Course: ENSF694 – Summer 2025
Lab #: Lab 5
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I have been keeping all the files in github. I hope by providing this github link will help you a little bit.
https://github.com/JZ-Zhou-UofC/ENSF-604-assignment-repo

Exercise A

Code:

```
//
//  AVL tree.cpp
//  AVL tree
// ENSF 694 - Lab 5 Exercise A
//  Created by Mahmood Moussavi on 2024-05-22.
// Completed by: John Zhou

#include "AVL_tree.h"
using namespace std;

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

int AVLTree::height(const Node *N)
{
   if (N == nullptr)
      return 0;

   return N->height;
}

int AVLTree::getBalance(Node *N)
{
   if (N == nullptr)
      return 0;
```

```
    int leftHeight = (N->left != nullptr) ? N->left->height : 0;
    int rightHeight = (N->right != nullptr) ? N->right->height : 0;

    return leftHeight - rightHeight;
}

Node *AVLTree::rightRotate(Node *y)
{
    Node *x = y->left;
    Node *T2 = x->right;
    x->right = y;
    y->left = T2;
    x->parent = y->parent;
    y->parent = x;

    if (T2 != nullptr)
        T2->parent = y;
    y->height = 1 + max(height(y->left), height(y->right));
    x->height = 1 + max(height(x->left), height(x->right));
    return x;
}

Node *AVLTree::leftRotate(Node *x)
{
    Node *y = x->right;
    Node *T2 = y->left;
    y->left = x;
    x->right = T2;
    y->parent = x->parent;
    x->parent = y;
    if (T2 != nullptr)
        T2->parent = x;
    x->height = 1 + max(height(x->left), height(x->right));
    y->height = 1 + max(height(y->left), height(y->right));

    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)
{
    if (node == nullptr)
        return new Node(key, value, parent);
    if (key < node->data.key)
    {
        node->left = insert(node->left, key, value, node);
    }
    else if (key > node->data.key)
    {
        node->right = insert(node->right, key, value, node);
    }
    else
    {
```

```
    return node;
}
node->height = 1 + max(height(node->left), height(node->right));

int balance = getBalance(node);

if (balance > 1 && key < node->left->data.key)

{
    return rightRotate(node);
}
if (balance > 1 && key > node->left->data.key)

{
    node->left = leftRotate(node->left);
    return rightRotate(node);
}

if (balance < -1 && key > node->right->data.key)

{
    return leftRotate(node);
}
if (balance < -1 && key < node->right->data.key)

{
    node->right = rightRotate(node->right);
    return leftRotate(node);
}
```

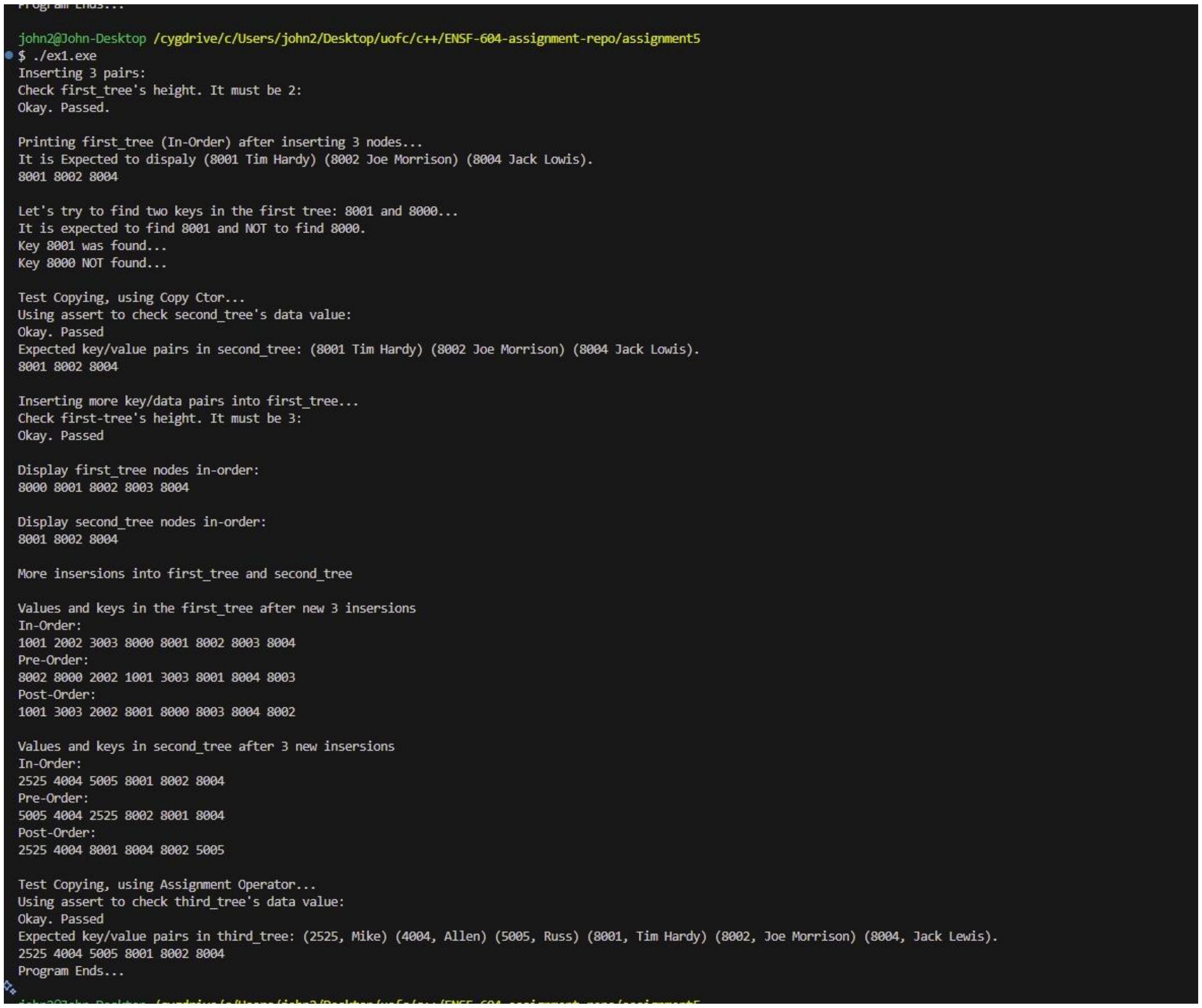
```
    return node;
}

// Recursive function
void AVLTree::inorder(const Node *root)
{

    if (root == nullptr)
        return;

    inorder(root->left);

    cout << root->data.key << " ";
    inorder(root->right);
}

// Recursive function
void AVLTree::preorder(const Node *root)
{
    if (root == nullptr)
        return;
    cout << root->data.key << " ";
    preorder(root->left);

    preorder(root->right);
}

// Recursive function
```

```
void AVLTree::postorder(const Node *root)

{

    if (root == nullptr)

        return;



    postorder(root->left);



    postorder(root->right);

    cout << root->data.key << " ";

}



const Node *AVLTree::getRoot()

{

    return root;

}



void AVLTree::find(int key)

{

    go_to_root();

    if (root != nullptr)

        find(root, key);

    else

        cout << "It seems that tree is empty, and key not found." << endl;

}



// Recursive funtion

void AVLTree::find(Node *root, int key)

{

    if (root == nullptr)
    {
        return;
    }
    if (key < root->data.key)
    {
        find(root->left, key);
    }
    else if (key > root->data.key)
    {
        find(root->right, key);
    }
    else
    {
        cursor = root;
    }
}

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)
{
    if (node == nullptr)
    {
        return nullptr;
    }
    Node *newNode = new Node(node->data.key, node->data.value, parent);

    newNode->left = copy(node->left, newNode);
    newNode->right = copy(node->right, newNode);
    newNode->height = node->height;

    return newNode;
}

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

const int &AVLTree::cursor_key() const
{
    if (cursor != nullptr)
        return cursor->data.key;
    else
    {
        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
    {
        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



```
john2@John-Desktop /cygdrive/c/Users/john2/Desktop/uofc/c++/ENSF-604-assignment-repo/assignment5
$ ./ex1.exe
Inserting 3 pairs:
Check first_tree's height. It must be 2:
Okay. Passed.

Printing first_tree (In-Order) after inserting 3 nodes...
It is Expected to dispaly (8001 Tim Hardy) (8002 Joe Morrison) (8004 Jack Lowis).
8001 8002 8004

Let's try to find two keys in the first tree: 8001 and 8000...
It is expected to find 8001 and NOT to find 8000.
Key 8001 was found...
Key 8000 NOT found...

Test Copying, using Copy Ctor...
Using assert to check second_tree's data value:
Okay. Passed
Expected key/value pairs in second_tree: (8001 Tim Hardy) (8002 Joe Morrison) (8004 Jack Lowis).
8001 8002 8004

Inserting more key/data pairs into first_tree...
Check first-tree's height. It must be 3:
Okay. Passed

Display first_tree nodes in-order:
8000 8001 8002 8003 8004

Display second_tree nodes in-order:
8001 8002 8004

More insersions into first_tree and second_tree

Values and keys in the first_tree after new 3 insersions
In-Order:
1001 2002 3003 8000 8001 8002 8003 8004
Pre-Order:
8002 8000 2002 1001 3003 8001 8004 8003
Post-Order:
1001 3003 2002 8001 8000 8003 8004 8002

Values and keys in second_tree after 3 new insersions
In-Order:
2525 4004 5005 8001 8002 8004
Pre-Order:
5005 4004 2525 8002 8001 8004
Post-Order:
2525 4004 8001 8004 8002 5005

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) (8002, Joe Morrison) (8004, Jack Lewis).
2525 4004 5005 8001 8002 8004
Program Ends...
```

Exercise B

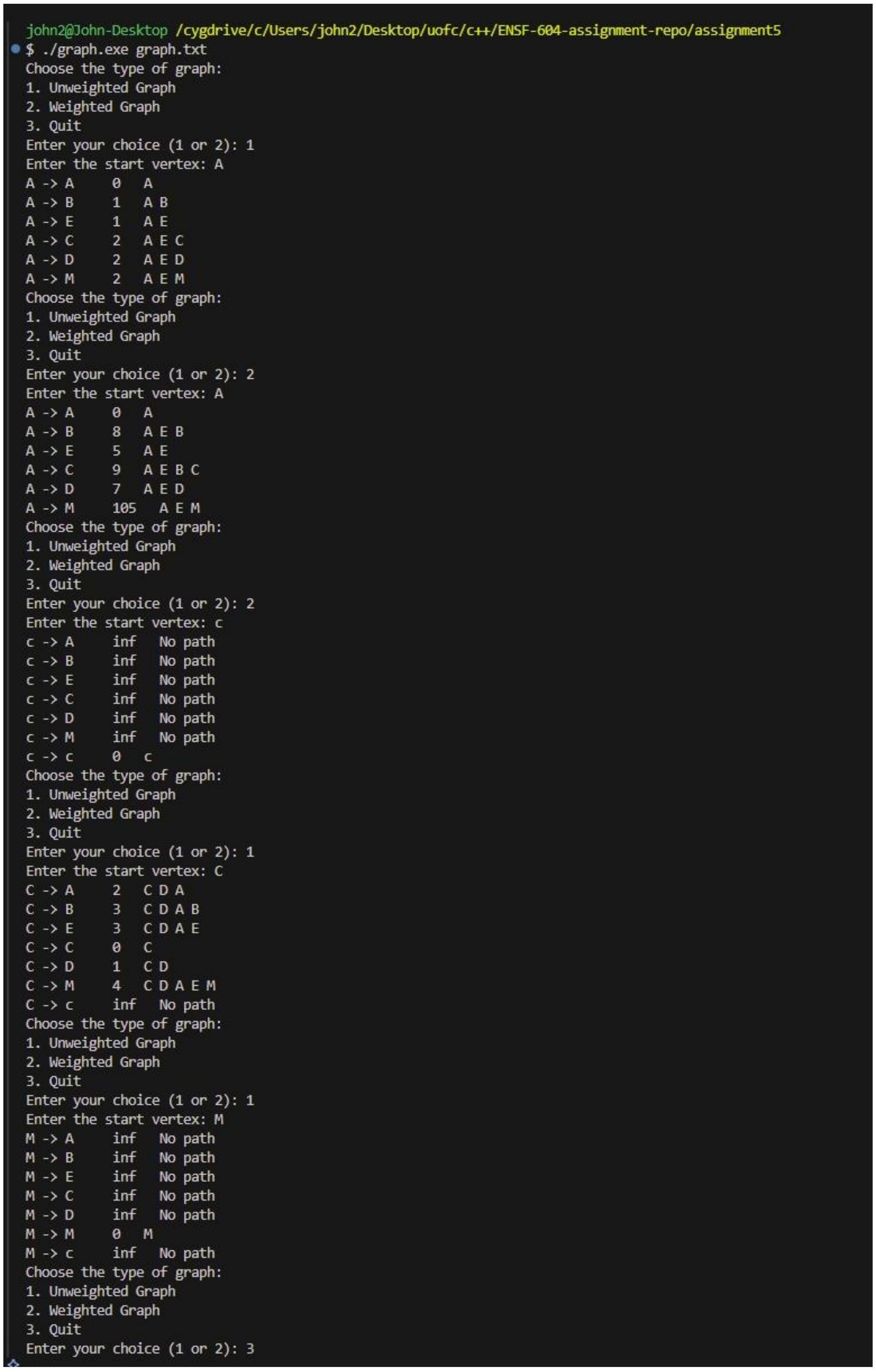
```
//
//  graph.cpp
//  graph
// ENSF 694 - Lab 5 Exercise B
//  Created by Mahmood Moussavi
// Completed by: John Zhou
#include "graph.h"

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
   clearAll();

   Vertex *startingVertex = getVertex(start);
   startingVertex->dist = 0;
   PriorityQueue que;
   que.enqueue(startingVertex);

   while (!que.isEmpty())
   {
      Vertex *currentVertex = que.dequeue();

      for (Edge *e = currentVertex->adj; e != nullptr; e = e->next)
      {
         Vertex *neighbourVertex = e->des;
         double  newDist = currentVertex->dist + e->cost;

         if (newDist < neighbourVertex->dist)
         {
            neighbourVertex->dist = newDist;
            neighbourVertex->prev = currentVertex;
            que.enqueue(neighbourVertex);
         }
      }
   }
}

void Graph::unweighted(const char start)
```

```
{
  // STUDENTS MUST COMPLETE THE DEFINITION OF THIS FUNCTION
    clearAll();


  Vertex *startingVertex = getVertex(start);
  startingVertex->dist = 0;
  PriorityQueue que;
  que.enqueue(startingVertex);


  while (!que.isEmpty())
  {
    Vertex *currentVertex = que.dequeue();


    for (Edge *e = currentVertex->adj; e != nullptr; e = e->next)
    {
      Vertex *neighbourVertex = e->des;
      double  newDist = currentVertex->dist + 1.0;


      if (newDist < neighbourVertex->dist)
      {
        neighbourVertex->dist = newDist;
        neighbourVertex->prev = currentVertex;
        que.enqueue(neighbourVertex);
      }
    }
  }


}
```

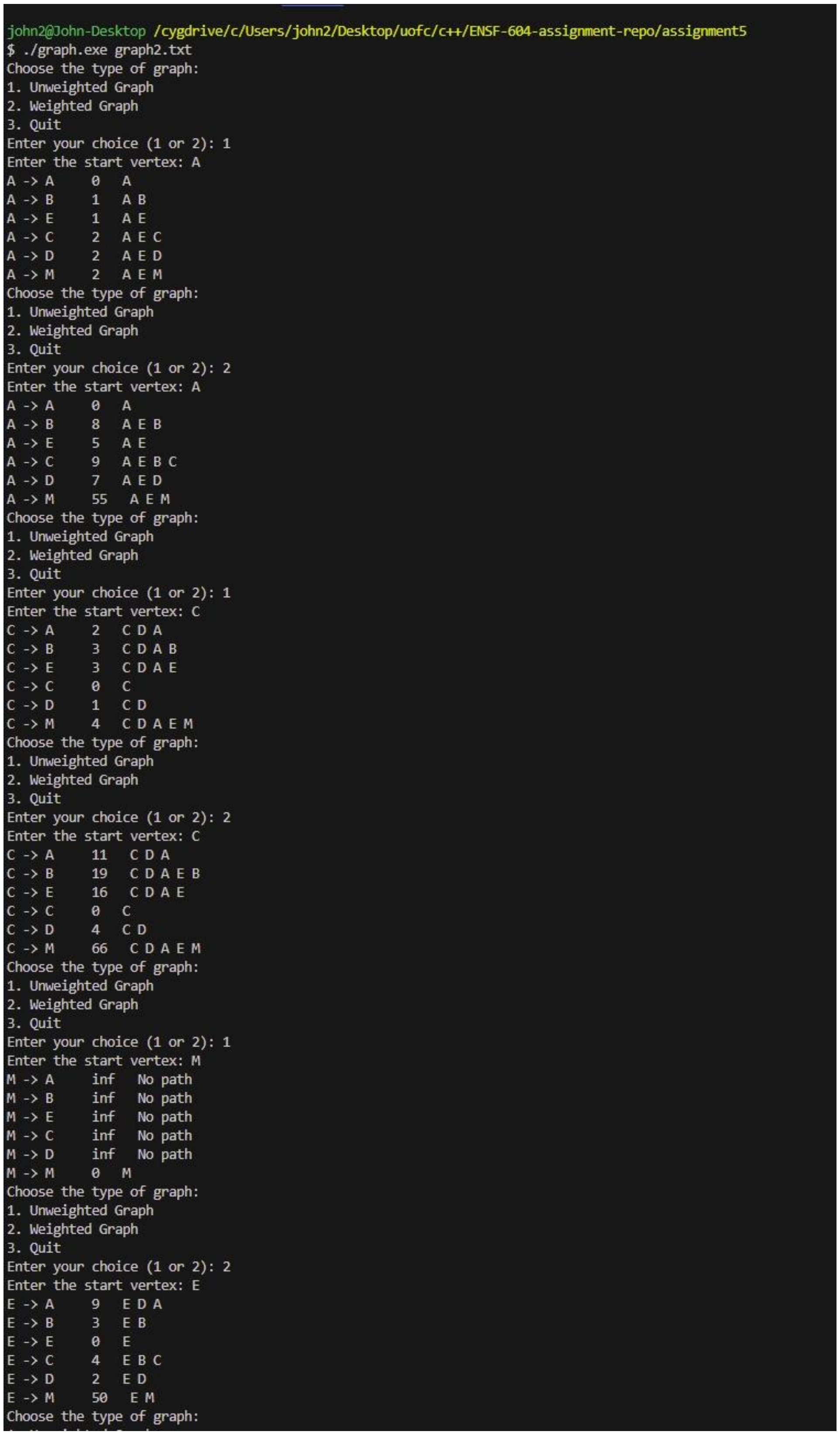
```
void Graph::readFromFile(const string &filename)
{
    ifstream infile(filename);
    if (!infile)
    {
        cerr << "Could not open file: " << filename << endl;
        exit(1);
    }

    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 1



```
john2@John-Desktop /cygdrive/c/Users/john2/Desktop/uofc/c++/ENSF-604-assignment-repo/assignment5
$ ./graph.exe 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: A
A -> A     0   A
A -> B     8   A E B
A -> E     5   A E
A -> C     9   A E B C
A -> D     7   A E D
A -> M     105   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     inf   No path
c -> B     inf   No path
c -> E     inf   No path
c -> C     inf   No path
c -> D     inf   No path
c -> M     inf   No path
c -> c     0   c
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
C -> c     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: 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
M -> c     inf   No path
Choose the type of graph:
1. Unweighted Graph
2. Weighted Graph
3. Quit
Enter your choice (1 or 2): 3
```

Program output 2



```
john2@John-Desktop /cygdrive/c/Users/john2/Desktop/uofc/c++/ENSF-604-assignment-repo/assignment5
$ ./graph.exe graph2.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: A
A -> A     0   A
A -> B     8   A E B
A -> E     5   A E
A -> C     9   A E B C
A -> D     7   A E D
A -> M     55   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: 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): 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     66   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): 2
Enter the start vertex: E
E -> A     9   E D A
E -> B     3   E B
E -> E     0   E
E -> C     4   E B C
E -> D     2   E D
E -> M     50   E M
Choose the type of graph:
```