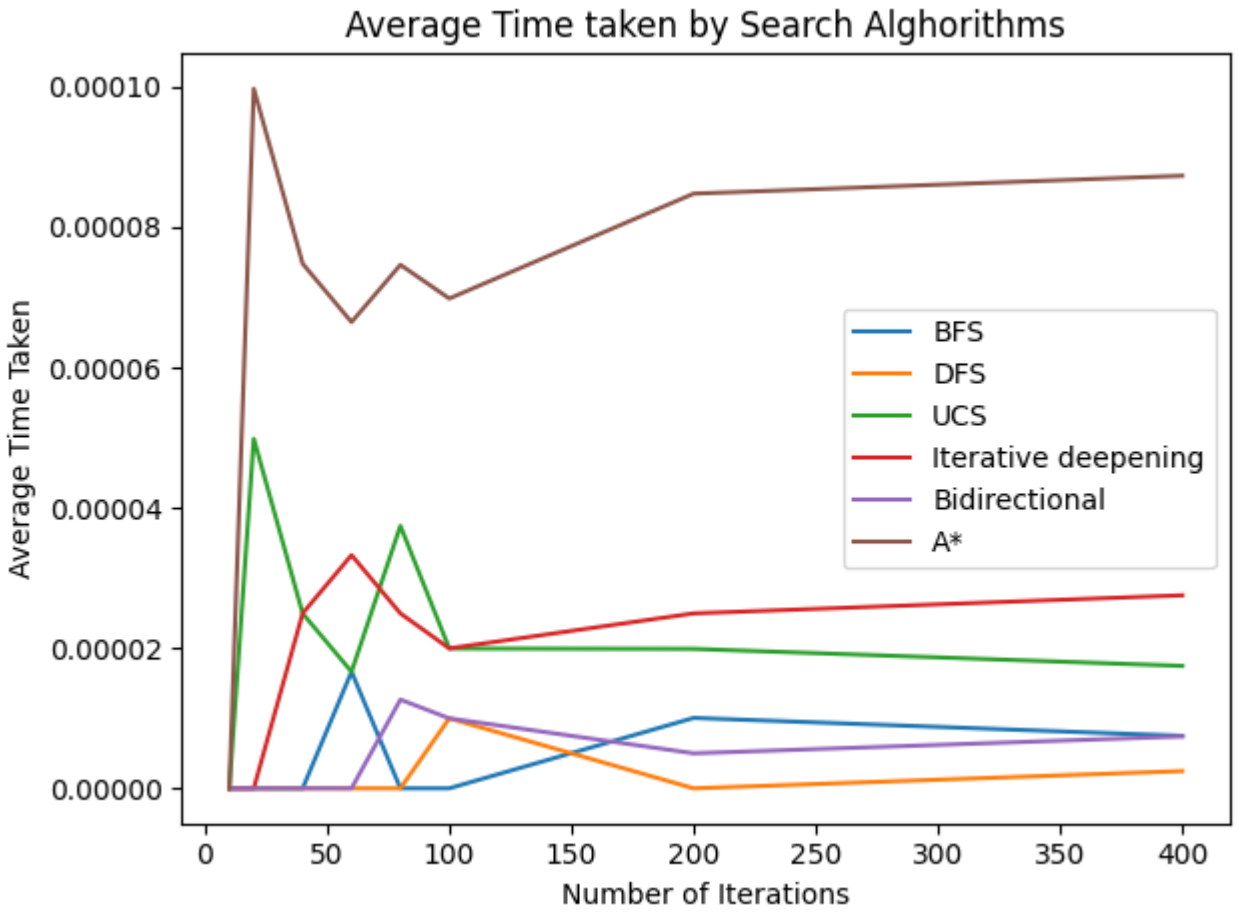
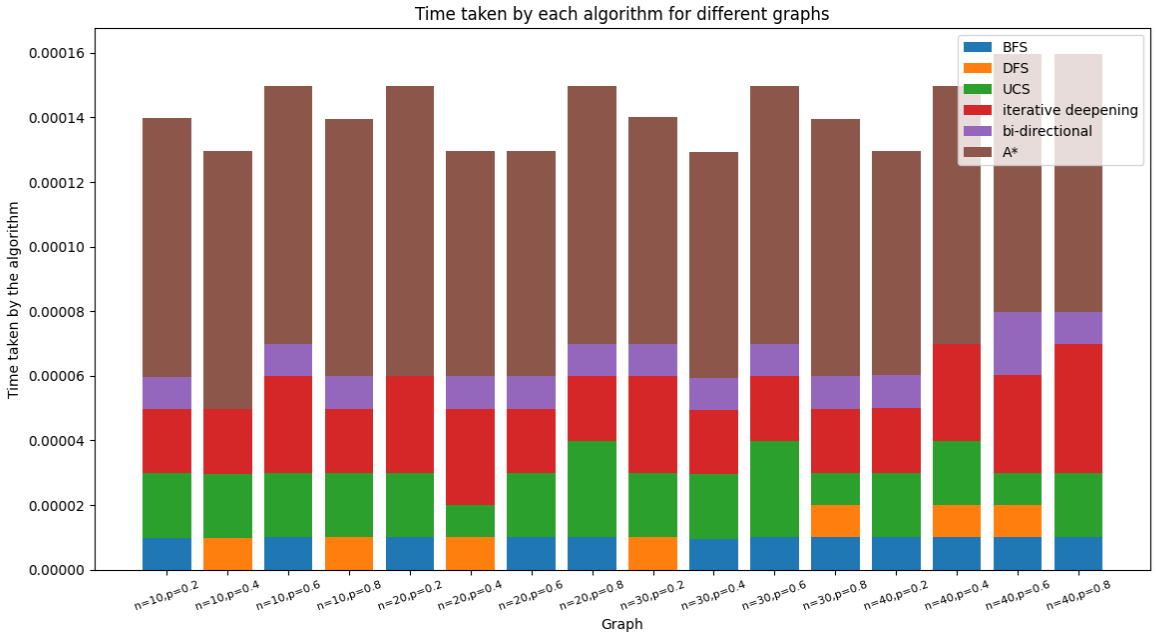
Observations
Number 2

➔ After running 10 randomized city searches for each algorithm and repeating the process for different iterations while averaging the results, we have concluded that DFS is the quickest algorithm in execution time compared to the other algorithms. We discovered that this is due to DFS having less computational overhead since it does not need to calculate the cost or heuristics of a path before expanding it. However, despite DFS being the fastest for large iterations, BFS is still faster in most cases and guarantees the shortest path. The chart below, generated using the code in "experiments.py", summarizes our observations.



➔ Both BFS and DFS are fast algorithms for finding solutions, but in most cases, BFS is faster than DFS and also guarantees the shortest path. This is because of the way BFS traverses and expands the nodes. We conducted 100 experiments on 16 graphs with varying nodes and probabilities, and the results were consistent. According to the chart generated using matplotlib in the "experiments.py" file, BFS is the fastest algorithm, followed by DFS, UCS, iterative deepening, and A*. We initially assumed that A* would outperform all the other algorithms, but our experiments showed the opposite. This is because A* has more computational overheads than BFS and DFS.



Number 3

Observations from Centrality Measures

The code for computing centrality measures can be found in the file named “centrality.py”

1. Degree

The table below shows the degree centrality values for each city. It is evident that the nodes with the highest number of neighbors are ranked at the top, while those with fewer neighbors follow suit.

Rank	City Name	Degree
1	Bucharest	4
2	Sibiu	4
3	Urziceni	3
4	Craiova	3
5	Pitesti	3
6	Rimnicu Vilcea	3
7	Arad	3
8	Iasi	2
9	Vaslui	2
10	Hirsova	2
11	Fagaras	2
12	Drobeta	2
13	Mehadia	2
14	Lugoj	2

15	Timisoara	2
16	Zerind	2
17	Oradea	2
18	Neamt	1
19	Eforie	1
20	Giurgiu	1

Degree is a simple measure of centrality that can be easily calculated. It is determined by the number of neighbors a node has. Therefore, as can be seen from the table above, nodes with more neighbors have a higher degree.

2. Closeness

The closeness value of each city is given below. We have multiplied the closeness value that we got from our function by 10,000 for ease of comparison.

Rank	City Name	Closeness
1	Pitesti	34.69
2	Bucharest	34.52
3	Rimnicu Vilcea	33.14
4	Sibiu	30.23
5	Craiova	28.67
6	Urziceni	27.21
7	Giurgiu	26.65
8	Oradea	26.13
9	Arad	25.31
10	Fagaras	24.71
11	Drobeta	24.1
12	Zerind	23.72
13	Vaslui	23.4
14	Mehadia	23.1
15	Hirsova	22.45
16	Lugoj	22.1
17	Timisoara	21.7
18	Iasi	19.99
19	Eforie	19

20	Neamt	17.16

As it can be inferred from the table above, nodes that have further distance from their neighbors tend to have less closeness, thus a high closeness value.

3. EigenVector

The eigenvector values are given below.

Rank	City Name	EigenVector
1	Neamt	4.05
2	Iasi	3.51
3	Oradea	0.73
4	Zerind	0.47
5	Arad	0.38
6	Sibiu	0.25
7	Rimnicu Vilcea	0.086
8	Timisoara	0.076
9	Fagaras	0.042
10	Pitesti	0.039
11	Lugoj	0.031
12	Mehadia	0.023
13	Drobeta	0.019
14	Craiova	0.016
15	Bucharest	0.013
16	Giurgiu	0.013
17	Hirsova	0.0023
18	Eforie	0.0023
19	Urziceni	0.002
20	Vaslui	0.00027

4. Betweenness

We have tried our best to implement betweenness correctly. But everytime the function returns a value of 0.0 for each node. We couldn't figure out where the mistake is.

5. PageRank

We have multiplied the PageRank value that we got from our function by 100 for ease of comparison.

Rank	City Name	PageRank

1	Bucharest	8.14
2	Sibiu	7.53
3	Urziceni	6.82
4	Arad	5.99
5	Craiova	5.78
6	Pitesti	5.7
7	Rimnicu Vilcea	5.6
8	Iasi	5.51
9	Hirsova	5.2
10	Vaslui	5.03
11	Lugoj	4.51
12	Mehadia	4.49
13	Timisoara	4.36
14	Drobeta	4.3
15	Zerind	4.2
16	Oradea	4.13
17	Fagaras	4.08
18	Neamt	3.09
19	Eforie	2.96
20	Giurgiu	2.48

It can be inferred from the table above that the more neighbors you have and the more neighbor you neighbors have, the higher your PageRank will be.

6. Kartz

The Katz centrality value for each city is given below.

Rank	City Name	Katz
1	Sibiu	1
2	Bucharest	0.99
3	Pitesti	0.93
4	Rimnicu Vilcea	0.93
5	Urziceni	0.91
6	Craiova	0.91

7	Arad	0.91
8	Fagaras	0.84
9	Oradea	0.83
10	Drobeta	0.82
11	Timisoara	0.82
12	Zerind	0.82
13	Vaslui	0.81
14	Hirsova	0.81
15	Mehadia	0.81
16	Lugoj	0.81
17	Iasi	0.8
18	Giurgiu	0.74
19	Eforie	0.73
20	Neamt	0.72