

## Requirements

1) In the folder “designs”, I have 4 designs. The image “problem.jpg” lays out the problem I am attempting to solve. Outside of the folder there is an image called “vvardenfellmap.png”, which is the picture of the map/graph from the video game. The image “GraphStructue.jpg” is the design behind how the code files work together to represent a graph. “ShortestPathDesign.pdf” is my design for the shortest path function. “MinSpanningTreeDesign.pdf” is my design for the minimum spanning tree function.

2) I have at least two tests for each piece of functionality.

### add\_node

```
49     cout << "\n-----Adding nodes: A, B, C, D, E, F-----" << endl;
50     alphabet_graph.add_node("A");
51     alphabet_graph.add_node("B");
52     alphabet_graph.add_node("C");
53     alphabet_graph.add_node("D");
54     alphabet_graph.add_node("E");
55     alphabet_graph.add_node("F");
56
57     cout << "\n-----Testing that the nodes have been added to alphabet_graph-----" << endl;
58     cout << "alphabet_graph.get_size(): " << alphabet_graph.get_size() << endl;
59     cout << "alphabet_graph.get_nodes().at(0)->get_name(): " << alphabet_graph.get_nodes().at(0)->get_name() << endl;
60     cout << "alphabet_graph.get_nodes().at(5)->get_name(): " << alphabet_graph.get_nodes().at(5)->get_name() << endl;
61
83     cout << "\n-----Adding nodes: A, B, C, D, E-----" << endl;
84     alphabet_graph_2.add_node("A");
85     alphabet_graph_2.add_node("B");
86     alphabet_graph_2.add_node("C");
87     alphabet_graph_2.add_node("D");
88     alphabet_graph_2.add_node("E");
89
90     cout << "\n-----Testing that the nodes have been added to alphabet_graph_2-----" << endl;
91     cout << "alphabet_graph_2.get_size(): " << alphabet_graph_2.get_size() << endl;
92     cout << "alphabet_graph_2.get_nodes().at(0)->get_name(): " << alphabet_graph_2.get_nodes().at(0)->get_name() << endl;
93     cout << "alphabet_graph_2.get_nodes().at(3)->get_name(): " << alphabet_graph_2.get_nodes().at(3)->get_name() << endl;
94
```

### connect\_nodes

```
95     cout << "\n-----Connecting nodes-----" << endl;
96     alphabet_graph_2.connect_nodes("A", "B", 10);
97     alphabet_graph_2.connect_nodes("A", "C", 5);
98     alphabet_graph_2.connect_nodes("A", "D", 3);
99     alphabet_graph_2.connect_nodes("B", "C", 4);
100    alphabet_graph_2.connect_nodes("B", "D", 1);
101    alphabet_graph_2.connect_nodes("C", "E", 1);
102    alphabet_graph_2.connect_nodes("D", "E", 2);
103
104    cout << "\n-----Testing that the nodes have been connected. Expected: source=D ; destination=B ; weight=1-----" << endl;
105    cout << "alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->source->get_name(): " << alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->source->get_name() << endl;
106    cout << "alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->destination->get_name(): " << alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->destination->get_name() << endl;
107    cout << "alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->weight: " << alphabet_graph_2.get_nodes().at(3)->get_neighbors().at(1)->weight << endl;
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```

I test shortest\_path and min\_spanning\_tree on two different graphs.

3) In the folder “code\_files” there is a file “graph.h” which defines the Graph class.

3.1) In the Graph class there is a function called add\_node. The function takes in a string, makes that input the name of a new node, and adds that node to a list of nodes.

```
33 // adds a GraphNode to the class
34 void add_node(string new_name) {
35     GraphNode *new_node = new GraphNode(new_name); // create node using inputted string
36     nodes.push_back(new_node); // add to end of nodes list
37 }
38
```

3.2) In the Graph class there is a function called connect\_nodes. This function adds two edges between nodes. It ensures that the graph is not directed.

```
39 // adds an edge between two GraphNodes
40 void connect_nodes(string source_name, string dest_name, int weight) {
41     GraphNode *source_node = nullptr;
42     GraphNode *dest_node = nullptr;
43
44     // find source and destination node addresses
45     for(auto current : nodes) {
46         if(source_name == current->get_name()) {
47             source_node = current;
48         }
49
50         if(dest_name == current->get_name()) {
51             dest_node = current;
52         }
53     }
54
55     // connect source to destination (undirected graph)
56     // this method creates two edge objects. So... not very efficient
57     if (source_node != nullptr && dest_node != nullptr) {
58         source_node->add_edge(dest_node, weight);
59         dest_node->add_edge(source_node, weight);
60     }
61 }
```

3.3) In the Graph class there is a function called shortest\_path. It takes in a string that should be the name of a node in the graph. It then finds the shortest path and distances from the node to all other nodes. It will return a string of that information.

```

68 // shortest path (implements Dijkstra's algorithm) returns a string that represents the
69 string shortest_path(string source_name) {
70     GraphNode *source_node = nullptr;
71
72     for(auto node : nodes) {
73         if(source_name == node->get_name()) { // finds source node's address
74             source_node = node;
75         }
76         node->set_distance(numeric_limits<int>::max()); // sets all node's distances to max
77         node->set_previous(nullptr); // sets all node's previous's to nullptr
78     }
79
80     // set source node's distance to 0
81     source_node->set_distance(0);
82
83     // queue of unvisited nodes
84     vector<GraphNode *> queue = nodes;
85
86     // finds the shortest distance from the source node to all other nodes
87     GraphNode *current = source_node;
88     while (queue.size() != 0) { // if all nodes have been visited the algorithm should stop
89
90         for (auto edge : current->get_neighbors()) { // iterates through "current's" neighbors
91             GraphNode *dest = edge->destination; // create destination node
92             if (dest->get_distance() > current->get_distance() + edge->weight) { // if current distance is less than the distance through the current node
93                 dest->set_distance(current->get_distance() + edge->weight); // update distance
94                 dest->set_previous(current); // update destination's previous
95             }
96         }
97
98         int count = 0;
99         int current_index = 0;
100         for (auto node : queue) {
101             if (node == current) { // finds index of the current

```

3.4) In the Graph class there is a function called `min_spanning_tree`. It will return the minimum spanning tree as a string.

```

153 // minimum spanning tree (implements Prim's algorithm) returns a string that represents the
154 string min_spanning_tree() {
155     GraphNode *source_node = nodes[0]; // source node is the first node added to the graph
156     vector<GraphNode *> visited; // list of visited nodes
157     visited.push_back(source_node);
158     vector<edge *> tree_edges; // list of edges in the minimum spanning tree
159     GraphNode *current = source_node;
160
161     int floating_nodes = 0;
162     for (auto node : nodes) { // checking if there are any nodes not connected to the tree
163         int neighbor_size = node->get_neighbors().size();
164         if (neighbor_size < 1) {
165             floating_nodes += 1;
166         }
167     }
168
169     // Prim's algorithm
170     while (visited.size() < nodes.size() - floating_nodes) { // the algorithm should stop when all nodes are visited
171         edge *lightest_edge_1 = new edge(); // lightest edge 1
172         edge *lightest_edge_2 = new edge(); // lightest edge 2
173         if (visited.size() > 1) {
174             for (auto visited_node : visited) { // iterates through the visited nodes
175                 for (auto neighbor : visited_node->get_neighbors()) { // iterates through the neighbors of the visited node
176                     bool contains = false;
177                     for (auto tree_edge : tree_edges) { // checks if neighbor is already in the tree
178                         if (tree_edge == neighbor) {
179                             contains = true;
180                         }
181                     }
182                     for (auto node : visited) { // checks if destination has already been visited
183                         if (node == neighbor->destination) {
184                             contains = true;
185                         }
186                     }

```

4) In “complexity.pdf”, I analyze the complexity of the behaviors of the graph.