Week 9-LAB B

Q1. Write a program for a B tree having functions for the following set of operations: ● Insert an element (no duplicates are allowed),
● Delete an existing element,
● Traverse the B Tree (in-order, pre-order, and post-order)

INPUT:
● Line 1 contains an integer NQ, the number of queries.
● Line 2 contains value for minimum number of child pointers of a B tree node. ● The next NQ lines contain queries and are of the form 'i xx' (Insert xx into a B tree) or 'd xx' (Delete xx from a B tree).

OUTPUT:
● Output is a three line answer printing number of split operations, number of merge operations, and the tree traversal of a B tree that results after the execution of all NQ queries.
● First line is the total number of split operations performed.
● Second line is the total number of merge operations performed.
● Third line is the 'Inorder traversal'

Ans:

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

class BTreeNode {
public:
vector<int> keys;
vector<BTreeNode*> children;
bool leaf;
int minDegree;

BTreeNode(int degree, bool leaf);

void traverseInOrder();
int findKey(int key);
void insertNonFull(int key);
void splitChild(int i, BTreeNode *y);
void deleteKey(int key);
void removeFromLeaf(int idx);
void removeFromNonLeaf(int idx);
int getPredecessor(int idx);
int getSuccessor(int idx);
void fill(int idx);
```

```
void borrowFromPrev(int idx);
void borrowFromNext(int idx);
void merge(int idx);

friend class BTree;
};

class BTree {
public:
BTreeNode *root;
int minDegree;
int splitCount;
int mergeCount;

BTree(int degree) {
root = nullptr;
minDegree = degree;
splitCount = 0;
mergeCount = 0;
}

void insert(int key);
void deleteKey(int key);
void traverseInOrder();
};

BTreeNode::BTreeNode(int degree, bool isLeaf) {
minDegree = degree;
leaf = isLeaf;
keys.resize(2 * minDegree - 1);
children.resize(2 * minDegree);
}

int BTreeNode::findKey(int key) {
int idx = 0;
while (idx < keys.size() && keys[idx] < key)
++idx;
return idx;
}

void BTreeNode::traverseInOrder() {
int i;
for (i = 0; i < keys.size(); i++) {
if (!leaf)
children[i]->traverseInOrder();
cout << " " << keys[i];
```

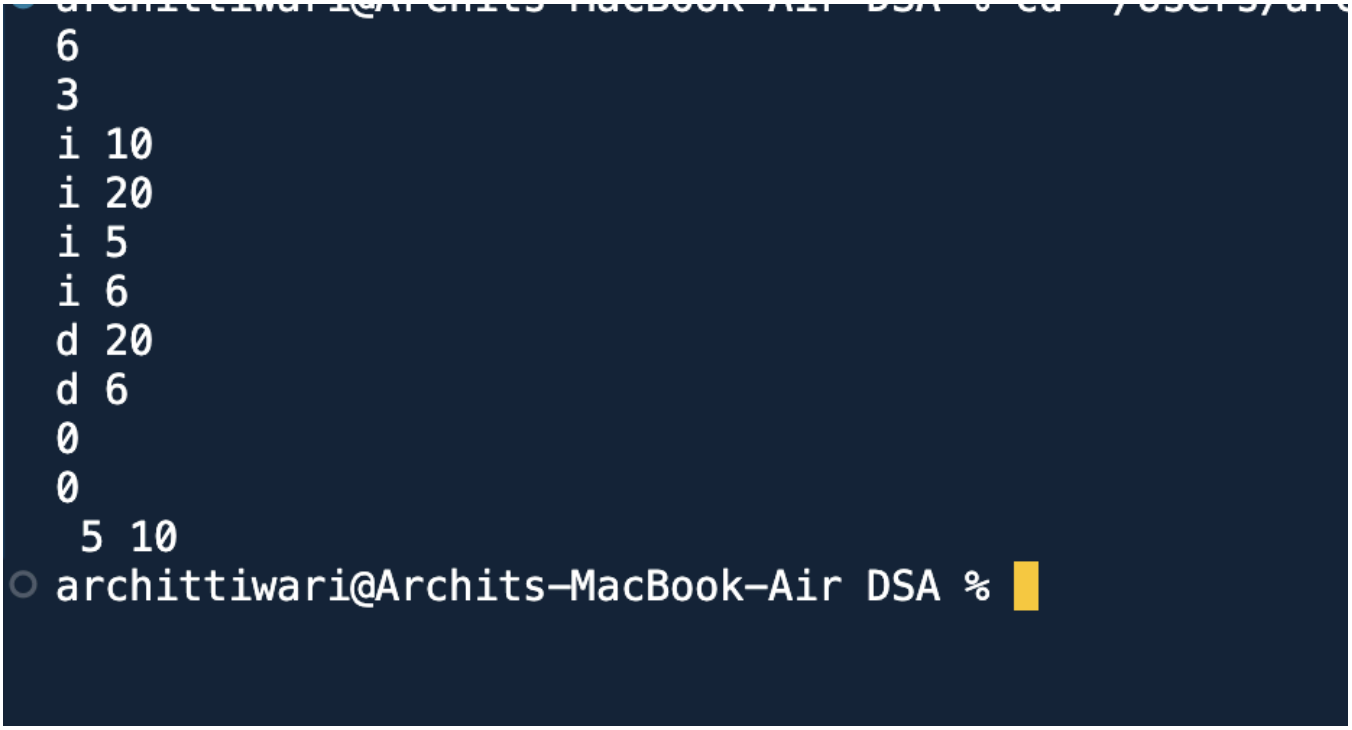
```
}
if (!leaf)
children[i]->traverseInOrder();
}

void BTree::traverseInOrder() {
if (root != nullptr)
root->traverseInOrder();
}

void BTree::insert(int key) {
if (root == nullptr) {
root = new BTreeNode(minDegree, true);
root->keys[0] = key;
root->keys.resize(1);
} else {
if (root->keys.size() == 2 * minDegree - 1) {
BTreeNode *s = new BTreeNode(minDegree, false); s->children[0] =
root;
s->splitChild(0, root);
root = s;
splitCount++;
int i = (root->keys[0] < key) ? 1 : 0;
root->children[i]->insertNonFull(key);
} else {
root->insertNonFull(key);
}
}
}

void BTreeNode::insertNonFull(int key) {
int i = keys.size() - 1;
if (leaf) {
keys.resize(keys.size() + 1);
while (i >= 0 && keys[i] > key) {
keys[i + 1] = keys[i];
i--;
}
keys[i + 1] = key;
} else {
while (i >= 0 && keys[i] > key)
i--;
if (children[i + 1]->keys.size() == 2 * minDegree - 1) { splitChild(i + 1,
children[i + 1]);
if (keys[i + 1] < key)
i++;
```

```
}
children[i + 1]->insertNonFull(key);
}
}

void BTreeNode::splitChild(int i, BTreeNode *y) { BTreeNode *z = new
BTreeNode(y->minDegree, y->leaf); z->keys.resize(minDegree - 1);

for (int j = 0; j < minDegree - 1; j++)
z->keys[j] = y->keys[j + minDegree];

if (!y->leaf) {
z->children.resize(minDegree);
for (int j = 0; j < minDegree; j++)
z->children[j] = y->children[j + minDegree];
}

y->keys.resize(minDegree - 1);
children.insert(children.begin() + i + 1, z);
keys.insert(keys.begin() + i, y->keys[minDegree - 1]); }

void BTree::deleteKey(int key) {
if (!root) {
return;
}

root->deleteKey(key);
if (root->keys.size() == 0) {
BTreeNode *tmp = root;
if (root->leaf)
root = nullptr;
else
root = root->children[0];
delete tmp;
}
}

void BTreeNode::deleteKey(int key) {
int idx = findKey(key);

if (idx < keys.size() && keys[idx] == key) {
if (leaf)
removeFromLeaf(idx);
else
removeFromNonLeaf(idx);
} else {
if (leaf) {
```

```
return;
}

bool flag = (idx == keys.size());
if (children[idx]->keys.size() < minDegree)
fill(idx);

if (flag && idx > keys.size())
children[idx - 1]->deleteKey(key);
else
children[idx]->deleteKey(key);
}
}

void BTreeNode::removeFromLeaf(int idx) {
keys.erase(keys.begin() + idx);
}

void BTreeNode::removeFromNonLeaf(int idx) { int key =
keys[idx];

if (children[idx]->keys.size() >= minDegree) { int pred =
getPredecessor(idx);
keys[idx] = pred;
children[idx]->deleteKey(pred);
} else if (children[idx + 1]->keys.size() >= minDegree) { int succ =
getSuccessor(idx);
keys[idx] = succ;
children[idx + 1]->deleteKey(succ);
} else {
merge(idx);
children[idx]->deleteKey(key);
}
}

int BTreeNode::getPredecessor(int idx) {
BTreeNode *cur = children[idx];
while (!cur->leaf)
cur = cur->children[cur->keys.size()];
return cur->keys[cur->keys.size() - 1];
}

int BTreeNode::getSuccessor(int idx) {
BTreeNode *cur = children[idx + 1];
while (!cur->leaf)
cur = cur->children[0];
return cur->keys[0];
```

```
}
void BTreeNode::fill(int idx) {
if (idx != 0 && children[idx - 1]->keys.size() >= minDegree)
borrowFromPrev(idx);
else if (idx != keys.size() && children[idx + 1]->keys.size() >= minDegree)
borrowFromNext(idx);
else {
if (idx != keys.size())
merge(idx);
else
merge(idx - 1);
}
}

void BTreeNode::borrowFromPrev(int idx) {
BTreeNode *child = children[idx];
BTreeNode *sibling = children[idx - 1];

child->keys.insert(child->keys.begin(), keys[idx - 1]);
if (!child->leaf)
child->children.insert(child->children.begin(), sibling->children[sibling->keys.size()]);

keys[idx - 1] = sibling->keys[sibling->keys.size() - 1];
sibling->keys.pop_back();
}

void BTreeNode::borrowFromNext(int idx) {
BTreeNode *child = children[idx];
BTreeNode *sibling = children[idx + 1];

child->keys.push_back(keys[idx]);

if (!child->leaf)
child->children.push_back(sibling->children[0]);

keys[idx] = sibling->keys[0];
sibling->keys.erase(sibling->keys.begin());
}

void BTreeNode::merge(int idx) {
BTreeNode *child = children[idx];
BTreeNode *sibling = children[idx + 1];

child->keys.push_back(keys[idx]);
for (int i = 0; i < sibling->keys.size(); i++)
child->keys.push_back(sibling->keys[i]);
```

```
if (!child->leaf) {
for (int i = 0; i <= sibling->keys.size(); i++)
child->children.push_back(sibling->children[i]);
}

keys.erase(keys.begin() + idx);
children.erase(children.begin() + idx + 1);
delete sibling;
}

int main() {
int NQ, degree;
cin >> NQ >> degree;

BTree btree(degree);
char op;
int val;

while (NQ--) {
cin >> op >> val;
if (op == 'i') {
btree.insert(val);
} else if (op == 'd') {
btree.deleteKey(val);
}
}

cout << btree.splitCount << endl;
cout << btree.mergeCount << endl;
btree.traverseInOrder();
cout << endl;

return 0;
}
```



Q2. Write a program to print the nodes of a Threaded Binary Tree from a given Binary Tree.

Hint: We will do a reverse in-order traversal, which means we will go to the right child first. Then in the recursive call, we will pass an additional parameter which is the previously visited node. If the right pointer of a node is NULL and the previously visited node is not NULL, we will point the right of the node to the previously visited node and set the boolean rightThread variable to true. The previously visited node should not be changed when making a recursive call to the right subtree, and the real previous visited node should be passed when making a recursive call to the left subtree.

Ans:

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

struct ThreadedNode {
int data;
ThreadedNode* left;
ThreadedNode* right;
bool rightThread; // true if right pointer is a thread

ThreadedNode(int data) {
this->data = data;
left = right = nullptr;
rightThread = false;
```

```
}
};

class ThreadedBinaryTree {
private:
ThreadedNode* root;

void createThreadedUtil(ThreadedNode* current, ThreadedNode*& prev) { if (current
== nullptr)
return;

createThreadedUtil(current->right, prev);

if (current->right == nullptr && prev != nullptr) {
current->right = prev;
current->rightThread = true;
}

prev = current;
createThreadedUtil(current->left, prev);
}

void inOrderTraversalUtil(ThreadedNode* node) {
ThreadedNode* current = leftmost(node);
while (current != nullptr) {
cout << current->data << " ";
if (current->rightThread)
current = current->right;
else
current = leftmost(current->right);
}
}

ThreadedNode* leftmost(ThreadedNode* node) {
if (node == nullptr)
return nullptr;
while (node->left != nullptr)
node = node->left;
return node;
}

public:
ThreadedBinaryTree() {
root = nullptr;
}
```

```
void setRoot(ThreadedNode* node) {
root = node;
}

void createThreaded() {
ThreadedNode* prev = nullptr;
createThreadedUtil(root, prev);
}

void inOrderTraversal() {
inOrderTraversalUtil(root);
}
};

int main() {
ThreadedBinaryTree tree;
ThreadedNode* root = new ThreadedNode(20); root->left
= new ThreadedNode(10);
root->right = new ThreadedNode(30);
root->left->left = new ThreadedNode(5);
root->left->right = new ThreadedNode(15);

tree.setRoot(root);
tree.createThreaded();
tree.inOrderTraversal();
return 0;
}
```

```
11 10 25 77 44 %
architiwari@Archits-MacBook-Air DSA %
```