Research on optimal path planning of indoor robot based on wireless sensor

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Abstract: Based on the work tasks and positioning characteristics of indoor robots, the environment is divided into grids, and wireless sensors are used to detect obstacles, and the density of obstacles in each grid is given. At the same time, the path planning algorithm is combined to realize the optimal path planning of indoor robot. The simulation results show that the wireless sensor network can realize the obstacle density detection, so that the robot can achieve fast optimal path planning and reach the target point.

1. INTRODUCTION

There are many indoor robots on the market today, such as guiding robots for hotels or large events, cleaning robots for homes and inspection robots for industry. This kind of robot generally has high mobility and the workplace environment is complex, so it needs more accurate indoor positioning ability. As a relatively mature positioning method, GPS positioning can only be carried out in outdoor occasions, but cannot be carried out in the indoor because of signal occlusion and other reasons. Wireless sensor network (WSN) is an energy-saving, low-cost and flexible detection method, which is suitable for indoor robot positioning requirements [1]. The wireless sensor network is used to construct a grid area and the sensors detect the obstacle density in the area. In this way, the area with fewer obstacles can be quickly shown and the optimal path can be pointed out to improve the working efficiency of the robot [2].

In this study, indoor guided robot is taken as an example to solve the related problems of the robot reaching the target node and returning to the starting point in the complex environment. In practical applications, the guiding robot will lead the user to visit the target position in a certain path, and then return to the initial position. When detecting the obstacle density of each grid, considering the influence of short-lived passing crowd or other obstacles on its movement route, the method of multiple detection can be selected to solve this problem. In this study, the method of three consecutive detection is adopted to detect the obstacle density. If the obstacle is detected within the detection range in more than three cycles, it can be determined that the obstacle has affected the robot's progress and the path should be changed. If the obstacle is detected only in one cycle but not in the next cycle, it will not affect the robot's progress.

The mesh segmentation method is adopted for the robot work area (Fig. 1). Sensors are evenly distributed in each grid and the sensors will detect obstacles in the area so that different areas will present different obstacle densities [3]. The results will be returned to the robot so that it can make a decision on the path. The grid partition is beneficial to improve the response speed and transmission efficiency.
2. Sensor Selection

2.1. Wireless sensor types and introduction

Firstly, the robot positioning problem can be solved by using multiple reference nodes. These nodes should be located on the same level above the ground to reduce the impact of ground obstacles on the signal. This study uses laser radar as the sensor. Laser radar has high precision, accurate measuring distance in a small range and small volume, which is suitable for the detection of environmental obstacles in the grid [4]. After ranging, the obstacle position detected by the lidar will be transmitted to the robot after numerical conversion [5].

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\begin{align*}
    x_n & = \rho \cos \beta \cos \alpha \\
    y_n & = \rho \sin \beta \\
    z_n & = h - \rho \cos \beta \cos \alpha
\end{align*}
\]

\(\alpha\) is the elevation Angle of lidar installation; \(h\) is the installation height; \(\rho\) is the distance from the scanning point; \(\beta\) is the lidar scanning Angle.

2.2. Feasibility and Innovation

In this study, the sensors were evenly distributed in each grid area. The sensors would detect the obstacles in the area so that different areas would present different obstacle densities. Results were returned to the robot, which allows the robot to make decisions about the route. The grid partition is beneficial to improve the response speed and transmission efficiency.

As shown in Fig. 1, the number of obstacles in each region and the distance to the boundary of the grid can be obtained through the lidar sensors distributed in each grid, so that the robot can get the...
optimal path. The detection node may treat some passing people and objects as obstacles and give wrong instructions to the robot to bypass, which will waste time and reduce user experience.

In this study, multiple detection is used to improve the reliability of obstacle detection results of wireless sensor [7]. If the same obstacle is detected in the sensor working area in three consecutive detection cycles, the robot determines that this obstacle will affect its own movement and change its path. If the obstacle is detected only within one cycle, it is proved that the obstacle is no longer within the detection range and does not affect the robot's movement. It is automatically ignored to reduce the time required for the robot's movement. (Fig. 3)

Figure 3. Multiple detection measures are taken to improve the detection accuracy.

3. Model Simulation and Analysis

As shown in Fig. 4, different obstacle densities were detected in the divided grid site. It was detected that the grid density on the right side of the starting point of the robot was small, so the robot moved to the right grid in the first step.

In the second grid, the sensor network detects that the density of obstacles in the grid above it is small, so the robot moves upward. Finally, it is detected that the grid of the end point is adjacent to the grid of the robot, and it directly enters the grid of the end point. The whole process ends.

Figure 4. Working principle diagram.

A common Q-learning model is selected in MATLAB simulation. In the simulation, the starting point and the end point should be determined first. The black square in the figure is the obstacle density points detected by the wireless sensor (Fig. 5). After three rounds of different detection, the position of each obstacle point is finally determined. Then the data is sent to the robot, which determines the best path according to the position of each obstacle point and its own position in the coordinate system.

Figure 5. Two simulation results.
It is not difficult to find from the experiment that with the help of the wireless sensor network, the obstacle density points in each grid are detected, and the method of three consecutive detection is adopted to improve the detection reliability. It can be proved that wireless sensor network has certain effect on robot path planning.

4. Existed Insufficiency

The wireless sensor network detection method mentioned in this paper is global detection, which is to detect obstacles in the working area before the robot sets out. Although multiple detection method is used to reduce the error, the possibility of new obstacle density changes in the process of robot movement cannot be ruled out. This problem has not been solved yet. The original path planning diagram is shown in Fig. 6 During the robot's journey, the obstacle density of one grid changes (Fig. 7), resulting in that the path at this time is not the optimal one and needs to be replanned.

![Figure 6. The density of originally detected obstacles and the corresponding walking route.](image)

![Figure 7. The density of obstacles changed during the work.](image)

5. Conclusion

In this paper, based on wireless sensor network and indoor robot, how to plan the optimal path of the robot is studied and the conclusions are as follows: By applying lidar and griding the region, the obstacle density in each region can be detected, and the data can be transmitted to the robot and the optimal path can be planned in the region. This method has the advantages of accurate detection and fast path planning. In order to improve the reliability of detection, the method of three consecutive detection is adopted. But at the same time, there are also shortcomings that the robot cannot avoid in time when obstacles change in the process of moving, which needs further research.

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