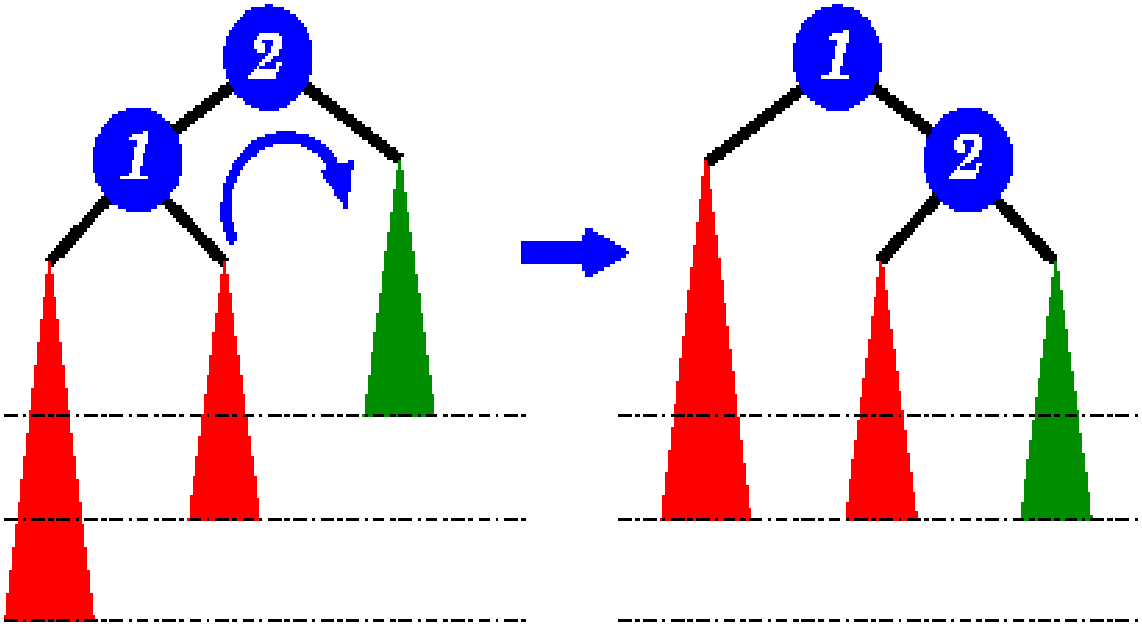
Avl Tree

In computer science, an **AVL tree** (Adelson-Velskii and Landis' tree, named after the inventors) is a self-balancing binary search tree. It was the first such data structure to be invented.[1] In an AVL tree, the heights of the two child subtrees of any node differ by at most one; if at any time they differ by more than one, rebalancing is done to restore this property. Lookup, insertion, and deletion all takeO(log *n*) time in both the average and worst cases, where *n* is the number of nodes in the tree prior to the operation. Insertions and deletions may require the tree to be rebalanced by one or more tree rotations.

The AVL tree is named after its two Soviet inventors, G. M. Adelson-Velskii and E. M. Landis, who published it in their 1962 paper "An algorithm for the organization of information".[2]

AVL trees are often compared with red-black trees because both support the same set of operations and take O(log *n*) time for the basic operations. For lookup-intensive applications, AVL trees are faster than red-black trees because they are more rigidly balanced.[3] Similar to red-black trees, AVL trees are height-balanced. Both are in general not weight-balanced nor μ-balanced for any $\mu \leq \frac{1}{2}$;[4] that is, sibling nodes can have hugely differing numbers of descendants.



CODES(C)

```
#include <stdio.h>
 #include <stdlib.h>

 struct AVLTree_Node {
     int data, bfactor;
     struct AVLTree_Node *link[2];
 };

 struct AVLTree_Node *root = NULL;

 struct AVLTree_Node * createNode(int data) {
     struct AVLTree_Node *newnode;
     newnode = (struct AVLTree_Node *)malloc(sizeof (struct AVLTree_Node));
     newnode->data    = data;
     newnode->bfactor = 0;
     newnode->link[0] = newnode->link[1] = NULL;
     return newnode;
 }


 void insertion (int data) {
     struct AVLTree_Node *bf, *parent_bf, *subtree, *temp;
     struct AVLTree_Node *current, *parent, *newnode, *ptr;
     int res = 0, link_dir[32], i = 0;

     if (!root) {
         root = createNode(data);
         return;
     }

     bf = parent_bf = root;
     /* find the location for inserting the new node*/
     for (current = root; current != NULL; ptr = current, current = current->link[res]) {
         if (data == current->data) {
             printf("Cannot insert duplicates!!\n");
             return;
         }
         res = (data > current->data) ? 1 : 0;
         parent = current;

         if (current->bfactor != 0) {
             bf = current;
             parent_bf = ptr;
             i = 0;
         }
         link_dir[i++] = res;
     }
     /* create the new node */
```

```
newnode = createNode(data);
parent->link[res] = newnode;
res = link_dir[i = 0];
/* updating the height balance after insertion */
for (current = bf; current != newnode; res = link_dir[++i]) {
        if (res == 0)
                current->bfactor--;
        else
                current->bfactor++;
        current = current->link[res];
}

/* right sub-tree */
if (bf->bfactor == 2) {
        printf("bfactor = 2\n");
        temp = bf->link[1];
        if (temp->bfactor == 1) {
                /*
                 * single rotation(SR) left
                 *        x             y
                 *         \          /   \
                 *          y    =>   x     z
                 *           \
                 *            z
                 */
                subtree = temp;
                bf->link[1] = temp->link[0];
                temp->link[0] = bf;
                temp->bfactor = bf->bfactor = 0;
        } else {
                /*
                 * double rotation (SR right + SR left)
                 *       x        x           z
                 *        \        \        /   \
                 *         y   =>   z   =>  x     y
                 *        /          \      ///
                 *       z            y
                 */
                subtree = temp->link[0];
                temp->link[0] = subtree->link[1];
                subtree->link[1] = temp;
                bf->link[1] = subtree->link[0];
                subtree->link[0] = bf;
                /* update balance factors */
                if (subtree->bfactor == -1) {
                        bf->bfactor = 0;
```

```
                temp->bfactor = 1;
            } else if (subtree->bfactor == 0) {
                bf->bfactor = 0;
                temp->bfactor = 0;
            } else if (subtree->bfactor == 1) {
                bf->bfactor = -1;
                temp->bfactor = 0;
            }
            subtree->bfactor = 0;
        }
    /* left sub-tree */
    } else if (bf->bfactor == -2) {
        temp = bf->link[0];
        if (temp->bfactor == -1) {
            /*
             * single rotation(SR) right
             *         x          y
             *        /         /   \
             *       y     =>  z     x
             *      /
             *     z
             */
            subtree = temp;
            bf->link[0] = temp->link[1];
            temp->link[1] = bf;
            temp->bfactor = bf->bfactor = 0;
        } else {
            /*
             * double rotation - (SR left + SR right)
             *        x         x         z
             *       /         /        /   \
             *      y    =>   z    =>  y     x
             *       \       /
             *        z     y
             */
            subtree = temp->link[1];
            temp->link[1] = subtree->link[0];
            subtree->link[0] = temp;
            bf->link[0] = subtree->link[1];
            subtree->link[1] = bf;
            /* update balance factors */
            if (subtree->bfactor == -1) {
                bf->bfactor = 1;
                temp->bfactor = 0;
            } else if (subtree->bfactor == 0) {
                bf->bfactor = 0;
```

```
                temp->bfactor = 0;
            } else if (subtree->bfactor == 1) {
                bf->bfactor = 0;
                temp->bfactor = -1;
            }
            subtree->bfactor = 0;
        }
    } else {
        return;
    }

    if (bf == root) {
        root = subtree;
        return;
    }
    if (bf != parent_bf->link[0]) {
        parent_bf->link[1] = subtree;
    } else {
        parent_bf->link[0] = subtree;
    }
    return;
}

void deletion(int data) {
    int link_dir[32], res = 0, i = 0, j = 0, index = 0;
    struct AVLTree_Node *ptr[32], *current, *temp, *x, *y, *z;

    current = root;
    if (!root) {
        printf("Tree not present\n");
        return;
    }

    if ((root->data == data) && (root->link[0] == NULL)
         && (root->link[1] == NULL)) {
        free(root);
        root = NULL;
        return;
    }
    /* search the node to delete */
    while (current != NULL) {
        if (current->data == data)
            break;
        res = data > current->data ? 1 : 0;
        link_dir[i] = res;
        ptr[i++] = current;
```

```
        current = current->link[res];
    }

    if (!current) {
        printf("Given data is not present!!\n");
        return;
    }
    index = link_dir[i - 1];
    temp = current->link[1];
    /* delete the node from the AVL tree - similar to BST deletion */
    if (current->link[1] == NULL) {
        if (i == 0) {
            temp = current->link[0];
            free(current);
            root = temp;
            return;
        } else {
            ptr[i - 1]->link[index] = current->link[0];
        }
    } else if (temp->link[0] == NULL) {
        temp->link[0] = current->link[0];
        temp->bfactor = current->bfactor;
        if (i > 0) {
            ptr[i-1]->link[index] = temp;
        } else {
            root = temp;
        }
        link_dir[i] = 1;
        ptr[i++] = temp;
    } else {
        /* delete node with two children */
        j = i++;
        while (1) {
            link_dir[i] = 0;
            ptr[i++] = temp;
            x = temp->link[0];
            if (x->link[0] == NULL)
                break;
            temp = x;
        }
        x->link[0] = current->link[0];
        temp->link[0] = x->link[1];
        x->link[1] = current->link[1];
        x->bfactor = current->bfactor;
        if (j > 0) {
            ptr[j - 1]->link[index] = x;
```

```
        } else {
                root = x;
        }
        link_dir[j] = 1;
        ptr[j] = x;
}
free(current);
for (i = i - 1; i >= 0; i = i--) {
        x = ptr[i];
        if (link_dir[i] == 0) {
                x->bfactor++;
                if (x->bfactor == 1) {
                        break;
                } else if (x->bfactor == 2) {
                        y = x->link[1];
                        if (y->bfactor == -1) {
                                /* double rotation - (SR right + SR left) */
                                z = y->link[0];
                                y->link[0] = z->link[1];
                                z->link[1] = y;
                                x->link[1] = z->link[0];
                                z->link[0] = x;
                                /* update balance factors */
                                if (z->bfactor == -1) {
                                        x->bfactor = 0;
                                        y->bfactor = 1;
                                } else if (z->bfactor == 0) {
                                        x->bfactor = 0;
                                        y->bfactor = 0;
                                } else if (z->bfactor == 1) {
                                        x->bfactor = -1;
                                        y->bfactor = 0;
                                }
                                z->bfactor = 0;
                                if (i > 0) {
                                        index = link_dir[i - 1];
                                        ptr[i - 1]->link[index] = z;
                                } else {
                                        root = z;
                                }
                        } else {
                                /* single rotation left */
                                x->link[1] = y->link[0];
                                y->link[0] = x;
                                if (i > 0) {
                                        index = link_dir[i - 1];
```

```
                        ptr[i - 1]->link[index] = y;
                    } else  {
                        root = y;
                    }
                    /* update balance factors */
                    if (y->bfactor == 0) {
                        x->bfactor = 1;
                        y->bfactor = -1;
                        break;
                    } else {
                        x->bfactor = 0;
                        y->bfactor = 0;
                    }
                }
            }
        } else {
            x->bfactor--;
            if (x->bfactor == -1) {
                break;
            } else if (x->bfactor == -2) {
                y = x->link[0];
                if  (y->bfactor == 1) {
                    /* double rotation - (SR right + SR left) */
                    z = y->link[1];
                    y->link[1] = z->link[0];
                    z->link[0] = y;
                    x->link[0] = z->link[1];
                    z->link[1] = x;
                    /* update balance factors */
                    if (z->bfactor == -1) {
                        x->bfactor = 1;
                        y->bfactor = 0;
                    } else if (z->bfactor == 0) {
                        x->bfactor = 0;
                        y->bfactor = 0;
                    } else if (z->bfactor == 1) {
                        x->bfactor = 0;
                        y->bfactor = -1;
                    }
                    z->bfactor = 0;
                    if (i > 0) {
                        index = link_dir[i - 1];
                        ptr[i - 1]->link[index] = z;
                    } else {
                        root = z;
                    }
```

```
                } else {
                    /* single rotation right */
                    x->link[0] = y->link[1];
                    y->link[1] = x;
                    if (i <= 0) {
                        root = y;
                    } else {
                        index = link_dir[i - 1];
                        ptr[i - 1]->link[index] = y;
                    }
                    /* update balance factors */
                    if (y->bfactor == 0) {
                        x->bfactor = -1;
                        y->bfactor = 1;
                        break;
                    } else {
                        x->bfactor = 0;
                        y->bfactor = 0;
                    }
                }
            }
        }
    }
}

void searchElement(int data) {
    int flag = 0, res = 0;
    struct AVLTree_Node *node = root;
    if (!node) {
        printf("AVL tree unavailable!!\n");
        return;
    }
    while (node != NULL) {
        if (data == node->data) {
            printf("%d is present in AVL Tree\n", data);
            flag = 1;
            break;
        }
        res = data > node->data ? 1 : 0;
        node = node->link[res];
    }
    if (!flag)
        printf("Search Element not found in AVL tree\n");
    return;
}
```

```
void inorderTraversal(struct AVLTree_Node *myNode) {
    if (myNode) {
        inorderTraversal(myNode->link[0]);
        printf("%d  ", myNode->data);
        inorderTraversal(myNode->link[1]);
    }
    return;
}

int main() {
    int key, ch;
    while (1) {
        printf("1. Insertion\t2. Deletion\n");
        printf("3. Searching\t4. Traversal\n");
        printf("5. Exit\nEnter your choice:");
        scanf("%d", &ch);
        switch (ch) {
            case 1:
                printf("Enter the key value:");
                scanf("%d", &key);
                insertion(key);
                break;
            case 2:
                printf("Enter the key value to delete:");
                scanf("%d", &key);
                deletion(key);
                break;
            case 3:
                printf("Enter the search key:");
                scanf("%d", &key);
                searchElement(key);
                break;
            case 4:
                inorderTraversal(root);
                printf("\n");
                break;
            case 5:
                exit(0);
            default:
                printf("Wrong Option!!\n");
                break;
        }
        printf("\n");
    }
```

```
    return 0;
}
```

CODES(JAVA)

```
import java.util.Scanner;

 /* Class AVLNode */
 class AVLNode
 {
    AVLNode left, right;
    int data;
    int height;

    /* Constructor */
    public AVLNode()
    {
        left = null;
        right = null;
        data = 0;
        height = 0;
    }
    /* Constructor */
    public AVLNode(int n)
    {
        left = null;
        right = null;
        data = n;
        height = 0;
    }
 }

 /* Class AVLTree */
 class AVLTree
```

```
{
    private AVLNode root;

    /* Constructor */
    public AVLTree()
    {
        root = null;
    }
    /* Function to check if tree is empty */
    public boolean isEmpty()
    {
        return root == null;
    }
    /* Make the tree logically empty */
    public void makeEmpty()
    {
        root = null;
    }
    /* Function to insert data */
    public void insert(int data)
    {
        root = insert(data, root);
    }
    /* Function to get height of node */
    private int height(AVLNode t )
    {
        return t == null ? -1 : t.height;
    }
    /* Function to max of left/right node */
    private int max(int lhs, int rhs)
```

```
{
    return lhs > rhs ? lhs : rhs;
}
/* Function to insert data recursively */
private AVLNode insert(int x, AVLNode t)
{
    if (t == null)
        t = new AVLNode(x);
    else if (x < t.data)
    {
        t.left = insert( x, t.left );
        if( height( t.left ) - height( t.right ) == 2 )
            if( x < t.left.data )
                t = rotateWithLeftChild( t );
            else
                t = doubleWithLeftChild( t );
    }
    else if( x > t.data )
    {
        t.right = insert( x, t.right );
        if( height( t.right ) - height( t.left ) == 2 )
            if( x > t.right.data)
                t = rotateWithRightChild( t );
            else
                t = doubleWithRightChild( t );
    }
    else
      ;  // Duplicate; do nothing
    t.height = max( height( t.left ), height( t.right ) ) + 1;
    return t;
```

```
}
/* Rotate binary tree node with left child */
private AVLNode rotateWithLeftChild(AVLNode k2)
{
    AVLNode k1 = k2.left;
    k2.left = k1.right;
    k1.right = k2;
    k2.height = max( height( k2.left ), height( k2.right ) ) + 1;
    k1.height = max( height( k1.left ), k2.height ) + 1;
    return k1;
}

/* Rotate binary tree node with right child */
private AVLNode rotateWithRightChild(AVLNode k1)
{
    AVLNode k2 = k1.right;
    k1.right = k2.left;
    k2.left = k1;
    k1.height = max( height( k1.left ), height( k1.right ) ) + 1;
    k2.height = max( height( k2.right ), k1.height ) + 1;
    return k2;
}
/**
 * Double rotate binary tree node: first left child
 * with its right child; then node k3 with new left child */
private AVLNode doubleWithLeftChild(AVLNode k3)
{
    k3.left = rotateWithRightChild( k3.left );
    return rotateWithLeftChild( k3 );
}
```

```
/**
 * Double rotate binary tree node: first right child
 * with its left child; then node k1 with new right child */
private AVLNode doubleWithRightChild(AVLNode k1)
{
    k1.right = rotateWithLeftChild( k1.right );
    return rotateWithRightChild( k1 );
}
/* Functions to count number of nodes */
public int countNodes()
{
    return countNodes(root);
}
private int countNodes(AVLNode r)
{
    if (r == null)
        return 0;
    else
    {
        int l = 1;
        l += countNodes(r.left);
        l += countNodes(r.right);
        return l;
    }
}
/* Functions to search for an element */
public boolean search(int val)
{
    return search(root, val);
}
```

```
private boolean search(AVLNode r, int val)
{
    boolean found = false;
    while ((r != null) && !found)
    {
        int rval = r.data;
        if (val < rval)
            r = r.left;
        else if (val > rval)
            r = r.right;
        else
        {
            found = true;
            break;
        }
        found = search(r, val);
    }
    return found;
}
/* Function for inorder traversal */
public void inorder()
{
    inorder(root);
}
private void inorder(AVLNode r)
{
    if (r != null)
    {
        inorder(r.left);
        System.out.print(r.data +" ");
```

```
        inorder(r.right);
    }
}
/* Function for preorder traversal */
public void preorder()
{
    preorder(root);
}
private void preorder(AVLNode r)
{
    if (r != null)
    {
        System.out.print(r.data +" ");
        preorder(r.left);
        preorder(r.right);
    }
}
/* Function for postorder traversal */
public void postorder()
{
    postorder(root);
}
private void postorder(AVLNode r)
{
    if (r != null)
    {
        postorder(r.left);
        postorder(r.right);
        System.out.print(r.data +" ");
    }
```

```
    }
}

/* Class AVL Tree Test */
public class AVLTreeTest
{
    public static void main(String[] args)
    {
        Scanner scan = new Scanner(System.in);
        /* Creating object of AVLTree */
        AVLTree avlt = new AVLTree();

        System.out.println("AVLTree Tree Test\n");
        char ch;
        /*  Perform tree operations  */
        do
        {
            System.out.println("\nAVLTree Operations\n");
            System.out.println("1. insert ");
            System.out.println("2. search");
            System.out.println("3. count nodes");
            System.out.println("4. check empty");
            System.out.println("5. clear tree");

            int choice = scan.nextInt();
            switch (choice)
            {
            case 1 :
                System.out.println("Enter integer element to insert");
                avlt.insert( scan.nextInt() );
```

```
            break;
        case 2 :
            System.out.println("Enter integer element to search");
            System.out.println("Search result : "+ avlt.search( scan.nextInt() ));
            break;
        case 3 :
            System.out.println("Nodes = "+ avlt.countNodes());
            break;
        case 4 :
            System.out.println("Empty status = "+ avlt.isEmpty());
            break;
        case 5 :
            System.out.println("\nTree Cleared");
            avlt.makeEmpty();
            break;
        default :
            System.out.println("Wrong Entry \n ");
            break;
        }
        /*  Display tree  */
        System.out.print("\nPost order : ");
        avlt.postorder();
        System.out.print("\nPre order : ");
        avlt.preorder();
        System.out.print("\nIn order : ");
        avlt.inorder();

        System.out.println("\nDo you want to continue (Type y or n) \n");
        ch = scan.next().charAt(0);
    } while (ch == 'Y'|| ch == 'y');
```

```
    }
}
```