



KENNESAW STATE UNIVERSITY

CS 7075

ARTIFICIAL INTELLIGENCE & ROBOTICS

PROJECT PROPOSAL

INSTRUCTOR

Dr. Waqas Majeed

Rohith Sundar Jonnalagadda

KSU ID: 001093082

Sai Veera Venkata Akshay Adabala

KSU ID: 001140226

Ramani Potlapati

KSU ID: 001125320

Uday Kumar Talasila

KSU ID: 001077488

Comparative Analysis of Maze Path Planning Using Enhanced Sparse A* Algorithm with Obstacle Variations

ABSTRACT

Our project evaluates path planning methods for mobile robots in complex mazes with varied obstacle shapes. Due to the inefficiencies of the traditional A* algorithm, which has high computational demands and redundancy, the efficiency of pathfinding is limited in achieving globally optimal paths. To address these issues, an improved Sparse A* algorithm is implemented, incorporating graph preprocessing and convex decomposition. The study compares the performance of this algorithm with traditional methods like Dijkstra, RRT*, and PRM in terms of path length, computation time, and stability. The findings demonstrate how map segmentation enhances efficiency, with the Sparse A* algorithm showing advantages in speed, path cost, and optimality over traditional approaches.

ROBOTICS PROBLEM DEFINITION

The primary problem involves planning a collision-free, optimal path for a mobile robot navigating through mazes and maps filled with obstacles of various shapes and sizes. The robot must efficiently find a path from an initial position to a target position, avoiding these obstacles and passing through narrow pathways, all while adhering to constraints such as limited computational resources and real-time requirements. This problem becomes particularly challenging when the environment is complex, with densely packed or irregularly shaped obstacles, which require the robot to make precise and efficient movements. Efficient and reliable path planning in such environments is a critical issue in robotics, especially for applications like autonomous navigation, industrial automation, and unmanned aerial vehicles (UAVs). In these scenarios, the ability to navigate through dynamic or complex environments while minimizing path cost (e.g., time, distance, or energy) is crucial for both safety and operational efficiency. Furthermore, ensuring that the pathfinding algorithm is scalable to larger, more complex environments is essential for real-world deployment in sectors like logistics, surveillance, and search and rescue operations.

AI AND ROBOTICS PROBLEMS ADDRESSED

Path Planning: Our project focuses on path planning for mobile robots, particularly optimizing the process of finding obstacle-free routes in complex environments. The Sparse A* algorithm is used to improve pathfinding efficiency and path optimality.

AI METHODS

- Traditional A* Algorithm: The baseline method for comparison, using grid-based path planning with a heuristic function to estimate the path cost.
- RRT* (Rapidly-exploring Random Trees): A sampling-based algorithm that guarantees probabilistic completeness and provides solutions in complex environments.
- PRM (Probabilistic Roadmap): Another sampling-based method that is efficient for complex maps but tends to generate suboptimal paths.
- Dijkstra Algorithm: A non-heuristic algorithm used to explore the entire state space, ensuring the shortest path but with higher computational costs.
- Sparse A* Algorithm: This algorithm will serve as the central technique, using map segmentation to reduce search space and improve path planning efficiency. By decomposing the free space into convex polygons, the algorithm optimizes pathfinding while maintaining solution stability.

METHODOLOGY

Maze and Map Construction

We are developing a diverse set of mazes and maps with varying levels of complexity, incorporating both single and multiple obstacles of various geometric shapes (e.g., polygons, circles). These maps are designed to test the robustness of the pathfinding algorithms by including both simple configurations and more intricate, obstacle-dense environments. This variation in complexity will challenge the algorithms, revealing their strengths and weaknesses in diverse scenarios, from straightforward paths to those requiring intricate maneuvers around obstacles.

Algorithm Implementation

We are implementing the Sparse A* algorithm based on the method outlined in the referenced paper, focusing on map segmentation and the division of regions around obstacles. This optimization aims to reduce computational load and improve the efficiency of pathfinding. In addition to the Sparse A* algorithm, we will integrate several traditional path planning algorithms, including A*, Dijkstra, RRT*, and PRM, into the simulation. This setup will enable a comprehensive comparative analysis, allowing us to evaluate the performance differences between the enhanced method and classical approaches across multiple parameters.

Simulation Setup

After constructing the mazes, we will simulate pathfinding scenarios using each of the algorithms. Key performance metrics will be recorded, such as:

- Path Length: The distance traveled by the robot from the starting point to the goal.
- Computation Time: The time taken by the algorithm to compute the path.
- Number of Expanded Nodes: The number of nodes explored during the search process, reflecting the computational effort required.
- Path Stability: The consistency of the generated paths across multiple simulations, which is crucial for reliable path planning in real-world applications.

Performance Evaluation

We will perform a detailed quantitative analysis of the algorithms, focusing on efficiency, optimality of the path, and the ability to handle complex environments. The enhanced Sparse A* algorithm will be compared with traditional methods in terms of:

- Pathfinding Speed: How quickly each algorithm computes a viable path.
- Path Stability: The consistency of the paths generated under varying conditions.
- Path Quality: The optimality of the path, particularly in terms of how close it comes to the shortest possible route.
- Robustness: The capability of the algorithms to maintain performance in increasingly complex environments.

EXPECTED RESULTS

- I. Improved Pathfinding Efficiency: The enhanced Sparse A* algorithm is expected to demonstrate superior efficiency in planning paths through complex environments, with fewer expanded nodes and shorter computation times compared to traditional methods.
- II. Optimal Path Generation: The proposed method will likely yield shorter and more optimal paths, particularly in maps where traditional grid-based algorithms like A* suffer from suboptimality due to limited neighborhood searches.
- III. Better Scalability: As map complexity increases, the Sparse A* algorithm's preprocessing and segmentation should result in faster performance, particularly in comparison to Dijkstra and RRT*, which are expected to struggle with larger state spaces.
- IV. Comparative Analysis: The study should provide a comprehensive comparison of the algorithms, illustrating the specific advantages and limitations of the Sparse A* algorithm in handling different maze configurations.

REFERENCES

Zhaoying L, Ruoling S, Zhao Z. A new path planning method based on sparse A* algorithm with map segmentation. Transactions of the Institute of Measurement and Control. 2022;44(4):916-925.
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