## Intuition

The key to solving this problem lies in identifying parts of the array that are already sorted in non-decreasing order. Once we've identified such parts, we can find the minimum subarray to be removed. The solution approach can be broken down into the following steps:

- Find the longest non-decreasing subarray from the start (`left` sorted subarray).
- Find the longest non-decreasing subarray from the end (`right` sorted subarray).
- Evaluate if the entire array is already non-decreasing by checking if the `left` and `right` overlap or touch each other. If they do, the shortest subarray to remove would be of length 0, which means we don't have to remove anything.
- If a removal is needed, we can consider two potential solutions:
  - Remove the elements from the end of the `left` sorted subarray to the beginning of the array, leaving only the `right` sorted subarray.
  - Remove the elements from the start of the `right` sorted subarray to the end of the array, leaving only the `left` sorted subarray.
- It's possible that by combining some portion of the `left` subarray with some portion of the `right` subarray, we could actually remove a shorter subarray in between and still maintain the non-decreasing order. Therefore, we iterate through the `left` sorted subarray and try to match its end with the beginning of the `right` sorted subarray, minimizing the length of the subarray to be removed.

Following these steps, we can determine the shortest subarray to remove, ensuring the array remains sorted in non-decreasing order after the removal.

## Solution Approach

The solution approach consists of several key steps that use loops and variables to track the progress through the array `arr`. Here's how the implementation works:

- Initialize two pointers, `i` at the beginning of the array and `j` at the end. These pointers are used to find the `left` and `right` sorted subarrays, respectively.
- Progress `i` forward through the array until we find the first element that is not in non-decreasing order. Until that point, the elements rest in a sorted subarray from the start.
- Similarly, move `j` backwards through the array to find the first element from the end that breaks the non-decreasing order. Until that point, the elements are in a sorted subarray from the end.
- If `i` has passed `j`, return 0, as the entire array is already non-decreasing or it has only one element that is out of order, which can be removed by itself.
- Compute the initial potential answers:
  - The length of a subarray from `i` to the end of the array:  $n - i - 1$
  - The length of a subarray from the start of the array to `j`: `j`We are interested in the minimal length of the subarray to be removed, so we take the minimum of these two potential answers.
- Then comes the crucial step: trying to find the shortest subarray for removal that possibly lies between the sorted subarrays identified in steps 2 and 3. Initialize a new pointer `r` (short for right) to `j`.
- Now, iterate through the array `arr` using the `left` pointer from 0 to `i` (inclusive). For each position of the `left` pointer, progress the `right` pointer until `arr[r]` is not less than `arr[l]`, ensuring that elements to the left and right are in non-decreasing order.
- Update answer `ans` each time to reflect the minimal value: the current `ans` and the number of elements between the `left` and `right` pointers, denoted by  $r - l - 1$ .

By following these steps, the function concludes by returning `ans`, which represents the length of the shortest subarray to remove to achieve a non-decreasing array after its removal.

This implementation is efficient and makes clever use of two-pointer technique along with a simple `for` loop and while loop constructs to keep track of the non-decreasing subarrays from both the start and end of the input array and to calculate the minimum length of the subarray that needs to be removed.

## Example Walkthrough

Let's walk through a small example to illustrate the solution approach. Consider the array `arr = [1, 3, 2, 3, 5]`.

- Starting from the left, we see that  $1 \leq 3$ , but  $3 > 2$ , so the longest non-decreasing subarray from the start is `[1, 3]` with `i = 1`.
- Starting from the right, we see that  $5 \geq 3, 3 \geq 2$ , but  $2 < 3$ , so the longest non-decreasing subarray from the end is `[2, 3, 5]` with `j = 2`.
- Since `i < j`, they do not overlap, and we must remove a subarray to make the entire array non-decreasing.
- If we remove elements starting from the end of the `left` sorted subarray to the beginning of the array, we would remove `[1, 3]`, leaving `[2, 3, 5]`, which is in non-decreasing order. However, this results in removing 2 elements.
- Conversely, if we remove elements from the start of the `right` sorted subarray to the end of the array, we would remove `[3, 5]`, leaving `[1, 3, 2]`, which is not in non-decreasing order, so this is not a valid option.
- Now, we check to see if it's possible to maintain a part of the `left` subarray `[1, 3]` and combine it with the `right` subarray `[2, 3, 5]` to minimize the length of the subarray to be removed. To find the shortest subarray for removal, initialize pointer `r` (short for right) to `j`, which is 2 at the moment.
- We iterate through the array from the left pointer `l = 0` to `i = 1`. When `l = 0`, `arr[l] = 1` is less than `arr[r] = 2` (since `r` is at `j`), so we don't need to move `r`. Next, when `l = 1`, `arr[l] = 3` is greater than `arr[r] = 2`, so we increment `r` to ensure that `arr[r]` is not less than `arr[l]`. Since `arr[r] = 3` is now greater than `arr[l] = 3`, we can stop.
- The minimal length of the subarray to be removed lies in between pointer `l` and pointer `r`, which in this case is the subarray `[2]` (since `r = 3` and `l = 1`, we have  $r - l - 1 = 3 - 1 - 1 = 1$  element to be removed).

Thus, by following the solution steps, the smallest subarray we need to remove to make `arr` sorted in non-decreasing order is `[2]` of length 1. Hence, the function returns 1 as the answer.

## Python Solution

```
1 from typing import List
2
3 class Solution:
4     def findLengthOfShortestSubarray(self, arr: List[int]) -> int:
5         # Length of the array
6         length = len(arr)
7
8         # Initialize two pointers for the beginning and end of the array
9         left = 0
10        right = length - 1
11
12        # Move the left pointer to the right as long as the subarray is non-decreasing
13        while left + 1 < length and arr[left] <= arr[left + 1]:
14            left += 1
15
16        # Move the right pointer to the left as long as the subarray is non-decreasing
17        while right - 1 >= 0 and arr[right - 1] <= arr[right]:
18            right -= 1
19
20        # If the whole array is already non-decreasing, return 0
21        if left >= right:
22            return 0
23
24        # Calculate the length of the remaining array to be removed
25        min_length_to_remove = min(length - left - 1, right)
26
27        # Reinitialize the right pointer for the next loop
28        new_right = right
29
30        # Check for the shortest subarray from the left side to the midpoint
31        for new_left in range(left + 1):
32            # Increment the right pointer until the elements on both sides are non-decreasing
33            while new_right < length and arr[new_right] < arr[new_left]:
34                new_right += 1
35            # Update the minimum length if a shorter subarray is found
36            min_length_to_remove = min(min_length_to_remove, new_right - new_left - 1)
37
38        # Return the minimum length of the subarray to remove to make array non-decreasing
39        return min_length_to_remove
40
```

## Java Solution

```
1 class Solution {
2     public int findLengthOfShortestSubarray(int[] arr) {
3         int n = arr.length;
4         // Find the length of the non-decreasing starting subarray.
5         int left = 0, right = n - 1;
6         while (left + 1 < n && arr[left] <= arr[left + 1]) {
7             left++;
8         }
9         // If the whole array is already non-decreasing, return 0.
10        if (left == n - 1) {
11            return 0;
12        }
13
14        // Find the length of the non-decreasing ending subarray.
15        while (right > 0 && arr[right - 1] <= arr[right]) {
16            right--;
17        }
18
19        // Compute the length of the subarray to be removed,
20        // considering only one side (either starting or ending subarray).
21        int minLengthToRemove = Math.min(n - left - 1, right);
22
23        // Try to connect a prefix of the starting non-decreasing subarray
24        // with a suffix of the ending non-decreasing subarray.
25        for (int leftIdx = 0, rightIdx = right; leftIdx <= left; leftIdx++) {
26            // Move the rightIdx pointer to the right until we find an element
27            // that is not less than the current element from the left side.
28            while (rightIdx < n && arr[rightIdx] < arr[leftIdx]) {
29                rightIdx++;
30            }
31            // Update the answer with the minimum length found so far.
32            minLengthToRemove = Math.min(minLengthToRemove, rightIdx - leftIdx - 1);
33        }
34        return minLengthToRemove;
35    }
36 }
37
```

## C++ Solution

```
1 #include <vector>
2 #include <algorithm>
3
4 class Solution {
5 public:
6     int findLengthOfShortestSubarray(std::vector<int>& arr) {
7         int n = arr.size(); // The size of the input array
8         int left = 0, right = n - 1; // Pointers to iterate through the array
9
10        // Expand the left pointer as long as the current element is smaller or equal than the next one
11        // This means the left part is non-decreasing
12        while (left + 1 < n && arr[left] <= arr[left + 1]) {
13            ++left;
14        }
15
16        // If the whole array is non-decreasing, no removal is needed
17        if (left == n - 1) {
18            return 0;
19        }
20
21        // Expand the right pointer inwards as long as the next element leftwards is smaller or equal
22        // This means the right part is non-decreasing
23        while (right > 0 && arr[right - 1] <= arr[right]) {
24            --right;
25        }
26
27        // Calculate the initial length of the subarray that we can potentially remove
28        int minSubarrayLength = std::min(n - left - 1, right);
29
30        // Attempt to merge the non-decreasing parts on the left and the right
31        for (int l = 0, r = right; l <= left; ++l) {
32            // Find the first element which is not less than arr[l] in the right part to merge
33            while (r < n && arr[r] < arr[l]) {
34                ++r;
35            }
36            // Update the answer with the minimum length after merging
37            minSubarrayLength = std::min(minSubarrayLength, r - l - 1);
38        }
39
40        // Return the answer which is the length of the shortest subarray to remove
41        return minSubarrayLength;
42    }
43 };
44
```

## Typescript Solution

```
1 function findLengthOfShortestSubarray(arr: number[]): number {
2     const n: number = arr.length; // The size of the input array
3     let left: number = 0; // Pointer to iterate from the start
4     let right: number = n - 1; // Pointer to iterate from the end
5
6     // Expand the left pointer as long as the current element is smaller than or equal to the next one
7     // This means the left part is non-decreasing
8     while (left + 1 < n && arr[left] <= arr[left + 1]) {
9         left++;
10    }
11
12    // If the whole array is non-decreasing, no removal is needed
13    if (left === n - 1) {
14        return 0;
15    }
16
17    // Expand the right pointer inward as long as the next element to the left is smaller than or equal
18    // This means the right part is non-decreasing
19    while (right > 0 && arr[right - 1] <= arr[right]) {
20        right--;
21    }
22
23    // Calculate the initial length of the subarray that we can potentially remove
24    let minSubarrayLength: number = Math.min(n - left - 1, right);
25
26    // Attempt to merge the non-decreasing parts on the left and the right
27    for (let l: number = 0, r: number = right; l <= left; l++) {
28        // Find the first element which is not less than arr[l] in the right part to merge
29        while (r < n && arr[r] < arr[l]) {
30            r++;
31        }
32        // Update the minimum length after merging
33        minSubarrayLength = Math.min(minSubarrayLength, r - l - 1);
34    }
35
36    // Return the minimum length, which is the length of the shortest subarray to remove
37    return minSubarrayLength;
38 }
39
```

## Time and Space Complexity

### Time Complexity

The time complexity of the provided code can be broken down as follows:

- Two while loops (before the `if` statement) are executed sequentially, each advancing at most `n` steps. The worst-case complexity for this part is  $O(n)$ .
- The `if` statement is a constant time check  $O(1)$ .
- The minimum of  $n - i - 1$  and `j` is also a constant time operation  $O(1)$ .
- A for loop runs from `0` to `i + 1`, and inside it, there is a while loop that could iterate from `j` to `n` in the worst case. In the worst-case scenario, this nested loop could run  $O(n^2)$  times because for each iteration of the for loop (at most `n` times), the while loop could also iterate `n` times.

Thus, the overall time complexity is dominated by the nested loop, giving us a worst-case time complexity of  $O(n^2)$ .

### Space Complexity

The space complexity is determined by the extra space used by the algorithm besides the input. In this case:

- Variables `i`, `j`, `n`, `ans`, and `r` use constant space  $O(1)$ .
- There are no additional data structures used that grow with the size of the input.

Therefore, the space complexity is  $O(1)$ , which corresponds to constant space usage.