SPEED OF SEARCH ALGORITHMS

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What is the fastest graph-searching algorithm?

WHY THE RESEARCHER CHOSE THIS PROJECT & BENEFITS

The researcher chose this project due to his interest in computer science. He has been coding since he was 8, and finding out about how GPSs work simply amazed him. This project will benefit many people, as many people use a wide variety of GPSs to commute from place to place, such as to work. Improvement to these algorithms will help everyone.

BACKGROUND INFORMATION
(TERMS)

Algorithm: A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

Python: an interpreted, object-oriented, high-level programming language

Algorithmic Complexity: a measure of how long an algorithm would take to complete given an input of size n

Graph (graph theory): models pairwise relations between objects/nodes.

Graph Traversal: process of visiting (or checking) each node in a graph

A*: the "gold standard" of shortest path finding. Used by Google Maps to find routes.

Big O Notation: notation used for complexity which drops all coefficients

Informed/Uninformed Search: Algorithm which does/doesn't use a heuristic.

Heuristic: Technique designed for solving a problem more quickly when classic methods are invalid/too slow

BACKGROUND INFORMATION
(ALGORITHMS)

Algorithms used:

- A*
- Bidirectional
- BFS
- Dijkstra's
- DFS
- Greedy Best-First Search
- Ant Colony Optimization (removed)
- IDA* (removed)

- Ant Colony Optimization and IDA* were removed.
- Ant Colony Optimization couldn't find a correct path.
- IDA* used recursion.

In Python, the max recursion limit is 1000 (for a good reason). When the graph has almost that number or above, Python crashes. (This is to prevent Python from using up infinite RAM).
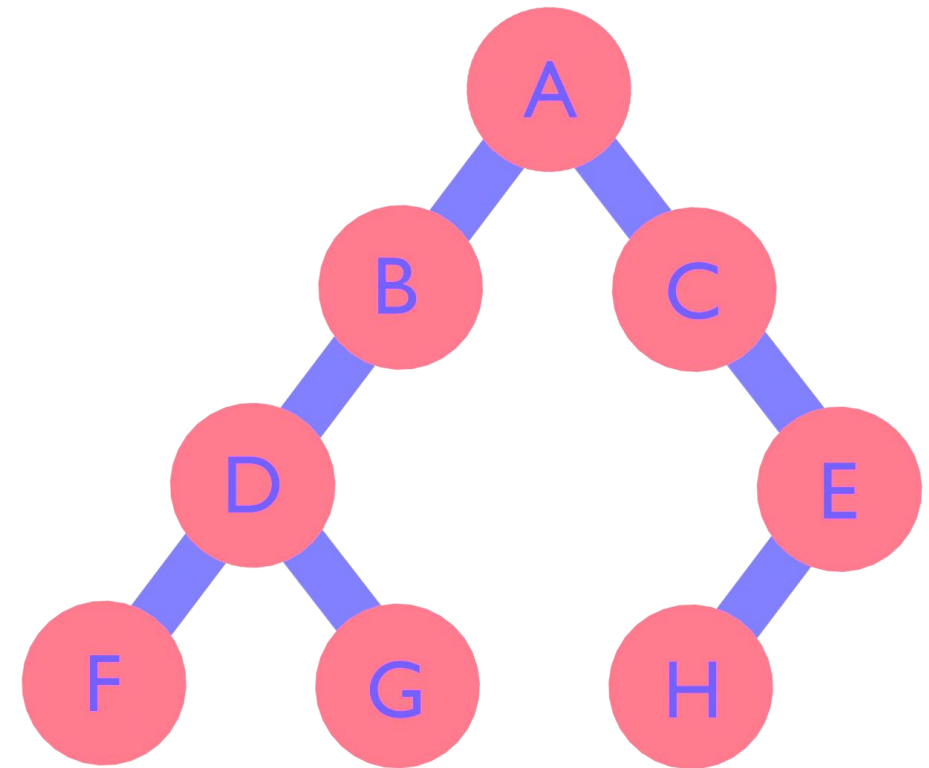
Depth-First Search (DFS, recursive):

- Goes to the max depth, then backtraces until it finds a parent with another child, then does the whole process again.

Breadth-First Search (BFS):

- Goes layer by layer until it has traversed all the nodes.

A*:

- Informed search which goes to the child which has the smallest distance from the parent + distance to target.

Variables:

Independent:
- Sorting Algorithm

Dependent:
- Time taken
- Cost of the path

Constants:
- Graph used for each trial.

HYPOTHESIS STATEMENT

- If the researcher searched for the shortest path between two randomly chosen nodes, BFS will have the fastest time compared to any other search algorithm.

- According to research, BFS has an algorithmic complexity of $O(V+E)$, which is better than Dijkstra's and Bidirectional. BFS also doesn't use a costly heuristic, which Greedy and A* use. Also, since there are many nodes, BFS is more likely to outcompete DFS.

MATERIALS

The code was altered to be compatible with graph data structure.

1. A* search, www.geeksforgeeks.org/a-search-algorithm/
2. Bidirectional search, www.geeksforgeeks.org/bidirectional-search/
3. BFS, www.geeksforgeeks.org/breadth-first-search-or-bfs-for-a-graph/
4. Dijkstra's Algorithm, www.geeksforgeeks.org/dijkstras-shortest-path-algorithm-greedy-algo-7/
5. DFS, www.geeksforgeeks.org/depth-first-search-or-dfs-for-a-graph/
6. Greedy Search, www.programiz.com/dsa/greedy-algorithm/
7. Python 3 and required dependencies used in the algorithms

These materials were used in development:

8. Microsoft Visual Studio Code

9. Jupyter Extension for Visual Studio Code

10. GitHub Desktop
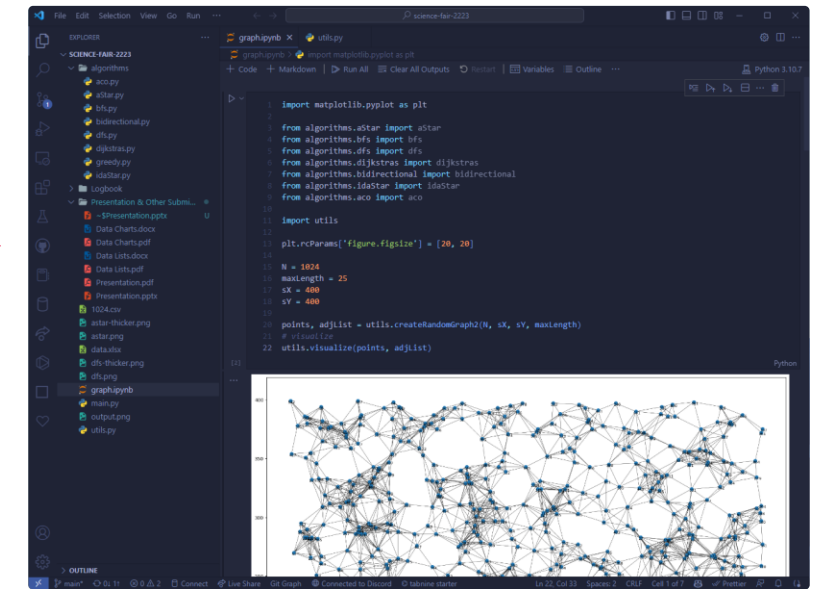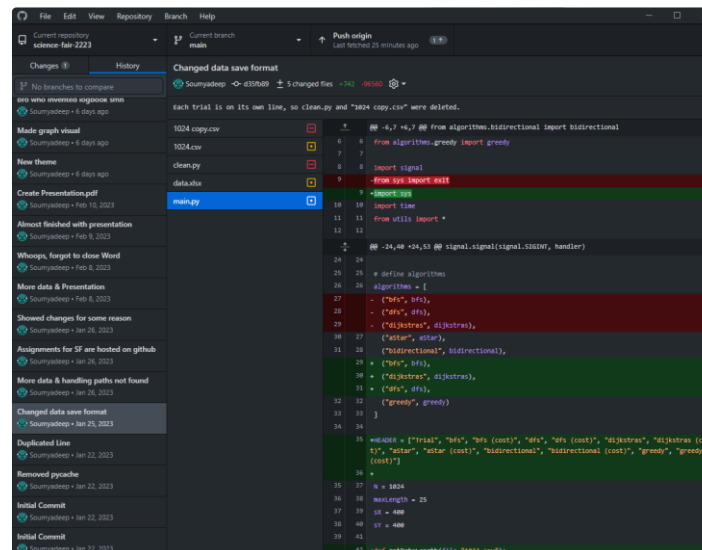
PROCEDURE

1.   Generate random graph with 1024 random vertices on a 400x400 plane, where vertices within 24 length between them are connected.

2.   Run algorithm on graph and measure time and cost. (-1 for invalid paths)

3.   Repeat step 2 for each algorithm

4.   Dump data to CSV

5.   Repeat steps 1-4 for each trial (36229 trials in total)

6.   Calculate average times and costs for each algorithm in comparison to the A* cost for that trial

7.   Create bar graph for each time and cost.
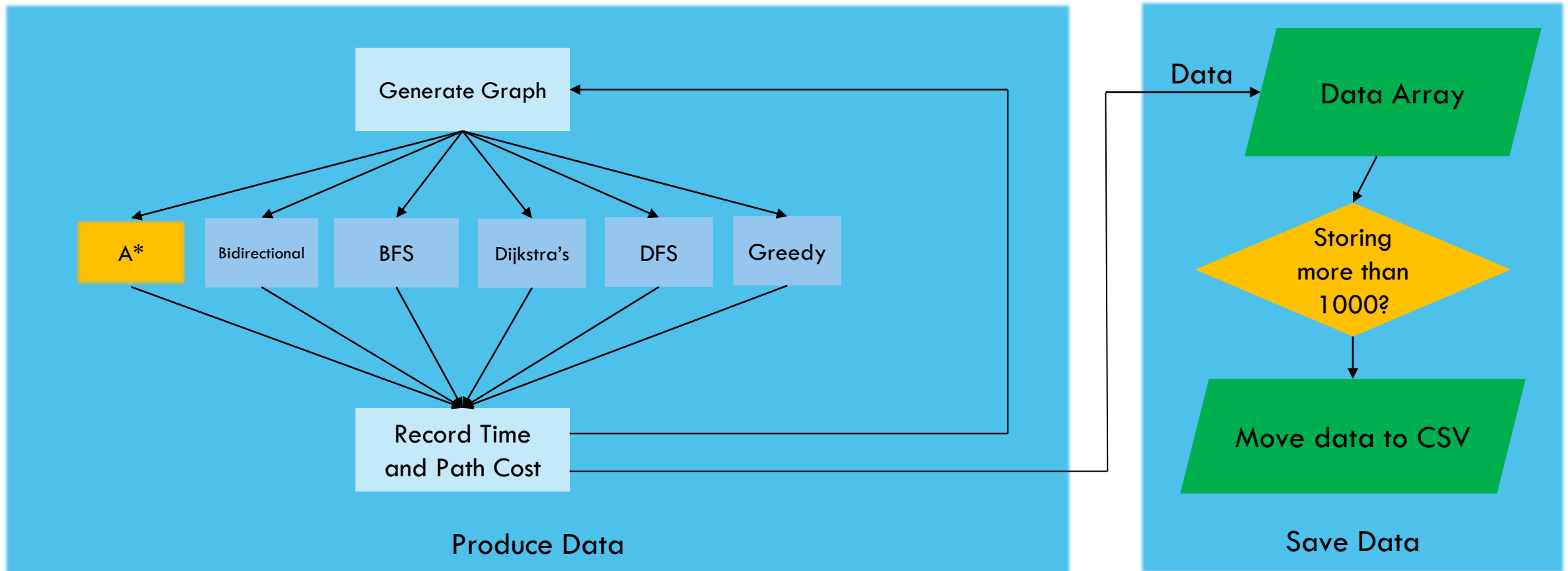
TIME COMPARISON CHART

Average Time Performance Compared to A* (over 36229 trials)
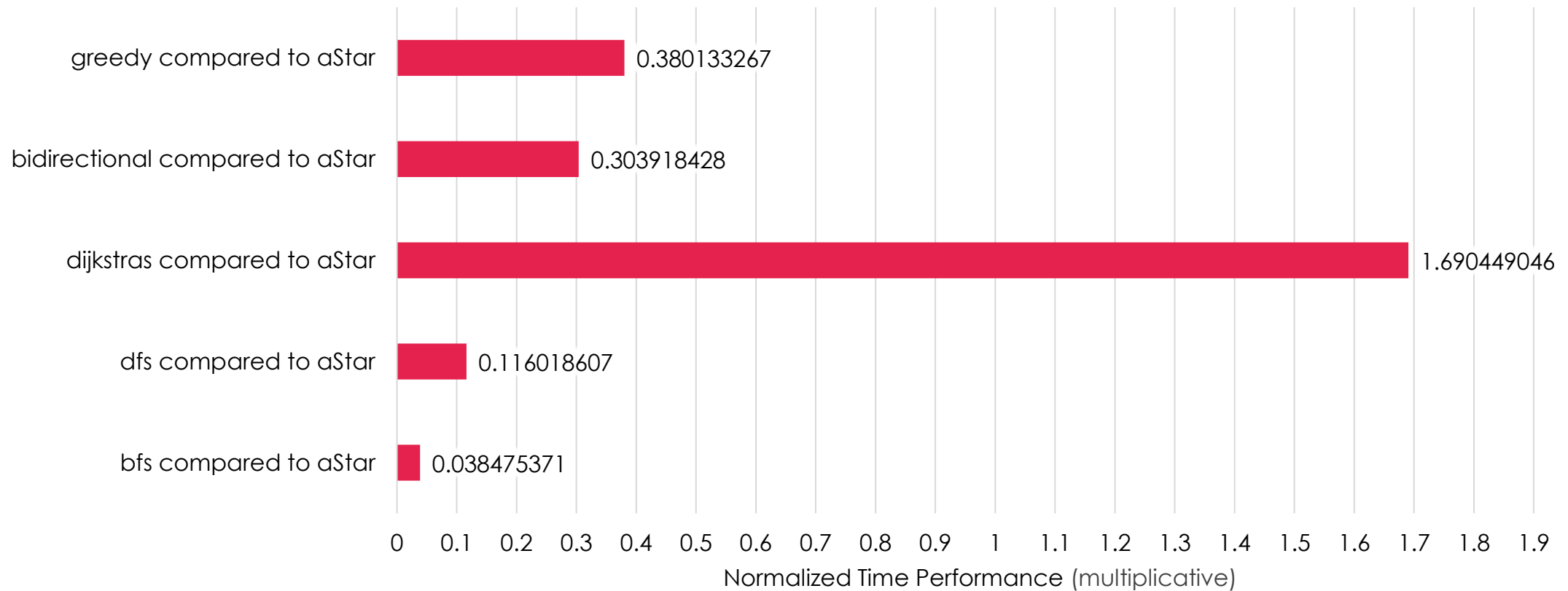
DATA CHARTS

Average Path Cost Compared to A* (over 36229 trials)

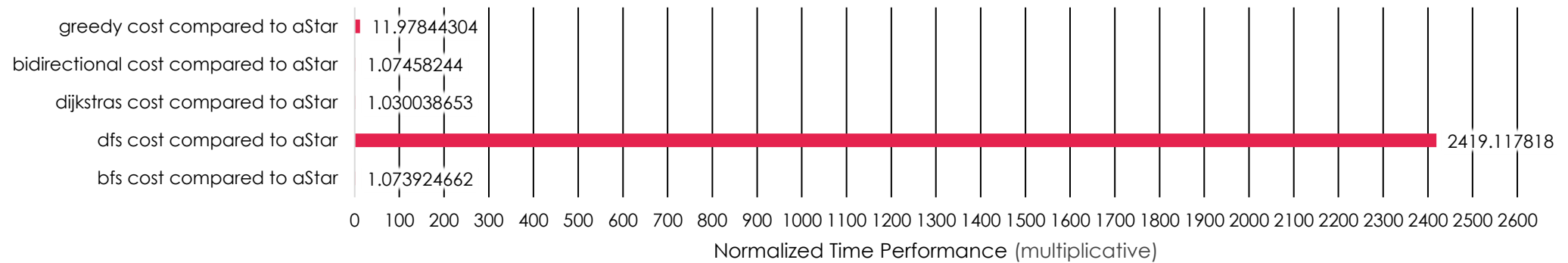| Category	Value
greedy cost compared to aStar	11.97844304
bidirectional cost compared to aStar	1.07458244
dijkstras cost compared to aStar	1.030038653
dfs cost compared to aStar	2419.117818
bfs cost compared to aStar	1.073924662

Normalized Time Performance (multiplicative)

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600

Average Path Cost Compared to A* (without DFS for viewing purposes)

Category	Value
greedy cost compared to aStar	11.97844304
bidirectional cost compared to aStar	1.07458244
dijkstras cost compared to aStar	1.030038653
bfs cost compared to aStar	1.073924662

Normalized Path Cost (multiplicative)

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13
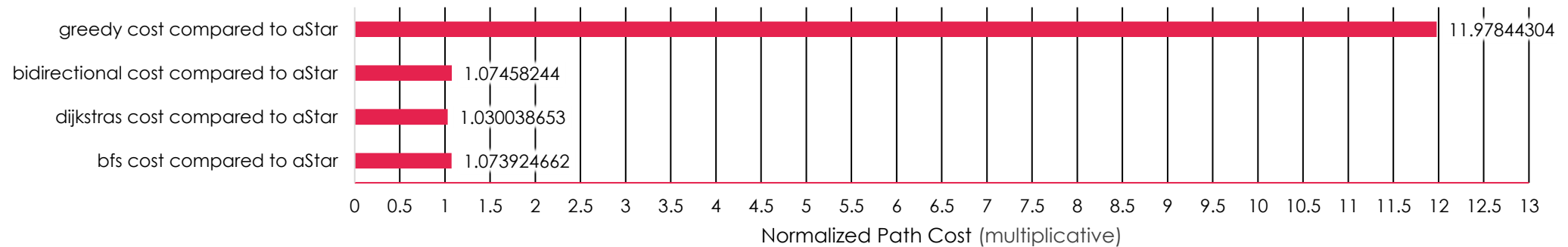
EXAMPLE GRAPHS
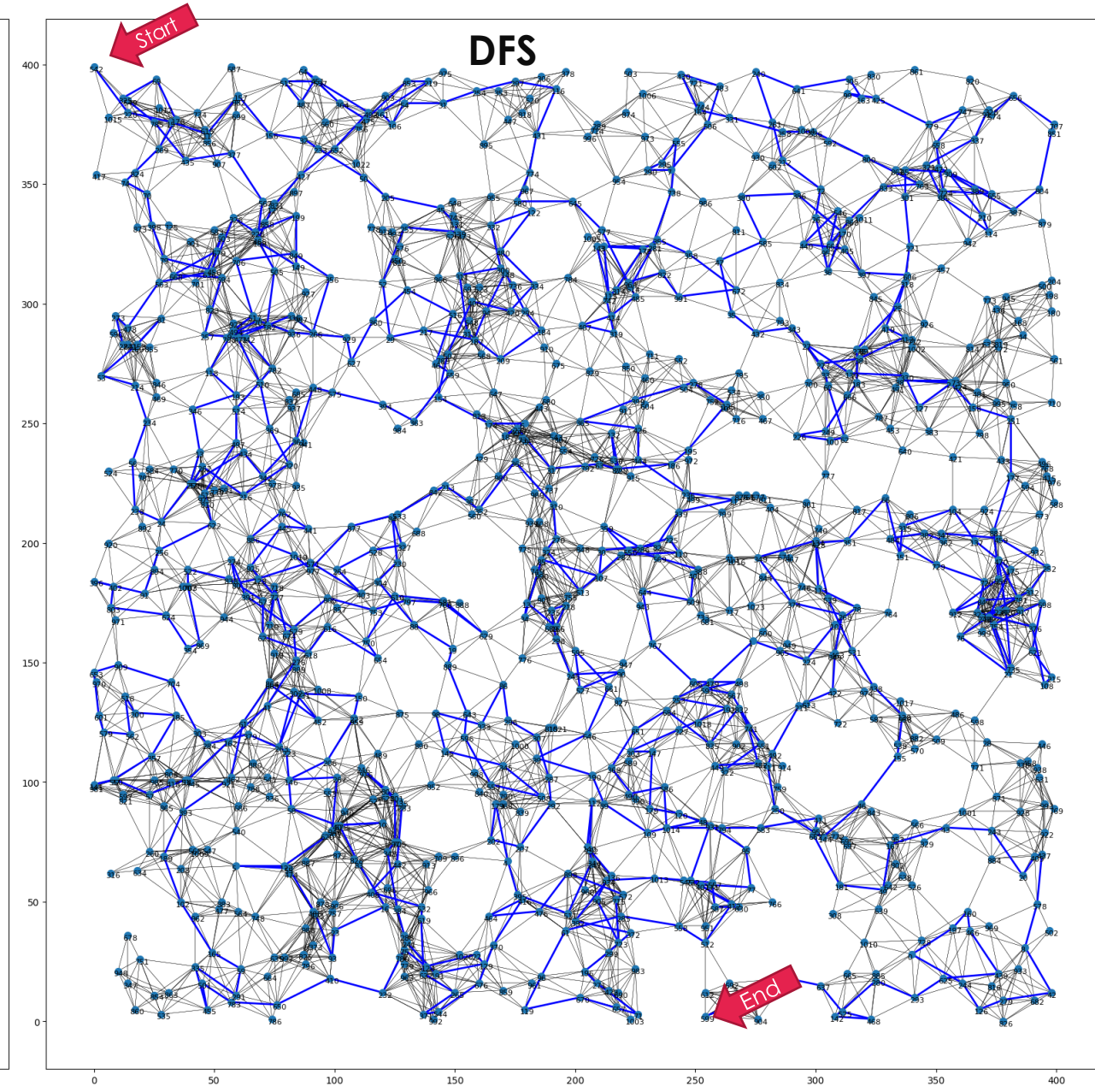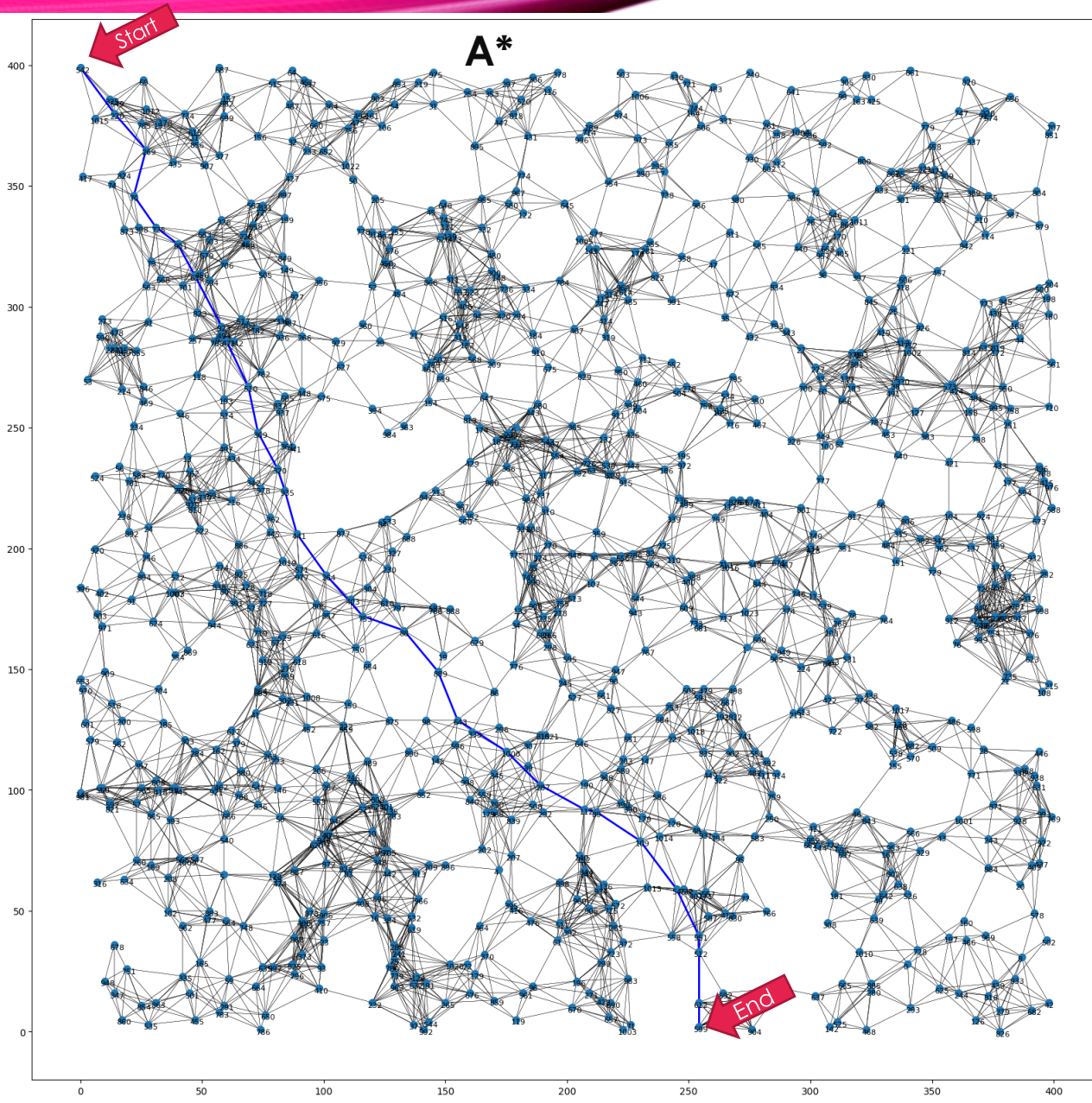
CONCLUSION

- The research question was, "What is the fastest graph searching algorithm?"

- The hypothesis was: If the researcher searched for the shortest path between two randomly chosen nodes, BFS will have the fastest time compared to any other search algorithm.

- According to research, BFS has the best factors compared to the other algorithms, in time complexity and time needed to calculate the heuristic (which BFS doesn't have).

CONCLUSION

As seen in the normalized time comparison chart, BFS had a ratio of about 0.03:1 which is the lowest out of all the algorithms. **The researcher's hypothesis is supported by the data.**

- BFS doesn't use heuristics, which makes it very fast. The heuristic for graph involves taking a square root, which is very costly.
- BFS has the lowest complexity, of O(V+E)

CONCLUSIONS

Errors:

- One error is that since the code runs so fast, the times recorded may be off by some value. If this code is run on a device with less processing power (e.g., Raspberry Pi), those margins make less of an effect.

- Choosing higher node counts is harder, because trial and error is required to get the minimum length that keeps all the nodes connected, but at the same time not connecting too many to create an easy path.

- The algorithms were not optimized for peak performance.

CONCLUSION

- Pathfinding is very important in the area of AI. In this case, it is being used with physical paths, however there may be other items that are represented through graphs, such as a game tree, which is used in gamebots.

- Google Maps, which is a very common application used to find routes to get from a source to a destination uses A*. Many other GPSs use A*.

SUGGESTIONS

One area for improvement is the coding language used. Interpreted languages are drastically slower than compiled languages due to how they are executed. Python is an interpreted language, and a great alternative is C++.

The only problem with C++ is how long it would take to develop the code. In Python it took about 10-15 hours, but in C++ it would likely 2-3x as much.

ADDITIONAL LINKS

GitHub Repo: https://github.com/python9160/science-fair-2223

main.py: https://github.com/python9160/science-fair-2223/blob/main/main.py

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THANK YOU