SLAM and Navigation of Indoor Wheeled Robot based on Ros with Intelligent Voice Recognition

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Abstract: The complexity and changeability of the working and living spaces have been observed to influence the difficulty of mobile robots to adapt to different indoor environments. When they enter the unknown environment, they become unfamiliar with the environment information and their own location. This observation requires mobile robots to have autonomous navigation capability. This study used Mecanum wheels to ascertain free movement of indoor robots in all directions, especially in the narrow indoor spaces. A hardware platform equipped with lidar and other sensors were developed to meet the challenges of indoor navigation. This enabled the indoor robot to efficiently realize indoor simultaneous localization and mapping, and navigate based on the map independently established by the robot. Additionally, voice interaction and graphical display of upper computer were realized in human-computer interaction.

1. Introduction

With the development of artificial intelligence technology, the types of intelligent service robots are becoming more and more abundant, and their autonomy is continuously enhanced[1]. From the first landing of market floor cleaning robots, food delivery robots, emotional robots, companion robots, educational robots, rehabilitation robots, supermarket robots, and the service fields and service objects are constantly expanding. Indoor robots are widely used in real life. For example, sweeping robots can help people complete tedious tasks such as daily household cleaning and improve their quality of life. It can reduce the number of cleaning staff and reduce the economic burden of enterprises. Service robots are increasingly used in catering, indoor tour guide, tourism explanation and other industries, and have a bright future.

But from the current development situation, the shortcomings in the field of mobile robots are increasingly obvious. Because of the complexity and changeability of human working environment and living environment, it is difficult for mobile robots to adapt to different indoor environments. When they enter the unknown environment, they do not know the environmental information and their own location, so it is very important for mobile robots to have the ability of autonomous navigation.

This study aimed to provide an indoor wheeled robot with voice recognition using slam and navigation algorithms. The robot uses lidar, combined with other sensors, to locate and establish a map indoor, automatically complete positioning, navigation and other tasks.

The wheeled robot developed by this research has the following feature. At first, it can locate itself in indoors without GPS. Secondly, it can perceive and understand the surrounding environment, and then simultaneous localization and mapping in the process of exploration. Third, it has the ability of path planning and obstacle avoidance strategy, and finally, it can interact with people through voice.

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2. Related work

At present, SLAM technology is applied in various fields and plays a very important role[2] in military, transportation daily life and other fields, such as indoor rescue, indoor reconnaissance, driverless, home robots, and wearable devices. The mobile robot SLAM technology not only provides a solution for robot intelligence, but also brings some fun and convenience to our daily entertainment and work. The robot's perception and positioning of its own position in the working environment is particularly important. Therefore, SLAM technology is a key technology for mobile robots to conduct autonomous exploration in unknown environments [3].

The solution of the mobile robot's simultaneous positioning and map creation (SLAM) problems directly affects the identification and avoidance of obstacles and whether the robot navigation path planning can be handled correctly. So far, the implementation of SLAM technology in a small-scale or structured environment is relatively mature, but its application in complex environments still has many problems. [4]

In recent years, the SLAM technology based on laser and sonar has become mature[5], but there are many problems. Slam technology, as one of the basic requirements of robot, needs to be improved and developed. The traditional SLAM algorithm has some disadvantages to its localization and mapping: Hector slam is a navigation technique which combines the robust scan-match 2d SLAM method with the inertial sensor system, but it is not suitable for the service robot because of its high requirement of hardware[6]. This algorithm is an approximate linear graph optimization, does not need to make initial assumptions, the calculation frequency is high, the cumulative error is fast. Cartographer, Insert sub-map can effectively reduce the cumulative error, but the operation process is too cumbersome[7]. Through the above comparison, this project adopts more accurate Gmapping algorithm on ROS[8] system: Adaptive Monte Carlo Positioning Algorithm, pose estimation, set of pose estimation maintained by particle filter, coordinate transformation information[9]. The Algorithm is optimized by closed-loop detection. The Algorithm is applied to the autonomous navigation of the robot, and the experiment shows that the algorithm has high accuracy.

3. Conceptual framework and problem statement

3.1 Conceptual Framework

Figure 1 was adopted from ROS Laser SLAM by Gray Letter Network. It summarizes the three interconnected parts of robot indoor movement like the:

Fig. 1. Conceptual Framework of the Study

Mapping. The position, direction and environmental information of the mobile robot in space are measured and obtained by combining the internal and external sensors of the mobile robot.

Localization. Using simultaneous location and map building algorithm to process the obtained environmental information to establish a map and environmental model.

Path planning. The path planning algorithm is used to find an optimal or sub-optimal collision-free path, so that the mobile robot can safely reach the designated destination.

3.2 Problem Statement

This study titled “Indoor Wheeled Robot with Voice Recognition using SLAM and Navigation

Algorithms" sought to provide an intelligent wheeled robot based on lidar and Simultaneous Localization and Mapping (SLAM). The robot uses lidar, combined with other sensors, to locate and establish a map indoor, automatically complete positioning, navigation, and other tasks.

Specifically, this study sought answers to the following questions:

1) What are the problems, and challenges encountered by the robot designers and users to adapt to indoor environment?

2) What model can be designed in developing the indoor wheeled robot with voice recognition using SLAM and Navigation Algorithm?

3) What indoor wheeled robot with voice recognition can be developed using SLAM and Navigation Algorithm?

4) What enhancement can be done to improve the intelligence level of robot during navigation?

4. Design of the wheeled robot

4.1 Kinematics Analysis of Mecanum Wheels

Omnidirectional movement is often a necessary function to realize flexible and accessible control of robots. Omnidirectional movement means that a researcher can translate in any direction in a plane and rotate simultaneously. To realize omnidirectional movement, general robots will use two unique wheels, Mecanum Wheel. In this design, 45-degree Mecanum wheels are used, and four wheels work independently, which can realize 3-degree-of-freedom movement in the plane. It is very suitable for working in places where the space is narrow and limited, and the demand of mobility of robots is high.

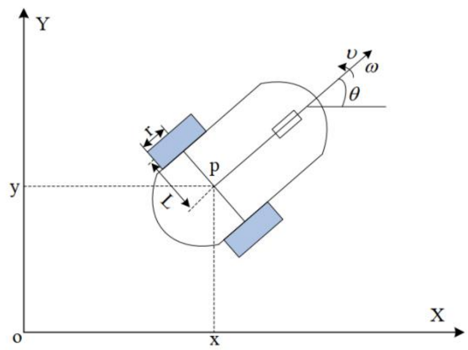


Fig. 2. Wheel Layout of Typical Omni-directional Platform

A typical omnidirectional moving platform with four Mecanum wheels is shown in fig.2. In the figure, the oblique line of the wheel indicates the offset angle between the wheel rim and the ground contact roller, and the roller can realize 2-degree-of-freedom movement. One is rotating around the axle, and the other is revolving around the axial direction of the roller.

When the motor drives the wheel to rotate, the wheel has two motions, one is to advance in the direction perpendicular to the driving shaft in a regular way, and the other is to rotate the roller contacting the ground around its axis. Take wheel one as an example, the speed of the wheel center in the global coordinate system.

$$v_1 = \begin{bmatrix} v_{1x} \\ v_{1y} \end{bmatrix} = \begin{bmatrix} 0 & -\cos\theta \\ R & \sin\theta \end{bmatrix} \begin{bmatrix} \omega_1 \\ v_{g1} \end{bmatrix}$$

On the other hand, the wheels are fixed on the mobile platform, which can be obtained by the overall speed of the omnidirectional, mobile platform.

$$v_1 = \begin{bmatrix} 1 & 0 & -l_2 \\ 0 & 1 & -l_1 \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}$$

And It can be obtained from the above two formulas.

$$\begin{bmatrix} 0 & -\cos\theta \\ R & \sin\theta \end{bmatrix}\begin{bmatrix} \omega_1 \\ v_{g1} \end{bmatrix} = \begin{bmatrix} 1 & 0 & -l_2 \\ 0 & 1 & -l_1 \end{bmatrix}\begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}$$

The same equations can be obtained for the other three wheels. The following relation can be obtained from the simultaneous equations:

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = \begin{bmatrix} \frac{1}{R\tan\alpha} & \frac{1}{R} & \frac{-(l_2+l_1\tan\alpha)}{R\tan\alpha} \\ \frac{-1}{R\tan\alpha} & \frac{1}{R} & \frac{(l_2+l_1\tan\alpha)}{R\tan\alpha} \\ \frac{-1}{R\tan\alpha} & \frac{1}{R} & \frac{-(l_2+l_1\tan\alpha)}{R\tan\alpha} \\ \frac{1}{R\tan\alpha} & \frac{1}{R} & \frac{(l_2+l_1\tan\alpha)}{R\tan\alpha} \end{bmatrix}\begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}$$

4.2 SLAM Algorithm

The SLAM Algorithm we used adopts the mainstream SLAM framework, that is, feature extraction, closed-loop detection and back-end optimization. A Submap subgraph is composed of a certain number of LaserScan, and a series of submap subgraphs constitute a global map. There is little accumulated error in the short-time process of constructing Submap with LaserScan, but there is a great accumulated error in the long-time process of constructing global map with Submap, so it is necessary to use closed-loop detection to correct the positions of these submaps. The basic unit of closed-loop detection is submap, and the closed-loop detection adopts Scan_Match strategy. The key content of cartographer is the creation of submap subgraph with multi-sensor data (odometry, IMU, LaserScan, etc.) and the implementation of Scan_Match strategy for closed-loop detection.

The pose estimation obtained by scan matching is reliable in a short time, but there will be accumulated errors in a long time. Therefore, we applied loop detection to optimize the accumulated error globally.

Compared with other slam algorithms, these are the following differences:

Introduces the concept of sub-map, which makes the front-end matching based on the matching between the current frame and the currently created sub-map (which can be understood as a series of scans before this).

Loop Detection is adopted, and branch and bound are used to optimize the search, which improves the efficiency and achieves the function of real-time loop.

4.3 Experimental steps

In order to conveniently control and view the SLAM effect on the host computer, we developed an upper computer system based on ROS, which runs on Ubuntu18 system and is compiled by QT. The running interface is shown in Figure 3.

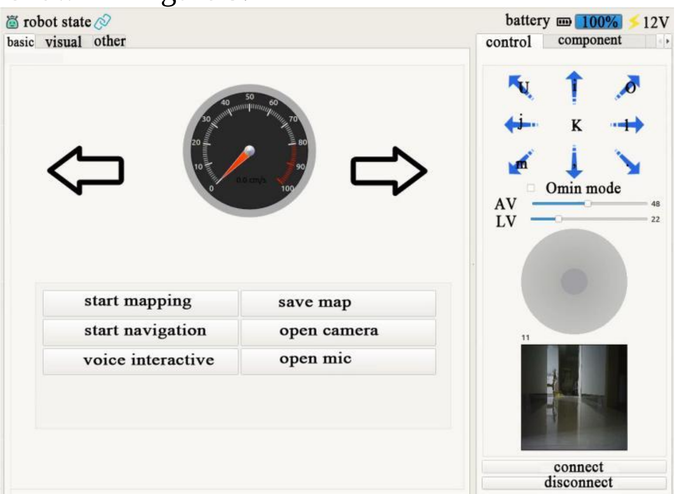


Fig.3 The data visualization by rviz

In the main interface, we can control the robot. Start the trolley service before operation. We can click the start mapping or start navigation button to start the mapping and navigation tasks respectively. After the task is started, the robot's master service is also started, and then we can click the connect button in the lower right corner of the interface to link to the server.

After connecting to the server, we can control the robot. There is a direction button controlled by the robot in the upper right corner. We can use the mouse or keyboard shortcut to control or rotate the car in various directions.

Among them, if you check the Omnidirectional button, the omni-directional robot will move horizontally to the left or right instead of turning.

LV and AV represent speed sliders, which can freely adjust the linear speed and turning speed of the robot. The following omnidirectional remote sensing can also control the movement of the robot by dragging and dropping the mouse.

If I click the open camera button, the image of the camera will appear on the right.

After switching to the visualization tab, we can see the process of mapping and navigation in the software.

In the visual component tab on the right, we can add some layers that need to be displayed on the left interface.

In the mapping task, it is recommended to add map layer, laserscan layer and robotmodel layer.

In the navigation task, it is recommended to add map layer, laserscan layer，robotmodel layer and navigate layer.

After adding appropriate layers, we can control our robot to move indoors and then build a map. Note that you must build the map before you can navigate. After the robot scans and plays all the places, we will get a complete map. Then we can switch back to the main interface and click the save map button to save the map.

After saving the map, we can click the start navigation button to start the navigation task. First, we need to click the 2D pose estimate button on the interface to determine the starting position of the robot. The method is to click and drag with the mouse to pull out a directed line segment to determine the position and direction of the robot on the map. In the same way, we can also use set return point to set the return point of the robot.

Then we can release the 2D nav goal button to release the navigation target point. At this time, after receiving the target point signal, the robot will automatically approach the target point according to the built-in navigation algorithm. If an obstacle is encountered in the middle, the robot will also bypass the obstacle through the obstacle avoidance algorithm.

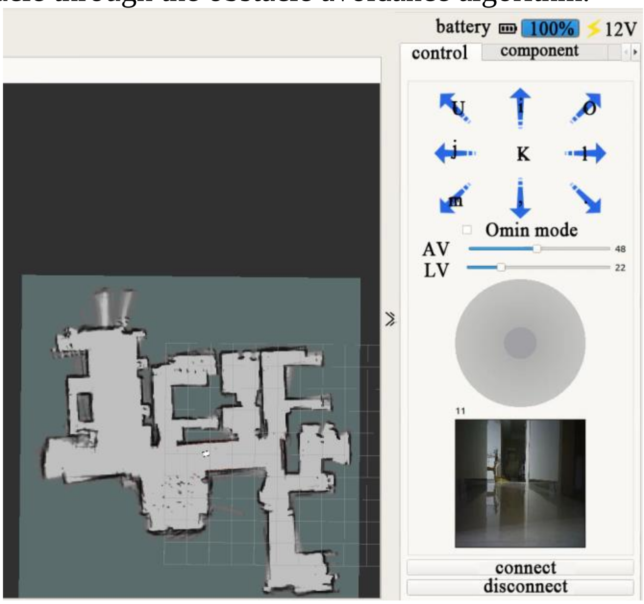
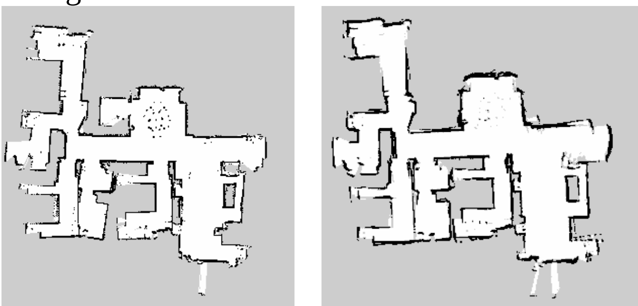


Fig.4 Mapping effect on host computer

4.4 Comparison of experimental data

We have conducted 10 groups of comparative experiments, and the experimental data show that under the same conditions, SLAM mapping using our algorithm can get better mapping effect when the ground friction is small and the mapping speed is greater than 10 cm/s. One group of contrast effect diagrams is shown in Figure 5.



(a).SLAM by gmaping algorithm (b).SLAM by our designed algorithm

Fig.5 Comparison of experimental data

From the comparison results, we can see that the left picture is obviously skewed in the lower left corner, while the right picture is much better. The reason is that in the field environment, there is a step of about 1cm in that area, and the wheels will idle when driving over the step, which will lead to inaccurate mapping. Our solution adopts loop detection, and when the robot walks through the same road section many times, it will automatically correct the previous figure. Of course, this can only improve the mapping effect to a certain extent. The best advice is to run as low as possible when driving through potholes or slippery sections.

5. Conclusion

The robot software and hardware framework satisfying autonomous navigation conditions is designed, including the mechanical platform with active sensing, voice input and motion control, and the wheel robot system with environmental sensing, ROS intermediate layer communication, data visualization application layer, mapping and navigation algorithm. The developed system would serve in such as a library, restaurant or hospital, to help people do some guide work. At the same time, the wheeled robot in this study has a good interactive experience, which can make the robot adapt to more application scenarios. Finally, the SLAM algorithm are applied to indoor robot navigation. Through accurate maps scanned by robots in advance and information fusion of various sensors, indoor navigation without GPS and other beacons is realized.

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