Safe Robot Navigation Through Low and High Risk Zones: Evaluation of A*, D*, and RRT Algorithms

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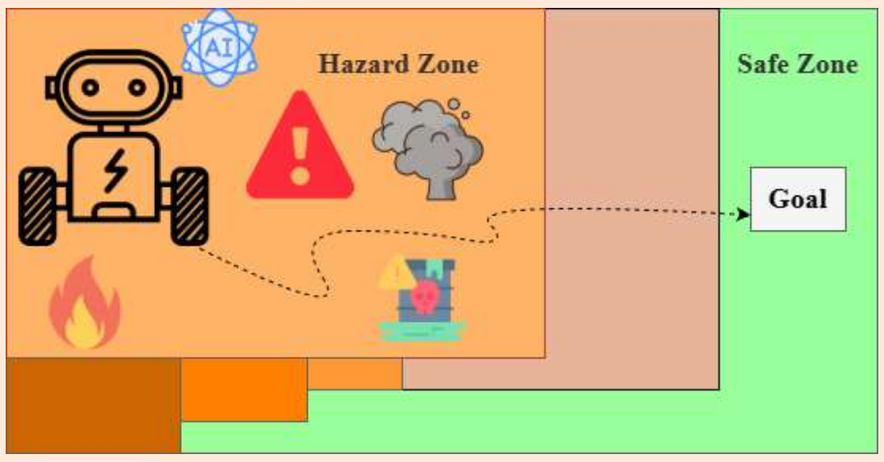
Introduction

Autonomous robots operating in hazardous environments rely heavily on efficient and safe path-planning strategies. Selecting an appropriate algorithm becomes critical as risk levels, terrain uncertainties, and environmental constraints vary. This study examines three prominent planning approaches—A*, D*, and RRT—to understand their suitability across different risk-intensive navigation scenarios.



Method

Environment Modelling — A 20 × 20 risk-aware grid with 50 low- and high-risk obstacles was generated to simulate hazardous navigation conditions.

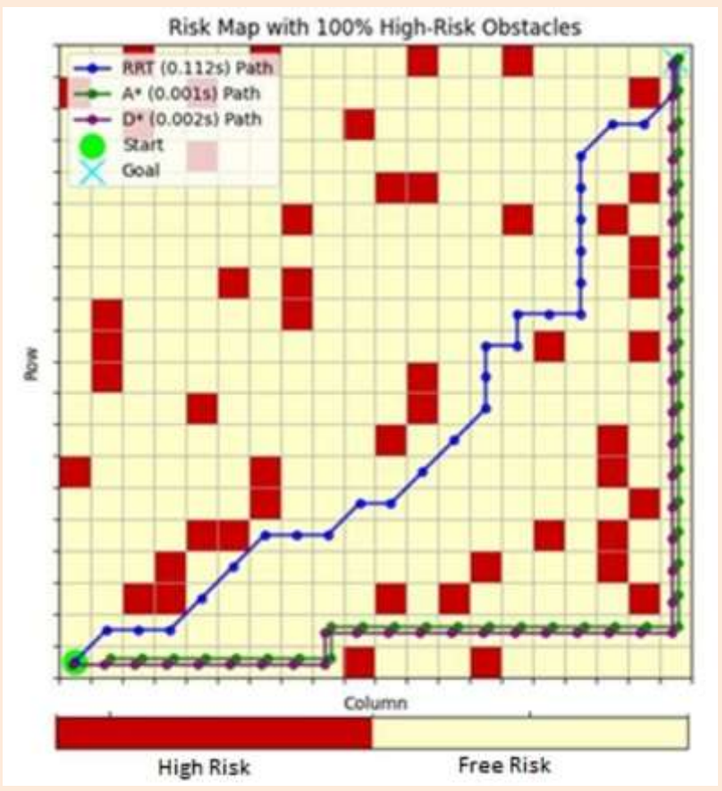
Algorithm Implementation — A*, D*, and RRT were implemented in Python using a uniform interface incorporating risk-based cost and collision checks.

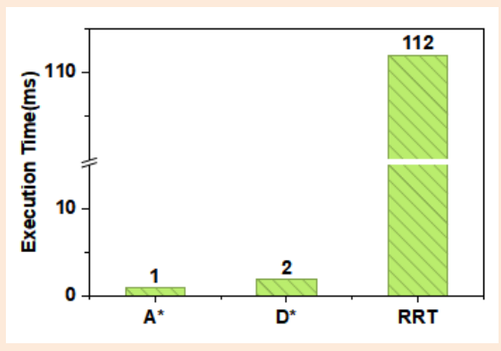
Performance Evaluation — Execution time, path length, and collision behaviour were recorded and visualized for direct comparison across all algorithms.

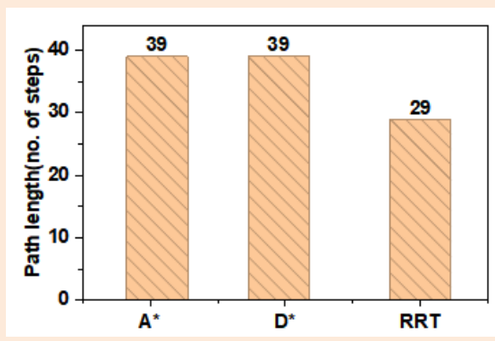
Visualization — Matplotlib with a custom risk color map was used to overlay the paths of all three algorithms for direct visual comparison.

Result and Discussion

High Risk



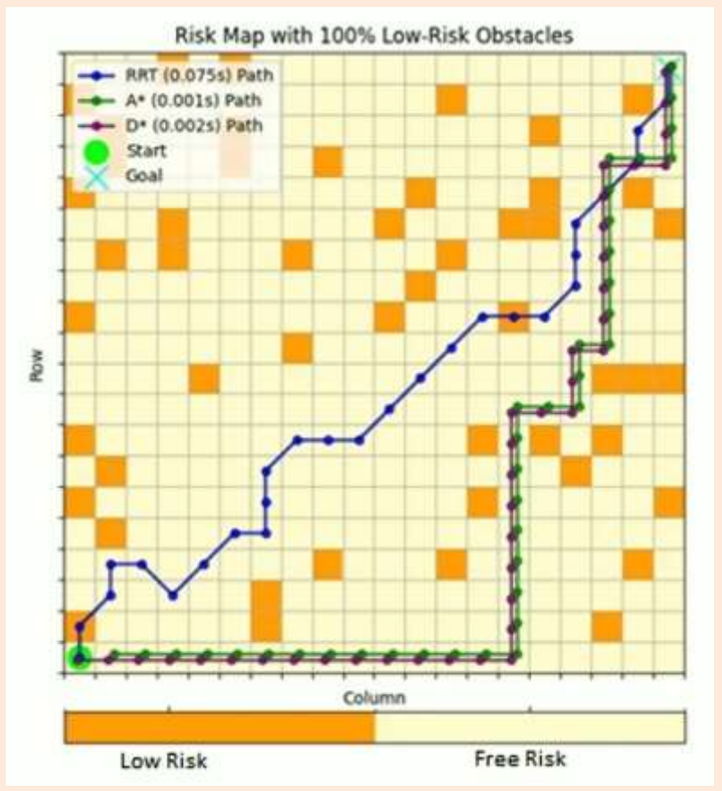


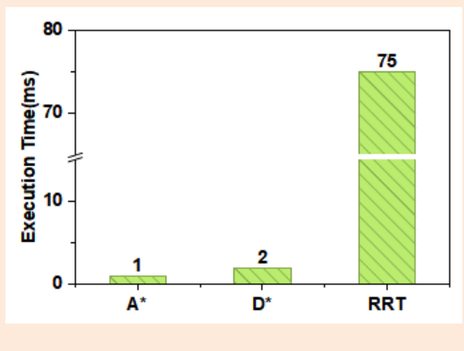


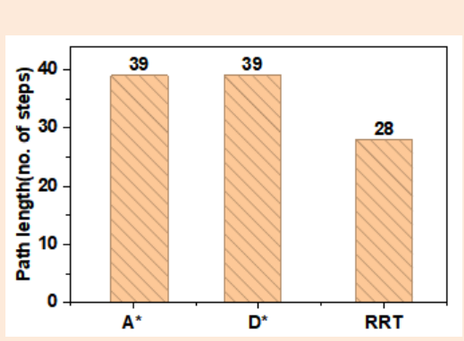
Key takeaways

- A*, D*, and RRT are all reliable.
- A* and D* take much less time than RRT.
- RRT produces the shortest path length.

Low Risk



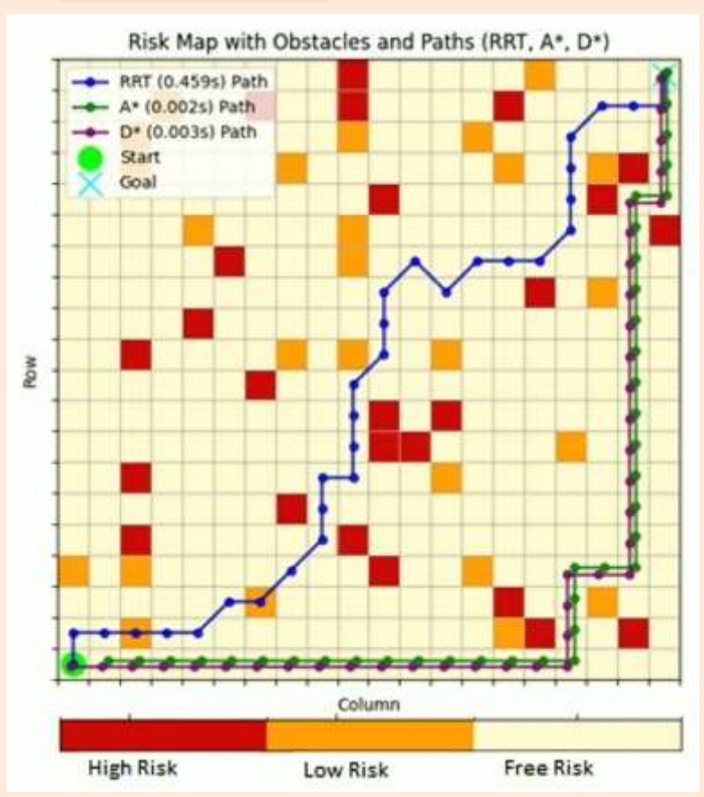


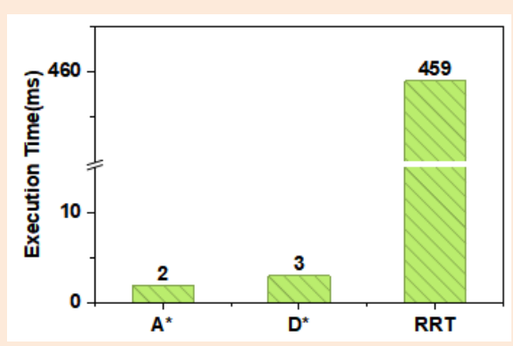


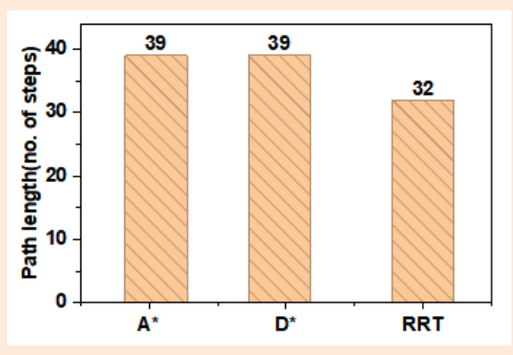
Key takeaways

- A* and D* are reliable and take much less time than RRT.
- RRT sometimes collides with low-risk objects.
- RRT has the shortest path length but is not reliable.

Mixed Risk







Key takeaways

- A* and D* are reliable and take much less time than RRT.
- RRT sometimes collides with low-risk objects.
- RRT has the shortest path length but is not reliable.

Conclusion & Summary

A* and D* demonstrated reliable and safe navigation in hazardous environments, with A* offering the best computational efficiency. RRT produced shorter paths but showed instability and occasional collisions, limiting its suitability for safety-critical tasks. Overall, graph-based planners remain more dependable for structured high-risk settings. Future work will explore risk-aware and hybrid planning approaches to enhance both safety and adaptability.