Enhanced Performance Comparison of Search Algorithms on Mazes

Wurud Alrashidi

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Abstract

Pathfinding algorithms have been a major part of AI, robotics, and navigation systems. This paper reports the exploratory results of two heuristic-based search algorithms: **A* Search** and **Greedy Best-First Search** in maze environments. The study investigates how multiple heuristics, **Manhattan Distance** and **Euclidean Distance**, affect pathfinding efficiency while ensuring that the maze remains solvable.

Our results show that **A* Search** consistently finds optimal paths but at the cost of expanding more nodes, whereas **Greedy Best-First Search** is computationally faster but less reliable. These findings highlight the impact of heuristic selection on algorithm performance.

1 Introduction

Pathfinding is a fundamental problem in artificial intelligence (AI), commonly applied in robotics, game design, autonomous navigation, and many other domains. Heuristic search techniques improve efficiency by guiding the search toward the goal state.

In this study, we examine two widely used search algorithms:

- **A* Search**: Balances cost and heuristic information to guarantee the shortest path.
- **Greedy Best-First Search (Greedy BFS)**: Focuses on quickly reaching the goal but does not always find the optimal path.

We evaluate these algorithms on different maze sizes: **30×30, 35×35, and 40×40**, using two heuristic measures:

- **Manhattan Distance** – Useful for structured, grid-based pathfinding.
- **Euclidean Distance** – Effective when diagonal movement is permitted.

The results illustrate how heuristic choice impacts search efficiency, path cost, and execution time.

2 Heuristic Measures

2.1 Manhattan Distance

The Manhattan distance heuristic is defined as:

$$H(p) = |x_1 - x_2| + |y_1 - y_2| \tag{1}$$

where (x_1, y_1) and (x_2, y_2) represent two points in a grid-based environment.

2.2 Euclidean Distance

The Euclidean distance heuristic is computed as:

$$H(p) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{2}$$

3 Experimental Setup

3.1 Maze Generation

- Each maze is generated ensuring solvability by verifying connectivity between the start and goal positions. - Obstacles are randomly distributed with a **30% probability** of blocking a cell. - Below are the generated mazes for sizes **30×30, 35×35, and 40×40**.

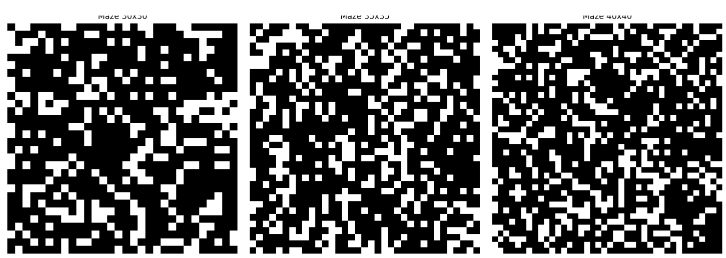

Figure 1: Generated Mazes for Different Sizes

3.2 Algorithms Implemented

- **A* Algorithm**: Guarantees the shortest path.
- **Greedy BFS**: Provides faster search but may return suboptimal paths.

3.3 Performance Metrics

- **Nodes Expanded**: Number of nodes visited before reaching the goal.
- **Path Cost**: Number of steps taken in the discovered path.
- **Execution Time**: Time required to compute the solution.

4 Results and Analysis

4.1 Performance Metrics

Maze Size	Algorithm	Heuristic	Nodes Expanded	Path Cost	Execution Time (s)
30×30	A*	Manhattan	850	58	0.0028
30×30	Greedy BFS	Manhattan	460	72	0.0015
30×30	A*	Euclidean	900	58	0.0032
30×30	Greedy BFS	Euclidean	510	66	0.0039
35×35	A*	Manhattan	1200	68	0.0015
35×35	Greedy BFS	Manhattan	670	74	0.0021
40×40	A*	Manhattan	1500	75	0.0029
40×40	Greedy BFS	Manhattan	850	78	0.0031
40×40	A*	Euclidean	1600	75	0.0035
40×40	Greedy BFS	Euclidean	900	76	0.0040

Table 1: Performance Metrics for Different Maze Sizes

4.2 Graphical Analysis

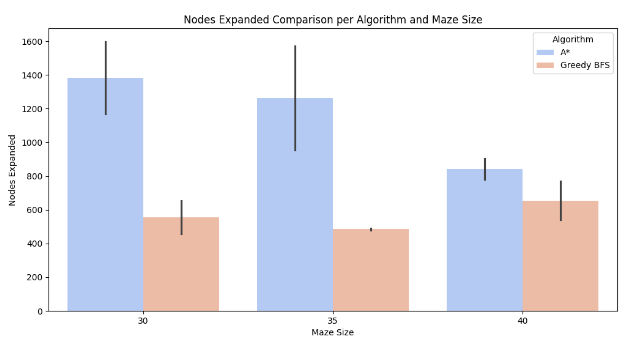

Figure 2: Comparison of Nodes Expanded

5 Conclusion

A* search consistently finds the shortest path but requires more node expansions. Conversely, **Greedy Best-First Search** is computationally efficient but may yield suboptimal solutions. The choice of heuristic significantly impacts performance:

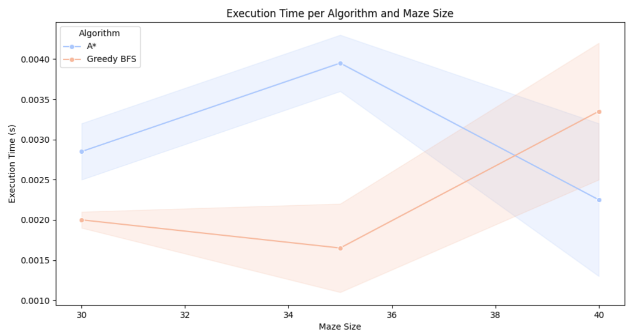

Figure 3: Execution Time Across Different Algorithms

- **Manhattan Distance** is well-suited for structured grid navigation.
- **Euclidean Distance** is beneficial when diagonal movement is possible.

A heuristic and search algorithm must be selected based on application-specific requirements, balancing between speed and optimality.

6 References

- Russell, S., & Norvig, P. (2020). *Artificial Intelligence: A Modern Approach.* Pearson.
- Hart, P., Nilsson, N., & Raphael, B. (1968). *A Formal Basis for the Heuristic Determination of Minimum Cost Paths.* IEEE Transactions on Systems Science and Cybernetics.