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Window Sliding Technique

This technique shows how a nested for loop in few problems can be converted to single for loop and hence reducing the time complexity.

2.4

Let's start with a problem for illustration where we can apply this technique –

```
Given an array of integers of size 'n'.
Our aim is to calculate the maximum sum of 'k'
consecutive elements in the array.

Input  : arr[] = {100, 200, 300, 400}
         k = 2
Output : 700

Input  : arr[] = {1, 4, 2, 10, 23, 3, 1, 0, 20}
         k = 4
Output : 39
We get maximum sum by adding subarray {4, 2, 10, 23}
of size 4.

Input  : arr[] = {2, 3}
         k = 3
Output : Invalid
There is no subarray of size 3 as size of whole
array is 2.
```

So, let's analyze the problem with **Brute Force Approach**. We start with first index and sum till **k-th** element. We do it for all possible consecutive blocks or groups of k elements. This method requires nested for loop, the outer for loop starts with the starting element of the block of k elements and the inner or the nested loop will add up till the k-th element.

Consider the below C++ implementation :

```
// O(n*k) solution for finding maximum sum of
// a subarray of size k
#include <iostream>
using namespace std;

// Returns maximum sum in a subarray of size k.
int maxSum(int arr[], int n, int k)
{
    // Initialize result
    int max_sum = INT_MIN ;
```

```
    // Consider all blocks starting with i.
    for (int i=0; i<n-k+1; i++)
    {
        int current_sum = 0;
        for (int j=0; j<k; j++)
            current_sum = current_sum + arr[i+j];

        // Update result if required.
        max_sum = max(current_sum , max_sum );
    }

    return max_sum;
}

// Driver code
int main()
{
    int arr[] = {1, 4, 2, 10, 2, 3, 1, 0, 20};
    int k = 4;
    int n = sizeof(arr)/sizeof(arr[0]);
    cout << maxSum(arr, n, k);
    return 0;
}
```

Output :

```
24
```

It can be observed from the above code that the time complexity is **O(k*n)** as it contains two nested loops.

Window Sliding Technique

The technique can be best understood with the window pane in bus, consider a window of length **n** and the pane which is fixed in it of length **k**. Consider, initially the pane is at extreme left i.e., at 0 units from the left. Now, co-relate the window with array arr[] of size n and plane with current_sum of size k elements. Now, if we apply force on the window such that it moves a unit distance ahead. The pane will cover next **k** consecutive elements.

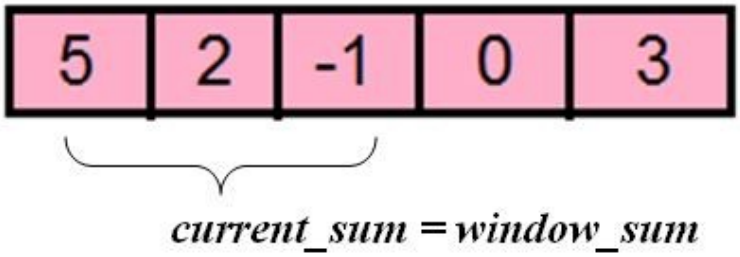
Consider an array **arr[]** = {5 , 2 , -1 , 0 , 3} and value of **k** = 3 and **n** = 5

Applying sliding window technique :

1. We compute the sum of first k elements out of n terms using a linear loop and store the sum in variable window_sum.
2. Then we will graze linearly over the array till it reaches the end and simultaneously keep track of maximum sum.
3. To get the current sum of block of k elements just subtract the first element from the previous block and add the last element of the current block .

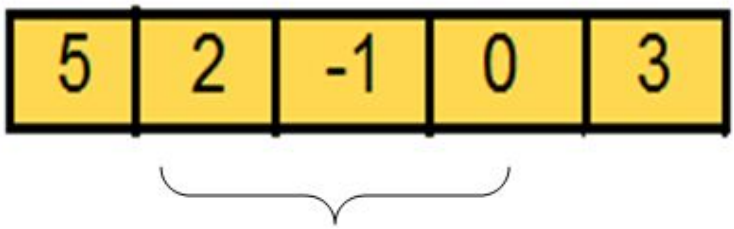
The below representation will make it clear how the window slides over the array.

This is the initial phase where we have calculated the initial window sum starting from index 0 . At this stage the window sum is 6. Now, we set the maximum_sum as current_window i.e 6.



$$current\_sum = window\_sum$$

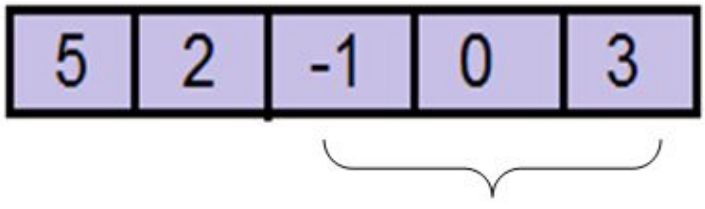
Now, we slide our window by a unit index. Therefore, now it discards 5 from the window and adds 0 to the window. Hence, we will get our new window sum by subtracting 5 and then adding 0 to it. So, our window sum now becomes 1. Now, we will compare this window sum with the maximum_sum. As it is smaller we wont the change the maximum_sum.



$$current\_sum = window\_sum + (-5) + (0)$$

Similarly, now once again we slide our window by a unit index and obtain the new window sum to be 2. Again we check if this current window sum is greater than the maximum_sum till now. Once, again it is smaller so we don't change the maximum_sum.

Therefore, for the above array our maximum_sum is 6.



$$current\_sum = window\_sum + (-2) + (3)$$

C++ code for the above description :

```
// O(n) solution for finding maximum sum of
// a subarray of size k
#include <iostream>
using namespace std;

// Returns maximum sum in a subarray of size k.
```

```
int maxSum(int arr[], int n, int k)
{
    // k must be greater
    if (n < k)
    {
       cout << "Invalid";
       return -1;
    }

    // Compute sum of first window of size k
    int max_sum = 0;
    for (int i=0; i<k; i++)
       max_sum += arr[i];

    // Compute sums of remaining windows by
    // removing first element of previous
    // window and adding last element of
    // current window.
    int window_sum = max_sum;
    for (int i=k; i<n; i++)
    {
       window_sum += arr[i] - arr[i-k];
       max_sum = max(max_sum, window_sum);
    }

    return max_sum;
}

// Driver code
int main()
{
    int arr[] = {1, 4, 2, 10, 2, 3, 1, 0, 20};
    int k = 4;
    int n = sizeof(arr)/sizeof(arr[0]);
    cout << maxSum(arr, n, k);
    return 0;
}
```

Output:24

Now, it is quiet obvious that the Time Complexity is linear as we can see that only one loop runs in our code. Hence, our Time Complexity is **O(n)**.

We can use this technique to find max/min k-subarray, XOR, product, sum, etc. Refer sliding window problems for such problems.

This article is contributed by **Kanika Thakral**. If you like GeeksforGeeks and would like to contribute, you can also write an article using contribute.geeksforgeeks.org or mail your article to contribute@geeksforgeeks.org. See your article appearing on the GeeksforGeeks main page and help other Geeks.

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