Slam and navigation of indoor robot based on ROS and lidar

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Abstract. For indoor service robot, this paper designs an indoor robot based on ROS (robot operating system) operating system. The robot uses two-dimensional lidar as the core sensor to collect the depth information of the environment and uses SLAM algorithm based on particle filter to realize the robot mapping; Based on the framework of ROS, A* algorithm and DWA algorithm are used to realize the navigation function of the robot. The map and navigation are simulated in the gazebo simulation environment to verify the function of path planning, local obstacle avoidance and navigation.

1. Introduction
In recent years, robots have gradually changed from fixed robots to free mobile robots. However, many technical problems have occurred. One of the central problems is indoor navigation, especially in complex environment, whether the robot navigation can be accurate or not is more important. Before that, we should solve three main problems: map construction, real-time positioning and path planning.

ROS provides a comprehensive operating system environment and is a distributed processing system, each process is relatively independent. Based on the characteristics of high cohesion and low coupling of ROS, in this paper, on the basis of ROS, environment scanning and real-time positioning are carried out by using lidar, and the popular laser SLAM algorithm is used to establish the map, and A* and DWA navigation algorithm are used to realize a set of indoor mobile robot based on lidar.

2. Selection of robot software platform

2.1. Introduction of mobile robot platform
The intelligent robot bobac is equipped with upper and lower controllers, as well as all the sensors required by the service robot, including ultrasonic, infrared sensors, collision sensors, voice sensors and two-dimensional lidar. Moreover, the robot is installed earlier with the ROS robot operating system, which is an open, simple and modular integrated robot platform.

2.2. Introduction of ROS system
At present, ROS has become the most widely used robot software development platform in the world. Its ROS package covers the fields of slam, motion planning, manipulator control and so on, and can even complete some difficult combined motions.[1]
2.3. Kinematic calculation
We can measure the speed of the left and right wheels by encoder \((V_L\text{ and } V_R)\). The velocity and angular velocity of the car are obtained by the forward kinematics solution \((V, \omega)\).

But we need to give the speed and angular speed of the car from the upper computer, and calculate the rotation speed of the left and right motors through the inverse kinematics solution. The pose and related data of the robot at two adjacent moments are shown in Figure 1. It is not difficult to get \(V_R = V + L \omega / 2\) and \(V_L = V - L \omega / 2\) by using geometry knowledge. The \(L\) is the distance between the left and right wheels of the robot.

![Figure 1: Pose of robot at two adjacent moments](image)

3. Map building and real-time positioning

3.1. Slam technology of lidar
In a strange environment, the robot uses odometer to record its motion information \(u_{1t} = u_1, u_2, u_3 \cdots u_t\) and laser radar information from its starting position \(z_{1t} = z_1, z_2, \cdots z_t\), combined with the motion model and sensor observation model, the robot's trajectory \(x_{1t} = x_1, x_2, \cdots x_t\) is estimated, while the environment map \(m\) is constructed. At the same time, the built map and sensor are used to realize real-time positioning. This is the robot slam technology, which is actually a Markov recursive process. From the perspective of probability theory, the formula of slam is obtained.

\[
\text{Bel}(x_t, m_t) = p(x_t, m_t|x_{t-1}, u_{1t})
\]

\[
= \alpha p(z_t|x_t, m_t) \int p(x_t, m_t|x_{t-1}, u_{1t}, m_{1t}) \text{Bel}(x_{t-1}, m_{t-1}) \, dx_{t-1} \, dm_{t-1}
\]

\(\alpha\) is the normalization constant, \(p(z_t|x_t, m_t)\) is a lidar observation model, \(p(x_t, m_t|x_{t-1}, m_{t-1}, u_{1t})\) is the joint posterior probability of the robot trajectory \(x_{1t}\) and map \(m\). [2]

3.2. Description method of map
Map is an important way to describe the environment of mobile robot. Different representation forms have different effects on path planning in navigation. Generally speaking, the more details in the map, the slower the operation speed of path planning; on the contrary, the less details in the map, the faster the path planning operation. There are grid representation, feature representation, topological
representation and direct representation. For the robot working in indoor environment, choose the grid representation which is more suitable for it.

The grid representation method discretizes the environment and divides it into several grids of the same size. Different gray values are used to represent the probability of a grid being occupied by obstacles. The map generated is called the occupancy grid map. The advantage is that it is easy to build and save, which is convenient for self localization and path planning; the disadvantage is that it is relatively complex to maintain in large-scale environment. However, the environment of indoor service robot is relatively small and simple, grid map can better record sufficient information without affecting the running speed of navigation algorithm. Figure 2 is the grid map established by two-dimensional lidar in the experimental environment. [3]

![Figure 2](image)

**Figure.2** The grid map established by two-dimensional lidar

4. **Research and implementation of robot navigation algorithm**

4.1. **Robot navigation**

Indoor robot navigation refers to the process of robot moving from the starting point to the target point. During this period, the robot determines its position according to the saved map and lidar, and then plans out the optimal path according to its own position and preset target point. Finally, the robot moves to the target point roughly according to this path. Path planning is divided into global planning and local planning according to the scope of action; Local planning is to plan the specific moving speed of the robot according to the local target points and the environmental information obtained by the radar.

4.2. **Global planning**

A* algorithm is selected for global path planning, and its evaluation function is $f(n) = g(n) + h(n)$, where $g(n)$ is the linear distance of node $n$ relative to the starting point, and $h(n)$ is the distance that node $n$ moves horizontally and vertically relative to the target point. The algorithm puts the possible points starting from the starting point into the open list, calculates the current the $f(n)$ location of the attachment node and selects the smallest node, so as to find the optimal path from the starting point to the target point.

4.3. **Local planning**

The DWA algorithm is selected for local path planning, and the velocity vector satisfying certain conditions $(v, \omega)$ (including linear velocity $v$ and angular velocity $\omega$) is sampled; According to the velocity vector of the sampling point and the forward and inverse kinematics solutions of the robot, the trajectory of the robot under the sampling velocity vector is predicted. Finally, the appropriate cost function is selected to score the predicted trajectory, and the optimal velocity vector is selected to control the next motion of the robot. Then the cost function is very important. The cost function of DWA is $G(v, \omega)$. 
\[ G(v, \omega) = \alpha \cdot \text{Cost}_{\text{Obstacle}} + \beta \cdot \text{Cost}_{\text{Path}} + \lambda \cdot \text{Cost}_{\text{Goal}} \]

The \( \text{Cost}_{\text{Obstacle}} \) indicates whether there are obstacles on the track and the distance between them, The \( \text{Cost}_{\text{Path}} \) is the nearest distance from the point on the track to the local reference path, The \( \text{Cost}_{\text{Goal}} \) represents the distance from the point on the track to the end of the local reference path. \( \alpha \), \( \beta \), \( \lambda \) are the weights of the above three sub functions, We adjust the three parameters of the robot environment to make the robot motion more in accordance with the needs of the current environment.[4] - [8]

So far, the three most important problems of robots: "where am I" "where am I going" and "how can I get there" have been solved. The specific flow chart is shown in Figure 3.

![Figure 3: The specific flow chart](image1.png)

5. Experimental analysis

Due to the reason of the experimental site, the gazebo simulation platform is selected to verify the robot mapping and navigation. The gazebo contains multiple physical engines and a variety of sensors, which can effectively simulate the robot in the indoor environment. After setting the actual position and pose of the car and the global target pose, the algorithm will automatically plan the path, as shown in Figure 4; after the car starts running, the car will automatically navigate to the set target pose, as shown in Figure 5.

![Figure 4: Automatically plan the path](image2.png)
![Figure 5: Reached the global target point](image3.png)
6. Summary
This paper studies the design and realization of the indoor service robot based on ROS. The environment map is constructed by slam technology, and the path planning is carried out by using A* and DWA algorithm. The global planning ability, local planning ability and autonomous action ability of the robot are verified by navigation experiments.

Although the robot map building and navigation functions have been completed, there are still many shortcomings and limitations. In the future, voice recognition system can be used to control the robot to select and navigate the target points; the depth camera can also be used in navigation to avoid low and small obstacles that cannot be detected by 2D laser radar.

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