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PES2UG19CS013
DBT lab-3

```
#include<iostream>
using namespace std;

// A BTree node
class BTreeNode
{
    int *keys;  // An array of keys
    int t;      // Minimum degree (defines the range for number of keys)
    BTreeNode **C; // An array of child pointers
    int n;     // Current number of keys
    bool leaf; // Is true when node is leaf. Otherwise false

public:

    BTreeNode(int _t, bool _leaf);   // Constructor

    // A function to traverse all nodes in a subtree rooted with this node
    void traverse();

    // A function to search a key in subtree rooted with this node.
    BTreeNode *search(int k);   // returns NULL if k is not present.

    // A function that returns the index of the first key that is greater
    // or equal to k
    int findKey(int k);

    // A utility function to insert a new key in the subtree rooted with
    // this node. The assumption is, the node must be non-full when this
    // function is called
    void insertNonFull(int k);

    // A utility function to split the child y of this node. i is index
    // of y in child array C[].  The Child y must be full when this
    // function is called
    void splitChild(int i, BTreeNode *y);

    // A wrapper function to remove the key k in subtree rooted with
    // this node.
```

```
    void remove(int k);

    // A function to remove the key present in idx-th position in
    // this node which is a leaf
    void removeFromLeaf(int idx);

    // A function to remove the key present in idx-th position in
    // this node which is a non-leaf node
    void removeFromNonLeaf(int idx);

    // A function to get the predecessor of the key- where the key
    // is present in the idx-th position in the node
    int getPred(int idx);

    // A function to get the successor of the key- where the key
    // is present in the idx-th position in the node
    int getSucc(int idx);

    // A function to fill up the child node present in the idx-th
    // position in the C[] array if that child has less than t-1 keys
    void fill(int idx);

    // A function to borrow a key from the C[idx-1]-th node and place
    // it in C[idx]th node
    void borrowFromPrev(int idx);

    // A function to borrow a key from the C[idx+1]-th node and place it
    // in C[idx]th node
    void borrowFromNext(int idx);

    // A function to merge idx-th child of the node with (idx+1)th child
of
    // the node
    void merge(int idx);

    // Make BTree friend of this so that we can access private members of
    // this class in BTree functions
    friend class BTree;
};

class BTree
{
    BTreeNode *root; // Pointer to root node
    int t;  // Minimum degree
public:
```

```
    // Constructor (Initializes tree as empty)
    BTree(int _t)
    {
        root = NULL;
        t = _t;
    }

    void traverse()
    {
        if (root != NULL) root->traverse();
    }

    // function to search a key in this tree
    BTreeNode* search(int k)
    {
        return (root == NULL)? NULL : root->search(k);
    }

    // The main function that inserts a new key in this B-Tree
    void insert(int k);

    // The main function that removes a new key in thie B-Tree
    void remove(int k);

};

BTreeNode::BTreeNode(int t1, bool leaf1)
{
    // Copy the given minimum degree and leaf property
    t = t1;
    leaf = leaf1;

    // Allocate memory for maximum number of possible keys
    // and child pointers
    keys = new int[2*t-1];
    C = new BTreeNode *[2*t];

    // Initialize the number of keys as 0
    n = 0;
}

// A utility function that returns the index of the first key that is
// greater than or equal to k
int BTreeNode::findKey(int k)
{
    int idx=0;
```

```
    while (idx<n && keys[idx] < k)
        ++idx;
    return idx;
}

// A function to remove the key k from the sub-tree rooted with this node
void BTreeNode::remove(int k)
{
    int idx = findKey(k);

    // The key to be removed is present in this node
    if (idx < n && keys[idx] == k)
    {

        // If the node is a leaf node - removeFromLeaf is called
        // Otherwise, removeFromNonLeaf function is called
        if (leaf)
            removeFromLeaf(idx);
        else
            removeFromNonLeaf(idx);
    }
    else
    {

        // If this node is a leaf node, then the key is not present in
tree
        if (leaf)
        {
            cout << "The key "<< k <<" is does not exist in the tree\n";
            return;
        }

        // The key to be removed is present in the sub-tree rooted with
this node
        // The flag indicates whether the key is present in the sub-tree
rooted
        // with the last child of this node
        bool flag = ( (idx==n)? true : false );

        // If the child where the key is supposed to exist has less that t
keys,
        // we fill that child
        if (C[idx]->n < t)
            fill(idx);
```

```
        // If the last child has been merged, it must have merged with the
previous
        // child and so we recurse on the (idx-1)th child. Else, we
recurse on the
        // (idx)th child which now has atleast t keys
        if (flag && idx > n)
            C[idx-1]->remove(k);
        else
            C[idx]->remove(k);
    }
    return;
}

// A function to remove the idx-th key from this node - which is a leaf
node
void BTreeNode::removeFromLeaf (int idx)
{

    // Move all the keys after the idx-th pos one place backward
    for (int i=idx+1; i<n; ++i)
        keys[i-1] = keys[i];

    // Reduce the count of keys
    n--;

    return;
}

// A function to remove the idx-th key from this node - which is a non-
leaf node
void BTreeNode::removeFromNonLeaf(int idx)
{

    int k = keys[idx];

    // If the child that precedes k (C[idx]) has atleast t keys,
    // find the predecessor 'pred' of k in the subtree rooted at
    // C[idx]. Replace k by pred. Recursively delete pred
    // in C[idx]
    if (C[idx]->n >= t)
    {
        int pred = getPred(idx);
        keys[idx] = pred;
        C[idx]->remove(pred);
    }
```

```
    // If the child C[idx] has less that t keys, examine C[idx+1].
    // If C[idx+1] has atleast t keys, find the successor 'succ' of k in
    // the subtree rooted at C[idx+1]
    // Replace k by succ
    // Recursively delete succ in C[idx+1]
    else if  (C[idx+1]->n >= t)
    {
        int succ = getSucc(idx);
        keys[idx] = succ;
        C[idx+1]->remove(succ);
    }

    // If both C[idx] and C[idx+1] has less that t keys,merge k and all of
C[idx+1]
    // into C[idx]
    // Now C[idx] contains 2t-1 keys
    // Free C[idx+1] and recursively delete k from C[idx]
    else
    {
        merge(idx);
        C[idx]->remove(k);
    }
    return;
}

// A function to get predecessor of keys[idx]
int BTreeNode::getPred(int idx)
{
    // Keep moving to the right most node until we reach a leaf
    BTreeNode *cur=C[idx];
    while (!cur->leaf)
        cur = cur->C[cur->n];

    // Return the last key of the leaf
    return cur->keys[cur->n-1];
}

int BTreeNode::getSucc(int idx)
{

    // Keep moving the left most node starting from C[idx+1] until we
reach a leaf
    BTreeNode *cur = C[idx+1];
    while (!cur->leaf)
        cur = cur->C[0];
```

```
    // Return the first key of the leaf
    return cur->keys[0];
}

// A function to fill child C[idx] which has less than t-1 keys
void BTreeNode::fill(int idx)
{

    // If the previous child(C[idx-1]) has more than t-1 keys, borrow a
key
    // from that child
    if (idx!=0 && C[idx-1]->n>=t)
        borrowFromPrev(idx);

    // If the next child(C[idx+1]) has more than t-1 keys, borrow a key
    // from that child
    else if (idx!=n && C[idx+1]->n>=t)
        borrowFromNext(idx);

    // Merge C[idx] with its sibling
    // If C[idx] is the last child, merge it with with its previous
sibling
    // Otherwise merge it with its next sibling
    else
    {
        if (idx != n)
            merge(idx);
        else
            merge(idx-1);
    }
    return;
}

// A function to borrow a key from C[idx-1] and insert it
// into C[idx]
void BTreeNode::borrowFromPrev(int idx)
{

    BTreeNode *child=C[idx];
    BTreeNode *sibling=C[idx-1];

    // The last key from C[idx-1] goes up to the parent and key[idx-1]
    // from parent is inserted as the first key in C[idx]. Thus, the
loses
    // sibling one key and child gains one key
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```
    // Moving all key in C[idx] one step ahead
    for (int i=child->n-1; i>=0; --i)
        child->keys[i+1] = child->keys[i];

    // If C[idx] is not a leaf, move all its child pointers one step ahead
    if (!child->leaf)
    {
        for(int i=child->n; i>=0; --i)
            child->C[i+1] = child->C[i];
    }

    // Setting child's first key equal to keys[idx-1] from the current
node
    child->keys[0] = keys[idx-1];

    // Moving sibling's last child as C[idx]'s first child
    if(!child->leaf)
        child->C[0] = sibling->C[sibling->n];

    // Moving the key from the sibling to the parent
    // This reduces the number of keys in the sibling
    keys[idx-1] = sibling->keys[sibling->n-1];

    child->n += 1;
    sibling->n -= 1;

    return;
}

// A function to borrow a key from the C[idx+1] and place
// it in C[idx]
void BTreeNode::borrowFromNext(int idx)
{

    BTreeNode *child=C[idx];
    BTreeNode *sibling=C[idx+1];

    // keys[idx] is inserted as the last key in C[idx]
    child->keys[(child->n)] = keys[idx];

    // Sibling's first child is inserted as the last child
    // into C[idx]
    if (!(child->leaf))
        child->C[(child->n)+1] = sibling->C[0];

    //The first key from sibling is inserted into keys[idx]
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    keys[idx] = sibling->keys[0];

    // Moving all keys in sibling one step behind
    for (int i=1; i<sibling->n; ++i)
        sibling->keys[i-1] = sibling->keys[i];

    // Moving the child pointers one step behind
    if (!sibling->leaf)
    {
        for(int i=1; i<=sibling->n; ++i)
            sibling->C[i-1] = sibling->C[i];
    }

    // Increasing and decreasing the key count of C[idx] and C[idx+1]
    // respectively
    child->n += 1;
    sibling->n -= 1;

    return;
}

// A function to merge C[idx] with C[idx+1]
// C[idx+1] is freed after merging
void BTreeNode::merge(int idx)
{
    BTreeNode *child = C[idx];
    BTreeNode *sibling = C[idx+1];

    // Pulling a key from the current node and inserting it into (t-1)th
    // position of C[idx]
    child->keys[t-1] = keys[idx];

    // Copying the keys from C[idx+1] to C[idx] at the end
    for (int i=0; i<sibling->n; ++i)
        child->keys[i+t] = sibling->keys[i];

    // Copying the child pointers from C[idx+1] to C[idx]
    if (!child->leaf)
    {
        for(int i=0; i<=sibling->n; ++i)
            child->C[i+t] = sibling->C[i];
    }

    // Moving all keys after idx in the current node one step before -
    // to fill the gap created by moving keys[idx] to C[idx]
    for (int i=idx+1; i<n; ++i)
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            keys[i-1] = keys[i];

        // Moving the child pointers after (idx+1) in the current node one
        // step before
        for (int i=idx+2; i<=n; ++i)
            C[i-1] = C[i];

        // Updating the key count of child and the current node
        child->n += sibling->n+1;
        n--;

        // Freeing the memory occupied by sibling
        delete(sibling);
        return;
    }

    // The main function that inserts a new key in this B-Tree
    void BTree::insert(int k)
    {
        // If tree is empty
        if (root == NULL)
        {
            // Allocate memory for root
            root = new BTreeNode(t, true);
            root->keys[0] = k;  // Insert key
            root->n = 1;  // Update number of keys in root
        }
        else // If tree is not empty
        {
            // If root is full, then tree grows in height
            if (root->n == 2*t-1)
            {
                // Allocate memory for new root
                BTreeNode *s = new BTreeNode(t, false);

                // Make old root as child of new root
                s->C[0] = root;

                // Split the old root and move 1 key to the new root
                s->splitChild(0, root);

                // New root has two children now.  Decide which of the
                // two children is going to have new key
                int i = 0;
                if (s->keys[0] < k)
                    i++;
```

```
            s->C[i]->insertNonFull(k);

            // Change root
            root = s;
        }
        else  // If root is not full, call insertNonFull for root
            root->insertNonFull(k);
    }
}

// A utility function to insert a new key in this node
// The assumption is, the node must be non-full when this
// function is called
void BTreeNode::insertNonFull(int k)
{
    // Initialize index as index of rightmost element
    int i = n-1;

    // If this is a leaf node
    if (leaf == true)
    {
        // The following loop does two things
        // a) Finds the location of new key to be inserted
        // b) Moves all greater keys to one place ahead
        while (i >= 0 && keys[i] > k)
        {
            keys[i+1] = keys[i];
            i--;
        }

        // Insert the new key at found location
        keys[i+1] = k;
        n = n+1;
    }
    else // If this node is not leaf
    {
        // Find the child which is going to have the new key
        while (i >= 0 && keys[i] > k)
            i--;

        // See if the found child is full
        if (C[i+1]->n == 2*t-1)
        {
            // If the child is full, then split it
            splitChild(i+1, C[i+1]);
```

```
            // After split, the middle key of C[i] goes up and
            // C[i] is splitted into two.  See which of the two
            // is going to have the new key
            if (keys[i+1] < k)
                i++;
        }
        C[i+1]->insertNonFull(k);
    }
}

// A utility function to split the child y of this node
// Note that y must be full when this function is called
void BTreeNode::splitChild(int i, BTreeNode *y)
{
    // Create a new node which is going to store (t-1) keys
    // of y
    BTreeNode *z = new BTreeNode(y->t, y->leaf);
    z->n = t - 1;

    // Copy the last (t-1) keys of y to z
    for (int j = 0; j < t-1; j++)
        z->keys[j] = y->keys[j+t];

    // Copy the last t children of y to z
    if (y->leaf == false)
    {
        for (int j = 0; j < t; j++)
            z->C[j] = y->C[j+t];
    }

    // Reduce the number of keys in y
    y->n = t - 1;

    // Since this node is going to have a new child,
    // create space of new child
    for (int j = n; j >= i+1; j--)
        C[j+1] = C[j];

    // Link the new child to this node
    C[i+1] = z;

    // A key of y will move to this node. Find location of
    // new key and move all greater keys one space ahead
    for (int j = n-1; j >= i; j--)
        keys[j+1] = keys[j];
```

```cpp
    // Copy the middle key of y to this node
    keys[i] = y->keys[t-1];

    // Increment count of keys in this node
    n = n + 1;
}

// Function to traverse all nodes in a subtree rooted with this node
void BTreeNode::traverse()
{
    // There are n keys and n+1 children, traverse through n keys
    // and first n children
    int i;
    for (i = 0; i < n; i++)
    {
        // If this is not leaf, then before printing key[i],
        // traverse the subtree rooted with child C[i].
        if (leaf == false)
            C[i]->traverse();
        cout << " " << keys[i];
    }

    // Print the subtree rooted with last child
    if (leaf == false)
        C[i]->traverse();
}

// Function to search key k in subtree rooted with this node
BTreeNode *BTreeNode::search(int k)
{
    // Find the first key greater than or equal to k
    int i = 0;
    while (i < n && k > keys[i])
        i++;

    // If the found key is equal to k, return this node
    if (keys[i] == k)
        return this;

    // If key is not found here and this is a leaf node
    if (leaf == true)
        return NULL;

    // Go to the appropriate child
    return C[i]->search(k);
}
```

```cpp
void BTree::remove(int k)
{
    if (!root)
    {
        cout << "The tree is empty\n";
        return;
    }

    // Call the remove function for root
    root->remove(k);

    // If the root node has 0 keys, make its first child as the new root
    //  if it has a child, otherwise set root as NULL
    if (root->n==0)
    {
        BTreeNode *tmp = root;
        if (root->leaf)
            root = NULL;
        else
            root = root->C[0];

        // Free the old root
        delete tmp;
    }
    return;
}

// Driver program to test above functions
int main()
{
    BTree t(2); // A B-Tree with minimum degree 2

    t.insert(1);
    t.insert(3);
    t.insert(7);
    t.insert(10);
    t.insert(11);
    t.insert(13);
    t.insert(14);
    t.insert(15);
    t.insert(18);
    t.insert(16);
    t.insert(19);
    t.insert(24);
    t.insert(25);
```

```
t.insert(26);
t.insert(21);
t.insert(4);
t.insert(5);
t.insert(20);
t.insert(22);
t.insert(2);
t.insert(17);
t.insert(12);
t.insert(6);

cout << "Traversal of tree constructed is\n";
t.traverse();
cout << endl;

t.remove(6);
cout << "Traversal of tree after removing 6\n";
t.traverse();
cout << endl;

t.remove(13);
cout << "Traversal of tree after removing 13\n";
t.traverse();
cout << endl;

t.remove(7);
cout << "Traversal of tree after removing 7\n";
t.traverse();
cout << endl;

t.remove(4);
cout << "Traversal of tree after removing 4\n";
t.traverse();
cout << endl;

t.remove(2);
cout << "Traversal of tree after removing 2\n";
t.traverse();
cout << endl;

t.remove(16);
cout << "Traversal of tree after removing 16\n";
t.traverse();
cout << endl;

t.remove(17);
```

```
    cout << "Traversal of tree after removing 17\n";
    t.traverse();
    cout << endl;



    t.remove(22);
    cout << "Traversal of tree after removing 22\n";
    t.traverse();
    cout << endl;


    if(t.search(12)!=NULL)
       cout<<"12 is present in tree";
       cout << endl;


    return 0;
}
```

Output

```
Traversal of tree constructed is
 1 2 3 4 5 6 7 10 11 12 13 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 6
 1 2 3 4 5 7 10 11 12 13 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 13
 1 2 3 4 5 7 10 11 12 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 7
 1 2 3 4 5 10 11 12 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 4
 1 2 3 5 10 11 12 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 2
 1 3 5 10 11 12 14 15 16 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 16
 1 3 5 10 11 12 14 15 17 18 19 20 21 22 24 25 26
Traversal of tree after removing 17
 1 3 5 10 11 12 14 15 18 19 20 21 22 24 25 26
Traversal of tree after removing 22
 1 3 5 10 11 12 14 15 18 19 20 21 24 25 26
12 is present in tree
```