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ENHANCED A* ALGORITHM FOR GLOBAL PATH PLANNING

Global path planning is a fundamental component of autonomous navigation systems, enabling robots and vehicles to traverse complex environments efficiently and safely. While the traditional A* algorithm is widely used for its optimality and completeness in static environments, it suffers from several limitations, including suboptimal path smoothness, insufficient safety margins, and lack of adaptability to varying obstacle densities. To address these challenges, we propose an Enhanced A* Algorithm for Safe and Smooth Navigation, which incorporates dynamic heuristic weighting, obstacle-aware safety mechanisms, and B-spline-based path smoothing. These enhancements enable the generation of globally optimal paths that are both safe and smooth, making the algorithm suitable for real-world navigation scenarios.

The proposed algorithm introduces three key innovations. First, a dynamic heuristic cost function is designed to adaptively balance the actual cost and heuristic cost during the search process. By incorporating factors such as path depth and obstacle density, the algorithm dynamically adjusts the heuristic weights, ensuring robust performance in environments with varying complexity. Second, inspired by [1], a safety enhancement mechanism evaluates obstacle density and enforces a minimum safety distance, ensuring that the generated paths maintain a safe clearance from obstacles. Third, a path smoothness optimization module removes redundant nodes and applies B-spline fitting to produce continuous and smooth trajectories, addressing the discontinuities and sharp turns often observed in traditional A*-based paths.

Table1 Comparison of global path with different methods

Method	ANP	APL	ATA	ANUP	APT
Dijkstra	22	29	341.15	9	0.0014
A*	23	28	349	8	0.0028
Enhanced A * (Ours)	13	32	357.27	0	0.0485

To validate the effectiveness of the proposed algorithm, we conducted extensive experiments on a custom dataset comprising 100 randomly generated grid maps with obstacle densities ranging from 10% to 40%. The evaluation metrics included average number of points (ANP) average path length (APL), average turning angle (ATA), average number of unsafe points (ANUP), and average planning time (APT) [2]. Comparative analysis with baseline methods, including the traditional A* and Dijkstra algorithms, demonstrated that our enhanced A* algorithm consistently outperforms these methods across all metrics in Table 1. Specifically, our approach achieves zero unsafe points across all obstacle densities, generates smoother trajectories with higher average turning angles, and reduces the average number of path points, thereby simplifying the path structure. Although the computational time of our method is slightly higher due to the optimization steps, it remains within the range of real-time feasibility.

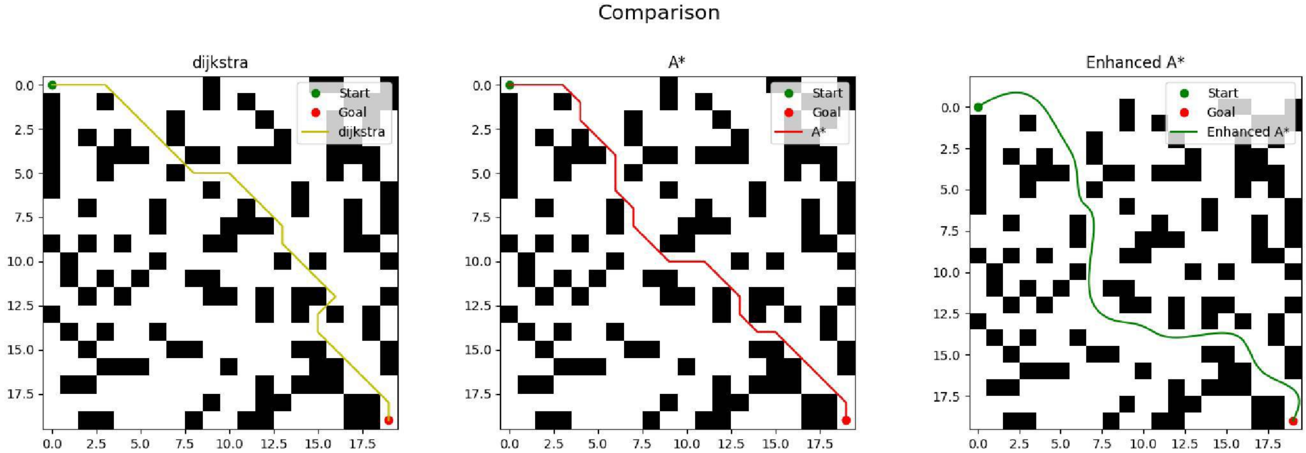

Figure 1 - Visualization of different global path planning algorithm

Qualitative results in Figure 1 further highlight the advantages of our approach. Visualization of the generated paths across varying obstacle densities shows that the enhanced A* algorithm produces safer and smoother trajectories compared to baseline methods. For example, in high-density environments, our algorithm effectively avoids unsafe regions, eliminates redundant nodes, and generates continuous paths suitable for practical navigation. In contrast, traditional A* and Dijkstra algorithms often produce fragmented paths with sharp turns and minimal clearance around obstacles, which are less suitable for real-world applications.

Reference

[1] Li, K., Gong, X., Tahir, M., Wang, T., & Kumar, R. (2023). Towards path planning algorithm combining with A-star algorithm and dynamic window approach algorithm. International Journal of Advanced Computer Science and Applications, 14(6).

[2] Li, X., Hu, X., Wang, Z., & Du, Z. (2020, October). Path planning based on combinaion of improved A-STAR algorithm and DWA algorithm. In 2020 2nd International Conference on Artificial Intelligence and Advanced Manufacture (AIAM) (pp. 99-103). IEEE.