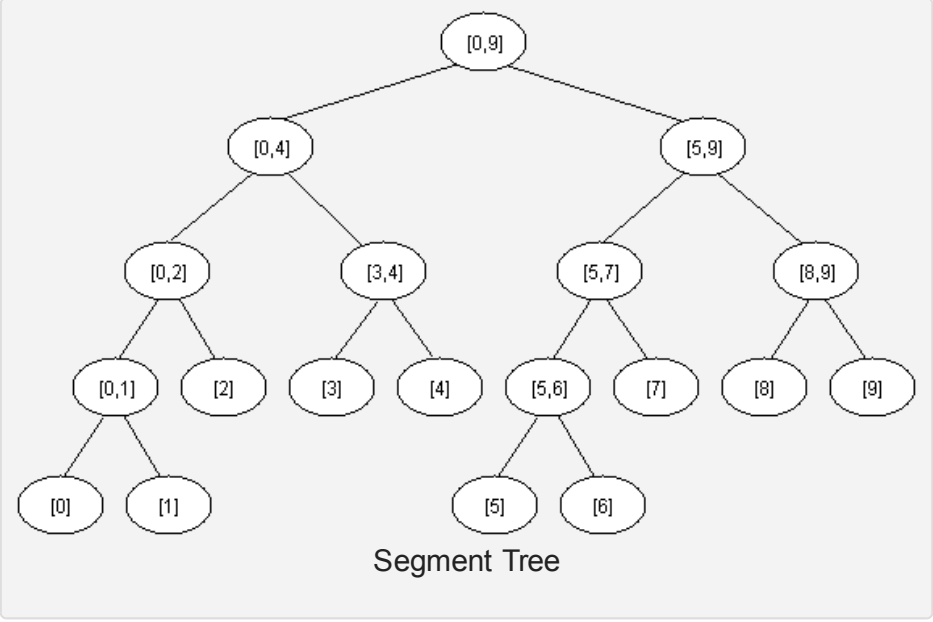
Segment Trees

with 18 comments

A segment tree is a heap-like data structure that can be used for making update/query operations upon array intervals in logarithmical time. We define the segment tree for the interval [i, j] in the following recursive manner:

- the first node will hold the information for the interval [i, j]
- if i<j the left and right son will hold the information for the intervals **[i, (i+j)/2]** and **[(i+j)/2+1, j]**

See the picture below to understand more :



Segment Tree

We can use segment trees to solve Range Minimum/Maximum Query Problems (RMQ). The time complexity is **T(N, log N)** where O(N) is the time required to build the tree and each query takes O(log N) time. Here's a C++ template implementation :

I am

A graduate from Institute of Technology,BHU. Coding, maths, number theory, oeis, music, reality shows, cs1.6 and sleeping, that pretty much sums up my life :)

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```
#include<iostream>
using namespace std;
#include<math.h>

template<class T>
class SegmentTree
{
      int *A,size;
      public:
      SegmentTree(int N)
      {
           int x = (int)(ceil(log2(N)))+1;
           size = 2*(int)pow(2,x);
           A = new int[size];
           memset(A,-1,sizeof(A));
      }
      void initialize(int node, int start,
                      int end, T *array)
      {

           if (start==end)
              A[node] = start;
           else
           {
               int mid = (start+end)/2;
               initialize(2*node,start,mid,array);
               initialize(2*node+1,mid+1,end,array);
               if (array[A[2*node]]<=
                      array[A[2*node+1]])
                  A[node] = A[2 * node];
               else
                   A[node] = A[2 * node + 1];
           }
      }
      int query(int node, int start,
                int end, int i, int j, T *array)
      {
          int id1,id2;
          if (i>end || j<start)
             return -1;

          if (start>=i && end<=j)
             return A[node];

          int mid = (start+end)/2;
          id1 = query(2*node,start,mid,i,j,array);
```

```
            id2 = query(2*node+1,mid+1,end,i,j,array);

            if (id1==-1)
               return id2;
            if (id2==-1)
               return id1;

            if (array[id1]<=array[id2])
               return id1;
            else
                return id2;
        }
};

int main()
{
     int i,j,N;
     int A[1000];
     scanf("%d",&N);
     for (i=0;i<N;i++)
         scanf("%d",&A[i]);

     SegmentTree<int> s(N);
     s.initialize(1,0,N-1,A);
     while (scanf("%d%d",&i,&j)!=EOF)
       printf("%d\n",A[s.query(1,0,N-1,i-1,j-1,A)]);
}
```

Resources:

1. Topcoder Tutorial

NJOY!
-fR0D

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Written by fR0DDY
September 15, 2009 at 8:21 PM

Posted in Programming
Tagged with C, code, complexity, data, RMQ, Segment, structure, time, Tree

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18 Responses

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Hey, nice tut. If u add a tutorial for updating the values in segment tree, it will be great!

Boris
September 18, 2010 at 12:34 PM

Reply

---

when i five n= 800 in input then this code crashes.
please help

Anuj
October 13, 2010 at 8:53 AM

Reply

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please add the nessary discription about n,A[i]. and also add the necassary printf statements . please reply immediately

berin
November 12, 2010 at 7:22 PM

Reply

Do you think this guy's your slave or what?

Andrés Mejía
November 14, 2010 at 8:55 PM

Reply

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could u plzzz add a good tutorial on binary indexed tree as they r easy to code????

aayush kumar
June 9, 2011 at 4:49 PM

Reply

There already is a post on that
https://comeoncodeon.wordpress.com/2009/09/17/binary-indexed-tree-bit/

fR0DDY
June 9, 2011 at 8:30 PM

Reply

Hi I Don't Understand Whats the application of segment tree ? i mean if we can search the element in given range of sorted array in O(logn) then why we need such complex DS or m i missing sum-thing so do u mean we can find the elements in unsorted array in O(logn) is it so .?? as Heap can unsorted array as 5 4 3 1 2 isn't it .?? also please explain the in detail the initialize & query part & also write update part as you have mentioned..i am really interest in algorithms & so i wants to know what we can do with segment tree once you will reply my question i will really look & analyze it…i mean really really interested & appreciate ur attempt.

i mean when i m giving input for i & j 0 ,5 or i=0 & j=1 to 9 for N=10 array then i am getting output of query is 0 m not getting what exactly query function is doing ?? whats the purpose of it does it s giving element in range or its searching particular element & returning that element.

Reply ASAP.

Algoseekar
June 12, 2011 at 10:08 PM

It can be used to find maximum/minimum element in a range of an unsorted array.
Also between the queries also, you can update any element.

fR0DDY
June 15, 2011 at 10:27 PM

Bugs in the code above.
-> log is logarithm to the base 10, whereas log to the base 2 should be used.
-> only the position should be returned in line numbers 50,52,55,57.

To verify the bug run the code with the following input
N = 8
array = { 1, 2, 0, -1, 5, 5, 5, 5 }
first i,j -> 1 2 (gives correct output of 0)

mozzak
October 1, 2011 at 12:43 PM

second i,j -> 3 4 (gives incorrect output of 0)

Reply

This is the output for this case- remember output is minimum element 🙂

8
1 2 0 -1 5 5 5 5
1 2
1
3 4
-1

Reply

shashank jain
August 2, 2012 at 7:25 PM

It would be better if in the tree initialization N = 2^X, you would get faster solution. Your current solution would get TL on some test cases… I don't remeber testcases, but I promise you that N should be equal 2^x 🙂

Reply

vilvler
February 27, 2012 at 3:02 PM

Why would it be faster if you are adding more nodes to the tree?

Reply

Andrés Mejía
February 28, 2012 at 5:38 AM

Nice tutorial, I also wanted to know about updation of segment trees. How is it achieved? Can you explain a little more?

Reply

aman
June 18, 2012 at 8:54 AM

hey how to implement if i need all intervals with 0<=i<j<n
like for eg in the above tree i need to fint the max from the interval [1,8]

Reply

aichemzee
December 9, 2012 at 2:55 AM

I beleive the time complexity of construction the segment tree is $O(n\log n)$.

Macropodus
February 23, 2013 at 9:51 PM

Reply

There's a small bug, not so important yet proves pain in neck if tested under certain input ranges. For very large range say 1 to 100000. The Query function goes so deep in recursion that it exceeds the recursion depth & hence will result as "Segmentation Fault". I've tried it locally on my machine and on online competition too to verify.

Ravi Ojha
May 12, 2013 at 1:59 PM

Reply

[…] wcipeg.com/wiki/Segment_tree comeoncodeon.wordpress.com/2009/09/15/segment-trees/ letuskode.blogspot.com/2013/01/segtrees.html […]

Segment Trees | Sport CoderSport Coder
December 5, 2013 at 1:25 AM

Reply

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Segment Trees - Lazy Updates
December 10, 2013 at 10:03 PM

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