Algorithms and Data Structures

MST Report

Daniel Tilley – C14337041

Introduction

This java program uses Prims Algorithm to figure out the MST (Minimum Spanning Tree) of an undirected weighted graph. Prims Algorithm is a greed algorithm that uses heaps and arrays along with linked lists to return the desired result. It starts at a node that is entered by the user, goes through all other nodes on the graph and calculates an MST accordingly. The graph is read in from a text file (explained below) and once the file has been read it will display the vertices and edge positions using heaps, arrays and linked lists. The program will then begin to execute the algorithm and return the MST along with the MST weight.

The Graph

Below is the graph I used to test my java program. It consists of 7 vertices and 9 edges. On the left we have the graph written down in number form. The first line indicates the number of vertices and the number of edges. From then on, each line is an indication of which vertex is connected to which vertex and how much weight their shared edge has. For example, the second line tells us that point 1 (vertex A) is connected to point 2 (vertex B) and has a weight of 3. This holds true for all lines that follow also.

7 9

1 2 3

1 4 7

1 5 5

2 3 9

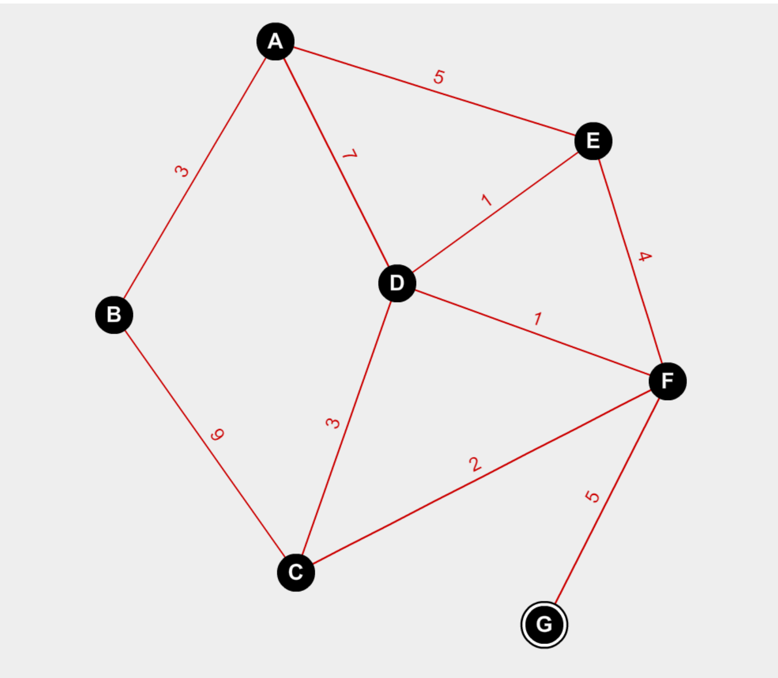
3 4 3

3 6 2

4 5 1

5 6 4

6 7 5



MST Graph and Construction

In order to implement prims algorithm in Java, you first need to create a few arrays and classes in order for it to work. The steps taken by the algorithm are listed below:

1. Initialise a tree with one vertex chosen by user.
2. Add one edge to the tree that connects the previous vertex to vertices that are not in the tree yet.
3. Repeat step 2 until all edges have been added

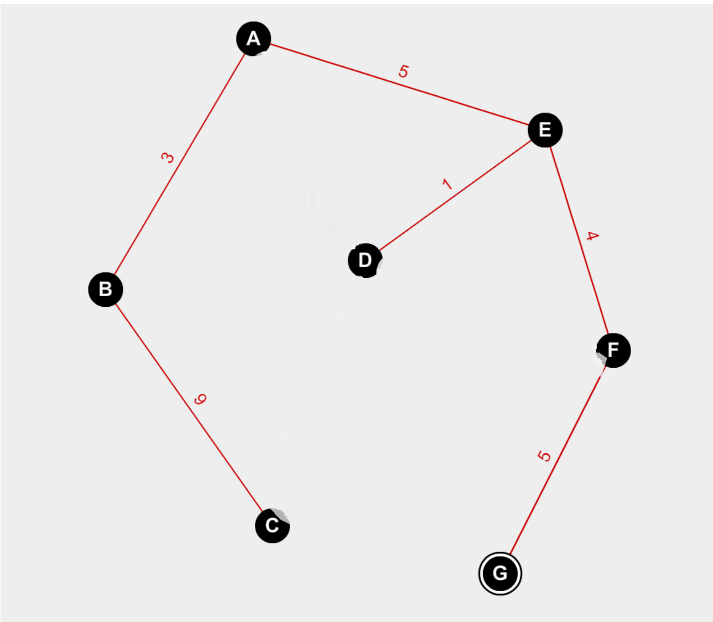
Heap h : This is a class that is used as a representation of the heap. It is used to find the next nearest vertex to the current vertex so that it can be added to the MST.

hPos[] : This is an integer array that is used to store the position of the vertices within the heap. This array is used in conjunction with the heap array a[] and it can be said that a point on the heap is stored at hPos[v] in the array a[].

Dist[] : This is an integer array that records the current distance of a vertex that is used in the MST

Parent[] : This is an integer array that is the used as a final storage place to hold the MST.

Below is a graphical representation of a MST given that you start from point A. The total weight is 27.



Below are the contents of both the parent[] and dist[] arrays after each transversal of the graph. I used simple for loops to print out the contents in Java. The max int value has been used when initialising the dist[] array.

```
Parent[] Array Traverse 1
A -> @
B -> A
C -> @
D -> A
E -> A
F -> @
G -> @

Dist[] Array Traverse 1
1 -> -1
2 -> 3
3 -> 2147483647
4 -> 7
5 -> 5
6 -> 2147483647
7 -> 2147483647
```

```
Parent[] Array Traverse 2
A -> @
B -> A
C -> @
D -> E
E -> A
F -> E
G -> @

Dist[] Array Traverse 2
1 -> -1
2 -> 1
3 -> 2147483647
4 -> 1
5 -> 0
6 -> 4
7 -> 2147483647
```

```
Parent[] Array Traverse 3
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> @

Dist[] Array Traverse 3
1 -> -1
2 -> 0
3 -> 9
4 -> 1
5 -> 0
6 -> 4
7 -> 2147483647
```

```
Parent[] Array Traverse 4
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> @

Dist[] Array Traverse 4
1 -> -1
2 -> 0
3 -> 1
4 -> 0
5 -> 0
6 -> 4
7 -> 2147483647
```

```
Parent[] Array Traverse 5
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> @

Dist[] Array Traverse 5
1 -> -1
2 -> 0
3 -> 0
4 -> 0
5 -> 0
6 -> 1
7 -> 2147483647
```

```
Parent[] Array Traverse 6
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> F

Dist[] Array Traverse 6
1 -> -1
2 -> 0
3 -> 0
4 -> 1
5 -> 0
6 -> 0
7 -> 5
```

```
Parent[] Array Traverse 7
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> F

Dist[] Array Traverse 7
1 -> -1
2 -> 0
3 -> 0
4 -> 0
5 -> 0
6 -> 0
7 -> 1
```

```
Parent[] Array Traverse 8
A -> @
B -> A
C -> B
D -> E
E -> A
F -> E
G -> F

Dist[] Array Traverse 8
1 -> -1
2 -> 0
3 -> 0
4 -> 0
5 -> 0
6 -> 0
7 -> -1
```

Execution of code and Adjacency list diagram

Below you can see what the code output looks like when run from the command line.

```
C:\Users\Daniel\Desktop\C14337041 Algorithims Assignment>javac PrimsAlgorithm.java

C:\Users\Daniel\Desktop\C14337041 Algorithims Assignment>java PrimsAlgorithm

Enter file name to read in: myGraph.txt

Number of verticies: 7
Number of edges: 9

Reading edges from text file
Edge A <-> (Wgt: 3) <-> Edge: B
Edge A <-> (Wgt: 7) <-> Edge: D
Edge A <-> (Wgt: 5) <-> Edge: E
Edge B <-> (Wgt: 9) <-> Edge: C
Edge C <-> (Wgt: 3) <-> Edge: D
Edge C <-> (Wgt: 2) <-> Edge: F
Edge D <-> (Wgt: 1) <-> Edge: E
Edge E <-> (Wgt: 4) <-> Edge: F
Edge F <-> (Wgt: 5) <-> Edge: G

Enter the vertex to start at using numbers (A = 1, B = 2 E.T.C) : 1

Adjacency Lists:
[A] -> (Vert: E)(Wgt: 5) -> (Vert: D)(Wgt: 7) -> (Vert: B)(Wgt: 3) ->
[B] -> (Vert: C)(Wgt: 9) -> (Vert: A)(Wgt: 3) ->
[C] -> (Vert: F)(Wgt: 2) -> (Vert: D)(Wgt: 3) -> (Vert: B)(Wgt: 9) ->
[D] -> (Vert: E)(Wgt: 1) -> (Vert: C)(Wgt: 3) -> (Vert: A)(Wgt: 7) ->
[E] -> (Vert: F)(Wgt: 4) -> (Vert: D)(Wgt: 1) -> (Vert: A)(Wgt: 5) ->
[F] -> (Vert: G)(Wgt: 5) -> (Vert: E)(Wgt: 4) -> (Vert: C)(Wgt: 2) ->
[G] -> (Vert: F)(Wgt: 5) ->

Total weight of MST: 27

The Minimum Spanning tree array is:
@ -> A
A -> B
B -> C
E -> D
A -> E
E -> F
F -> G
```

Conclusion

This assignment has been very useful for a number of reasons. The first thing I found helpful about the assignment was re-enforcing my knowledge of how to use the command line with Java. It also made me think about what methods I had to use whilst writing the code in Java as Eclipse or most other Java IDE's will give you hints when typing out code.

Secondly, this assignment has vastly improved my knowledge on heaps and of course prims algorithm. The heap is a very powerful data structure coding and executing the program has helped me to realise this as well as some different ways of using the heap.

Finally I have learned how to take a graph and change it to a format that is readable through text. This can be very helpful and powerful when creating programs in the future.

Code

```
//Simple weighted graph representation
//Uses an Adjacency Linked Lists, suitable for sparse graphs
//Prims Algorithim
//Daniel Tilley
//C14337041

import java.io.*;
import java.util.Scanner;

class Heap {
	public int[] h; // heap array
	public int[] hPos; // hPos[h[k]] == k
	public int[] dist; // dist[v] = priority of v

	private int N; // heap size

	// The heap constructor gets passed from the Graph:
	//    1. maximum heap size
	//    2. reference to the dist[] array
	//    3. reference to the hPos[] array
	public Heap(int maxSize, int[] dist, int[] hPos) {
		N = 0;
		h = new int[maxSize + 1];
		this.dist = dist;
		this.hPos = hPos;
	}//end constructor

	public boolean isEmpty() {
		return (N == 0);
	}//end id empty

	//Method used from previous lab test
	public void siftUp(int k) {
```

```
        int v = h[k];
        h[0] = 0;
        dist[0] = 0;

        while (dist[v] < dist[h[k / 2]]) {
                h[k] = h[k / 2];
                hPos[h[k]] = k;
                k = k / 2;
        }//end while

        h[k] = v;
}//end sift up

//Method used from previous lab test
public void siftDown(int k) {
        int v;
        v = h[k];
        h[0] = Integer.MAX_VALUE;

        while (k <= N / 2) {
                int j = 2 * k;
                if (j < N && dist[h[j]] > dist[h[j + 1]]) {
                        j++;
                }//end if

                if (dist[v] <= dist[h[j]]) {
                        break;
                }//end if

                h[k] = h[j];
                hPos[h[k]] = k;
                k = j;
        }//end while

        h[k] = v;
        hPos[v] = k;
}//end sift down

public void insert(int x) {
        h[++N] = x;
        siftUp(N);
```

```
        }//end insert

        public int remove() {
                int v = h[1];
                hPos[v] = 0; // v is no longer in heap
      h[N+1] = 0;  // put null node into empty spot

                h[1] = h[N--];
                siftDown(1);

                return v;
        }//end remove
}//end class heap


class Graph {
        class Node {
                public int vertex; // vertex variable
                public int weight; // weight variable
                public Node next; //next node in array

                //node constructor
                Node(int vertex, int weight, Node n) {
                        this.vertex = vertex;
                        this.weight = weight;
                        next = n;
                }//end node constructor

                //default constructor
                Node(){

                }//end default constructor
        }//end class node

        // V = number of vertices
   // E = number of edges
   // adj[] is the adjacency lists array
        private int V, E;
        private Node[] adj;
        private Node z;
        //Array to hold MST
```

```
	private int[] MST;

	//Used for calculating size of array
	private int count = 0;
	private int last = Integer.MIN_VALUE;

	// used for moving through graph
	private int[] visited;
	private int id;

	//size of graph array
	public int getCount() {
		return (count);
	}//end get count

	//return last vertex in graph
	public int getLast() {
		return (last);
	}//end get last


	public Graph(String graphFile) throws IOException {
		int u, v;
		int e, weight;
		Node t;

		//for reading  in data from file
		FileReader fr = new FileReader(graphFile);
		BufferedReader reader = new BufferedReader(fr);

		//multiple whitespace as delimiter
		String splits = " +";
		String line = reader.readLine();
		String[] parts = line.split(splits);
		System.out.println("Number of verticies: " + parts[0] + "\nNumber of edges: "
+ parts[1] + "\n");

		V = Integer.parseInt(parts[0]);
		E = Integer.parseInt(parts[1]);

		//create sentinel node
```

```
            z = new Node();
            z.next = z;

            //create adjacency lists, initialised to sentinel node z
            adj = new Node[V + 1];
            for (v = 1; v <= V; ++v)
            adj[v] = z;

            // read the edges
            System.out.println("Reading edges from text file");
            //loops through all elements in array
            for (e = 1; e <= E; ++e) {
                line = reader.readLine();
                parts = line.split(splits);
                u = Integer.parseInt(parts[0]);//first vertex
                v = Integer.parseInt(parts[1]);//second vertex
                weight = Integer.parseInt(parts[2]);//weight

                System.out.println("Edge " + toChar(u) + " <-> (Wgt: " + weight + ") <->
Edge: " + toChar(v));

                //figure out which node is the biggest
                if (u > last){
                    last = u;
                }//end if

                if (v > last){
                    last = v;
                }//end if

                //update adjacency array
                adj[v] = new Node(u, weight, adj[v]);
                adj[u] = new Node(v, weight, adj[u]);

                //increment number of elements in array
                count++;
            }//end for
        }//end Graph Class

        // convert vertex into char for pretty printing
        private char toChar(int u) {
```

```
		return (char)(u + 64);
	}//end toChar

	// method to display the graph representation
	public void display() {
		int v;
		Node n;

		//print out adjacency lists
		System.out.print("\nAdjacency Lists:");
		for (v = 1; v <= V; ++v) {
			System.out.print("\n[" + toChar(v) + "] ->");
			for (n = adj[v]; n != z; n = n.next){
				System.out.print(" (Vert: " + toChar(n.vertex) + ")(Wgt: " +
n.weight + ") ->");
			}//end for
		}//end for
	}//end display

	public void MST_Prim(int s, int count) {

		int v, u;
		int weight, wgt_sum = 0;
		//create new arrays for storing graph data
		int[] dist = new int[count];
		int[] parent = new int[count];
		int[] hPos = new int[count];
		Node t;

		int countVar = 1; //variable used to calculate traverse

		//initialise arrays
		for (v = 0; v <= V; v++) {
			dist[v] = Integer.MAX_VALUE;
			parent[v] = 0;
			hPos[v] = 0;
		}//end for

		//create a new heap and insert last element (s)
		Heap h = new Heap(V, hPos, dist);
		h.insert(s);
```

```
		dist[s] = 0;
		Heap pq = new Heap(V, dist, hPos);
		pq.insert(s);

		//Most of alogrithim here
		//run while heap is empty
		while (!h.isEmpty()) {
			v = h.remove();
			dist[v] = -dist[v];
			Node n;
			int w;

			//run loop while node is not equal to the sentinal node
			for (n = adj[v]; n != z; n = n.next) {

				u = n.vertex;
				w = n.weight;

				//check if current weight is less that distance stored in array
				if (w < dist[u]) {
					if (dist[u] != Integer.MAX_VALUE) {
						wgt_sum -= dist[u];
					}//end if

					dist[u] = w;
					parent[u] = v;
					wgt_sum += w;

					//if node is at position 0 in array, insert into array
					if (hPos[u] == 0) {
						h.insert(u);
					}//end if

					//otherwise sift the element up the graph until it
reaches position 0
					else {
						h.siftUp(hPos[u]);
					}//end else
				}//end if
			}//end for
```

```
		//print out the traverse of each array

	///////////////////////////////////////////////////////////////////////////////////////
				System.out.println("");
				System.out.println("Parent[] Array Traverse " + countVar);
				for(int i = 1; i <= V; i ++){
					System.out.println( toChar(i) + " -> " + toChar(parent[i]));
				}//end for

				System.out.println("");
				System.out.println("Dist[] Array Traverse " + countVar);
				for(int j = 1; j <= V; j ++)  {
					System.out.println(j + " -> " + dist[j]);
				}//end for

				//update count var
				countVar++;

	///////////////////////////////////////////////////////////////////////////////////////
		}//end while

		//set count var back to 1 for error checking
		countVar = 1;

		//end of algorithim and print out results
		System.out.print("\n\nTotal weight of MST: " + wgt_sum);
		MST = parent;
	}

	//display min spanning tree
	public void displayMST() {
		System.out.println("\n\nThe Minimum Spanning tree array is:");
		for (int v = 1; v <= V; ++v) {
			System.out.println(toChar(MST[v]) + " -> " + toChar(v)); // copied and
changed from skeleton code
		}//end for
	}//end display MST
}//End Class Graph


public class PrimsAlgorithm {
```

```
	// get user input
	public static String getInput(String userFile) throws IOException {
		Console console = System.console();
		String input = console.readLine(userFile);
		return input;
	}//end getInput

	//main method
	public static void main(String[] args) throws IOException {

		// error handling
		System.out.println(" ");
		String fname = new String(getInput("Enter file name to read in: "));
		System.out.println(" ");

		//variables
		boolean checkFile = true; //used to check if file has been read or not
		Graph graph = null;

		//while loop that checks for any user errors when entering the file name
		while (checkFile) {

			//file name to read in graph
			String newfName = new String();
			try {
				graph = new Graph(fname);
				//update checkFile so that loop wont run again if there is an
error when reading the file
				checkFile = !checkFile;
			}//end try

			// checks if the file name is incorrect
			catch (IOException e) {
				try {
					newfName = getInput("File not found, enter a file
name: ");
				}//end try

				catch (IOException f) {
					System.out.println("Invalid input");
				}//end inner catch
```

```
                        //change fname to new file name
                        fname = newfName;
                }//end outter catch
        }//end while

        //copied from skeleton code to stop errors in code
        if (graph == null) {
                graph = new Graph("wgraph3.txt");
        }//end if

        checkFile = true;
        int getNum = graph.getLast();

        //loop to calculate MST
        while (checkFile) {
                getNum = 0;

                try {
                        System.out.println(" ");
                        getNum = Math.abs(Integer.parseInt(getInput("Enter the
vertex to start at using numbers (A = 1, B = 2 E.T.C) : ")));
                        checkFile = false;
                }//end try

                //checks user has not enetered a string or character
                catch (IOException f) {
                        System.out.println("Invalid input, must be of type integer");
                }//end catch

                //checks the number is not higher than elements in array
                if (checkFile == false && getNum > graph.getLast()) {
                        System.out.println("Number is too high, please enter a
number under  " + (graph.getLast() + 1));
                        checkFile = true;
                }//end if
        }//end while

        // updaters
        graph.display();
        graph.MST_Prim(getNum, graph.getCount());
```

```
            graph.displayMST();
        }//end main
}//end class Prims Algorithim
```