Dependance of Path planning algorithms performance in varying environment

Ahmed Kamal – Ahmed Fathy – Ahmed Gamal – Ziad Monster – Farouk Mohamed
Cairo University Faculty Of Engineering – Computer Engineering Department

MTH2253

Supervised By: Prof. Maha A. Hassanein

Abstract

This report analyzes the performance of A*, Dijkstra's, and RRT path planning algorithms in dynamic and complex environments. Using simulations, the study evaluates these algorithms based on execution time, path optimality, and computational efficiency. The findings provide evidence-based recommendations for selecting suitable algorithms for real-time applications, contributing to advancements in autonomous systems.

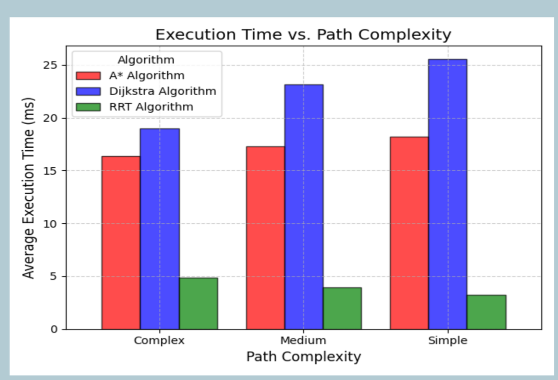
Introduction

Path planning is essential for autonomous systems in applications like robotics and autonomous vehicles. Widely used algorithms such as A*, Dijkstra's, and RRT perform differently under varying conditions like obstacle density and path complexity. However, existing research lacks comprehensive comparisons across diverse scenarios.

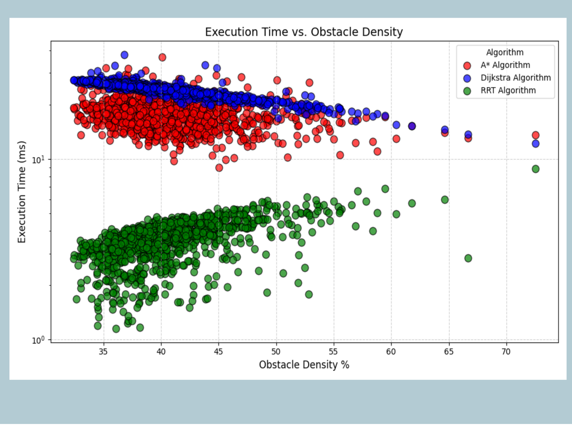
This study bridges that gap by evaluating these algorithms using metrics like execution time, path optimality, and computational efficiency. The findings aim to guide algorithm selection for real-time applications, enhancing the performance of autonomous systems.

Data Description

Algorithm Performance Dataset
Measures execution time, path optimality, and complexity for A*, Dijkstra, and RRT algorithms across various obstacle densities.



Environmental Conditions Dataset
Describes testing environments, including obstacle density, path complexity, and dynamic changes.



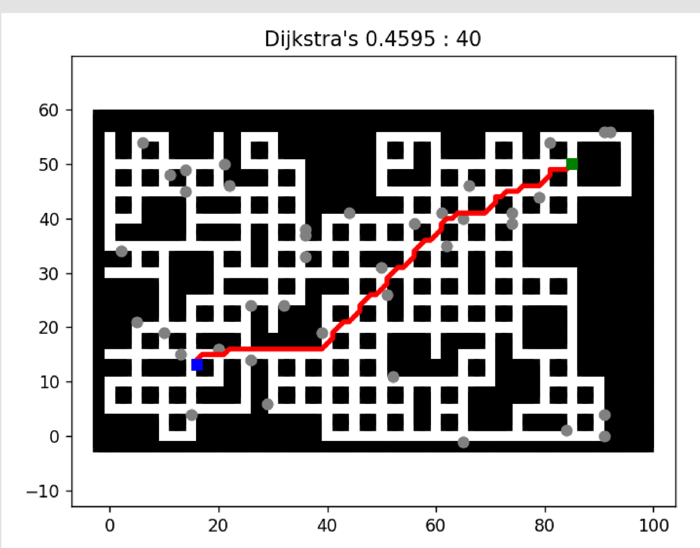
Methodology

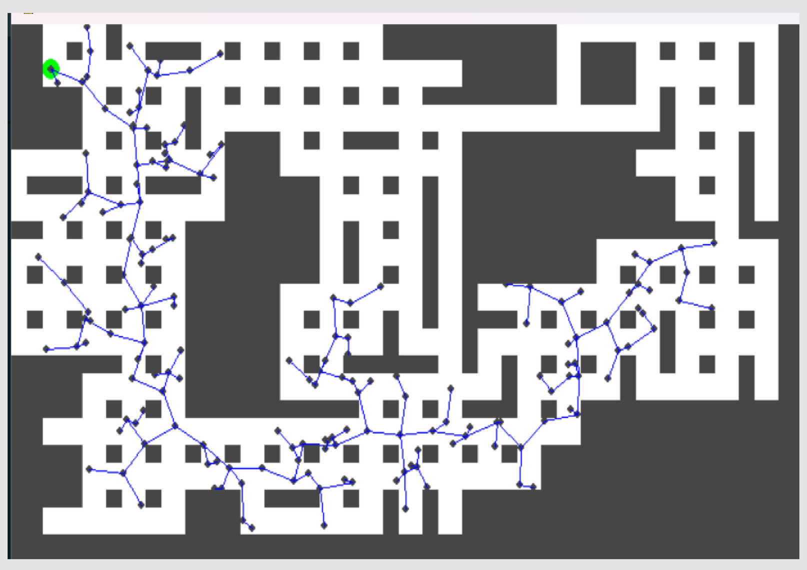
Dynamic Environment Setup
Simulations included varying obstacle densities, path complexities, and dynamic changes like new obstacles or shifting positions to mimic real-world scenarios.
Experimental Process
Tested A*, Dijkstra, and RRT across 5–10 unique environments with multiple configurations, logging metrics like execution time and path optimality over long runs.
Variables

- **Independent**: Obstacle density, path complexity, algorithm type.
- **Dependent**: Execution time, path optimality, computational consistency.

Data Analysis

- **Descriptive**: Calculated mean, median, and standard deviation for key metrics.
- **Visualization**: Time series (trends), boxplots (variability), scatter plots (relationships).
- **Inferential**: Used ANOVA to compare algorithm performance and analyze statistical significance.





Results

1.ANOVA for Execution Time: A significant difference in execution time was found between the algorithms (p-value = 0.001). RRT had the fastest execution time, followed by A* and Dijkstra.

2.ANOVA for Path Optimality: Significant differences in path optimality were observed (p-value = 0.0296), with A* providing the most optimal paths, and RRT and Dijkstra showing less optimal paths.

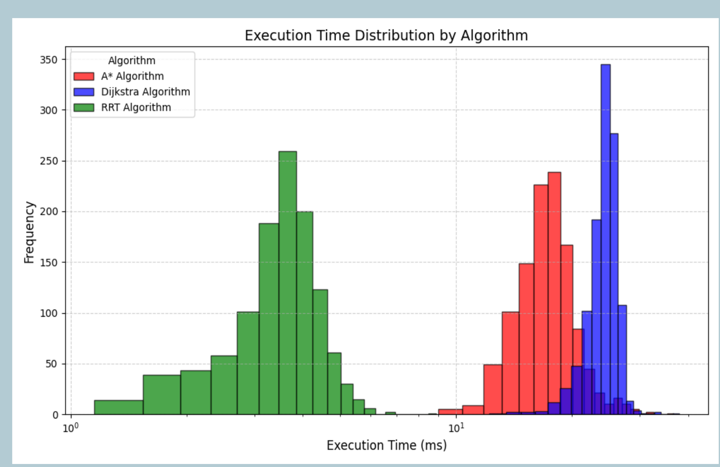
3.Correlation between Obstacle Density and Path Optimality: A negative correlation was found between obstacle density and path optimality, indicating that higher obstacle density led to less optimal paths.

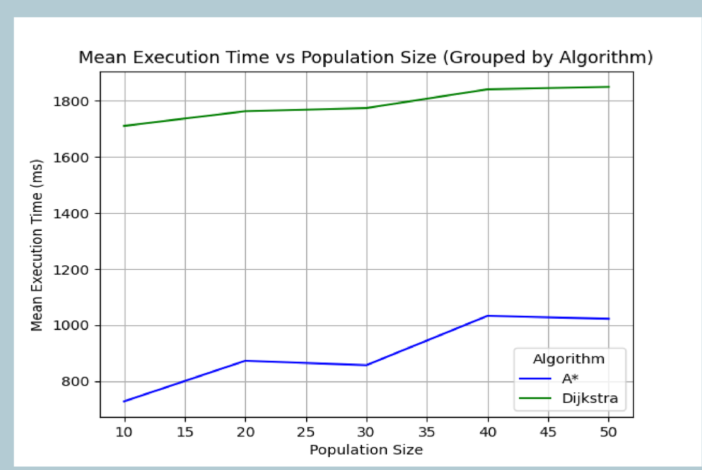
4.Confidence Interval for Execution Time: The 95% confidence intervals for execution times: A*: 17.53 ms to 17.90 ms Dijkstra: 24.05 ms to 24.30 ms RRT: 3.57 ms to 3.67 ms

5.ANOVA for Environmental Factors: Obstacle density and algorithm type significantly impacted execution time (p-value < 0.001). Path length was influenced by algorithm type (p-value < 0.001), but not by obstacle density.

Mathematical Modeling:

ANOVA: ANOVA was used to test differences in execution time and path optimality between algorithms. The p-values showed significant differences, with RRT being faster and A* more optimal. Correlation: The Pearson correlation between obstacle density and path optimality revealed a negative relationship, indicating that higher obstacle density results in less optimal paths. Confidence Interval: Confidence intervals for execution times were calculated to estimate the range within which true values lie, with RRT showing the shortest execution times. Environmental Factors: ANOVA confirmed that obstacle density and algorithm type significantly influenced execution time. Path length was mainly affected by the choice of algorithm





Conclusion

The study reveals significant differences in execution time and path optimality across algorithms. **RRT** is the fastest, while **A*** provides the most optimal paths. In dynamic environments, **RRT** remains efficient, though path optimality decreases with higher obstacle density. These findings highlight the importance of choosing the right algorithm based on the environment: **RRT** for speed and **A*** for optimality.

Future Work

Future efforts will focus on enhancing algorithm efficiency in highly dynamic environments, incorporating real-world datasets, and optimizing for scalability in large, complex scenarios. Additionally, integrating machine learning techniques to improve adaptability and performance is a key direction.

References

1. LaValle, S. M. (1998). *Rapidly-exploring random trees: A new tool for path planning*. Retrieved from http://msl.cs.uiuc.edu/~lavalle/papers/Lav98c.pdf
2. Hart, P. E., Nilsson, N. J., & Raphael, B. (1968). *A formal basis for the heuristic determination of minimum cost paths*. IEEE Transactions on Systems Science and Cybernetics, 4(2), 100–107. https://doi.org/10.1109/TSSC.1968.300136