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Realization of Multi-point Navigation and Obstacle Avoidance Based on ROS

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***Abstract*—At present, in ROS core framework system, the realization of autonomous cruising and obstacle avoidance is the only way for robots to become more perfect. For this reason, this paper proposes and establishes a physical model of a two-wheel differential-driven mobile robot with nonholonomic motion constraints. SLAM and autonomous navigation are simulated, verified and optimized on STDR and Gazebo platforms, and gmapping and amcl algorithms are selected to realize mapping and navigation on Cater prototype platform. According to the experimental results of simulation verification and optimization, it is shown that using the above platform and algorithm to give the robot an environment map can basically realize accurate positioning and real-time motion planning for positioning targets. In the verification of the prototype, the experimental results are consistent with the theoretical analysis. The feasibility of the method applied in this paper is proved.**

Keywords-STDR and Gazebo Platforms; Gmapping and Amcl Algorithms; Robot Simulation Navigation; Multi-Point Cruise and Simulation Verification of Intelligent Robot

I. INTRODUCTION

A. *Background*

The application of robots has not only been limited to the development of the industrial field, but also can be seen everywhere in the military field, medical field, family labor service field, public service field, etc.[1]. With the development of mechanical engineering, control engineering, computer science and intelligent communication technology, it is possible for robots to become more autonomous and perfect[2-3]. How to let the robot know exactly where it is, where it should go and where it should go safely and effectively becomes an interesting but challenging problem. This function is more representative in home service robots.

Jibo, born at the Massachusetts Institute of Technology (MIT), is also one of the most concerned intelligent home service robots. It is about 28cm high and weighs about 3kg. It has electronic eyes, ears and mouth. Its head can rotate 360 degrees and can perform sound positioning. However, its disadvantage is that the robot as a whole cannot move freely. Jibo's service goal is to become an intelligent housekeeper for individuals and families, capable of taking photos, chatting, telling stories, reminding schedules and other functions. Jibo can also recognize different family members through voice and visual systems, and provide different service experiences according to different usage habits of each person[4-5].

Domestic service robots started relatively late. Whether in theoretical research or engineering implementation, China's research technology lags behind developed countries such as Europe, America, Japan and South Korea. In recent years, under the strong support and promotion of national policies such as the national "863" plan, the "Special Plan for the 12th five-year Plan" and the national guidelines, our country has also made certain achievements in the research of service robots[6-7].

For example, Loomo released by Nambu provides researchers with advanced data collection platform and algorithm model verification platform in the field of robots. Enterprises can make robot products more in line with the company's needs according to their own advantages and combined with their businesses. The latest small and medium-sized robot development platform Apollo released by Silan Technology can meet the needs of application development of small and medium-sized robots. Relying on the built-in high-performance SLAMWARE autonomous navigation and positioning system, it can carry out different applications and work in a variety of commercial environments[8].

B. *Introduction of Research Ideas and Framework*

With the rapid development and popularization of information technology and the Internet, marked by the presentation of the deep learning model in 2006, artificial intelligence has ushered in the third accelerated development. At the same time, the continuous expansion of application scenarios and service modes of intelligent public service robots relying on artificial intelligence technology has promoted the realization of autonomous cruising and obstacle avoidance methods of intelligent robots [9].The market demand is large, and the domestic market is still very single in the work done by robots, and the problems such as high price have yet to be solved.

In this paper, a ROS intelligent robot -Cater based on open source robot operating system is designed. Its research focus is on the STDR Simulator and Gazebo platform, and a large number of software and algorithms are verified and optimized to ensure the realization of autonomous cruise and obstacle avoidance methods. Simultaneous localization and map building (SLAM), ambient intelligence perception algorithm and autonomous motion decision-making in the environment are studied to realize autonomous navigation and enable the robot to carry out autonomous intelligent cruise and intelligent monitoring.

II. INTRODUCTION OF THEORETICAL FOUNDATION

A. STDR and Gazebo platforms

STDR Simulator (Simple Two Dimensional Robot Simulator) is a simple two-dimensional robot simulator, on which it is easy to simulate the independent motion of a single robot and the coordinated motion of multiple robots. It can not only run on the graphical interface, but also simulate through ssh connection. It is fully compatible with ROS. Data such as sensors on robots are published in the form of ROS topics, which is convenient for subscription and monitoring.

Gazebo is a powerful open source 3-D physical simulation platform, which can be used for indoor and outdoor robot simulation. It has a huge physical engine, graphics rendering, and an interface convenient for programming in ROS. The robot model added in Gazebo needs to add some physical properties of the robot body and the surrounding environment, such as mass, friction coefficient, etc. At the same time, it also supports the simulation of robot sensors, such as lidar, camera, etc.

B. Gmapping and amcl algorithms

Gmapping is a common open source SLAM algorithm based on filtering SLAM framework. Gmapping is based on RBpf particle filter algorithm, i.e. the process of location and mapping is separated, and location is carried out before mapping. Gmapping has made two major improvements in RBpf algorithm: improving the proposed distribution and selective resampling.

III. THE THEORETICAL PROOF OF THIS METHOD

A. Realization of Automatic Navigation

In order to realize the automatic navigation of mobile robots, the following six points need to be completed:

- A complete high-precision global map under which robots need to complete automatic navigation, which is a necessary and important prerequisite for automatic navigation;
- on which position on the map the robot is located, determine the current pose of the robot, and use it to determine the initial state of the robot;
- Where is the destination the robot needs to reach on the map, and the final pose of the robot on the map is determined for determining the end state of the robot;
- according to the robot's current position and orientation on the map and the target position and orientation, how to plan a perfect moving path so that it can move from the current position to the target position;
- To move the robot according to the global map as much as possible, local path planning is required at the same time to prevent obstacles from appearing suddenly on the global path. Therefore, it is necessary to plan the local path continuously at a small distance to move the robot to avoid obstacles.
- With the continuous movement of the robot, the global path also needs to be continuously re-planned, because it takes time to move from the current position to the destination position, and the global path planning is effective only at a certain time point. With the continuous change of the robot position and the passage of time, the global path planned at the beginning has become unreliable, so the global path needs to be continuously updated.

B. Method selection

Accurate positioning of robots is the basis for robots to walk autonomously indoors. In order to complete tasks safely and reliably, it is necessary to study more accurate positioning methods, which lays the foundation for autonomous navigation of robots.

The robot collects gyroscope and odometer data for processing in design, uses laser radar and vision to simultaneously locate and build a map system, establishes an environment map, and estimates the robot's own pose. The method comprises the following steps of: firstly, scanning an indoor environment by using a laser radar, fitting an indoor map by using collected data, and planning a traveling route according to destination information and indoor environment information; Then that data obtain by continuous scanning with lase radar is compared with map data to determine the position, meanwhile, odometer and gyroscope data are used to obtain the driving direction, sensor data are combine to judge the position and attitude of the robot, and the deviation is corrected in time.

IV. ANALYSIS OF EXPERIMENTAL RESULTS

A. Multi-point Automatic Cruise and Real-time Obstacle Avoidance

When the robot is planning its path, SLAM will scan and build a global environment map. However, it is not enough to rely on a global map alone. Because this map is static, the obstacle information on the map cannot be updated in time. In the real world, there will always be unexpected new obstacles in the map or old obstacles will be removed, so it is necessary to update the map in time. The automatic cruise simulation was carried out on Gazebo platform. Obstacles were updated continuously during the cruise, and its dynamic obstacle avoidance was verified. The effect is shown in the Fig.1.

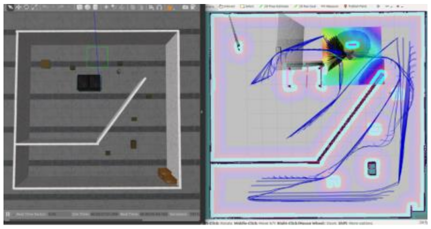
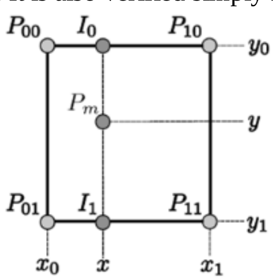


Figure 1. Real-time Obstacle Avoidance for Multiple Dynamic Obstacles in Cruise

B. Hector-slam algorithm validation

Hector slam uses Gauss-Newton method to solve the scan-matching problem [10]. It requires high laser radar (high update frequency, low measurement noise) and does not need odometer, so it is feasible for robots to build maps in uneven scenes. It is also verified simply here.



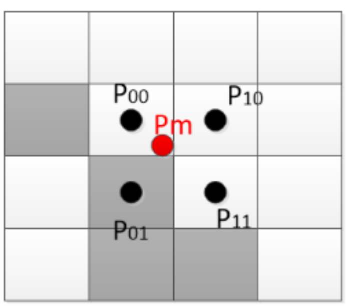


Figure 2. Fence Map Simulation

During initialization, the acquired laser data is mapped into the map as the first frame process. At time T, the laser acquires new laser data. To match with the map at time t-1, the laser data must first be transformed into a raster map. For example, laser points Pm are transformed into grid map. What we hope is that the laser points can be transformed into an "occupied" grid (gray). If all the laser points can be transformed into the occupied grid at time T, it means the matching is successful.

$$M(Pm) \approx \frac{\psi-\psi 0}{\psi 1-\psi 0}\left(\frac{\xi-\xi 0}{x1-x0}M(P11)+\frac{x1-x}{x1-x0}M(P01)\right) + \frac{\psi-\psi 0}{y1-\psi 0}\left(\frac{\xi-\xi 0}{x1-x0}M(P10)+\frac{x1-x}{x1-x0}M(P00)\right)$$

Finally, it can be obtained

$$\partial\frac{M\ (\Pi\mu)}{Pm}=\left[\partial\frac{M(Pm)}{x},\partial\frac{M(Pm)}{y}\right]1*2$$

In order to describe whether the laser points map into the occupied grid and the corresponding degree, bilinear interpolation method is used to calculate M(Pm).Fig.3 shows the simulation results:

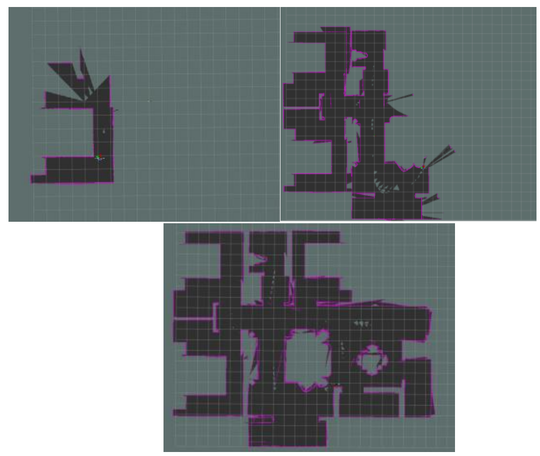


Figure 3. Hector slam Simulation Process in STDR

C. Results and Analysis

1) Experimental Verification: The algorithm is verified and optimized on STDR Simulator and Gazebo platforms to ensure the realization of autonomous cruise and obstacle avoidance methods. The robot collects gyroscope and odometer data for processing in design, uses laser radar and vision to simultaneously locate and build a map system, establishes an environment map, and estimates the robot's own pose.

Figure 4. Avoiding Obstacles during Cruise

2) Results and Analysis: A complete global map construction ensures that the robot can complete accurate autonomous navigation on the map, and a perfect moving path is needed between the current pose and the target pose. The use of lidar and gmapping algorithm on Gazebo platform ensures the real-time performance of global map and cost map. The choice is due to its small computation and high precision, which can make the simulation results more accurate, while hector-slam has more accurate local maps and stricter requirements on lidar. The calculation method is relatively complex, and good results can be obtained when applied to simulation, but the simple purpose cannot be achieved in the actual experiment process. of course, as the scene increases, the number of particles required increases. Because each particle carries a map, the amount of memory and computation required to build a large map increases. Therefore, gmapping is not suitable for building large scene maps. Therefore, amcl algorithm is matched to ensure automatic navigation on the basis of global map.

V. Conclusion

Based on the development of artificial intelligence technology and the continuous expansion of service robot application scenarios and service modes, this paper designs an intelligent robot-CATER-based on ROS platform to realize autonomous positioning, navigation and other functions of the robot, and carries out simulation and result verification on STDR and Gazebo platforms. The main contents of the work include the following:

The control system of the intelligent home robot Cater is designed and the electrical hardware is selected. Combining with the structural design, the physical prototype of the Cater is built. SLAM and autonomous navigation are simulated and verified on STDR and Gazebo, and finally realized on Cater physical platform. In the verification process, gmapping algorithm is relatively more suitable for intelligent home robots to perform SLAM indoors at low cost.

In motion planning, the improved gmapping algorithm is used for path planning, and the laser radar is used to ensure path searching in local map planning. this is a dynamic heuristic path searching algorithm just like CMU. it enables the robot to move freely in unfamiliar environment and is more comfortable in rapidly changing environment.

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