Segment Tree | Set 1 (Sum of given range)

Let us consider the followin s.

We have an array arr[0 . . . n-1]. We should be able to

1 Find the sum of elements from index l to r where 0 <= l <= r <= n-1

2 Change value of a specified element of the array to a new value x. We need to do arr[i] = x where 0 <= i <= n-1.

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Recommended: Please solve it on "*PRACTICE*" first, before moving on to the solution.

A **simple solution** is to run a loop from l to r and calculate the sum of elements in the given range. To update a value, simply do arr[i] = x. The first operation takes O(n) time and the second operation takes O(1) time.

Another solution is to create another array and store sum from start to i at the ith index in this array. The sum of a given range can now be calculated in O(1) time, but update operation takes O(n) time now. This works well if the number of query operations is large and very few updates.

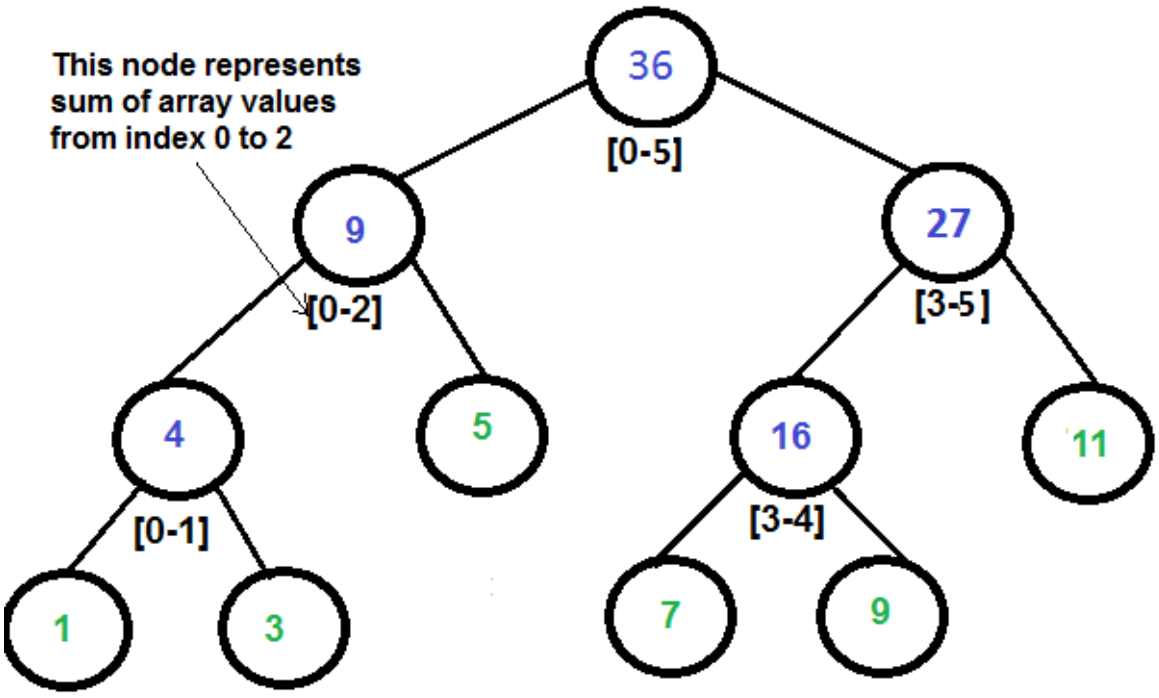
What if the number of query and updates are equal? **Can we perform both the operations in O(log n) time once given the array?** We can use a Segment Tree to do both operations in O(Logn) time.

Representation of Segment trees

1. Leaf Nodes are the elements of the input array.

2. Each internal node represents some merging of the leaf nodes. The merging may be different for different problems. For this problem, merging is sum of leaves under a node.

An array representation of tree is used to represent Segment Trees. For each node at index i, the left child is at index 2*i+1, right child at 2*i+2 and the parent is at $\lfloor (i-1)/2 \rfloor$.



Segment Tree for input array {1, 3, 5, 7, 9, 11}

How does above segment tree look in memory?

Like Heap, the segment tree is also represented as an array. The difference here is, it is not a complete binary tree. It is rather a full binary tree (every node has 0 or 2 children) and all levels are filled except possibly the last level. Unlike Heap, the last level may have gaps between nodes. Below are the values in the segment tree array for the above diagram.

> *Below is memory representation of segment tree for input array {1, 3, 5, 7, 9, 11}*
> *st[] = {36, 9, 27, 4, 5, 16, 11, 1, 3, DUMMY, DUMMY, 7, 9, DUMMY, DUMMY}*

The dummy values are never accessed and have no use. This is some wastage of space due to simple array representation. We may optimize this wastage using some clever implementations, but code for sum and update becomes more complex.

Construction of Segment Tree from given array

We start with a segment arr[0 . . . n-1]. and every time we divide the current segment into two halves(if it has not yet become a segment of length 1), and then call the same procedure on both halves, and for each such segment, we store the sum in the corresponding node.

All levels of the constructed segment tree will be completely filled except the last level. Also, the tree will be a Full Binary Tree because we always divide segments in two halves at every level. Since the constructed tree is always a full binary tree with n leaves, there will be n-1 internal nodes. So the total number of nodes will be 2*n – 1. Note that this does not include dummy nodes.

What is the total size of the array representing segment tree?

If n is a power of 2, then there are no dummy nodes. So the size of the segment tree is 2n-1 (n leaf nodes and n-1) internal nodes. If n is not a power of 2, then the size of the tree will be 2*x – 1 where x is the smallest power of 2 greater than n. For example, when n = 10, then size of array representing segment tree is 2*16-1 = 31.

An alternate explanation for size is based on heignt. Height of the segment tree will be $\lceil \log_2 n \rceil$. Since the tree is represented using array and relation between parent and child indexes must be maintained, size of memory allocated for segment tree will be $2 * 2^{\lceil \log_2 n \rceil} - 1$.

Query for Sum of given range

Once the tree is constructed, how to get the sum using the constructed segment tree. The following is the algorithm to get the sum of elements.

```
int getSum(node, l, r)
{
   if the range of the node is within l and r
        return value in the node
   else if the range of the node is completely outside l and r
        return 0
   else
    return getSum(node's left child, l, r) +
           getSum(node's right child, l, r)
}
```

Update a value

Like tree construction and query operations, the update can also be done recursively. We are given an index which needs to be updated. Let *diff* be the value to be added. We start from the root of the segment tree and add *diff* to all nodes which have given index in their range. If a node doesn't have a given index in its range, we don't make any changes to that node.

Implementation:

Following is the implementation of segment tree. The program implements construction of segment tree for any given array. It also implements query and update operations.

```
// C++ program to show segment tree operations like construction, query
// and update
#include <bits/stdc++.h>
using namespace std;

// A utility function to get the middle index from corner indexes.
int getMid(int s, int e) { return s + (e -s)/2; }

/* A recursive function to get the sum of values in the given range
    of the array. The following are parameters for this function.

    st --> Pointer to segment tree
    si --> Index of current node in the segment tree. Initially
            0 is passed as root is always at index 0
    ss & se --> Starting and ending indexes of the segment represented
                by current node, i.e., st[si]
    qs & qe --> Starting and ending indexes of query range */
int getSumUtil(int *st, int ss, int se, int qs, int qe, int si)
{
    // If segment of this node is a part of given range, then return
    // the sum of the segment
    if (qs <= ss && qe >= se)
        return st[si];

    // If segment of this node is outside the given range
    if (se < qs || ss > qe)
        return 0;

    // If a part of this segment overlaps with the given range
    int mid = getMid(ss, se);
    return getSumUtil(st, ss, mid, qs, qe, 2*si+1) +
        getSumUtil(st, mid+1, se, qs, qe, 2*si+2);
}

/* A recursive function to update the nodes which have the given
index in their range. The following are parameters
    st, si, ss and se are same as getSumUtil()
    i --> index of the element to be updated. This index is
            in the input array.
diff --> Value to be added to all nodes which have i in range */
void updateValueUtil(int *st, int ss, int se, int i, int diff, int si)
{
    // Base Case: If the input index lies outside the range of
    // this segment
    if (i < ss || i > se)
        return;

    // If the input index is in range of this node, then update
    // the value of the node and its children
    st[si] = st[si] + diff;
    if (se != ss)
    {
        int mid = getMid(ss, se);
        updateValueUtil(st, ss, mid, i, diff, 2*si + 1);
        updateValueUtil(st, mid+1, se, i, diff, 2*si + 2);
    }
}

// The function to update a value in input array and segment tree.
// It uses updateValueUtil() to update the value in segment tree
```

```
void updateValue(int arr[], int *st, int n, int i, int new_val)
{
    // Check for erroneous input index
    if (i < 0 || i > n-1)
    {
        cout<<"Invalid Input";
        return;
    }

    // Get the difference between new value and old value
    int diff = new_val - arr[i];

    // Update the value in array
    arr[i] = new_val;

    // Update the values of nodes in segment tree
    updateValueUtil(st, 0, n-1, i, diff, 0);
}

// Return sum of elements in range from index qs (quey start)
// to qe (query end). It mainly uses getSumUtil()
int getSum(int *st, int n, int qs, int qe)
{
    // Check for erroneous input values
    if (qs < 0 || qe > n-1 || qs > qe)
    {
        cout<<"Invalid Input";
        return -1;
    }

    return getSumUtil(st, 0, n-1, qs, qe, 0);
}

// A recursive function that constructs Segment Tree for array[ss..se].
// si is index of current node in segment tree st
int constructSTUtil(int arr[], int ss, int se, int *st, int si)
{
    // If there is one element in array, store it in current node of
    // segment tree and return
    if (ss == se)
    {
        st[si] = arr[ss];
        return arr[ss];
    }

    // If there are more than one elements, then recur for left and
    // right subtrees and store the sum of values in this node
    int mid = getMid(ss, se);
    st[si] = constructSTUtil(arr, ss, mid, st, si*2+1) +
            constructSTUtil(arr, mid+1, se, st, si*2+2);
    return st[si];
}

/* Function to construct segment tree from given array. This function
allocates memory for segment tree and calls constructSTUtil() to
fill the allocated memory */
int *constructST(int arr[], int n)
{
    // Allocate memory for the segment tree
    //Height of segment tree
    int x = (int)(ceil(log2(n)));

    //Maximum size of segment tree
    int max_size = 2*(int)pow(2, x) - 1;

    // Allocate memory
    int *st = new int[max_size];

    // Fill the allocated memory st
    constructSTUtil(arr, 0, n-1, st, 0);

    // Return the constructed segment tree
    return st;
}

// Driver program to test above functions
int main()
{
    int arr[] = {1, 3, 5, 7, 9, 11};
    int n = sizeof(arr)/sizeof(arr[0]);

    // Build segment tree from given array
    int *st = constructST(arr, n);

    // Print sum of values in array from index 1 to 3
    cout<<"Sum of values in given range = "<<getSum(st, n, 1, 3)<<endl;

    // Update: set arr[1] = 10 and update corresponding
    // segment tree nodes
    updateValue(arr, st, n, 1, 10);

    // Find sum after the value is updated
    cout<<"Updated sum of values in given range = "
            <<getSum(st, n, 1, 3)<<endl;
    return 0;
}
//This code is contributed by rathbhupendra
```

C

```
// C program to show segment tree operations like construction, query
// and update
#include <stdio.h>
#include <math.h>

// A utility function to get the middle index from corner indexes.
int getMid(int s, int e) {  return s + (e -s)/2;   }

/*  A recursive function to get the sum of values in given range
    of the array. The following are parameters for this function.

    st    --> Pointer to segment tree
    si    --> Index of current node in the segment tree. Initially
              0 is passed as root is always at index 0
    ss & se  --> Starting and ending indexes of the segment represented
                 by current node, i.e., st[si]
    qs & qe  --> Starting and ending indexes of query range */
```

```
int getSumUtil(int *st, int ss, int se, int qs, int qe, int si)
{
    // If segment of this node is a part of given range, then return
    // the sum of the segment
    if (qs <= ss && qe >= se)
        return st[si];

    // If segment of this node is outside the given range
    if (se < qs || ss > qe)
        return 0;

    // If a part of this segment overlaps with the given range
    int mid = getMid(ss, se);
    return getSumUtil(st, ss, mid, qs, qe, 2*si+1) +
           getSumUtil(st, mid+1, se, qs, qe, 2*si+2);
}

/* A recursive function to update the nodes which have the given
   index in their range. The following are parameters
    st, si, ss and se are same as getSumUtil()
    i    --> index of the element to be updated. This index is
             in the input array.
   diff --> Value to be added to all nodes which have i in range */
void updateValueUtil(int *st, int ss, int se, int i, int diff, int si)
{
    // Base Case: If the input index lies outside the range of
    // this segment
    if (i < ss || i > se)
        return;

    // If the input index is in range of this node, then update
    // the value of the node and its children
    st[si] = st[si] + diff;
    if (se != ss)
    {
        int mid = getMid(ss, se);
        updateValueUtil(st, ss, mid, i, diff, 2*si + 1);
        updateValueUtil(st, mid+1, se, i, diff, 2*si + 2);
    }
}

// The function to update a value in input array and segment tree.
// It uses updateValueUtil() to update the value in segment tree
void updateValue(int arr[], int *st, int n, int i, int new_val)
{
    // Check for erroneous input index
    if (i < 0 || i > n-1)
    {
        printf("Invalid Input");
        return;
    }

    // Get the difference between new value and old value
    int diff = new_val - arr[i];

    // Update the value in array
    arr[i] = new_val;

    // Update the values of nodes in segment tree
    updateValueUtil(st, 0, n-1, i, diff, 0);
}

// Return sum of elements in range from index qs (quey start)
// to qe (query end).  It mainly uses getSumUtil()
int getSum(int *st, int n, int qs, int qe)
{
    // Check for erroneous input values
    if (qs < 0 || qe > n-1 || qs > qe)
    {
        printf("Invalid Input");
        return -1;
    }

    return getSumUtil(st, 0, n-1, qs, qe, 0);
}

// A recursive function that constructs Segment Tree for array[ss..se].
// si is index of current node in segment tree st
int constructSTUtil(int arr[], int ss, int se, int *st, int si)
{
    // If there is one element in array, store it in current node of
    // segment tree and return
    if (ss == se)
    {
        st[si] = arr[ss];
        return arr[ss];
    }

    // If there are more than one elements, then recur for left and
    // right subtrees and store the sum of values in this node
    int mid = getMid(ss, se);
    st[si] =  constructSTUtil(arr, ss, mid, st, si*2+1) +
              constructSTUtil(arr, mid+1, se, st, si*2+2);
    return st[si];
}

/* Function to construct segment tree from given array. This function
   allocates memory for segment tree and calls constructSTUtil() to
   fill the allocated memory */
int *constructST(int arr[], int n)
{
    // Allocate memory for the segment tree

    //Height of segment tree
    int x = (int)(ceil(log2(n)));

    //Maximum size of segment tree
    int max_size = 2*(int)pow(2, x) - 1;

    // Allocate memory
    int *st = new int[max_size];

    // Fill the allocated memory st
    constructSTUtil(arr, 0, n-1, st, 0);

    // Return the constructed segment tree
    return st;
}

// Driver program to test above functions
```

```
int main()
{
    int arr[] = {1, 3, 5, 7, 9, 11};
    int n = sizeof(arr)/sizeof(arr[0]);

    // Build segment tree from given array
    int *st = constructST(arr, n);

    // Print sum of values in array from index 1 to 3
    printf("Sum of values in given range = %dn",
            getSum(st, n, 1, 3));

    // Update: set arr[1] = 10 and update corresponding
    // segment tree nodes
    updateValue(arr, st, n, 1, 10);

    // Find sum after the value is updated
    printf("Updated sum of values in given range = %dn",
             getSum(st, n, 1, 3));
    return 0;
}
```

Java

```
// Java Program to show segment tree operations like construction,
// query and update
class SegmentTree
{
    int st[]; // The array that stores segment tree nodes

    /* Constructor to construct segment tree from given array. This
       constructor  allocates memory for segment tree and calls
       constructSTUtil() to  fill the allocated memory */
    SegmentTree(int arr[], int n)
    {
        // Allocate memory for segment tree
        //Height of segment tree
        int x = (int) (Math.ceil(Math.log(n) / Math.log(2)));

        //Maximum size of segment tree
        int max_size = 2 * (int) Math.pow(2, x) - 1;

        st = new int[max_size]; // Memory allocation

        constructSTUtil(arr, 0, n - 1, 0);
    }

    // A utility function to get the middle index from corner indexes.
    int getMid(int s, int e) {
        return s + (e - s) / 2;
    }

    /*  A recursive function to get the sum of values in given range
        of the array.  The following are parameters for this function.

      st    --> Pointer to segment tree
      si    --> Index of current node in the segment tree. Initially
                0 is passed as root is always at index 0
```

```
   ss & se  --> Starting and ending indexes of the segment represented
                by current node, i.e., st[si]
   qs & qe  --> Starting and ending indexes of query range */
 int getSumUtil(int ss, int se, int qs, int qe, int si)
 {
     // If segment of this node is a part of given range, then return
     // the sum of the segment
     if (qs <= ss && qe >= se)
         return st[si];

     // If segment of this node is outside the given range
     if (se < qs || ss > qe)
         return 0;

     // If a part of this segment overlaps with the given range
     int mid = getMid(ss, se);
     return getSumUtil(ss, mid, qs, qe, 2 * si + 1) +
             getSumUtil(mid + 1, se, qs, qe, 2 * si + 2);
 }

 /* A recursive function to update the nodes which have the given
    index in their range. The following are parameters
     st, si, ss and se are same as getSumUtil()
     i    --> index of the element to be updated. This index is in
              input array.
    diff --> Value to be added to all nodes which have i in range */
 void updateValueUtil(int ss, int se, int i, int diff, int si)
 {
     // Base Case: If the input index lies outside the range of
     // this segment
     if (i < ss || i > se)
         return;

     // If the input index is in range of this node, then update the
     // value of the node and its children
     st[si] = st[si] + diff;
     if (se != ss) {
         int mid = getMid(ss, se);
         updateValueUtil(ss, mid, i, diff, 2 * si + 1);
         updateValueUtil(mid + 1, se, i, diff, 2 * si + 2);
     }
 }

 // The function to update a value in input array and segment tree.
// It uses updateValueUtil() to update the value in segment tree
 void updateValue(int arr[], int n, int i, int new_val)
 {
     // Check for erroneous input index
     if (i < 0 || i > n - 1) {
         System.out.println("Invalid Input");
         return;
     }

     // Get the difference between new value and old value
     int diff = new_val - arr[i];

     // Update the value in array
     arr[i] = new_val;

     // Update the values of nodes in segment tree
```

```
        updateValueUtil(0, n - 1, i, diff, 0);
    }

    // Return sum of elements in range from index qs (quey start) to
   // qe (query end).  It mainly uses getSumUtil()
    int getSum(int n, int qs, int qe)
    {
        // Check for erroneous input values
        if (qs < 0 || qe > n - 1 || qs > qe) {
            System.out.println("Invalid Input");
            return -1;
        }
        return getSumUtil(0, n - 1, qs, qe, 0);
    }

    // A recursive function that constructs Segment Tree for array[ss..se].
    // si is index of current node in segment tree st
    int constructSTUtil(int arr[], int ss, int se, int si)
    {
        // If there is one element in array, store it in current node of
        // segment tree and return
        if (ss == se) {
            st[si] = arr[ss];
            return arr[ss];
        }

        // If there are more than one elements, then recur for left and
        // right subtrees and store the sum of values in this node
        int mid = getMid(ss, se);
        st[si] = constructSTUtil(arr, ss, mid, si * 2 + 1) +
                 constructSTUtil(arr, mid + 1, se, si * 2 + 2);
        return st[si];
    }

    // Driver program to test above functions
    public static void main(String args[])
    {
        int arr[] = {1, 3, 5, 7, 9, 11};
        int n = arr.length;
        SegmentTree  tree = new SegmentTree(arr, n);

        // Build segment tree from given array

        // Print sum of values in array from index 1 to 3
        System.out.println("Sum of values in given range = " +
                           tree.getSum(n, 1, 3));

        // Update: set arr[1] = 10 and update corresponding segment
        // tree nodes
        tree.updateValue(arr, n, 1, 10);

        // Find sum after the value is updated
        System.out.println("Updated sum of values in given range = " +
                tree.getSum(n, 1, 3));
    }
}
//This code is contributed by Ankur Narain Verma
```

Python3

```python
# Python3 program to show segment tree operations like
# construction, query and update
from math import ceil, log2;

# A utility function to get the
# middle index from corner indexes.
def getMid(s, e) :
    return s + (e -s) // 2;

""" A recursive function to get the sum of values
    in the given range of the array. The following
    are parameters for this function.

    st --> Pointer to segment tree
    si --> Index of current node in the segment tree.
           Initially 0 is passed as root is always at index 0
    ss & se --> Starting and ending indexes of the segment
                represented by current node, i.e., st[si]
    qs & qe --> Starting and ending indexes of query range """
def getSumUtil(st, ss, se, qs, qe, si) :

    # If segment of this node is a part of given range,
    # then return the sum of the segment
    if (qs <= ss and qe >= se) :
        return st[si];

    # If segment of this node is
    # outside the given range
    if (se < qs or ss > qe) :
        return 0;

    # If a part of this segment overlaps
    # with the given range
    mid = getMid(ss, se);

    return getSumUtil(st, ss, mid, qs, qe, 2 * si + 1) + \
           getSumUtil(st, mid + 1, se, qs, qe, 2 * si + 2);

""" A recursive function to update the nodes
which have the given index in their range.
The following are parameters st, si, ss and se
are same as getSumUtil()
i --> index of the element to be updated.
      This index is in the input array.
diff --> Value to be added to all nodes
which have i in range """
def updateValueUtil(st, ss, se, i, diff, si) :

    # Base Case: If the input index lies
    # outside the range of this segment
    if (i < ss or i > se) :
        return;

    # If the input index is in range of this node,
    # then update the value of the node and its children
    st[si] = st[si] + diff;
    if (se != ss) :

        mid = getMid(ss, se);
        updateValueUtil(st, ss, mid, i,
                        diff, 2 * si + 1);
        updateValueUtil(st, mid + 1, se, i,
                         diff, 2 * si + 2);

# The function to update a value in input array
# and segment tree. It uses updateValueUtil()
# to update the value in segment tree
def updateValue(arr, st, n, i, new_val) :

    # Check for erroneous input index
    if (i < 0 or i > n - 1) :

        print("Invalid Input", end = "");
        return;

    # Get the difference between
    # new value and old value
    diff = new_val - arr[i];

    # Update the value in array
    arr[i] = new_val;

    # Update the values of nodes in segment tree
    updateValueUtil(st, 0, n - 1, i, diff, 0);

# Return sum of elements in range from
# index qs (quey start) to qe (query end).
# It mainly uses getSumUtil()
def getSum(st, n, qs, qe) :

    # Check for erroneous input values
    if (qs < 0 or qe > n - 1 or qs > qe) :

        print("Invalid Input", end = "");
        return -1;

    return getSumUtil(st, 0, n - 1, qs, qe, 0);

# A recursive function that constructs
# Segment Tree for array[ss..se].
# si is index of current node in segment tree st
def constructSTUtil(arr, ss, se, st, si) :

    # If there is one element in array,
    # store it in current node of
    # segment tree and return
    if (ss == se) :

        st[si] = arr[ss];
        return arr[ss];

    # If there are more than one elements,
    # then recur for left and right subtrees
    # and store the sum of values in this node
    mid = getMid(ss, se);
    st[si] = constructSTUtil(arr, ss, mid, st, si * 2 + 1) +\
             constructSTUtil(arr, mid + 1, se, st, si * 2 + 2);

    return st[si];

""" Function to construct segment tree
from given array. This function allocates memory
for segment tree and calls constructSTUtil() to
fill the allocated memory """
def constructST(arr, n) :

    # Allocate memory for the segment tree

    # Height of segment tree
    x = (int)(ceil(log2(n)));

    # Maximum size of segment tree
    max_size = 2 * (int)(2**x) - 1;

    # Allocate memory
    st = [0] * max_size;

    # Fill the allocated memory st
    constructSTUtil(arr, 0, n - 1, st, 0);

    # Return the constructed segment tree
    return st;

# Driver Code
if __name__ == "__main__" :

    arr = [1, 3, 5, 7, 9, 11];
    n = len(arr);

    # Build segment tree from given array
    st = constructST(arr, n);

    # Print sum of values in array from index 1 to 3
    print("Sum of values in given range = ",
                       getSum(st, n, 1, 3));

    # Update: set arr[1] = 10 and update
    # corresponding segment tree nodes
    updateValue(arr, st, n, 1, 10);

    # Find sum after the value is updated
    print("Updated sum of values in given range = ",
                     getSum(st, n, 1, 3), end = "");

# This code is contributed by AnkitRai01
```

C#

```
// C# Program to show segment tree
// operations like construction,
// query and update
using System;
```

```
class SegmentTree
{
    int []st; // The array that stores segment tree nodes

    /* Constructor to construct segment
    tree from given array. This constructor
    allocates memory for segment tree and calls
    constructSTUtil() to fill the allocated memory */
    SegmentTree(int []arr, int n)
    {
        // Allocate memory for segment tree
        //Height of segment tree
        int x = (int) (Math.Ceiling(Math.Log(n) / Math.Log(2)));

        //Maximum size of segment tree
        int max_size = 2 * (int) Math.Pow(2, x) - 1;

        st = new int[max_size]; // Memory allocation

        constructSTUtil(arr, 0, n - 1, 0);
    }

    // A utility function to get the
    // middle index from corner indexes.
    int getMid(int s, int e)
    {
        return s + (e - s) / 2;
    }

    /* A recursive function to get
    the sum of values in given range
        of the array. The following
        are parameters for this function.

    st --> Pointer to segment tree
    si --> Index of current node in the
            segment tree. Initially
                0 is passed as root is
                always at index 0
    ss & se --> Starting and ending indexes
                    of the segment represented
                    by current node, i.e., st[si]
    qs & qe --> Starting and ending indexes of query range */
    int getSumUtil(int ss, int se, int qs, int qe, int si)
    {
        // If segment of this node is a part
        // of given range, then return
        // the sum of the segment
        if (qs <= ss && qe >= se)
            return st[si];

        // If segment of this node is
        // outside the given range
        if (se < qs || ss > qe)
            return 0;

        // If a part of this segment
        // overlaps with the given range
        int mid = getMid(ss, se);
        return getSumUtil(ss, mid, qs, qe, 2 * si + 1) +
                getSumUtil(mid + 1, se, qs, qe, 2 * si + 2);
    }

    /* A recursive function to update
    the nodes which have the given
    index in their range. The following
    are parameters st, si, ss and se
    are same as getSumUtil() i --> index
    of the element to be updated. This
    index is in input array. diff --> Value
    to be added to all nodes which have i in range */
    void updateValueUtil(int ss, int se, int i,
                                int diff, int si)
    {
        // Base Case: If the input index
        // lies outside the range of this segment
        if (i < ss || i > se)
            return;

        // If the input index is in range of
        // this node, then update the value
        // of the node and its children
        st[si] = st[si] + diff;
        if (se != ss)
        {
            int mid = getMid(ss, se);
            updateValueUtil(ss, mid, i, diff, 2 * si + 1);
            updateValueUtil(mid + 1, se, i, diff, 2 * si + 2);
        }
    }

    // The function to update a value
    // in input array and segment tree.
    // It uses updateValueUtil() to
    // update the value in segment tree
    void updateValue(int []arr, int n, int i, int new_val)
    {
        // Check for erroneous input index
        if (i < 0 || i > n - 1)
        {
            Console.WriteLine("Invalid Input");
            return;
        }

        // Get the difference between
        // new value and old value
        int diff = new_val - arr[i];

        // Update the value in array
        arr[i] = new_val;

        // Update the values of nodes in segment tree
        updateValueUtil(0, n - 1, i, diff, 0);
    }

    // Return sum of elements in range
    // from index qs (quey start) to
    // qe (query end). It mainly uses getSumUtil()
    int getSum(int n, int qs, int qe)
    {
        // Check for erroneous input values
        if (qs < 0 || qe > n - 1 || qs > qe)
        {
            Console.WriteLine("Invalid Input");
            return -1;
        }
        return getSumUtil(0, n - 1, qs, qe, 0);
    }

    // A recursive function that constructs
    // Segment Tree for array[ss..se].
    // si is index of current node in segment tree st
    int constructSTUtil(int []arr, int ss, int se, int si)
    {
        // If there is one element in array,
        // store it in current node of
        // segment tree and return
        if (ss == se) {
            st[si] = arr[ss];
            return arr[ss];
        }

        // If there are more than one elements,
        // then recur for left and right subtrees
        // and store the sum of values in this node
        int mid = getMid(ss, se);
        st[si] = constructSTUtil(arr, ss, mid, si * 2 + 1) +
                constructSTUtil(arr, mid + 1, se, si * 2 + 2);
        return st[si];
    }

    // Driver code
    public static void Main()
    {
        int []arr = {1, 3, 5, 7, 9, 11};
        int n = arr.Length;
        SegmentTree tree = new SegmentTree(arr, n);

        // Build segment tree from given array

        // Print sum of values in array from index 1 to 3
        Console.WriteLine("Sum of values in given range = " +
                                        tree.getSum(n, 1, 3));

        // Update: set arr[1] = 10 and update
        // corresponding segment tree nodes
        tree.updateValue(arr, n, 1, 10);

        // Find sum after the value is updated
        Console.WriteLine("Updated sum of values in given range = " +
                tree.getSum(n, 1, 3));
    }
}

/* This code contributed by PrinciRaj1992 */
```

Output:

```
Sum of values in given range = 15
Updated sum of values in given range = 22
```

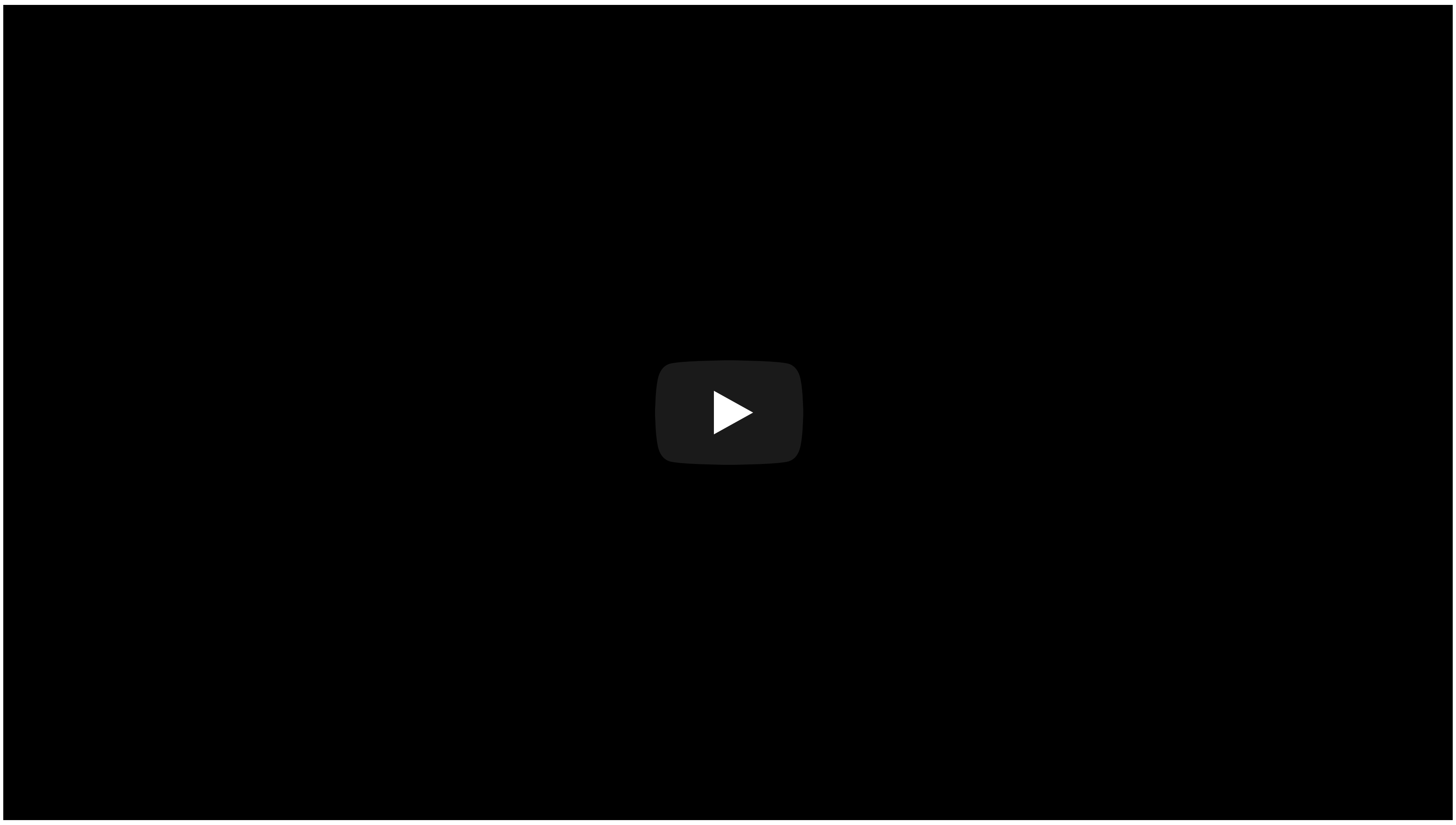
Time Complexity:

Time Complexity for tree construction is O(n). There are total 2n-1 nodes, and value of every node is calculated only once in tree construction.

Time complexity to query is O(Logn). To query a sum, we process at most four nodes at every level and number of levels is O(Logn).

The time complexity of update is also O(Logn). To update a leaf value, we process one node at every level and number of levels is O(Logn).

Segment Tree | Set 2 (Range Minimum Query)



References:

IIT Kanpur paper.

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36

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