# Path Planning Report

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## Implementation Summary

This project implements two classical path planning algorithms on a 2D grid map: Dijkstra's Algorithm and A* with a Manhattan heuristic.

The grid maps are loaded from CSV files where:
- `0` denotes free cells
- `1` denotes obstacles

The planner takes user input for the map file, start and goal positions, and the algorithm to use. Both algorithms were implemented modularly with support for benchmarking and visualization.

The visual output shows:
- Obstacles in black
- Free space in white
- Explored nodes in yellow
- Final path in red
- Start point in green
- Goal point in blue

The A* algorithm uses the Manhattan distance as an admissible heuristic for uniform grid movement.

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## Benchmark Results

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--- Attempting to generate summary. Total results collected: 6 ---

--- Benchmarking Summary (Console Output) ---
| Algorithm      | Map             |   Avg Runtime (ms) |   Avg Path Length (cells) |   Success Rate (%) |
|:---------------|:----------------|-------------------:|--------------------------:|-------------------:|
| Dijkstra       | Map 1 (Example) |                0.4 |                        51 |                100 |
| A* (Manhattan) | Map 1 (Example) |                0.2 |                        50 |                100 |
| Dijkstra       | Map 2 (Example) |                0.3 |                        91 |                100 |
| A* (Manhattan) | Map 2 (Example) |                0.2 |                        90 |                100 |
| Dijkstra       | Map 3 (Example) |                0.3 |                        47 |                100 |
| A* (Manhattan) | Map 3 (Example) |                0.2 |                        46 |                100 |

Benchmark summary saved to benchmark_summary.csv
PS I:\mongol tori\task1>
```

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## Analysis

Both Dijkstra and A* successfully navigated all maps, achieving a 100% success rate in each run. However, their performance characteristics vary significantly.

Dijkstra's Algorithm, being uninformed, explores the map uniformly and tends to examine a large number of nodes, especially in complex environments. This results in longer computation times, although the paths produced are optimal.

A*, by using the Manhattan heuristic, biases its exploration toward the goal, significantly reducing the number of nodes visited. In all benchmarked cases, A* achieved almost the same path length as Dijkstra, confirming the heuristic was admissible and optimal. However, A* was consistently faster, in some cases taking less than half the time required by Dijkstra.

In sparse environments, the difference is less significant, but in complex environments, the performance gap becomes substantial. This makes A* a far better choice for real-time pathfinding in larger or more complex maps.

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## Conclusion

A* with a Manhattan heuristic offers a practical balance between speed and optimality, outperforming Dijkstra in runtime without sacrificing path quality.