CHANDIGARH COLLEGE OF ENGINEERING & TECHNOLOGY (DEGREE WING)

Government institute under Chandigarh (UT) Administration, affiliated to Punjab University, Chandigarh

Department of Computer Science & Engineering

Semester: CSE 3rd

SUBJECT: Data Structures Practical (CS351)

Problem 9: Case Study of Binary Tree Variants

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CODE

```
#include <bits/stdc++.h>
#include <vector>
using namespace std;
#define MAX_KEYS 4
#define MIN_KEYS 2
//AVL DATA STRUCTURE
//Representation of AVL
struct AVL
{
    int key;
    AVL*left;
    AVL*right;
    int height;
};
//Creating AVL node
AVL* createAVLNode(int data) {
    AVL* node = new AVL();
    node->key = data;
    node->left = nullptr;
    node->right = nullptr;
    node->height = 1;
    return node;
}
//Finding Height of node
int height(AVL* node) {
    return node ? node->height : 0;
}
// Get balance factor of node
int getBalance(AVL* &node) {
    return node ? height(node->left) - height(node->right) : 0;
}
//Rotate Leftwise
AVL* L_Rotate(AVL* &x)
{
    AVL* y = x->right;
    AVL* T2 = y->left;
    y->left = x;
    x->right = T2;
    x->height = max(height(x->left), height(x->right)) + 1;
    y->height = max(height(y->left), height(y->right)) + 1;
    return y;
}
// Rotate Rightwise
AVL* R_Rotate(AVL* &y)
{
    AVL* x = y->left;
    AVL* T2 = x->right;
    x->right = y;
    y->left = T2;
    y->height = max(height(y->left), height(y->right)) + 1;
    x->height = max(height(x->left), height(x->right)) + 1;
    return x;
```

```
}
// Insert a node into the AVL Tree
AVL* insertAVL(AVL* node,int key)
{
    if(!node)   return(createAVLNode(key));//Empty Tree
    else if (key<node->key) node->left=insertAVL(node->left,key);
    else if(key>node->key)  node->right=insertAVL(node->right,key);
    else return node;

    node->height=1+max(height(node->left),height(node->right));
    int balance=getBalance(node);
    //4 CASES
    //case 1: Right Rotation
    if (balance>1&&key<node->left->key) return(R_Rotate(node));
    //Case 2: Left Rotation
    if(balance<-1&&key>node->right->key) return(L_Rotate(node));
    //Case 3: Right & Left Rotation
    if(balance>1&&key>node->left->key)
    {
        node->left=L_Rotate(node->left);
        return R_Rotate(node);
    }
    //Case 4: Left & Right Rotation
    if(balance<-1&&key<node->right->key)
    {
        node->right=R_Rotate(node->right);
        return L_Rotate(node);
    }
    return node;
}
//Find the Minimum Value Node
AVL*MinValueNode(AVL*node)
{
    AVL* current = node;
    // Traverse the left subtree to find the minimum value node
    while (current && current->left != nullptr)
        current = current->left;
    return current;
}
AVL* DeleteAVL(AVL* root, int key)
{
    if (!root) return root;
    if (key < root->key)
        root->left = DeleteAVL(root->left, key);
    else if (key > root->key)
        root->right = DeleteAVL(root->right, key);
    else
    {
        // node with only one child or no child
        if (!root->left || !root->right)
        {
            AVL* temp = root->left ? root->left : root->right;
            if (!temp)  // No child
            {
                temp = root;
                root = nullptr;
            }
            else  // One child
                *root = *temp;
            delete temp;
        }
        else
        {
            // node with two children: Get the inorder successor
            AVL* temp = MinValueNode(root->right);
            root->key = temp->key;
            root->right = DeleteAVL(root->right, temp->key);
        }
    }

    if (!root) return root;

    root->height = 1 + max(height(root->left), height(root->right));
    int balance = getBalance(root);

    // Left Left Case
    if (balance > 1 && getBalance(root->left) >= 0)
        return R_Rotate(root);

    // Left Right Case
    if (balance > 1 && getBalance(root->left) < 0)
    {
        root->left = L_Rotate(root->left);
        return R_Rotate(root);
    }

    // Right Right Case
    if (balance < -1 && getBalance(root->right) <= 0)
        return L_Rotate(root);

    // Right Left Case
    if (balance < -1 && getBalance(root->right) > 0)
    {
        root->right = R_Rotate(root->right);
        return L_Rotate(root);
    }

    return root;
}
AVL* AVLsearch(AVL* root, int key)
{

    // Base Cases: root is null or key is
    // present at root
    if (root == NULL || root->key == key)
        return root;

    // Key is greater than root's key
    if (root->key < key)
        return AVLsearch(root->right, key);

    // Key is smaller than root's key
    return AVLsearch(root->left, key);
}
void preOrder(AVL *root)
{
    if(root != NULL)
    {
        printf("%d ", root->key);
        preOrder(root->left);
        preOrder(root->right);
    }
}

//BVL DATA STRUCTURE
struct BTreeNode {
    int keys[MAX_KEYS];           // Array of keys
    BTreeNode* children[MAX_KEYS + 1]; // Array of children pointers
    int numKeys;                  // Number of keys in the node
    bool isLeaf;                  // True if the node is a leaf

    BTreeNode(bool leaf) : isLeaf(leaf), numKeys(0) {
        for (int i = 0; i < MAX_KEYS + 1; i++) {
            children[i] = nullptr;
        }
    }
};
void splitChild(BTreeNode* parent, int i, BTreeNode* fullChild) {
    BTreeNode *newNode=new BTreeNode(fullChild->isLeaf);
    newNode->numKeys = MIN_KEYS;

    // Move the last MIN_KEYS keys of fullChild to newNode
    for (int j = 0; j < MIN_KEYS; j++)
        newNode->keys[j] = fullChild->keys[j + MIN_KEYS + 1];

    // Move the last MIN_KEYS + 1 children of fullChild to newNode
    if (!fullChild->isLeaf) {
        for (int j = 0; j < MIN_KEYS + 1; j++)
            newNode->children[j] = fullChild->children[j + MIN_KEYS +
1];
    }

    fullChild->numKeys = MIN_KEYS;

    // Shift parent's children to make room for newNode
    for (int j = parent->numKeys; j >= i + 1; j--)
        parent->children[j + 1] = parent->children[j];

    parent->children[i + 1] = newNode;

    // Move the middle key of fullChild to the parent
    for (int j = parent->numKeys - 1; j >= i; j--)
```

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        parent->keys[j + 1] = parent->keys[j];

    parent->keys[i] = fullChild->keys[MIN_KEYS];
    parent->numKeys++;
}

// Recursive function to insert a new key
void insertNonFull(BTreeNode* node, int key) {
    int i = node->numKeys - 1;

    if (node->isLeaf) {
        while (i >= 0 && key < node->keys[i]) {
            node->keys[i + 1] = node->keys[i];
            i--;
        }
        node->keys[i + 1] = key;
        node->numKeys++;
    } else {
        while (i >= 0 && key < node->keys[i])
            i--;
        i++;
        if (node->children[i]->numKeys == MAX_KEYS) {
            splitChild(node, i, node->children[i]);
            if (key > node->keys[i])
                i++;
        }
        insertNonFull(node->children[i], key);
    }
}

// Function to insert a key into the B-Tree and return the root node
BTreeNode* insertBTree(BTreeNode* root, int key) {
    if (root->numKeys == MAX_KEYS) {
        BTreeNode* newRoot = new BTreeNode(false);
        newRoot->children[0] = root;
        splitChild(newRoot, 0, root);
        int i = (newRoot->keys[0] < key) ? 1 : 0;
        insertNonFull(newRoot->children[i], key);
        return newRoot;
    } else {
        insertNonFull(root, key);
        return root;
    }
}
BTreeNode *BTreeSearch(BTreeNode* root,int k)
{
    int i=0;
    while (i<root->numKeys&&k>root->keys[i])    i++;
    if (root->keys[i]==k)   return root;
    if(root->isLeaf)    return NULL;
    return BTreeSearch(root->children[i],k);
}

void remove(BTreeNode* root, int key) {
    if (!root) {
        cout << "Tree is empty." << endl;
        return;
    }

    // Handle deletion for non-root node and root node
    if (root->isLeaf) {
        // Handle key deletion for leaf nodes (simple case)
        for (int i = 0; i < root->numKeys; i++) {
            if (root->keys[i] == key) {
                // Shift all keys after the deleted key
                for (int j = i; j < root->numKeys - 1; j++) {
                    root->keys[j] = root->keys[j + 1];
                }
                root->numKeys--;
                return;
            }
        }
    } else {
        // Recursive deletion logic for internal nodes
        // You would need to handle cases like merging or
redistributing nodes here
    }
}
// Function to traverse and print the tree
void inorderTraversal(BTreeNode* node) {
    if (node != nullptr) {
        // Traverse all children and print keys between them
        for (int i = 0; i < node->numKeys; i++) {
            // Recur for the left child
            if (!node->isLeaf)
                inorderTraversal(node->children[i]);

            // Print the current key
            cout << node->keys[i] << " ";
        }

        // Visit the rightmost child
        if (!node->isLeaf)
            inorderTraversal(node->children[node->numKeys]);
    }
}

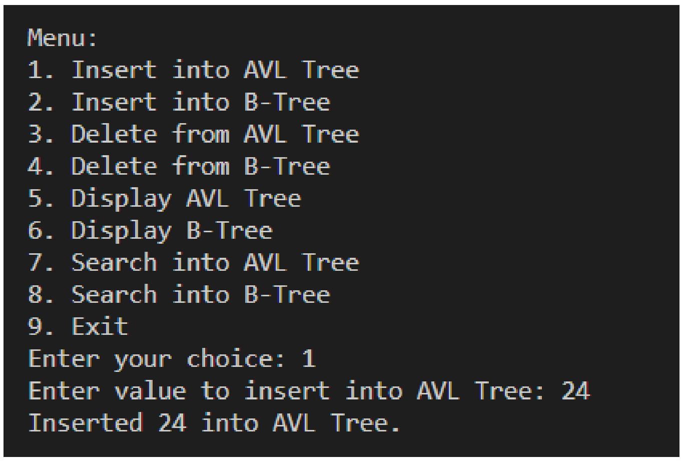
int main() {
    vector<int> Data = {2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97};
    AVL* Aroot = NULL;
    BTreeNode* Broot = new BTreeNode(true);
    for (int value : Data) {
        Aroot = insertAVL(Aroot, value);
        Broot = insertBTree(Broot, value);
    }
    int choice, value;
    // Menu loop
    while (true) {
        cout << "\nMenu:\n";
        cout << "1. Insert into AVL Tree\n";
        cout << "2. Insert into B-Tree\n";
        cout << "3. Delete from AVL Tree\n";
        cout << "4. Delete from B-Tree\n";
        cout << "5. Display AVL Tree\n";
        cout << "6. Display B-Tree\n";
        cout << "7. Search into AVL Tree\n";
        cout << "8. Search into B-Tree\n";
        cout << "9. Exit\n";
        cout << "Enter your choice: ";
        cin >> choice;
        switch (choice) {
            case 1:
                cout << "Enter value to insert into AVL Tree: ";
                cin >> value;
                Aroot = insertAVL(Aroot, value);
                cout << "Inserted " << value << " into AVL Tree." <<
endl;
                break;
            case 2:
                cout << "Enter value to insert into B-Tree: ";
                cin >> value;
                Broot = insertBTree(Broot, value);
                cout << "Inserted " << value << " into B-Tree." <<
endl;
                break;
            case 3:
                cout << "Enter value to be deleted from AVL Tree:
";cin>>value;
                DeleteAVL(Aroot,value);
                cout << "Deleted " << value << " from AVL Tree." <<
endl;
                break;
            case 4:
                cout << "Enter value to be deleted from B Tree: ";
                remove(Broot,value);
                cout << "Deleted " << value << " from B Tree." << endl;
                break;
            case 5:
                cout << "AVL Tree: ";
                preOrder(Aroot);
                cout << endl;
                break;
            case 6:
                cout << "B Tree: ";
                inorderTraversal(Broot);
                cout << endl;
                break;
            case 7:
                cout<<"Enter Value to be searched in AVL: ";
cin>>value;
```

```
                if(AVLsearch(Aroot,value)!=NULL) cout<<"Found 
"<<value<<" in AVL Tree at Level: "<<height(AVLsearch(Aroot,value));
                break;
            case 8:
                cout<<"Enter Value to be searched in B Tree: "; 
cin>>value;
                if (BTreeSearch(Broot,value)!=NULL) cout<<"Found 
"<<value<<" in B Tree.";
                break;
            case 9:
                cout << "Exiting program." << endl;
                return 0;
        }
    }
}
```

CODE OUTPUT

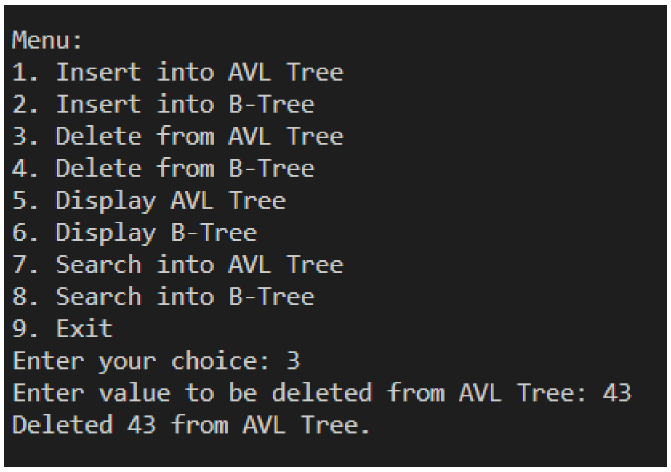
I. AVL Tree

1. Insert



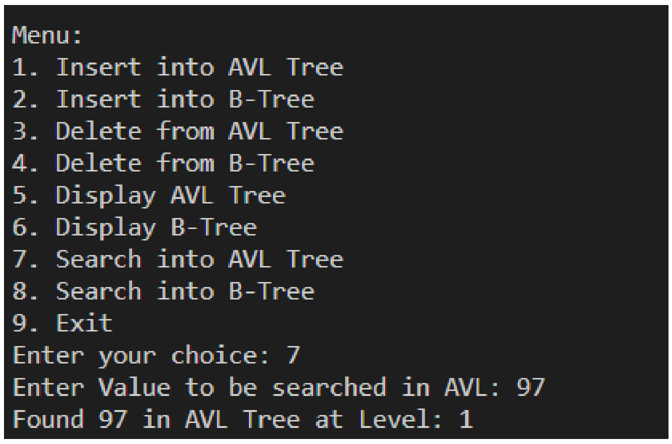
```
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 1
Enter value to insert into AVL Tree: 24
Inserted 24 into AVL Tree.
```

2. Delete



```
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 3
Enter value to be deleted from AVL Tree: 43
Deleted 43 from AVL Tree.
```

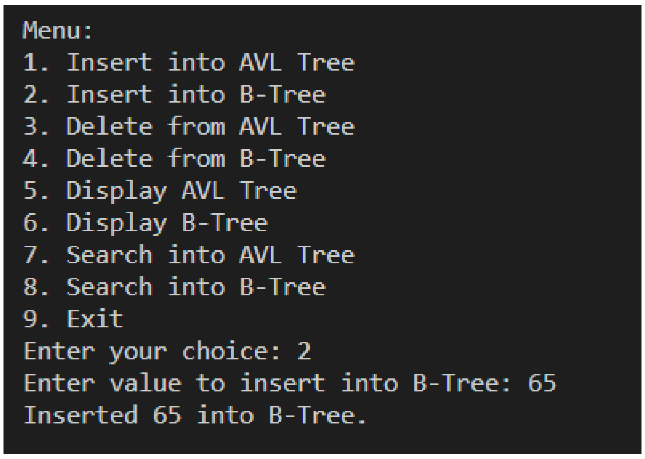
3. Search



```
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 7
Enter Value to be searched in AVL: 97
Found 97 in AVL Tree at Level: 1
```

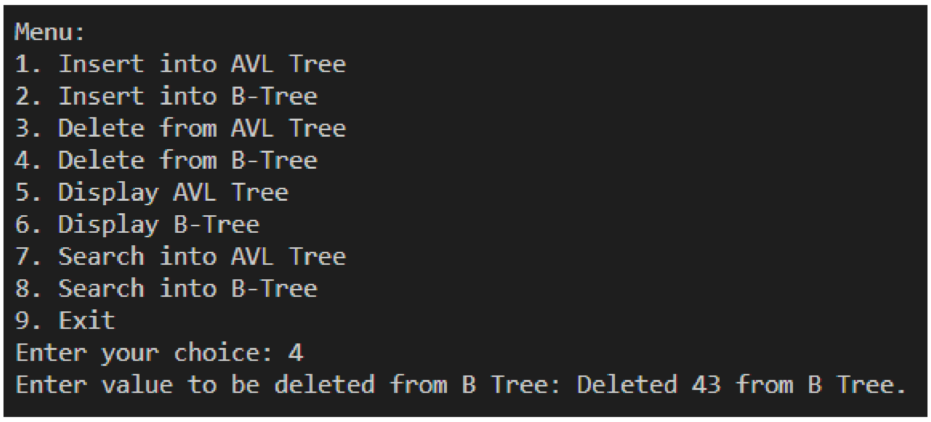
II. B-Tree

1. Insert



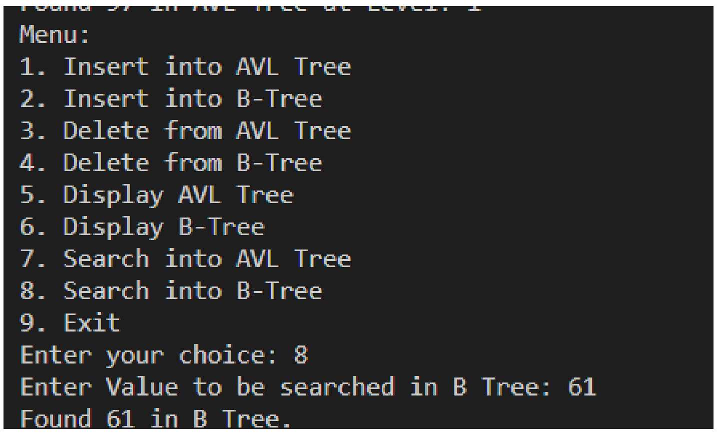
```
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 2
Enter value to insert into B-Tree: 65
Inserted 65 into B-Tree.
```

2. Delete



```
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 4
Enter value to be deleted from B Tree: Deleted 43 from B Tree.
```

3. Search



```
Found 97 in AVL Tree at Level: 1
Menu:
1. Insert into AVL Tree
2. Insert into B-Tree
3. Delete from AVL Tree
4. Delete from B-Tree
5. Display AVL Tree
6. Display B-Tree
7. Search into AVL Tree
8. Search into B-Tree
9. Exit
Enter your choice: 8
Enter Value to be searched in B Tree: 61
Found 61 in B Tree.
```