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An Improved A* Based Path Planning and Control Strategy for Autonomous Sanitation Vehicles in Campus Environments

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Abstract

To address the problems of "missed operation tasks, high risk of path scraping, and low search efficiency" in the path planning of autonomous sanitation vehicles in smart parks, this paper proposes an optimization scheme based on an improved A* algorithm and Bézier curve. Based on the traditional A* algorithm, the neighborhood expansion is optimized to reduce invalid traversal, and redundant nodes are pruned through the "collinearity judgment + safe distance verification" strategy. A cubic Bézier curve is introduced to smooth the polyline path, adapting to the kinematic constraints of sanitation vehicles. Experimental results show that the number of traversed nodes of the improved A* algorithm is reduced, with significantly improved path safety and real-time performance guaranteed. The Bézier curve achieves continuous curvature, solving the problem of sudden steering. The proposed path planning scheme balances the requirements of operation completeness, kinematic safety, and planning efficiency, providing technical support for the intellectualization of environmental maintenance in smart parks.

Keywords

Autonomous Sanitation Vehicle; Path Planning; Improved A* Algorithm; Bézier Curve.

1. INTRODUCTION

With the continuous advancement of smart park construction, autonomous sanitation vehicles, as the core equipment for park environmental maintenance, their operational efficiency and safety directly determine the park's service quality [1]. Such vehicles need to complete composite tasks including "designated garbage collection - main road cleaning - temporary obstacle avoidance" within a limited time, and global path planning must simultaneously meet the threefold requirements of "path optimality, operational pertinence, and kinematic adaptability" [2-4].

The A* algorithm has become a mainstream method for unmanned vehicle path planning due to its concise principle and strong interpretability [5-8], but it has significant limitations in the exclusive scenario of sanitation vehicles [9-10]. The traditional A* only targets the shortest path between "start and end points" [11], failing to consider the operational characteristics and kinematic constraints of sanitation vehicles [12], which easily leads to missed garbage collection points [13] and increased scratch risks caused by sharp turning points in the planned path. Existing studies have improved efficiency by optimizing the A* search strategy [14-15], providing ideas for subsequent research.

This study focuses on the global path planning needs of autonomous sanitation vehicles in smart parks, aiming to propose a solution balancing operational completeness, kinematic safety, and planning efficiency, and provide technical support for the intelligent upgrading of park environmental maintenance.

Table 1. Your table here and center

Name	A	B
1	1A	1B
2	2A	2B
3	3A	3B

2. PROPERTIES

The A* algorithm is a path planning algorithm based on heuristic search [16]. It evaluates the node cost via the evaluation function ($f(n) = g(n) + h(n)$), thus achieving efficient solution of the optimal path [17]. Among the components, $g(n)$ refers to the actual cost from the start point to the current node, which is characterized as the moving distance between nodes in the grid map; $h(n)$ denotes the estimated cost from the current node to the target point i.e., the heuristic function. Common types of heuristic functions include Manhattan distance, Euclidean distance and Chebyshev distance. In this study, Euclidean distance is adopted for its adaptability to the movement requirements of sanitation vehicles. The specific process is shown in the figure below:

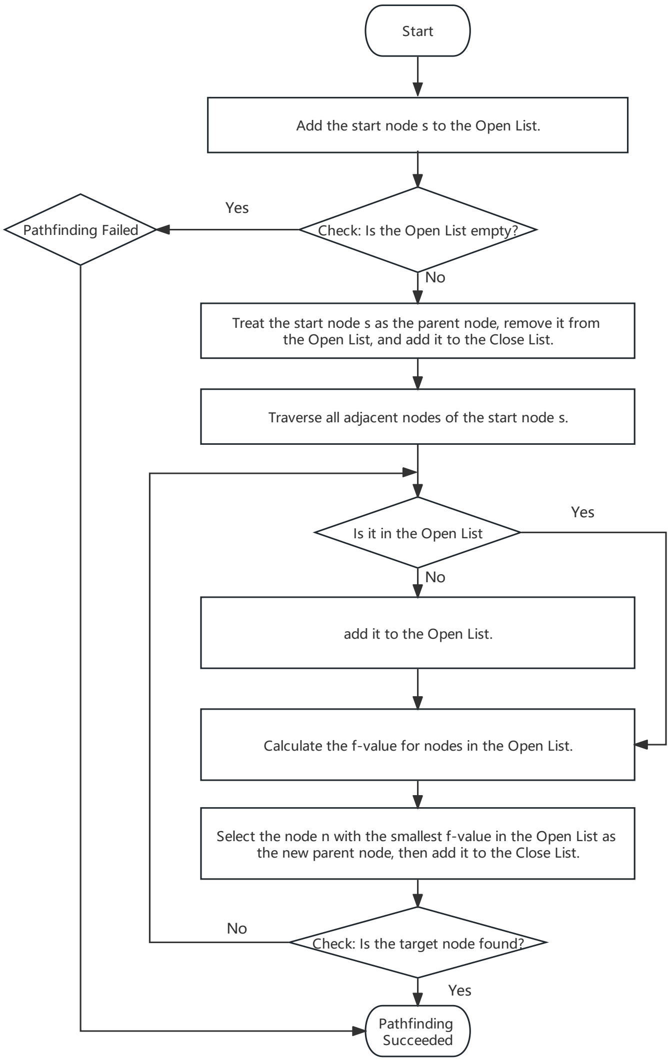

Figure 1. A* Algorithm Flowchart

2.1. Core Optimization Design of the Improved A* Algorithm

To address the limitations of the traditional algorithm and meet the demands of "operational reachability, kinematic safety, and planning efficiency" for park sanitation vehicles, optimizations are implemented from three aspects: heuristic function, cost model, and constraint conditions.

2.2. Optimization of Search Point Selection Strategy

The traditional A* algorithm expands 8 neighboring grids of the current node, but the fixed target direction renders expansion in some directions meaningless. For instance, if the target is directly east of the current node, neighboring nodes in directions like northwest, north, and southwest will deviate the search from the target, causing invalid traversal and wasting computing resources.

2.3. Design of Neighborhood Screening Rules

To solve this problem, this study proposes an angle-adaptive search point selection strategy based on the idea of "dynamically discarding redundant directions according to target orientation". Taking the current node as the origin, the line connecting the target and current node is used as the baseline; the angle between this baseline and the northeast direction is calculated, and 3 search directions far from the target are discarded according to the angle range, retaining only 5 effective directions close to the target. The core logic is to identify the target's orientation interval via the angle, eliminate directions deviating from the target, focus the algorithm on effective node expansion toward the target, and reduce invalid nodes from the source.

2.4. Redundant Node Deletion Strategy

Paths generated by the traditional A* algorithm contain numerous "collinear redundant nodes" that lie on the line between the start point and key turning points, without changing the path direction but leading to a lengthy node sequence. For example, in the collinear path "current point (P1) → intermediate point (P2) → key turning point (P3)", P2 only plays a transitional role; its deletion does not affect the global direction and safety of the path but can significantly simplify the path structure and reduce the computational pressure of subsequent trajectory tracking.

The judgment and elimination rules are as follows: 1) Traverse all nodes in the path sequentially; if the current node is collinear with the previous and next nodes, eliminate it. 2) After eliminating collinear redundant nodes, let the path nodes be $\{P_k \mid k=1, 2, \ldots, n\}$; connect P1 and P3. If the distance between line segment P1P3 and obstacles is greater than the set safety distance, connect P1 and P4, and so on until the distance between P1Pk and obstacles is less than the set safety distance; then connect P1Pk−1, eliminate intermediate nodes, and repeat the above operation starting from Pk−1 until all nodes are traversed. After this strategy, the path planned by the A* algorithm only includes the start point, end point, and necessary nodes, effectively reducing the path length.

2.5. Bézier Curve Optimization

Bézier curve is a parametric curve based on control points, featuring strong shape controllability, easy curvature adjustment, and good endpoint interpolation. Its order is determined by the number of control points. Considering the balance between path smoothing requirements and computational complexity of mobile robots, cubic Bézier curve is adopted in this study. It can eliminate sharp turns in the path to better adapt to vehicle kinematic constraints, ensure continuous path curvature, and has strong local adjustability during optimization. This improves path smoothness without damaging the global direction of the original path, balancing local optimization effect and global planning logic.

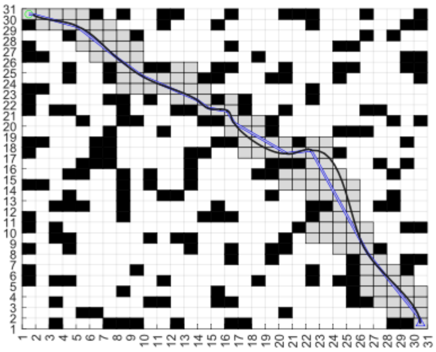

Figure 2. Path Planning Optimized by Bézier Curve

3. TESTS

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The improved A* algorithm optimizes the search logic and obstacle avoidance mechanism. At the cost of a slight increase in planning time and path length, it effectively achieves a nearly 50% reduction in redundant nodes to enhance search efficiency, while generating obstacle avoidance paths with superior safety. This makes it more suitable for the global path planning scenario of autonomous vehicles under the dual constraints of "efficiency and safety".

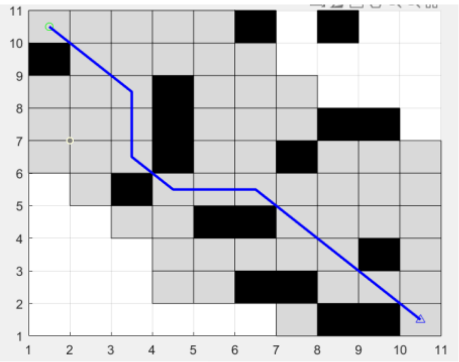

Figure 3. Path planning based on the traditional A* algorithm

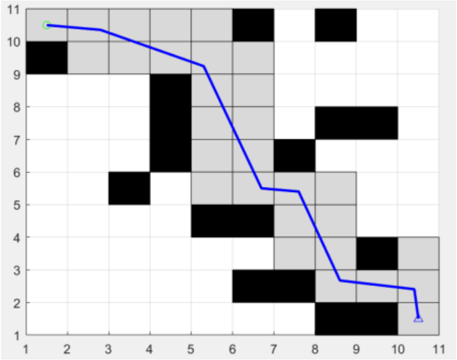

Figure 4. Path planning based on the improved A* algorithm

Table 2. Performance Comparison of Traditional A and Improved A Algorithms

Metric	Traditional A* Algorithm	Improved A* Algorithm
Planning Time	0.017636	0.041042
Number of Turns	4	6
Path Length	13.8995	14.5820
Number of Traversed Nodes	57	29

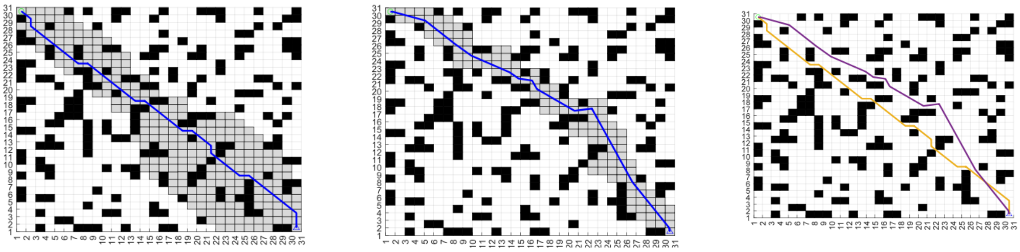

Figure 5. Comparison Diagram of Improved A* Path Planning

Table 3. Performance Comparison of Traditional A and Improved A Algorithms

Metric	Traditional A* Algorithm	Improved A* Algorithm
Planning Time	0.028912	0.064256
Number of Turns	13	12
Path Length	43.3553	43.7667
Number of Traversed Nodes	251	124

The Improved A* Algorithm significantly improves search efficiency and drastically reduces the traversal of redundant nodes by optimizing the search point selection strategy. Relying on the obstacle avoidance optimization design, it enhances path safety and obstacle avoidance capability, and the path morphology is more consistent with actual driving scenarios. Although the planning time is slightly prolonged, it still satisfies the real-time requirements of global planning for unmanned vehicles, representing a reasonable performance trade-off.

REFERENCES

[1] M.F. Zhu, F.Y. Hu, N.K. Li, and others: A Review of Path Planning Algorithms for Autonomous Vehicles, Agricultural Equipment & Vehicle Engineering, Vol. 61 (2023) No.11, p.18-22.

[2] L. Teng: Research on Path Planning and Trajectory Tracking Control Algorithms for Autonomous Vehicles (Ph.D., Zhejiang University of Science and Technology, China 2024).

[3] H.Q. Guo, L.X. Fu, Y. Zhang, and others: Path Planning of Safety A* Algorithm Fused with Dynamic Window Method, Ordnance Industry Automation, Vol. 41 (2022) No.12, p.41-48.

[4] Y.L. Wu: Simulation Application of Improved A* Algorithm in 3D Path Planning, Agricultural Equipment & Vehicle Engineering, Vol. 57 (2019) No.06, p.50-54.

[5] Q.Q. Xiang: Research on Dynamic Obstacle Avoidance Path Planning of Robots Based on Machine Vision (Ph.D., Hefei University of Technology, China 2021).

[6] J.Y. Wei, G.H. Kang, H. Zhang, and others: Research on 3D A* Optimized Obstacle Avoidance Algorithm for Dynamic Obstacles, Modern Navigation, Vol. 11 (2020) No.06, p.396-401.

[7] J.W. Zhan: Navigation Algorithm and Platform Construction of Mobile Robots in Indoor Scenarios (Ph.D., Anhui Polytechnic University, China 2022).

[8] H.Y. Feng, Y.S. Tang: A Review of Path Planning Algorithms for Autonomous Vehicles, Automobile Knowledge, Vol. 24 (2024) No.10, p.26-28.

[9] Q.N. Zhao: Path Planning Algorithm and Verification Platform Implementation of Mobile Robots in Indoor Environments (Ph.D., Anhui Polytechnic University, China 2023).

[10] D.D. Li: Research on Robot Path Planning Based on Improved Intelligent Optimization Algorithms (Ph.D., Anhui Polytechnic University, China 2023).

[11] P.K. Yan: Research on Path Planning and Trajectory Tracking Technology for Unmanned Vehicles (Ph.D., Harbin Engineering University, China 2024).

[12] J.P. Gao: Path Optimization Node Algorithm for Autonomous Vehicles (Ph.D., Qingdao University of Technology, China 2024).

[13] Z.H. Yuan: Research on Global Path Planning of Unmanned Vehicles in Complex Environments (Ph.D., Kunming University of Science and Technology, China 2024).

[14] J.W. Liu: Research on Path Planning Algorithms and Trajectory Tracking Control of Autonomous Vehicles (Ph.D., Bohai University, China 2023).

[15] Z. Li: Research on Path Planning and Trajectory Tracking Algorithms for Autonomous Vehicles (Ph.D., North China University of Science and Technology, China 2024).

[16] X.Y. Zheng: Research on Path Planning and Trajectory Tracking Control Strategies for Autonomous Vehicles (Ph.D., Yancheng Institute of Technology, China 2025).

[17] J. Lu: Research on Dynamic Path Planning and Control of Autonomous Vehicles (Ph.D., Guangxi University of Science and Technology, China 2023).