CIS 350 – SUMMER 2021
Professor Steiner
Demetrius E Johnson
Program 3 Documentation
22 July, 2021

1. Problem Statement

Create an MST using Prim's Algorithm given a connected graph providing the MST and the total cost.

2. Requirements

2.1. Assumptions

Input file values will be integers
File FORMAT is correct
Number of vertices and number of edges in input file
    Consider correct values if 0 or greater
    Negative values are invalid
    Negative value for edges – no edges will appear in the input file for this graph
File may contain multiple graphs
Undirected graph
Graph input will be a connected graph even after discarding invalid edges

2.2. Specifications

Display message "Welcome to the MST Test Program" to user
Display message "Enter output file name: " to user
Read and use the user entered output file name
If output file cannot be used
    Display message "file <user output file name> cannot be opened – program terminated" to user
Display message "Welcome to the MST Test Program" to output file
Display message "Testing Default Scenario" to user and output file
Create an empty graph and test functionality – No MST
Display message "Testing File Data" to user and output file
Display message "Enter file name for graph data: " to user
Read user entered input data file name
Display message "File name for graph data: <input file name>" to ouput file
Perform file validation
  If cannot open
    Display message "file <user input file name> cannot be opened or does not exist – program terminated"
  If file exists but is empty

```
        Display message "file <user input file name> contains no data –
        program terminated"

    For each graph in the input file data
        Create full graph
            Number of vertices and number of edges is first line of each set of
            graph data
            if number of vertices less than zero
              display message "ERROR: number of vertices: <number of
              vertices> is less than zero" to user and output file
              display message "Empty Graph Will Be Created" to user and
              output file
              create empty graph
            otherwise
            if number of vertices is equal to 0
              display message "Number of vertices: <number of vertices> is
              equal to zero" to user and output file
              display message "Empty Graph Will Be Created" to user and
              output file
              create empty graph
            otherwise vertices value is greater than 0
               display message "Number of vertices: <number of vertices> is
              valid" to user and output file

              if  number of edges is less than number of vertices - 1 (zero or
              less - input file will have NO edge data; greater than zero but
              less than number of vertices – 1 cannot be connected graph)
                      display message "ERROR: <number of edges> edges
                      invalid to create connected graph" to user and output file
                      display message "Empty Graph Will Be Created" to user
                      and output file
                      create empty graph
                      if number of edges is less than 0
                              program will treat as zero edges – file will not
                              contain edges
              otherwise
                      display "Graph with <number of vertices> and <number
                      of edges> will be created" to user and output file
```

create graph with specified number of vertices

Display “Number of input edges to process is: <number of edges>” to user and output file

attempt to add all edges from the input file to the graph

if empty graph edges cannot be added
display message “Empty Graph – Cannot Add Edge: <source>, <destination>, <weight>” to user and output file
if invalid value for vertex (non-existent vertex – negative vertex value, 6 vertices in graph and vertex value is 10)
display message “Invalid Source or Destination Vertex – Cannot Add Edge: <source>, <destination>, <weight> - Edge request ignored” to user and output file
if invalid value for weight (weight must be greater than 0)
display message “Invalid Weight – Cannot Add Edge: <source>, <destination>, <weight> - Edge request ignored” to user and output file
otherwise edge can be added to graph
undirected graph so there are two edges added to graph adjacency list
display message “Edge Added: <source>, <destination>, <weight>” to user and output file

Print the full graph adjacency list
display message “Full Graph – Adjacency List” to user and output file
For each vertex display graph adjacency list to user and output file in format
Adj[vertex] -> (destination1, cost1) (destination2, cost2)

Create the MST
Start with vertex 0
add edges to partial MST until complete (Prim’s algorithm) using a priority queue

Print the MST

display message “Minimum Spanning Tree” to user and output file

if empty graph

display message “Empty Graph – No MST” to user and output file

otherwise

list all edges and weights of the MST

display message “Edge: <nbr> - < connected vertex> weight: <edge weight>” to user and output file

display message “Total cost of MST: <total MST Weight>” to user and output file

display message “MST Graph – Adjacency List” to user and output file

for each vertex display MST adjacency list to user and output file in format

Adj[vertex] -> (destination1, cost1) (destination2, cost2)

Display message “Thank you for running the MST Test Program written by <your name>!” to user and output file

3. Decomposition Diagram (Used to break program down into components visually. Can have as many components as needed. Defines functionality that will solve the problem – does NOT define a flow)

Main

- Input
  - User file name
    - File validation
  - File Data
    - File data edits
      - Format:
        - number of vertices, number of edges
        - source vertex, destination vertex, weight
- Process
  - Create graph
  - Create MST
- Output
  - Welcome message
  - Input error messages
  - Print full graph – adjacency list
  - Print MST – edge sequence and adjacency list
  - End message

4. Test Strategy

File Testing (exist, empty)
Valid data
Invalid data

5. Test Plan Version 1

Test Strategy	Test Number	Description	Input	Expected Output	Actual Output	Pass/Fail
File Testing	1	File does not exist				
File Testing	2	File exists but empty				
Valid data	1	Valid connected graph vertices and edges				
Valid data	2	Empty graph				
Invalid data	1	Invalid number of vertices				
Invalid data	2	Invalid number of edges				
Invalid data	3	Invalid edge source vertex				
Invalid data	4	Invalid edge destination vertex				
Invalid data	5	Invalid edge weight				

6. Initial Algorithm

<u>Data: Object Definitions</u>

Struct pqData
<u>Data</u>:
integers: keyWeight, keyDestinationVertex, keySourceVertex

Class edge
Data:
integers: sourceVertex, destinationVertex, edgeWeight
link: nextEdge
Actions:
default constructor: initalize all data to -1

3 paramater constructor: integers source, destination, weight
Assign to appropriate class variables

Class resultSetClass
Data:
integers: parent, weight
Actions:
Default constructor: set all variables to value of -1

Class graph
Data:
integer: numberOfVertices
array of linked lists (must be able to hold all vertices): adjacencyList Graph, adjacencyListMST
Actions:
default constructor:
Set numberOfVertices to zero
display messsage “Default - Empty Graph Created”

1 parameter constructor: integer vertices
Set numberOfVertices to vertices
initialize adjacencyListGraph for each vertex as empty list; points to edge object

<u>addEdge</u>: 3 integer parameters source, destination, weight

if numberOfVertices equals zero

display message "Empty Graph – Cannot Add Edge: <source>, <destination>, <weight>" to user and output file

otherwise

if either source or destination is less than zero or greater than numberOfVertices

display message "Invalid Source or Destination Vertex – Cannot Add Edge: <source>, <destination>, <weight> - Edge request ignored" to user and output file

if either weight is zero or less

display message "Invalid Weight – Cannot Add Edge: <source>, <destination>, <weight> - Edge request ignored" to user and output file

otherwise edge can be added to graph

create edge object – source, destination, weight

add to source vertex in adjacencyListGraph

display message "Edge Added: <source>, <destination>, <weight>" to user and output file

create edge object – destination, source, weight since undirected graph

add to destination vertex in adjacencyListGraph

display message "Edge Added: <destination>, <source>, <weight>" to user and output file

<u>printGraph</u> – no parameters

display message "Full Graph – Adjacency List" to user and output file

Loop through adjacencyListGraph

For each vertex display to user and output file adjacency list in format:

Adj[vertex] -> (destination1, cost1) (destination2, cost2)

primMST – no parameters
Create pqData extractedPQData
Create pqData intoPQData
Create boolean array mst of size numberOfVertices
Initialize mst values to false

Create resultSetClass array resultSet of size numberOfVertices) default constructor

Initialize resultSet to point to resultSetClass instances
Create integer array weights of size numberOfVertices
Initialize weights values to maximum integer value (e.g. C++ INT_MAX)

Vertex 0 is starting vertex – create non-edge priority queue entry to start MST
Set weights[0] to zero
Set pqData keyWeight to weights[0]
and keyDestinationVertex to 0
and keySourceVertex to 0

Add pqData to min-heap priority queue (you are to code your own priority queue – you cannot use library methods)

Set resultSet[0].parent to -1 (vertex 0 has no parent)
Loop while priority queue is not empty
Dequeue root from priority queue into extractedPQData – dequeueing minimum edge where keyDestinationVertex is vertex that will be added to the MST
Set mst[extractedPQData.keyDestinationVertex] to true

If extractedPQData.keyDestinationVertex and extractedPQData.keySourceVertes are both zero
skip over – vertex 0 start priority queue entry that is not an edge
otherwise
Add edges to adjacencyListMST for source and destination vertices (since undirected graph) for extractedPQData keySourceVertex and keyDestinationVertex and keyWeight values

Iterate through all the adjacent vertices to newly added vertex and update the weights as needed

For each edge in extractedPQData.keyDestinationVertex adjacency list

If mst[edge.destinationVertex] is equal to false (the destination vertex not in MST)

If weights[edge.destinationVertex] is greater than edge.edgeWeight

Assign edge.edgeWeight, edge.destinationVertex, and edge.sourceVertex to intoPQData keyWeight, keyDestinationVertex, and keySourceVertex

Add intoPQData to priority queue

Update resultSetClass

Set resultSet[edge.destinationVertex]. parent to extractedPQData.keyDestinationVertex

Set resultSet[edge.destinationVertex].weight to edge.edgeWeight

Set weights[edge.destinationVertex] to edge.edgeWeight

<u>printMST</u> – no parameters

Create integer totalMSTWeight, initialize to zero

Display message “Minimum Spanning Tree”

If numberOfVertices equals zero

Display message “Empty Graph – No MST”

Return from method

Loop through resultSet (nbr from 1 to number of vertices - 1)

Display message “Edge: <nbr> - <resultSet[nbr].parent> weight: <resultSet[nbr].weight”

Add resultSet[nbr].weight to totalMSTWeight

Display message “Total cost of MST: <totalMSTWeight>”

Display message “MST Graph – Adjacency List”

Loop through adjacencyListMST

For each vertex display adjacency list in format

Adj[vertex] -> (destination1, cost1) (destination2, cost2)

destructor: deallocate objects in adjacency list

Program: main

Main:

Display message “Welcome to the MST Test Program” to user
Display message “Enter output file name: ” to user
Read user entered output file name
Open output file
If output file cannot be opened
    Display message “file <user output file name> cannot be opened – program terminated” to user
    Terminate program
Display message “Output file: <user output file name>” to output file
Display message “Testing Default Scenario” to user and output file
Create default graph constructor instance – empty graph
Call method mstPrim – no MST created
Call method printMST – no MST created message
Display message “Testing File Data” to user and output file
Display message “Enter file name for graph data” to user
Read user entered input file name
Display message “File name for graph data: <input file name>” to ouput file
Open file
  If file cannot be opened
    Display message “File <user file name> cannot be opened or does not exist – program terminated” to user and output file
    Terminate program
  otherwise
  If file opens but has no data in it
    Display message “File <user file name> contains no data – program terminated” to user and output file
    Terminate program
  otherwise file has data to process

Loop until end of file – each loop instance is one graph

Number of vertices and number of edges is first line of each set of graph data
if number of vertices is less than zero
display message “ERROR: number of vertices: <vertices> is less than zero”
display message “Empty Graph Will Be Created”
create graph object with parameter of 0 vertices – empty graph
otherwise
if number of vertices is equal to zero
display message “Number of vertices: <vertices> is equal to zero”
display message “Empty Graph Will Be Created”
create graph object with parameter of 0 vertices – empty graph
otherwise vertices value is greater than zero
display message “Number of vertices: <vertices> is valid”

if number of edges is less than number of vertices - 1 (zero or less - input file will have NO edge data; greater than zero but less than number of vertices – 1 cannot be connected graph)
display message “ERROR: <number of edges> edges invalid to create connected graph” to user and output file
display message “Empty Graph Will Be Created” to user and output file
create graph object with parameter of 0 vertices – empty graph
if number of edges is less than 0
program will treat as zero edges – file will not contain edges
otherwise
display “Graph with <number of vertices> and <number of edges> will be created” to user and output file
create graph object with parameter of number of vertices
Display “Number of input edges to process is: <number of edges>” to user and output file
Loop for second data in the file (number of edges)
Read fileSource, fileDestination, fileWeight
Call addEdge in graph instance

Call printGraph
Call mstPrim
Call printMST
Deallocate graph object
Read from file to see if more graphs
End graph loop
Display message "Thank you for running the MST Test Program written by <your name>!" to user and output file

7. Test Plan Version 2

Test Strategy	Test Number	Description	Input	Expected Output	Actual Output	Pass/Fail
File Testing	1	File does not exist	File name that does not exist	"File <user file name> cannot be opened or does not exist – program terminated"		
File Testing	2	File exists but empty	File name that exists but has no data	"File <user file name> contains no data – program terminated"		
Valid data	1	Valid connected graph vertices and edges	File mst1.dat	MST with cost of 9		

Valid data	2	Empty graph – default constructor	Coded in program	"Empty Graph – No MST"		
Valid data	3	Display messages to user	Coded in program	All messages verified on screen and in output file		
Valid data	4	Print full graph	File mst2.dat	2 graph adjacency lists verified		
Valid data	5	Print MST	File mst2.dat	2 MST edge lists and adjacency lists and total cost of MSTs verified		
Invalid data	1	Invalid number of vertices	File mst4.dat	"Empty Graph – No MST"		
Invalid data	2	Invalid number of edges	File mst4.dat	"Empty Graph – No MST"		
Invalid data	3	Invalid edge source vertex	File mst3.dat	3 error edges		
Invalid data	4	Invalid edge destination vertex	File mst3.dat	2 error edges		
Invalid data	5	Invalid edge weight	File mst3.dat	2 error edges		
Invalid data	6	Try to add edges to empty graph	File mst4.dat Graph 0 5	Graph 0 5 edges cannot add edge error message		
Invalid data	7	Not enough edges for connected graph	File mst.4 Graph 5 3	"ERROR: 3 edges invalid to create connected graph"		

Part 1 ends here!!!!!!

8. Code

Copy and paste your code here. MAKE SURE TO COMMENT YOUR CODE!

MAIN FILE:

```
// This file contains the 'main' function. Program execution begins and ends there.
//Author: Demetrius E Johnson
//Purpose: create a program that uses a priority queue (using a heap) to implement Prim's
aglorithm and effectively execute Minimum Spanning Tree Protocol
//Date Created: 7/14/21
//Date Modified: 7/15/21



#include <iostream>
#include <sstream>
#include<string>
#include <fstream>
#include "graph.h"
using namespace std;



int main()
{
	string userInputFile;
	string userOutputFile;

	cout << "Welcome to the MST Test Program\n";
	cout << "Enter output file name: ";
	cin >> userOutputFile;
	ofstream outputFile(userOutputFile);

	//output file not opened sucessfully case:
	if (!outputFile.good()) {
		cout << "file " << userOutputFile << " cannot be opened - program
terminated...\n";
		return 1;
	}

	outputFile << "Welcome to the MST Test Program\n";
	outputFile << "Output file: " << userOutputFile << endl;

		//Create an empty graph and test functionality - No MST
	cout << "Testing Default Scenario...\n";
	outputFile << "Testing Default Scenario...\n";
	graph emptyGraphTest;
	emptyGraphTest.primMST(outputFile);
```

```
	emptyGraphTest.printMST(outputFile);

	cout << "Enter file name for graph data: ";
	cin >> userInputFile;
	outputFile << "File name for graph data: " << userInputFile << endl;
	ifstream inputFile(userInputFile);

	//input file not open successfully case:
	if (!inputFile.good()) {
		cout << "file " << userInputFile << " cannot be opened or does not exist - 
program terminated...\n";
		outputFile << "file " << userInputFile << " cannot be opened or does not 
exist - program terminated...\n";
		system("pause");
		return 1;
	}
	//empty input file case:
	while (inputFile.peek() == ' ' || inputFile.peek() == '\n')
{ inputFile.ignore(); } //ignore leading white spaces and newlines until we reach a char 
or EOF
	if (inputFile.peek() == EOF) {

		cout << "file " << userInputFile << " contains no data - program 
terminated...\n";
		outputFile << "file " << userInputFile << " contains no data - program 
terminated...\n";
		system("pause");
		return 1;
	}

	//loop until end of file; each loop instance is one graph:

	stringstream ss;		//use this to input an integer stored in a string into 
an int
	string lineParse;		//use this to parse each line from the input file
	int numVertices;		//store current numVertices for a graph in the input 
file
	int numEdges;			//store current numEdges for a graph in the input file
	graph* fileInputGraph;		//this is necessary so that each iteration of while 
loop we can create the proper graph instance

	while (inputFile.peek() != EOF) {

		cout << endl << endl;
		outputFile << endl << endl;

		while (inputFile.peek() == ' ' || inputFile.peek() == '\n')
{ inputFile.ignore(); } //if necessary: ignore leading white spaces / lines before next 
graph


		getline(inputFile, lineParse);	//store current line from input file into 
lineParse
		ss << lineParse;			//output to stream
		ss >> numVertices >> numEdges;	//convert char/string to integer values
//side note: istream::operator>> only extracts characters; it does not also discard them; 
use cin.ignore() function to clear buffer if necessary
```

```
            ss.clear();                                     //clear stream in case of
any bad bits set



            //next set of if statements will check number of vertices from the passed
in graph:
            if (numVertices < 0) {

                  cout << "ERROR: number of vertices: " << numVertices << " is less
than zero\n"
                        << "Empty Graph Will Be Created\n";
                  outputFile << "ERROR: number of vertices: " << numVertices << " is
less than zero\n"
                        << "Empty Graph Will Be Created\n";
                  fileInputGraph = new graph(0);
            }
            else if (numVertices == 0) {

                  cout << "Number of vertices: " << numVertices << " is equal to
zero\n"
                        << "Empty Graph Will Be Created\n";
                  outputFile << "Number of vertices: " << numVertices << " is equal to
zero\n"
                        << "Empty Graph Will Be Created\n";
                  fileInputGraph = new graph(0);

            }
            else {

                  cout << "Number of vertices: " << numVertices << " is valid\n";
                  outputFile << "Number of vertices: " << numVertices << " is
valid\n";

                  //next set of if statements will check number of edges from the
passed in graph:

                  if (numEdges < (numVertices - 1) || numEdges < 0) {

                        cout << "ERROR: number of edges: " << numEdges << " is invalid
to create connected graph\n"
                              << "Empty Graph Will Be Created\n";
                        outputFile << "ERROR: number of edges: " << numEdges << " is
invalid to create connected graph\n"
                              << "Empty Graph Will Be Created\n";
                        fileInputGraph = new graph(0);


                  }
                  else {

                        cout << "Graph with " << numVertices << " vertices and " <<
numEdges << " edges will be created\n";
                        outputFile << "Graph with " << numVertices << " vertices and "
<< numEdges << " edges will be created\n";
                        fileInputGraph = new graph(numVertices);
                        cout << "Number of input edges to process is: " << numEdges <<
endl;
```

```
                            outputFile << "Number of input edges to process is: " <<
numEdges << endl;
                        }
                }



                //second loop (process all edges given from the file):

                for (int i = 0; i < numEdges; i++) {

                        int fileSource, fileDestination, fileWeight;           //use these
to store the current edge
                        getline(inputFile, lineParse);
        //get current line (edge) which is a string
                        ss << lineParse;
        //output string into stringstream for integer conversion on next line
                        ss >> fileSource >> fileDestination >> fileWeight;     //input the
values into the appropriate integers
                        ss.clear();
                //clear stream in case of bad bit set; helps with felxibility of input file
format
                        fileInputGraph->addEdge(fileSource, fileDestination, fileWeight,
outputFile); //add edge

                }

                //now call appropriate functions of the graph to create MST and output all
results:
                fileInputGraph->printGraph(outputFile);
                fileInputGraph->primMST(outputFile);
                fileInputGraph->printMST(outputFile);

                delete fileInputGraph; // end of loop: delete graph; MST and other
algorithms already ran; will create new graph at start of loop for next graph if
necessary

        }//end of while loop

        cout << "Thank you for running the MST Test Program written by Demetrius
Johnson!\n";
        outputFile << "Thank you for running the MST Test Program written by Demetrius
Johnson!\n";

        //close files
        outputFile.close();
        inputFile.close();

        system("pause");
}
```

GRAPH class .H FILE:

```
#ifndef GRAPH
#define GRAPH
#include <iostream>
#include <fstream>
#include "pqData.h"
#include "resultSetClass.h"
#include "edge.h"

class graph
{
private:
	int numberOfVertices;
	edge* adjacencyListGraph;
	edge* adjacencyListMST;
public:
	graph();
	graph(int vertices);
	void addEdge(int source, int destination, int weight, std::ofstream& outFile);
	void printGraph(std::ofstream& outFile);
	void primMST(std::ofstream& outFile);
	void printMST(std::ofstream& outFile);;
	~graph();
};

#endif
```

GRAPH class .CPP:

```
#include "graph.h"

graph::graph() {

	numberOfVertices = 0;
	adjacencyListGraph = new edge[numberOfVertices];
	adjacencyListMST = new edge[numberOfVertices];
	std::cout << "Default - Empty Graph Created\n";

}
graph::graph(int vertices) {

	numberOfVertices = vertices;
	adjacencyListGraph = new edge[numberOfVertices];
	adjacencyListMST = new edge[numberOfVertices];
}

//Description: adds an edge to the graph
//Pre-condition: need source, dest, and weight, and also output stream so we can output
text to the user output file
//Post-condition: edge will be added to the adjacency array and proper outputs will occur
to the screen and user file
void graph::addEdge(int source, int destination, int weight, std::ofstream& outFile) {
```

```
	//3 if-statements to check if request is valid:

	if (numberOfVertices == 0) {

		std::cout << "Empty Graph - Cannot Add Edge: " << source << "," <<
destination << "," << weight << std::endl;
		outFile << "Empty Graph - Cannot Add Edge: " << source << "," <<
destination << "," << weight << std::endl;
		return;
	}
	if (source < 0 || destination < 0 || source > (numberOfVertices - 1) ||
destination > (numberOfVertices - 1)) {

		std::cout << "Invalid Source or Destination Vertex - Cannot Add Edge: " <<
source << "," << destination << "," << weight
				<< " - Edge request ignored" << std::endl;
		outFile << "Invalid Source or Destination Vertex - Cannot Add Edge: " <<
source << "," << destination << "," << weight
			<< " - Edge request ignored" << std::endl;
		return;
	}

	if (weight <= 0) {

		std::cout << "Invalid Weight - Cannot Add Edge: " << source << "," <<
destination << "," << weight
				<< " - Edge request ignored" << std::endl;
		outFile << "Invalid Weight - Cannot Add Edge: " << source << "," <<
destination << "," << weight
			<< " - Edge request ignored" << std::endl;
		return;
	}


	//otherwise add edges (keep in mind that if we reach here, num of vertices != 0
and all other valid checks have been passed):

	edge* edgePtr = &adjacencyListGraph[source]; //point to start of list for the
given source vertex

	while(true) {

		if (edgePtr->sourceVertex == -1) {

			edgePtr->sourceVertex = source;
			edgePtr->destinationVertex = destination;
			edgePtr->edgeWeight = weight;
			break;						//edge added;
break from loop
		}
		if (edgePtr->nextEdge == nullptr) {
			edgePtr->nextEdge = new edge(source, destination, weight);
			break;						//edge added;
break from loop
		}
		edgePtr = edgePtr->nextEdge;			//edge already occupied;
move to next edge and repeat loop
	}
```

```
	std::cout << "Edge Added: " << source << ", " << destination << ", " << weight << 
std::endl;
	outFile << "Edge Added: " << source << ", " << destination << ", " << weight << 
std::endl;

	//now add the additional edge since graph is undirected (destination, source, same 
weight):
	edgePtr = &adjacencyListGraph[destination]; //point to start of list for the given 
source vertex

	while (true) {

		if (edgePtr->sourceVertex == -1) {

			edgePtr->sourceVertex = destination; //notice how destination and 
source are reversed
			edgePtr->destinationVertex = source;
			edgePtr->edgeWeight = weight;
			break;						//edge added; 
break from loop
		}
		if (edgePtr->nextEdge == nullptr) {
			edgePtr->nextEdge = new edge(destination, source, weight);
			break;						//edge added; 
break from loop
		}
		edgePtr = edgePtr->nextEdge;		//edge already occupied; 
move to next edge and repeat loop
	}

	std::cout << "Edge Added: " << destination << ", " << source << ", " << weight << 
std::endl;
	outFile << "Edge Added: " << destination << ", " << source << ", " << weight << 
std::endl;

}

//Description: will print the adjacency list for the graph
//Pre-condition: graph must be a valid graph
//Post-condition: output adjacency list for the undirected graph
void graph::printGraph(std::ofstream& outFile) {

	std::cout << "Full Graph - Adjacency List: \n";
	outFile << "Full Graph - Adjacency List: \n";

	edge* edgePtr;	//use this pointer to navigate through linked list
	for (int i = 0; i < numberOfVertices; i++) {

		edgePtr = &adjacencyListGraph[i];	//set edge ptr to the current 
corresponding vertex
		std::cout << "Adj[" << i << "]-> ";		//print adjacency messages 
for the current vertex
		outFile << "Adj[" << i << "]-> ";

		while (edgePtr != nullptr && edgePtr->sourceVertex != -1) {
```

```
                    std::cout << "(" << edgePtr->destinationVertex << "," << edgePtr-
>edgeWeight << ")";
                    outFile << "(" << edgePtr->destinationVertex << "," << edgePtr-
>edgeWeight << ")";
                    edgePtr = edgePtr->nextEdge;      //move to next edge in the
adjacency list for the given vertex
              }
              std::cout << std::endl;
              outFile << std::endl;
       }



}

//Description: primes the MST (builds MST) using a priority queue implemented as a heap
//Pre-condition: must have a valid graph
//Post-condition: MST will be built and stored in the proper adjacency array
void graph::primMST(std::ofstream& outFile) {

       pqData extractedPQData, intoPQData;
       bool* mst;
       mst = new bool[numberOfVertices] {false};
       resultSetClass* resultSet;
       resultSet = new resultSetClass[numberOfVertices];
       int* weights;
       weights = new int[numberOfVertices] {INT_MAX};
}

//Description: print adjacency list of MST and other information to screen and the output
file
//Pre-condition: must have a valid graph
//Post-condition: MST adjacency list and MST value will be printed to user screen and
output file
void graph::printMST(std::ofstream& outFile) {}

graph::~graph() {

       //deallocate dynamically allocated memory from constructor
       delete[] adjacencyListGraph;
       delete[] adjacencyListMST;
}
```

RESULTSETCLASS H FILE:

```
#ifndef RESULTSETCLASS
#define RESULTSETCLASS

class resultSetClass
{
private:

       int parent;
       int weight;

public:

       resultSetClass();
```

```
};

#endif
```

Result set class cpp file:

```
#include "resultSetClass.h"

resultSetClass::resultSetClass() {

	parent = -1;
	weight = -1;

}
```

Edge class .H file:

```
#ifndef EDGE
#define EDGE
class edge
{

private:
	int sourceVertex;
	int destinationVertex;
	int edgeWeight;
	edge* nextEdge;
	friend class graph;  //make graph a friend of edge so that graph can access the
private members of this class
public:
	edge(); //default constructor
	edge(int source, int destination, int weight);


};

#endif
```

Edge class .CPP file:

```
#include "edge.h"


edge::edge() {

	sourceVertex = -1;
	destinationVertex = -1;
	edgeWeight = -1;
	nextEdge = nullptr;
```

```
}
edge::edge(int source, int destination, int weight) {

	sourceVertex = source;
	destinationVertex = destination;
	edgeWeight = weight;
	nextEdge = nullptr;


}
```

PQ DATA .H FILE:

```
#ifndef PQDATA
#define PQDATA
struct pqData
{
	int keyWeight;
	int keyDestinationVertex;
	int keySourceVertex;
};

#endif
```

9. Updated Algorithm

Copy and paste Initial Algorithm and make any updates to reflect the changes you made in your code. HIGHLIGHT THE CHANGES YOU MAKE! Strike out deleted statements. Any statements that just have a wording change – make change and highlight (i.e. no need to strike out individual word changes). This is the FINAL documentation of your program and needs to match what code you created.

10. Test Plan Version 3

Test Strategy	Test Number	Description	Input	Expected Output	Actual Output	Pass/Fail
File Testing	1	File does not exist	File name that does not exist	"File <user file name> cannot be opened or does not exist – program terminated"	See screenshot	pass
File Testing	2	File exists but empty	File name that	"File <user file name>	See screenshot	pass

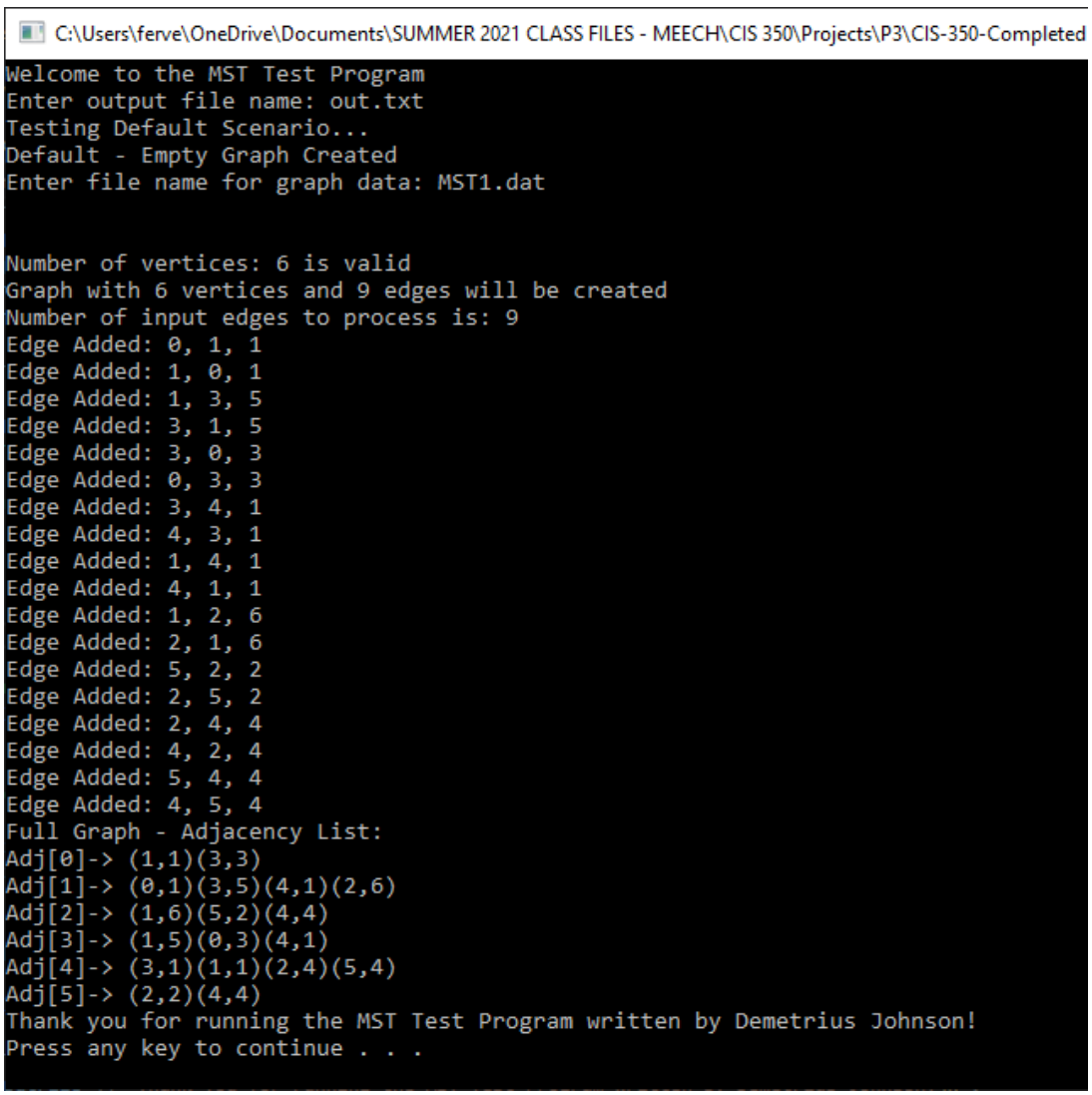
			exists but has no data	contains no data – program terminated”		
Valid data	3	Valid connected graph vertices and edges	File mst1.dat	MST with cost of 9	See screenshot	pass
Valid data	4	Empty graph – default constructor	Coded in program	“Empty Graph – No MST”	See screenshot	pass
Valid data	5	Display messages to user	Coded in program	All messages verified on screen and in output file	See screenshot	pass
Valid data	6	Print full graph	File mst2.dat	2 graph adjacency lists verified	See screenshot	pass
Valid data	7	Print MST	File mst2.dat	2 MST edge lists and adjacency lists and total cost of MSTs verified	See screenshot	pass
Invalid data	8	Invalid number of vertices	File mst4.dat	“Empty Graph – No MST”	See screenshot	pass
Invalid data	9	Invalid number of edges	File mst4.dat	“Empty Graph – No MST”	See screenshot	pass
Invalid data	10	Invalid edge source vertex	File mst3.dat	3 error edges	See screenshot	pass
Invalid data	11	Invalid edge destination vertex	File mst3.dat	2 error edges	See screenshot	pass
Invalid data	12	Invalid edge weight	File mst3.dat	2 error edges	See screenshot	pass

Invalid data	13	Try to add edges to empty graph	File mst4.dat Graph 0 5	Graph 0 5 edges cannot add edge error message	See screenshot	pass
Invalid data	14	Not enough edges for connected graph	File mst.4 Graph 5 3	"ERROR: 3 edges invalid to create connected graph"	See screenshot	pass

11. Screenshots

TEST 3, 4 – valid data and default empty graph created, and show output messages

MST1.dat :



CIS 350 – PROGRAM 3 – DEMETRIUS JOHNSON

TEST 6, 7 – valid data; multiple graphs

MST2.dat:

```
C:\Users\ferve\OneDrive\Documents\SUMMER 2021 CLASS FILES - MEECH\CIS 350\Projects\P3\CIS-350-Completed EX
Welcome to the MST Test Program
Enter output file name: outMST2.txt
Testing Default Scenario...
Default - Empty Graph Created
Enter file name for graph data: MST2.dat


Number of vertices: 6 is valid
Graph with 6 vertices and 7 edges will be created
Number of input edges to process is: 7
Edge Added: 0, 1, 4
Edge Added: 1, 0, 4
Edge Added: 2, 3, 4
Edge Added: 3, 2, 4
Edge Added: 1, 3, 2
Edge Added: 3, 1, 2
Edge Added: 0, 2, 3
Edge Added: 2, 0, 3
Edge Added: 4, 5, 6
Edge Added: 5, 4, 6
Edge Added: 1, 2, 1
Edge Added: 2, 1, 1
Edge Added: 3, 4, 2
Edge Added: 4, 3, 2
Full Graph - Adjacency List:
Adj[0]-> (1,4)(2,3)
Adj[1]-> (0,4)(3,2)(2,1)
Adj[2]-> (3,4)(0,3)(1,1)
Adj[3]-> (2,4)(1,2)(4,2)
Adj[4]-> (5,6)(3,2)
Adj[5]-> (4,6)


Number of vertices: 5 is valid
Graph with 5 vertices and 5 edges will be created
Number of input edges to process is: 5
Edge Added: 0, 1, 1
Edge Added: 1, 0, 1
Edge Added: 1, 3, 5
Edge Added: 3, 1, 5
Edge Added: 3, 0, 3
Edge Added: 0, 3, 3
Edge Added: 2, 4, 1
Edge Added: 4, 2, 1
Edge Added: 3, 4, 6
Edge Added: 4, 3, 6
Full Graph - Adjacency List:
Adj[0]-> (1,1)(3,3)
Adj[1]-> (0,1)(3,5)
Adj[2]-> (4,1)
Adj[3]-> (1,5)(0,3)(4,6)
Adj[4]-> (2,1)(3,6)
Thank you for running the MST Test Program written by Demetrius Johnson!
Press any key to continue . . .
```

TEST 10, 11, 12 – large graph with valid edges and vertices, but also some invalid edges to add and be ignored
MST3.dat:

```
C:\Users\ferve\OneDrive\Documents\SUMMER 2021 CLASS FILES - MEECH\CIS 350\Projects\P3\CIS-350-Completed EXE and TXT file
Welcome to the MST Test Program
Enter output file name: outMST3.txt
Testing Default Scenario...
Default - Empty Graph Created
Enter file name for graph data: MST3.dat


Number of vertices: 6 is valid
Graph with 6 vertices and 16 edges will be created
Number of input edges to process is: 16
Edge Added: 0, 1, 1
Edge Added: 1, 0, 1
Edge Added: 1, 3, 5
Edge Added: 3, 1, 5
Invalid Source or Destination Vertex - Cannot Add Edge: -3,1,4 - Edge request ignored
Edge Added: 3, 0, 3
Edge Added: 0, 3, 3
Edge Added: 3, 4, 1
Edge Added: 4, 3, 1
Invalid Source or Destination Vertex - Cannot Add Edge: 6,1,6 - Edge request ignored
Edge Added: 1, 4, 1
Edge Added: 4, 1, 1
Invalid Source or Destination Vertex - Cannot Add Edge: 1,-3,4 - Edge request ignored
Invalid Weight - Cannot Add Edge: 2,4,0 - Edge request ignored
Edge Added: 1, 2, 6
Edge Added: 2, 1, 6
Edge Added: 5, 2, 2
Edge Added: 2, 5, 2
Invalid Weight - Cannot Add Edge: 2,4,-3 - Edge request ignored
Edge Added: 2, 4, 4
Edge Added: 4, 2, 4
Invalid Source or Destination Vertex - Cannot Add Edge: 5,14,5 - Edge request ignored
Edge Added: 5, 4, 4
Edge Added: 4, 5, 4
Invalid Source or Destination Vertex - Cannot Add Edge: 15,3,7 - Edge request ignored
Full Graph - Adjacency List:
Adj[0]-> (1,1)(3,3)
Adj[1]-> (0,1)(3,5)(4,1)(2,6)
Adj[2]-> (1,6)(5,2)(4,4)
Adj[3]-> (1,5)(0,3)(4,1)
Adj[4]-> (3,1)(1,1)(2,4)(5,4)
Adj[5]-> (2,2)(4,4)
Thank you for running the MST Test Program written by Demetrius Johnson!
Press any key to continue . . .
```

TEST 8, 9, 13, 14 – testing graphs with 0 vertices or edges, invalid number of edges compared to vertices, and invalid vertex number
MST4.dat:

```
C:\Users\ferve\OneDrive\Documents\SUMMER 2021 CLASS FILES - MEECH\CIS 35...
Welcome to the MST Test Program
Enter output file name: outMST4.txt
Testing Default Scenario...
Default - Empty Graph Created
Enter file name for graph data: MST4.dat


Number of vertices: 0 is equal to zero
Empty Graph Will Be Created
Full Graph - Adjacency List:


ERROR: number of vertices: -1 is less than zero
Empty Graph Will Be Created
Empty Graph - Cannot Add Edge: 0,1,1
Empty Graph - Cannot Add Edge: 1,2,1
Empty Graph - Cannot Add Edge: 2,3,4
Full Graph - Adjacency List:


Number of vertices: 6 is valid
ERROR: number of edges: -4 is invalid to create connected graph
Empty Graph Will Be Created
Full Graph - Adjacency List:


Number of vertices: 5 is valid
ERROR: number of edges: 0 is invalid to create connected graph
Empty Graph Will Be Created
Full Graph - Adjacency List:


Number of vertices: 0 is equal to zero
Empty Graph Will Be Created
Empty Graph - Cannot Add Edge: 0,1,3
Empty Graph - Cannot Add Edge: 1,2,6
Empty Graph - Cannot Add Edge: 2,3,5
Empty Graph - Cannot Add Edge: 3,4,6
Empty Graph - Cannot Add Edge: 4,5,3
Full Graph - Adjacency List:


Number of vertices: 5 is valid
ERROR: number of edges: 3 is invalid to create connected graph
Empty Graph Will Be Created
Empty Graph - Cannot Add Edge: 0,3,5
Empty Graph - Cannot Add Edge: 0,4,6
Empty Graph - Cannot Add Edge: 1,2,4
Full Graph - Adjacency List:
Thank you for running the MST Test Program written by Demetrius Johnson!
Press any key to continue . . .
```

TEST 1 – file does not exist
Invalid output file name:

```
C:\Users\ferve\OneDrive\Documents\SUMMER 2021 CLASS FILES - MEECH\CIS 350\Projects\P3\CIS-350-Completed EXE and TXT files\CIS-
Welcome to the MST Test Program
Enter output file name: invalidInputFileTest.txt
Testing Default Scenario...
Default - Empty Graph Created
Enter file name for graph data: invalidname.dat
file invalidname.dat cannot be opened or does not exist - program terminated...
Press any key to continue . . .
```

TEST 2 – file exists but is empty:

```
C:\Users\ferve\OneDrive\Documents\SUMMER 2021 CLASS FILES - MEECH\CIS 350\Projects\P3\CIS-350-Completed
Welcome to the MST Test Program
Enter output file name: emptyFileTest.txt
Testing Default Scenario...
Default - Empty Graph Created
Enter file name for graph data: MSTempty.dat
file MSTempty.dat contains no data - program terminated...
Press any key to continue . . .
```

12. Error Log

Any issues you had while testing your code are recorded in the error log as you perform testing of the “completed” code – that is, when you run through all of the test cases in the test plan.

Error Type	Cause of Error	Solution to Error
Log 2 types of errors: Logic Runtime	What specifically caused the error to occur	What did you do/change to fix the error
Logic error	Told program to do cin.ignore; caused infinite loop	Meant to do inputfile.ignore()

Do not list any syntax errors or errors detected in unit testing as you build your program.

13. Status

Status is incomplete: I was able to do everything but make the priority queue and thus primMST and printMST functions were not completed. Everything else was completed and works fine. Just a matter of the time table, I should be able to complete the rest by this Saturday, July 24 and have 100% completion. Other than that, the rest of the program works exactly up to specification.