ASSIGNMENT 4: SEARCHING WITH GRAPHS

CS3D5A, Trinity College Dublin

Deadline: 22:00 29/11/2023

Grading: The assignment will be graded on Submitty based on your code and your report, and based on your demo during the lab hours of 01/12/23

Questions: You will able to ask questions during the lab hours on 24/11/2023

Submission: Submit via Submitty. Include the files specified for each task, and the short assignment report in pdf, word, or text file.
The report should indicate for task 1 and 2 the outputs you obtained. For task 3 it should document your approach and results.

Goals:

- Learn how to implement a graph, weighted and unweighted, directed and undirected
- Become familiar and learn how to implement graph traversals
- Learn how to implement Dijkstra and use it on a real-world example

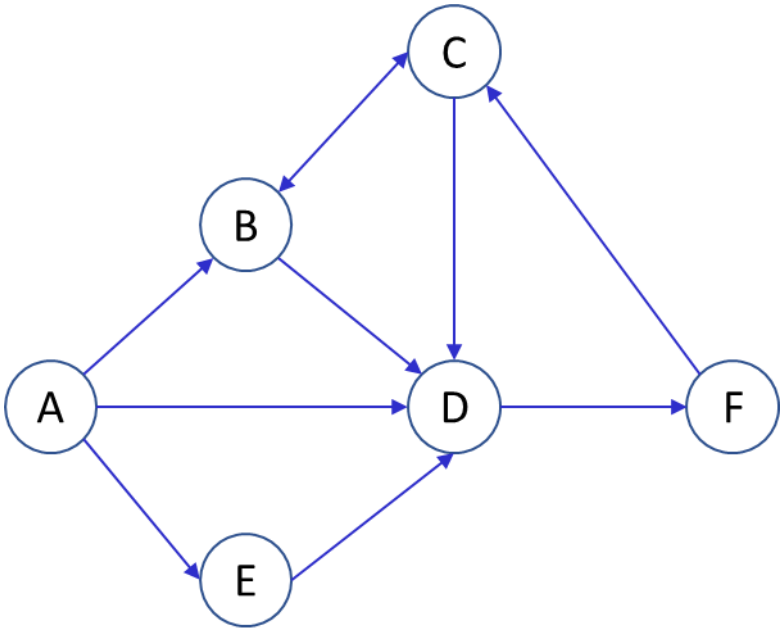
Task 1 – BFS and DFS – 6 marks

Edit the `Graph` type in `t1.h` to represent graphs using **adjacency lists**, and create a file `t1.c` that implements the following functions:

- `Graph* create_graph(int num_nodes);` // creates a graph with num_nodes nodes, assuming nodes are stored in alphabetical order (A, B, C..)
- `void add_edge(Graph *g, int from, int to);` // adds a directed edge
- `void bfs(Graph* g, int origin);` //implements breath first search and prints the results
- `void dfs(Graph* g, int origin);` //implements depth first search and prints the results
- `void delete_graph(Graph* g);` // delete the graph and all its data structures.

For both dfs and bfs, when several node choices are available, use alphabetical order to choose a node to process. Print the nodes in the order you visit them.

Submitty will test your algorithms on the graph below, by performing both a Depth First Search and a Breath First search with A as the start vertex, as per the `t1_test.c` file. Note that Submitty might also test your code on other graphs!



Sample output:

```
DFS: A B C D F E
BFS: A B D E C F
```

Submit the edited `t1.h` and your `t1.c` on Submitty for task 1 (you may submit other .c and .h files but do NOT submit the file which contains your main).

Task 1 mark allocations	
Building a graph with the functions above	1
Correct Depth First Search implementation	2
Correct Breadth First Search implementation	2
No memory loss	1

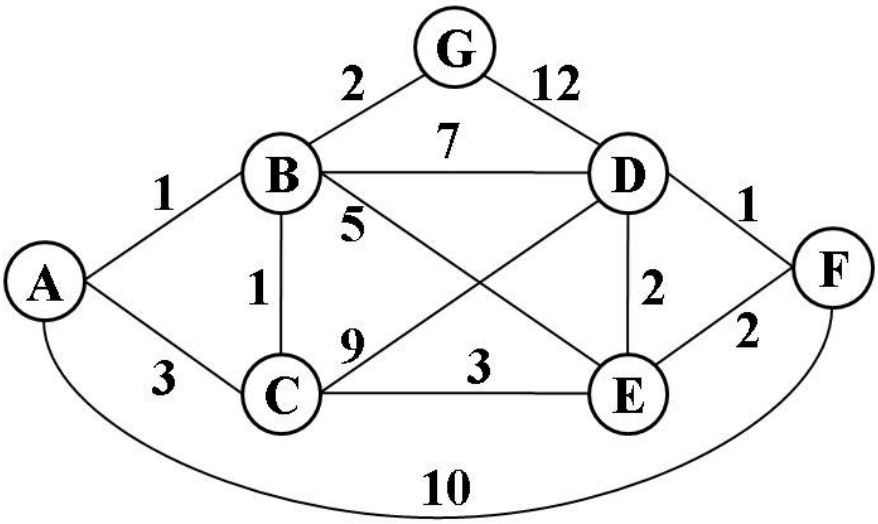
Task 2 – Dijkstra – 5 marks

Edit the `Graph` type in `t2.h` to represent graphs using an **adjacency matrix**, and create a file `t2.c` that implements the following functions:

- `Graph* create_graph(int num_nodes);` // creates a graph with num_nodes nodes, assuming nodes are stored in alphabetical order (A, B, C..)
- `void add_edge(Graph *g, int from, int to, int weight);` // adds a weighted edge between from and to
- `void dijkstra(Graph* g, int origin);` //implements the dijkstra algorithm and prints the order in which the nodes are made permament, and the length of the shortest path between the origin node and all the other nodes
- `void delete_graph(Graph* g);` // delete the graph and all its data structures.

When several node choices are available, use alphabetical order to choose a node to process. Your algorithm should output the list of the nodes in the order in which they were made permanent, and the shortest distance from the start node to each of the other nodes.

Submitty will test your submission on the graph below, as per the `t2_test.c` file, but also potentially on other graphs!



Sample output:

```
A B C G E D F
The length of the shortest path between A and A is 0
The length of the shortest path between A and B is 1
The length of the shortest path between A and C is 2
The length of the shortest path between A and D is 7
The length of the shortest path between A and E is 5
The length of the shortest path between A and F is 7
The length of the shortest path between A and G is 3
```

Submit the edited `t2.h` and your `t2.c` on Submitty for task 2 (you may submit other .c and .h files but do NOT submit the file which contains your main).

Task 2 mark allocations	
Building a graph with the functions above	1
Correct Dijkstra implementation	3
No memory loss	1

Task 3 – On the buses – 4 marks

Dublin Bus now provides real-time updates on the location and expected time of arrival for their buses. Google Maps use this information to advise you on the best sequence of buses/trains to take in order to reach your desired destination in the shortest possible time. This is achieved by viewing Dublin as being comprised of a number of nodes in a graph (locations) and edges between those nodes (roads/bus routes/train tracks). Each edge has a weight which depends on how long it will take you to travel towards your intended destination via that route. Given nodes, edges and weights, Dijkstra's algorithm can be used to determine the optimal route to get you from where you are to where you want to be.

For this assignment you have been provided with two files – one contains a list of all bus stops in Dublin (nodes) and the other contains a list of routes between those bus stops (edges). The weights on each of the edges is the distance in metres between each bus stop.

(This is real data which is publicly available via a live API. You can grab more complete information from here if you are interested in extending this problem: https://data.smartdublin.ie/)

Your task is to load the data from both files and use them to build a graph which models the public transport system of Dublin city. Then, using Dijkstra's algorithm on the graph, print the optimal sequence of bus stops from a given source to a given destination.

To do so, implement the functions in `t3.h`:

`int load_edges ( char *fname );` //loads the edges from the CSV file of name fname

`int load_vertices ( char *fname );` //loads the vertices from the CSV file of name fname

`void shortest_path(int startNode, int endNode);` // prints the shortest path between startNode and endNode, if there is any

`void free_memory ( void );` // frees up any memory that was used

The sample output below shows the route to get from stop 300 (Eden Quay) to stop 253 (Beaumont Hospital). Stops are provided with latitude and longitude information so you can actually check your route on Google Maps if you wish. Submitty will test with these values as per the `t2_test.c` file, and others.

Note that we are taking a very simplistic, unrealistic view of how the bus service in Dublin works. We don't account for how long you will need to wait at a stop before a bus arrives. We don't account for traffic. We assume that a bus follows the exact same route in both directions. Don't overcomplicate this for yourself. It can be implemented very naturally based on the code you have written for task 2.

Keep in mind that this is an **undirected** graph. So when you load an edge from the edges file, you must ensure that both nodes contain a reference to each other.

Sample output from stop 300 (Eden Quay) to stop 253 (Beaumont Hospital)

```
Loaded 4806 vertices
Loaded 6179 edges
 300 Eden Quay          53.348269 -6.255763
 497 Amiens Street      53.350503 -6.250701
 515 Amiens Street      53.353504 -6.248089
 516 North Strand Rd    53.355680 -6.245662
4384 North Strand Rd    53.357671 -6.242686
 519 North Strand Rd    53.360302 -6.239553
 521 Annesley Bridge    53.361625 -6.237989
 522 Marino Mart        53.363272 -6.235341
 523 Marino Mart        53.364281 -6.231608
 669 Malahide Road      53.366311 -6.228657
 670 Malahide Road      53.368950 -6.226009
 671 Malahide Road      53.370719 -6.224138
 672 Malahide Road      53.373465 -6.221061
4382 Malahide Road      53.374900 -6.219600
1185 Collins Ave        53.376371 -6.221506
1186 Collins Ave        53.377642 -6.226322
1187 Collins Ave        53.378606 -6.231340
1188 Collins Ave        53.380014 -6.235577
1189 Collins Ave        53.380722 -6.237977
 216 Beaumont Road      53.382329 -6.238176
 217 Beaumont Road      53.384324 -6.236780
 242 Beaumont Road      53.385650 -6.231992
 243 Beaumont Road      53.385779 -6.229525
 253 Beaumont Hospital  53.389942 -6.224379
```

Submit the potentially edited `t3.h` and your `t3.c` on Submitty for task 3 (you may submit other .c and .h files but do NOT submit the file which contains your main).

Task 3 mark allocations	
Loading data from files (it's in CSV format so just use the parser we've already written), and able to choose locations based on stop ID	1
Printing the optimal route between two given bus stops	3