**Course: ENSF 694** – Summer 2025
**Lab #:** 05
**Instructor:** Dr. Mahmood Moussavi
**Student Name:** Jack Shenfield
**Submission Date:** Wednesday, August 6th, 2025

**Exercise A**

Source Code:

```
/*
 *  AVL_tree.cpp
 *  ENSF 694 Lab 5, exercise A
 *  Created by Mahmood Moussavi on 2024-05-22
 *  Completed by: Jack Shenfield
 *  Development Date: August 5th, 2025
 */


#include "AVL_tree.h"

AVLTree::AVLTree() : root(nullptr), cursor(nullptr){}

int AVLTree::height(const Node* N) {
    // Student must complete and if necessary change the return value of
    // this function this function

    // return 0 if there are no children
    // return height if there are children
    return (N == nullptr) ? 0 : N->height;

}

int AVLTree::getBalance(Node* N) {
    // Student must complete and if necessary change the return value of
    // this function this function


    if (N == nullptr) {
        return 0;
    }

    return(height(N->left) - height(N->right));
}
```

```cpp
Node* AVLTree::rightRotate(Node* y) {
    // Student must complete and if necessary change the return value of
    // this function this function

    // y is the unbalanced node. must pivot around y->right

    // y is the parent node
    // x is the pivot node
    // T2 is tree 2, the right subtree of x
    // these 3 nodes must be moved.

    // extract nodes
    Node* x = y->left;
    Node* T2 = x->right;

    // "rotate" parent node around
    x->right = y;
    y->left = T2;

    // if T2 exists, it's new parent is y.
    if (T2){
        T2->parent = y;
    }

    // x is the new parent
    x->parent = y->parent;
    // adjust y to be x's child
    y->parent = x;

    // re-calculate heights
    y->height = std::max(height(y->left), height(y->right)) + 1;
    x->height = std::max(height(x->left), height(x->right)) + 1;

    return x;
}
```

```
 Node* AVLTree::leftRotate(Node* x) {
    // Student must complete and if necessary change the return value of
    // this function this function

    // see comments above. same logic just for left rotate.

   Node* y = x->right;
   Node* T2 = y->left;

   y->left = x;
   x->right = T2;

   if (T2){
       T2->parent = x;
   }

   y->parent = x->parent;
   x->parent = y;

   x->height = std::max(height(x->left), height(x->right)) + 1;
   y->height = std::max(height(y->left), height(y->right)) + 1;

   return y;
 }

void AVLTree::insert(int key, Type value) {
   root = insert(root, key, value, nullptr);
}

// Recursive function
 Node* AVLTree::insert(Node* node, int key, Type value, Node* parent) {
   // Student must complete and if necessary change the return value of
   // this function this function

   // base case
   if (node == nullptr) // insert where the current node points to nullptr
```

```
      return new Node(key, value, parent);

   if (key < node->data.key) // root node is less than current node key, recursively call
      node->left = insert(node->left, key, value, node);
   else if (key > node->data.key) // if it is more than current node key, recursively call back
      node->right = insert(node->right, key, value, node);
   else // key = node->data.key this is a duplicate, and we do not insert
      return node;

   node->height = 1 + std::max(height(node->left), height(node->right)); // update height at current node
   int balance = getBalance(node); // calculate balance where node is being inserted

   // Rotation may be required
   // LL
   if (balance > 1 && key < node->left->data.key){
      return rightRotate(node);
   }
   // RR
   if (balance < -1 && key > node->right->data.key){
      return leftRotate(node);
   }
   // LR
   if (balance > 1 && key > node->left->data.key) {
      node->left = leftRotate(node->left);
      return rightRotate(node);
   }
   // RL
   if (balance < -1 && key < node->right->data.key) {
      node->right = rightRotate(node->right);
      return leftRotate(node);
   }

   return node;
}
```

```cpp
// Recursive function
void AVLTree::inorder(const Node* root) {
    // Student must complete this function

    if (!root){ // IF DNE, return
        return;
    }

    // recursive call/print order for inorder
    inorder(root->left);
    std::cout << "(" << root->data.key << " " << root->data.value << ") ";
    inorder(root->right);

}

// Recursive function
void AVLTree::preorder(const Node* root) {
    // Student must complete this function

    if (!root){ // if DNE, return
        return;
    }

    // recursive call/print order for preorder
    std::cout << "(" << root->data.key << " " << root->data.value << ") ";
    preorder(root->left);
    preorder(root->right);

}

// Recursive function
void AVLTree::postorder(const Node* root) {
    // Student must complete this function

    // base case, if not root
    if (!root){
        return;
```

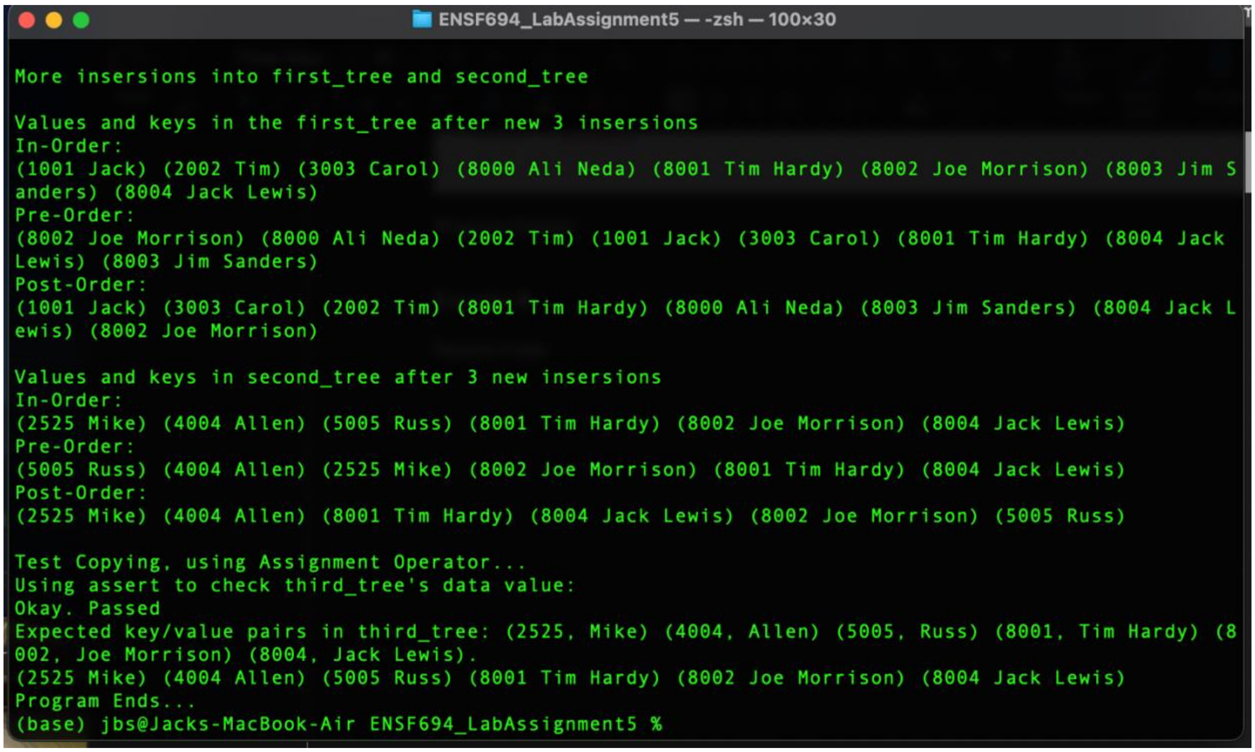
```cpp
    }

    // recursive call/print order for postorder
    postorder(root->left);
    postorder(root->right);
    std::cout << "(" << root->data.key << " " << root->data.value << ") ";

}

const Node* AVLTree::getRoot(){
    return root;
}

void AVLTree::find(int key) {
    go_to_root();
    if(root != nullptr)
        find(root, key);
    else
        std::cout << "It seems that tree is empty, and key not found." << std::endl;
}

// Recursive funtion
void AVLTree::find(Node* root, int key){
    // Student must complete this function

    if (!root) { // If root DNE, print root not found
        cursor = nullptr;
        std::cout << "Key " << key << " NOT found...\n";
        return;
    }

    if (key == root->data.key) { // if found, print key and value
        cursor = root;
        std::cout << "Key " << key << " found with value: " << root->data.value << "\n";
    }

    else if (key < root->data.key){ // if the key is less than current node, recursively call left (to lesser values)
```

```
        find(root->left, key);
    }
    else{ // if the key is greater than current node, recursively call right (to greater values).
        find(root->right, key);
    }


}

AVLTree::AVLTree(const AVLTree& other) : root(nullptr), cursor(nullptr) {
    root = copy(other.root, nullptr);
    cursor = root;
}

AVLTree::~AVLTree() {
    destroy(root);
}

AVLTree& AVLTree::operator=(const AVLTree& other) {
    if (this == &other) return *this;
    destroy(root);
    root = copy(other.root, nullptr);
    cursor = root;
    return *this;
}

// Recursive funtion
Node* AVLTree::copy(Node* node, Node* parent) {
    // Student must complete and if necessary change the return value of this function this function

    if (node == nullptr) return nullptr; // if node DNE, return nullptr

    Node* newNode = new Node(node->data.key, node->data.value, parent); // the node
    newNode->left = copy(node->left, newNode); // copy left sub-tree
    newNode->right = copy(node->right, newNode); // recurisvely call to copy right sub-tree

    newNode->height = node->height; // calculate new heights
```

```
    return newNode;

}

// Recusive function
void AVLTree::destroy(Node* node) {
    if (node) {
        destroy(node->left);
        destroy(node->right);
        delete node;
    }
    // Student must complete this function
}

const int& AVLTree::cursor_key() const{
    if (cursor != nullptr)
        return cursor->data.key;
    else{
        std::cout << "looks like tree is empty, as cursor == Zero.\n";
        exit(1);
    }
}

const Type& AVLTree::cursor_datum() const{
    if (cursor != nullptr)
        return cursor->data.value;
    else{
        std::cout << "looks like tree is empty, as cursor == Zero.\n";
        exit(1);
    }
}

int AVLTree::cursor_ok() const{
    if(cursor == nullptr)
        return 0;
    return 1;
```

```
}

void AVLTree::go_to_root(){
    if(!root) cursor = root;
    cursor = nullptr;
}
```

Program Output:



```
ENSF694_LabAssignment5 — -zsh — 100×30

More insersions into first_tree and second_tree

Values and keys in the first_tree after new 3 insersions
In-Order:
(1001 Jack) (2002 Tim) (3003 Carol) (8000 Ali Neda) (8001 Tim Hardy) (8002 Joe Morrison) (8003 Jim S
anders) (8004 Jack Lewis)
Pre-Order:
(8002 Joe Morrison) (8000 Ali Neda) (2002 Tim) (1001 Jack) (3003 Carol) (8001 Tim Hardy) (8004 Jack
Lewis) (8003 Jim Sanders)
Post-Order:
(1001 Jack) (3003 Carol) (2002 Tim) (8001 Tim Hardy) (8000 Ali Neda) (8003 Jim Sanders) (8004 Jack L
ewis) (8002 Joe Morrison)

Values and keys in second_tree after 3 new insersions
In-Order:
(2525 Mike) (4004 Allen) (5005 Russ) (8001 Tim Hardy) (8002 Joe Morrison) (8004 Jack Lewis)
Pre-Order:
(5005 Russ) (4004 Allen) (2525 Mike) (8002 Joe Morrison) (8001 Tim Hardy) (8004 Jack Lewis)
Post-Order:
(2525 Mike) (4004 Allen) (8001 Tim Hardy) (8004 Jack Lewis) (8002 Joe Morrison) (5005 Russ)

Test Copying, using Assignment Operator...
Using assert to check third_tree's data value:
Okay. Passed
Expected key/value pairs in third_tree: (2525, Mike) (4004, Allen) (5005, Russ) (8001, Tim Hardy) (8
002, Joe Morrison) (8004, Jack Lewis).
(2525 Mike) (4004 Allen) (5005 Russ) (8001 Tim Hardy) (8002 Joe Morrison) (8004 Jack Lewis)
Program Ends...
(base) jbs@Jacks-MacBook-Air ENSF694_LabAssignment5 %
```

**Exercise B**

Source Code:

```
#include "graph.h"

PriorityQueue::PriorityQueue() : front(nullptr) {}

bool PriorityQueue::isEmpty() const {
    return front == nullptr;
}
```

```
void PriorityQueue::enqueue(Vertex* v) {
    ListNode* newNode = new ListNode(v);
    if (isEmpty() || v->dist < front->element->dist) {
        newNode->next = front;
        front = newNode;
    } else {
        ListNode* current = front;
        while (current->next != nullptr && current->next->element->dist <= v->dist) {
            current = current->next;
        }
        newNode->next = current->next;
        current->next = newNode;
    }
}

Vertex* PriorityQueue::dequeue() {
    if (isEmpty()) {
        cerr << "PriorityQueue is empty." << endl;
        exit(0);
    }
    Vertex* frontItem = front->element;
    ListNode* old = front;
    front = front->next;
    delete old;
    return frontItem;
}


void Graph::printGraph() {
    Vertex* v = head;
    while (v) {
        for (Edge* e = v->adj; e; e = e->next) {
            Vertex* w = e->des;
            cout << v->name << " -> " << w->name << "  " << e->cost << "   " << (w->dist == INFINITY ? "inf" : to_string(w-
>dist)) << endl;
        }
```

```
        v = v->next;
    }
}

Vertex* Graph::getVertex(const char vname) {
    Vertex* ptr = head;
    Vertex* newv;
    if (ptr == nullptr) {
        newv = new Vertex(vname);
        head = newv;
        tail = newv;
        numVertices++;
        return newv;
    }
    while (ptr) {
        if (ptr->name == vname)
            return ptr;
        ptr = ptr->next;
    }
    newv = new Vertex(vname);
    tail->next = newv;
    tail = newv;
    numVertices++;
    return newv;
}

void Graph::addEdge(const char sn, const char dn, double c) {
    Vertex* v = getVertex(sn);
    Vertex* w = getVertex(dn);
    Edge* newEdge = new Edge(w, c);
    newEdge->next = v->adj;
    v->adj = newEdge;
    (v->numEdges)++;
    // point 1
}

void Graph::clearAll() {
```

```
    Vertex* ptr = head;
    while (ptr) {
        ptr->reset();
        ptr = ptr->next;
    }
}

void Graph::dijkstra(const char start) {
// STUDENTS MUST COMPLETE THE DEFINITION OF THIS FUNCTION
// chatgpt assisted a couple of lines of code to get me started.

    clearAll(); // reset data


    Vertex* s = getVertex(start); // point s to start vertex

    if (!s){ // return if DNE
        return;
    }

    s->dist = 0; // set distance to zero

    PriorityQueue pq; // create queue
    pq.enqueue(s); // enqueue current vertex

    while (!pq.isEmpty()) { // while there are vertices to visit, continue the following code
        Vertex* v = pq.dequeue();
        if (v->scratch) continue; // already been visited
        v->scratch = 1;

        for (Edge* e = v->adj; e != nullptr; e = e->next) { // iterate through all neighbours of v
            Vertex* w = e->des;
            double newDist = v->dist + e->cost;
            if (w->dist > newDist) {

                w->dist = newDist;
                w->prev = v;
```

```
            pq.enqueue(w);

          }

        }
    }
}

void Graph::unweighted(const char start) {
// STUDENTS MUST COMPLETE THE DEFINITION OF THIS FUNCTION
// a lot of logic copied from Dijkstra's solution.

    clearAll(); // Reset all data

    Vertex* s = getVertex(start); // point s to start vertex

    if (!s){ // if s DNE, return
        return;
    }


    s->dist = 0; // set distance to 0

    queue<Vertex*> q; // new queue
    q.push(s); // add s to queue

    while (!q.empty()) { // check all edges connected to current vertex
        Vertex* v = q.front(); q.pop();

        for (Edge* e = v->adj; e != nullptr; e = e->next) {
            Vertex* w = e->des;

            if (w->dist == INFINITY) {

                w->dist = v->dist + 1;
                w->prev = v;
                q.push(w);
```

```
            }

        }

    }
}

void Graph::readFromFile(const string& filename) {
    ifstream infile(filename);
    if (!infile) {
        cerr << "Could not open file: " << filename << endl;
        exit(1);
    }

    char sn, dn;
    double cost;
    while (infile >> sn >> dn >> cost) {
        addEdge(sn, dn, cost);
    }

    infile.close();
}

void Graph::printPath(Vertex* dest) {
    if (dest->prev != nullptr) {
        printPath(dest->prev);
        cout << " " << dest->name;
    } else {
        cout << dest->name;
    }
}

void Graph::printAllShortestPaths(const char start, bool weighted) {
    if (weighted) {
        dijkstra(start);
    } else {
```

```
    unweighted(start);
  }
  setiosflags(ios::fixed);
  setprecision(2);
  Vertex* v = head;
  while (v) {
    if (v->name == start) {
      cout << start << " -> " << v->name << "     0   " << start << endl;
    } else {

      cout << start << " -> " << v->name << "     " << (v->dist == INFINITY ? "inf" : to_string((int)v->dist)) << "   ";
      if (v->dist == INFINITY) {
        cout << "No path" << endl;
      } else {
        printPath(v);
        cout << endl;
      }
    }
    v = v->next;
  }
}
```

Program Output:

```
(base) jbs@Jacks-MacBook-Air ENSF694_LabAssignment5 % ./graphsolution
graph.txt
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 1
Enter the start vertex: A
A -> A     0   A
A -> B     1   A B
A -> E     1   A E
A -> C     2   A E C
```

A -> D 2 A E D
A -> M 2 A E M
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 2
Enter the start vertex: C
C -> A 11 C D A
C -> B 19 C D A E B
C -> E 16 C D A E
C -> C 0 C
C -> D 4 C D
C -> M 116 C D A E M
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 2
Enter the start vertex: A
A -> A 0 A
A -> B inf No path
A -> E inf No path
A -> C inf No path
A -> D inf No path
A -> M inf No path
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 1
Enter the start vertex: C
C -> A 2 C D A
C -> B 3 C D A B
C -> E 3 C D A E
C -> C 0 C
C -> D 1 C D

```
C -> M     4   C D A E M
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 1
Enter the start vertex: M
M -> A     inf   No path
M -> B     inf   No path
M -> E     inf   No path
M -> C     inf   No path
M -> D     inf   No path
M -> M     0   M
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 3
(base) jbs@Jacks-MacBook-Air ENSF694_LabAssignment5 %
```