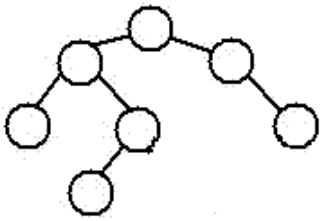
How to determine if a binary tree is height-balanced?

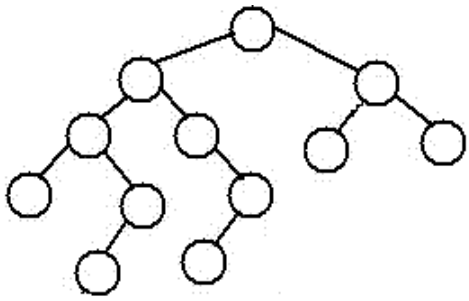
A tree where no leaf is much farther away from the root than any other leaf. Different balancing schemes allow different definitions of “much farther” and different amounts of work to keep them balanced.

Consider a height-balancing scheme where following conditions should be checked to determine if a binary tree is balanced.
An empty tree is height-balanced. A non-empty binary tree T is balanced if:
1) Left subtree of T is balanced
2) Right subtree of T is balanced
3) The difference between heights of left subtree and right subtree is not more than 1.

The above height-balancing scheme is used in AVL trees. The diagram below shows two trees, one of them is height-balanced and other is not. The second tree is not height-balanced because height of left subtree is 2 more than height of right subtree.



A height-balanced Tree



Not a height-balanced tree

To check if a tree is height-balanced, get the height of left and right subtrees. Return true if difference between heights is not more than 1 and left and right subtrees are balanced, otherwise return false.

```
/* program to check if a tree is height-balanced or not */
#include<stdio.h>
#include<stdlib.h>
#define bool int

/* A binary tree node has data, pointer to left child
   and a pointer to right child */
struct node
{
```

```
    int data;
    struct node* left;
    struct node* right;
};

/* Returns the height of a binary tree */
int height(struct node* node);

/* Returns true if binary tree with root as root is height-balanced */
bool isBalanced(struct node *root)
{
   int lh; /* for height of left subtree */
   int rh; /* for height of right subtree */

   /* If tree is empty then return true */
   if(root == NULL)
    return 1;

   /* Get the height of left and right sub trees */
   lh = height(root->left);
   rh = height(root->right);

   if( abs(lh-rh) <= 1 &&
       isBalanced(root->left) &&
       isBalanced(root->right))
     return 1;

   /* If we reach here then tree is not height-balanced */
   return 0;
}

/* UTILITY FUNCTIONS TO TEST isBalanced() FUNCTION */

/* returns maximum of two integers */
int max(int a, int b)
{
  return (a >= b)? a: b;
}

/*  The function Compute the "height" of a tree. Height is the
    number of nodes along the longest path from the root node
    down to the farthest leaf node.*/
int height(struct node* node)
{
   /* base case tree is empty */
   if(node == NULL)
       return 0;

   /* If tree is not empty then height = 1 + max of left
      height and right heights */
   return 1 + max(height(node->left), height(node->right));
}

/* Helper function that allocates a new node with the
   given data and NULL left and right pointers. */
struct node* newNode(int data)
{
    struct node* node = (struct node*)
                                malloc(sizeof(struct node));
    node->data = data;
    node->left = NULL;
    node->right = NULL;

    return(node);
}
```

```
int main()
{
    struct node *root = newNode(1);
    root->left = newNode(2);
    root->right = newNode(3);
    root->left->left = newNode(4);
    root->left->right = newNode(5);
    root->left->left->left = newNode(8);

    if(isBalanced(root))
      printf("Tree is balanced");
    else
      printf("Tree is not balanced");

    getchar();
    return 0;
}
```

Run on IDE

Time Complexity: O(n^2) Worst case occurs in case of skewed tree.

Optimized implementation: Above implementation can be optimized by calculating the height in the same recursion rather than calling a height() function separately. Thanks to Amar for suggesting this optimized version. This optimization reduces time complexity to O(n).

```
/* program to check if a tree is height-balanced or not */
#include<stdio.h>
#include<stdlib.h>
#define bool int

/* A binary tree node has data, pointer to left child
   and a pointer to right child */
struct node
{
  int data;
  struct node* left;
  struct node* right;
};

/* The function returns true if root is balanced else false
   The second parameter is to store the height of tree.
   Initially, we need to pass a pointer to a location with value
   as 0. We can also write a wrapper over this function */
bool isBalanced(struct node *root, int* height)
{
  /* lh --> Height of left subtree
     rh --> Height of right subtree */
  int lh = 0, rh = 0;

  /* l will be true if left subtree is balanced
    and r will be true if right subtree is balanced */
  int l = 0, r = 0;

  if(root == NULL)
  {
    *height = 0;
     return 1;
```

```
  }

  /* Get the heights of left and right subtrees in lh and rh
    And store the returned values in l and r */
  l = isBalanced(root->left, &lh);
  r = isBalanced(root->right,&rh);

  /* Height of current node is max of heights of left and
     right subtrees plus 1*/
  *height = (lh > rh? lh: rh) + 1;

  /* If difference between heights of left and right
     subtrees is more than 2 then this node is not balanced
     so return 0 */
  if((lh - rh >= 2) || (rh - lh >= 2))
    return 0;

  /* If this node is balanced and left and right subtrees
    are balanced then return true */
  else return l&&r;
}


/* UTILITY FUNCTIONS TO TEST isBalanced() FUNCTION */

/* Helper function that allocates a new node with the
   given data and NULL left and right pointers. */
struct node* newNode(int data)
{
    struct node* node = (struct node*)
                                malloc(sizeof(struct node));
    node->data = data;
    node->left = NULL;
    node->right = NULL;

    return(node);
}

int main()
{
  int height = 0;

  /* Constructed binary tree is
             1
           /   \
         2      3
       /  \    /
     4     5  6
    /
   7
  */
  struct node *root = newNode(1);
  root->left = newNode(2);
  root->right = newNode(3);
  root->left->left = newNode(4);
  root->left->right = newNode(5);
  root->right->left = newNode(6);
  root->left->left->left = newNode(7);

  if(isBalanced(root, &height))
    printf("Tree is balanced");
  else
    printf("Tree is not balanced");

  getchar();
```

```
  return 0;
}
```

Run on IDE

Time Complexity: O(n)

Please write comments if you find any of the above codes/algorithms incorrect, or find other ways to solve the same problem.

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Now at root do a abs(maxheight - minheight) and check if it's >1 (then return false, else true)

I mean essentially it's doing the same thing, just easier to understand...no?
Complexity : O[n+n] = O[n]

• Reply • Share ›

Ramendu Shandilya • a month ago

//Works in O(n), Java implementation ; isHtBal is a global variable

```
public int heightBalance(BSTNode root){
                if(root == null)
                {
                        return 0;
                }
                int lh = heightBalance(root.getLeftChild());
                int rh = heightBalance(root.getRightChild());
                int difference = Math.abs(lh - rh);
                if(difference > 1 && htCount == 0)
                {
                        isHtBal = false;
                        htCount++;
                }
                else
                {
                        isHtBal = true;
                }
                return (lh > rh ? lh+1 : rh +1);
        }
```

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Shambhavi Shinde • 2 months ago

This is a simpler code with O(n)

int isBalanced(struct node *n)
{

if(!n->left&&!n->right)

return 1;

int l=0,r=0;

if(n->left)

l=isBalanced(n->left);

else

l=0;

if(n->right)

see more

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Anonymous • 3 months ago

In the second soln we have -

l = isBalanced(root->left, &lh);
r = isBalanced(root->right,&rh);

I think we should return false as soon as we determine that either left subtree or right subtree is not balanced.

l = isBalanced(root->left, &lh);
if (!l) return false;
r = isBalanced(root->right,&rh);

if (!r) return false;

This is an optimization for cases where the input binary tree is not balanced.

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Praveen Yadav • 3 months ago

Another O(n) solution using reference in c++:
#include "bits/stdc++.h"

using namespace std;

typedef struct node{

int data;

node *left;

node *right;

}node;

node *newNode(int new_data)

{

node *new_node=new node;

see more

• Reply • Share ›

Apoorv Shrivastava • 4 months ago

Why wont simple postorder traversal with left and right count at each node work?

• Reply • Share ›

lucy ➦ Apoorv Shrivastava • 3 months ago

no, in postorder it will return no. of node in left and right side but u require height of left and right of any node

• Reply • Share ›

sasha • 4 months ago

What does abs signifies in first method

• Reply • Share ›

Deepak Sharma ➦ sasha • 4 months ago

abs means absolute value. Consider this for example abs(-10)=10 and abs(5)=5.

1 • Reply • Share ›

sasha ➦ Deepak Sharma • 4 months ago

Thankuuu so much

• Reply • Share ›

sasha ➦ Deepak Sharma • 4 months ago

thankuu so much

• Reply • Share ›

tree_ds • 4 months ago

can anybody plz explain the function calls in isBalance function

• Reply • Share ›

Bibek Luitel • 5 months ago

```
int isbalance( struct tree *root){
if(root==NULL){ return 0;}
int left, right;
left= isbalance( root->left);
right= isbalance( root->right);
if( left==-1 || right==-1){ return -1;}
int diff;
if(left>right){ diff= left- right;}
```

```
else { diff = right-left;}
if(diff>1){ return -1;}
else {
return ((left>right)? left:right)+1;
}
}
```

O(n) complexity

is there any bug in these conditions ???

infinity • 5 months ago

The above illustrated O(n) code is not giving correct result for the below input for the given "Balanced" definition :-

---

```
struct node *root = newNode(10);

root->left = newNode(8);

root->left->left= newNode(7);

root->left->right= newNode(9);

root->left->left->left= newNode(6);
```

nikhilnvj • 5 months ago

```
public boolean isBalanced(BTNode root){

if(root==null) return true;

int lheight=getHeight(root.left);

int rheight=getHeight(root.right);

if(Math.abs(lheight-rheight)>1)

return false;

return isBalanced(root.left) && isBalanced(root.right);

}

public int getHeight(BTNode node){

if(node==null) return 0;
```

```
else

return 1+Math.max(getHeight(node.left), getHeight(node.right));

}
```

• Reply • Share ›

Pankaj Kushwaha • 5 months ago

we can use global variable also:

```
int diameterlength=0;
void diameter(struct node * tree)

{

/* base case where tree is empty */

if (tree == 0)

{

return;

}

/* get the height of left and right sub-trees */

int lheight = height(tree->left);
```

see more

• Reply • Share ›

pk • 5 months ago

```
int maxd(node* r){ //Maximum depth

if (r == NULL)
return 0;

return 1 + max(maxd(r->left), maxd(r->right));

}

int mind(node* r){ //Minimum depth

if (r == NULL)
return 0;

return 1 + min(mind(r->left), mind(r->right));
```

}

int isBalanced(struct node* r){

return (maxd(r) - mind(r)) <= 1;

}

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DS+Algo pk • 5 months ago

Kyun bhai.. aur waise bhi it's failing
. 1
. / \
. 2 3
. /
. 4

4 is left child of 3

• Reply • Share ›

Anand • 6 months ago

Why do we need to traverse whole tree ? If we check abs(lh-kh) <= 1; isn't it enough for us to know tree is balanced ? please explain... thanks.

• Reply • Share ›

GOPI GOPINATH Anand • 6 months ago

Only if we traverse the tree, we can get the values lh and rh.

• Reply • Share ›

rbchtt GOPI GOPINATH • 5 months ago

this is wrong.
take this tree:
10
/ \
3 15
/ / \
2 14 16
/ \
1 20

if you check roots' height it will give you 3 on left and 3 on right.
but as you can see, we have a problem at node #3 where left height is 2 and right height is 0 - what give you an illegal AVL tree...
we should traverse the whole nodes for that purpose.

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Anand GOPI GOPINATH • 6 months ago

we are getting lh and kh from function height.

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GOPI GOPINATH Anand • 6 months ago

We need to get lh and rh at every node. lh and rh varies at each node ryt. Thats the reason we traverse the nodes and find lh and rh at each node to check the condition.

Understand that we are finding the first node where the hights are not balanced.

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Anand GOPI GOPINATH • 6 months ago

At root, height of right subtree should be either equal or max difference of 1 from height of left subtree. If we check this that's enough. because at any level downward in the tree we are not going to find some different trend. so what is the purpose to check that.

• Reply • Share ›

Siddharth Anand • 6 months ago

I don't think that would be enough to only check difference between left and right subtree height at the root of the tree. As, there can be other nodes(parents) in tree as well that are not balanced but at root, it's left and right subtree may seem to be balanced. So, we need to traverse entire tree until we find one unbalanced node(parent).

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GOPI GOPINATH Anand • 6 months ago

Thats the second optimized solution in the post!!

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Ashish GOPI GOPINATH • 3 months ago

@Anand rbchtt has clearly given an example where your logic fails. Thus, we will need to compare the heights at each node

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thevagabond85 • 7 months ago

the optimized version should be organized like this :

http://ideone.com/xHkQD0

• Reply • Share ›

Aryan Parker • 7 months ago

In the second method, why are we returning l&&r ? cant we just return 1. or can we change the last two lines of method 2 to these (similar to the one in 1st method)

if((abs(lh-rh)<=1)&&l&&r)return 1;
else return 0;

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Guest • 7 months ago

Can anyone tell me why in the function is_balanced we need to still do recursion on is_balanced? Why not just compare once if abs(lh-rh) > 1 return 0; else return 1?

• Reply • Share ›

Jerry Goyal • 8 months ago

shorter is better.

```
bool is(struct node *root)
{
   if(root==NULL){
        return 1;
   }
   is(root->left);
   is(root->right);
   return (abs(height(root->left)-height(root->right))<2);
}
```

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Guest • 8 months ago

```
int height(struct node* node){  //height function
        if(node==NULL){
                return 0;
        }
        int a=height(node->left);
        int b=height(node->right);
        return (1+(a>b?a:b));
}
//call the height function for left and right subtree
int isBalanced(struct node* node)
{
        if(abs(height(node->left)-height(node->right))<2){
```

```
                return 1;
            }
            else return 0;
    }
```

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Aditya Goel • 8 months ago

It is a DP problem.

• Reply • Share ›

Batman Aditya Goel • 8 months ago

how ?

• Reply • Share ›

Aditya Goel Batman • 8 months ago

well in method 1, if you draw a recursion tree you will find that height() is called several times for same node. We can use memoization to reduce complexity.

• Reply • Share ›

Brahma Reddy Chilakala Aditya Goel • 7 months ago

It requires additional space. For this same purpose we can use above second method.

• Reply • Share ›

Some guy • 8 months ago

Isn't this so much simpler?...

int maxDepth(TreeNode root)
{
if (root == null)
{
return 0;
}

return 1 + Math.max(maxDepth(root.left), maxDepth(root.right));
}

int minDepth(TreeNode root)
{
i f (root == null)
{
return 0;
}

```
return 1 + Math.min(minDepth(root.left), minDepth(root.right));
}

bool isBalanced(TreeNode root)
{
return (maxDepth(root) - minDepth(root) <= 1);
}
```

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Ankita Jain ➚ Some guy • 8 months ago

Is complexity of your solution O(logn) ?

• Reply • Share ›

surbhijain93 • 8 months ago

(Just for my reference)

```
int i(struct node *node)
{
if(node==NULL)
return 1;
if(node->left==NULL && node->right==NULL)
return 1;
i(abs(h(node->left)-h(node->right))<=1)
{
return (1 && (i(node->left))&&(i(node->right)));
}
else return 0;
}
```

• Reply • Share ›

Mr. Lazy • 9 months ago

simple, short and clean.
http://ideone.com/mNFQ1X

3 • Reply • Share ›

malhotra ➚ Mr. Lazy • 4 months ago

can u please explain me your code :) thank you in advance :)

1 • Reply • Share ›

Mr. Lazy ➚ malhotra • 4 months ago

What I am doing is passing two separate variables in each function call to get the height of left and right subtrees so that I can get the height of current subtree and also returning boolean which tells whether left subtree and right subtree are height balanced or not . As both subtrees should be

height balanced so I multiplied the boolean values returned for checking left and right subtrees (We can also & the values).

• Reply • Share ›

gamer guy ➚ Mr. Lazy • 2 days ago

space complexity?

• Reply • Share ›

surbhijain93 ➚ Mr. Lazy • 6 months ago

Thank you :)

1 • Reply • Share ›

Mr. Lazy ➚ surbhijain93 • 6 months ago

anytime :)

2 • Reply • Share ›

malhotra ➚ Mr. Lazy • 4 months ago

nice work man :)

1 • Reply • Share ›

surbhijain93 • 9 months ago

is this correct??
https://ideone.com/JXUyuT

• Reply • Share ›

rohit_90 • 10 months ago

Here is simple Java implementation:

http://ideone.com/luo10m

• Reply • Share ›

RainMan • a year ago

@GeeksForGeeks:
The problem with your code is that you take the difference in heights for an internal node even if a left or a right sub-tree for that node is NULL. This case should be handled.
For example, the code does not work for:

```
struct node *root = newNode(1);
root->left = newNode(2);
root->left->left = newNode(3);
root->left->left->left = newNode(4);
root->left->left->left->left = newNode(5);
root->left->left->left->left->left = newNode(8);
root->left->left->left->left->right = newNode(9);
```

The tree has only 2 leaves 8 and 9.

1 • Reply • Share ›

rihansh • a year ago

Enjoy this simple implementation .

http://ideone.com/fB2R28

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