Research on Multi-sensor Path Planning Based on Corridor Environment

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Abstract. Aiming at the problems of traditional A* algorithm with many inflection points, large turning angles and not adapting to dynamic environment, the current optimized A* algorithm is analyzed and researched. Designed and built a wheeled robot platform with 4WD trolley as the carrier, single-line lidar Rplidar_A3, depth camera Kinect V2 and ultrasonic sensor TeraRanger one as environmental detection sensors. The platform conducted simulation research on the three optimized A* algorithms in the indoor corridor environment, compared the pros and cons of the planned paths, and set up path planning experiments based on the static network improved A* algorithm and dynamic obstacles and static Obstacle avoidance experiment. Experiments prove that the trajectory planned by the improved A* algorithm based on the static network contains 7 inflection points, which is relatively smooth, takes 49.8s and can effectively avoid dynamic and static obstacles.

Keywords: ROS, wheeled robot, multi-sensor fusion, path planning.

1. Introduction
Path planning means that the mobile robot collects environmental information with sensors under the condition of a known map to find the optimal collision-free path from the start point to the end point. Path planning is divided into global path planning and local path planning.

Global path planning algorithms are mainly divided into graph search algorithms, random sampling algorithms, and intelligent algorithms. The A* algorithm is a typical graph search algorithm. The core is to compare the assigned nodes to reduce the search range and improve the search efficiency [1]. The probabilistic road sign algorithm is a random sampling algorithm. By creating a path network graph in the learning phase for use in the query phase [2]; Ant colony algorithm is an intelligent algorithm that uses parallel methods to iteratively find the global optimal path, suitable for complex environments [3].

A* algorithm guarantees accuracy when guaranteeing the shortest path, quick response but many inflection points. Literature [4] optimizes path nodes on the basis of traditional A* algorithm based on static network, sets rules for deleting and adding nodes, smooths the path trajectory, has fewer inflection points and is time-consuming. Literature [5] expands the search neighborhood to 7*7, removes redundant child nodes in the same direction, and optimizes the search angle. Because the A* algorithm is only suitable for static environments, literature [6] predicts the boundary of encountering dynamic obstacles based on the escape distance strategy, determines the collision rectangle range, and
standardizes the obstacles to the smallest rectangle, so that the path is closer to the obstacle and the trajectory is more short.

At present, the mainstream local path planning algorithms include artificial potential field method, simulated annealing method, and dynamic window method and so on. The artificial potential field method abstracts the environment into an artificial gravitational field. The target point produces a "gravity" to the robot, and an obstacle produces a "repulsion" to the robot. The movement of the mobile robot is controlled by the resultant force. The structure is simple, the real-time performance is high, and the path is smooth [7]. The dynamic window method is to sample in the robot speed space, use the evaluation function to determine the optimal sampling point, reduce the computational complexity [8].

The first chapter of this article mainly introduces the commonly used path planning algorithms; the second chapter is the introduction of wheeled robot platforms and sensors; the third chapter is the introduction and simulation comparison of the improved path planning algorithms at this stage; the fourth chapter is the comparison of experiments and Analysis; The fifth chapter is a summary.

2. Wheeled Robot Platform
The overall framework of the wheeled experimental platform is shown in Figure 1. The entire platform is based on the Robot Operating System (ROS) implementation. First, the upper computer obtains map information. If the map information is unknown, use the lidar and depth camera to call the SLAM algorithm. Environmental map. Second, lidar, ultrasonic sensors, and depth cameras detect obstacles. If there is an obstacle lower than the installation position of the lidar, the local path planning algorithm is called to complete the obstacle avoidance according to the obstacle information detected by the depth camera and the ultrasonic sensor; the global path planning algorithm is called when the obstacle is not detected. Finally, the speed and corner information is sent to the chassis to control the movement to reach the target point.

![Figure 1. Wheeled experimental platform.](image)

3. Path Planning Algorithm Simulation
Set up a simulation environment under Gazebo, and make path planning for the above three improved A* algorithms, as shown in Figure 2. A comparative analysis is made in the four aspects of path smoothness, inflection point, path length and time.
Table 1. Parameter comparison.

| Algorithm                                      | Turning point | Path length | Time  |
|------------------------------------------------|---------------|-------------|-------|
| Improvement of A* Algorithm for Static Network | 7             | 42.35m      | 49.8s |
| Improvement of A* Algorithm for Escape Distance Strategy | 15           | 38.74m      | 65.5s |
| Improvement of A* Algorithm for Expanding Search Neighbourhood | 3            | 46.02m      | 52.7s |

As shown in Figure 2(d), the escape distance strategy mainly considers the shape and size of the obstacle and the distance to the obstacle. The coordinate information is updated. It can be observed from ① that the distance between the path and the obstacle is more than the other two algorithms. However, the algorithm only considers dynamic obstacles, so there are many inflection points in the path; the extended search neighborhood strategy deletes redundant child nodes in the same direction on the basis of expanding the search neighborhood, as shown in Figure 2(c). Compared with Figure 2(b), it is more gentle and has fewer inflection points, but there is an unstable route at ② in Figure 2(c), which will cause the robot to be unstable when driving and increase time consumption; Figure 2(c) ③④ both appear the phenomenon of trajectory deviation. As shown in Figure 2(b) ③④, no trajectory deviation is found in the path based on the static network strategy.

3.1. Wheeled Experimental Platform
The wheeled experimental platform uses a 4WD trolley as a mobile carrier, adopts a four-wheel drive mode, and uses STM32 as the chassis chip [9]. The entire control system is powered by a 12V battery, the motherboard is embedded with an IMU chip, the model is MPU9250, which provides the trajectory and posture relative to a certain starting position from a certain moment. The overall structure is shown in Figure 3, length × width × height=30cm×26cm×41cm, and the wheel diameter is 6.5cm. The depth camera is 45.5cm from the ground, and the lidar is 51.2cm from the ground. The front end of the ultrasonic sensor emits a cone-shaped sound cone. In order to minimize the blind area, it is installed at the center of the front end of the robot chassis, 2cm from the ground. The chassis includes batteries and motors. Encoder, IMU and motor control board.
Compared with single-line to 64-line lidar, the single-line lidar Rplidar_A3 has a measurement range of 0.2m to 25m, and a positioning accuracy of ±4cm. It is suitable for long-distance and long-distance corridor environments with few obstacles [10].

Compared with monocular, binocular, and depth cameras, choose the depth camera Kinect V2, which is based on TOF technology and carries color, depth and infrared cameras with a wide field of view and an accuracy of ±4cm [11].

Comparing the ultrasonic sensors, choose TeraRanger One sensor, which is suitable for the requirement of large distance detection range in the promenade environment and can quickly identify the obstacle in front. TeraRanger One uses TOF technology to output the distance information between the obstacle and the accuracy of ±4cm, the measuring distance reaches 14m [12].

3.2. Experimental Design and Analysis

In order to verify the feasibility and environmental adaptability of the path planning algorithm based on the static network, two situations of dynamic obstacles and static obstacles were set in the corridor environment, and the path planning and autonomous obstacle avoidance performance of the wheeled robot were observed. The environment is shown in Figure 4. As shown, the path is shown in Figure 5, the static obstacle is set as a carton (rectangular/cuboid obstacle), and the dynamic obstacle is set as a walking person. The path planning and autonomous obstacle avoidance effects are shown in Figure 6 and Figure 7, where the left side is the perspective of the robot, and the left side is the path.
Figure 6. Static obstacle avoidance effect

As shown in Figure 6(a)①, the total length of the path planned by the A* algorithm based on the static network is 134.8m, which takes 178.6s and has 8 inflection points. As shown in Figure 6 (b) ②, the green box is the boundary of the robot. Keep the obstacles as close as possible within the safety distance to make the path the shortest. The total length of the path is 3.16m, the maximum turning angle is 0.13rad, and the total time is 7.18s. As shown in Figure 6(c), the entire path is smooth and has no inflection points. When a dynamic obstacle is encountered, it is judged whether there is a collision point between the robot and the dynamic obstacle according to the sampling of the velocity space. As shown in Figure 7(b)① and 7(c)①, the robot adjusts its direction to the direction opposite to the direction of pedestrians and reaches the target point. The total path length is 1.74m, the maximum turning angle is 0.24rad, and the total time is 5.62 s.

4. Conclusions

Aiming at the problems of traditional A* algorithm with many inflection points, large turning angles and not adapting to dynamic environment, the current optimized A* algorithm is analyzed and researched. Designed and built a wheeled robot platform with 4WD trolley as the carrier, single-line lidar Rplidar_A3, depth camera Kinect V2 and ultrasonic sensor TeraRanger one as environmental detection sensors. The platform conducted simulation research on the three optimized A* algorithms in the indoor corridor environment, compared the pros and cons of the planned paths, and set up path planning experiments based on the static network improved A* algorithm and dynamic obstacles and static Obstacle avoidance experiment. Experiments show that the trajectory planned by the improved A* algorithm based on the static network contains 7 inflection points, which is relatively smooth, takes 49.8s and can effectively avoid dynamic and static obstacles.

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