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Overview of the positioning technology of the sweeping robot

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Abstract. Nowadays, the sweeping robot has been widely used in every household, the positioning technology of the sweeping robot, as one of the key technologies, is constantly updated, different technologies have different advantages and disadvantages and characteristics. Therefore, it is very necessary to summarize and summarize the positioning of the sweeping robot. Firstly, according to the existing review, according to the dimension of positioning technology, it is divided into four parts: simultaneous localization and mapping (S LAM), beacon-based positioning technology, environmental map matching positioning technology, and dead reckoning, and summarizes it. Finally, the future development prospect of the sweeping robot positioning technology is summarized.

Keywords: positioning technology, simultaneous localization and mapping, beacon-based positioning technology, environmental map matching and positioning technology, dead reckoning.

1. Introduction

Positioning technology is one of the indispensable key technologies of the sweeping robot. The sweeping robot obtains information according to its own environment, and through certain algorithms to obtain its own position information and the position information of other equipment, such as charging pile. An ideal sweeping robot should be achieved, in a completely unfamiliar environment, can independently implement the positioning and planning of the route, to achieve the purpose of cleaning. The high-precision positioning technology is a hot spot in the research of sweeping robot technology, and it has also become one of the directions of people's continuous research and breakthrough.

At present, there is a large number of literature in the field of related positioning technology. Ahasanun and others have conducted a comprehensive investigation of the positioning technology supporting machine learning (ML), and discussed the integration of other algorithms to achieve indoor positioning through ML algorithm [1]. In addition, Wang Huiqiang et al. made a detailed comment on the positioning technology and positioning methods, and predicted the future development of the positioning network [2]. Jayakanth et al. summarized the evolution of indoor positioning technology, including pedestrian navigation position calculation and various communication technologies [3]. After inspection and summary, the positioning technology is divided into the following four categories: 1) Simultaneous localization and mapping (SLAM); 2) Dead reckoning; 3) Environmental map matching positioning technology; 4) Beacon-based positioning technology.

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2. Simultaneous localization and mapping

SLAM is a map of the environment in an uncertain environment and can determine its position with incremental mapping. Collect information from the sensor, model the required environment, and locate it synchronously. At present, SLAM technology is a hot spot and direction to be improved in the field of sweeping robot. SLAM technology is mainly divided into: laser SLAM, visual SLAM, multi-sensor fusion of SLAM.

Different environments need different lidar to detect. In some simple environments, the requirements for sweeping robot are low, so two-dimensional lidar can be used. In more complex environments with many obstacles, 3D lidar is used to scan the space. The main localization algorithms of laser SLAM are KF, Fast SLAM, Gmapping, Cartographer and Hector. Zhou Zhiguo and others tested the open source algorithms through the algorithm performance evaluation standards. Most of the open source algorithms are real-time, and can even accelerate the processing of [4]. Laser SLAM has less calculation, higher accuracy, and little influence by illumination. Lidar is also developing towards solid state, improving the scanning speed of the system, reducing power consumption, and obtaining a larger scanning range [5], but if applied to sweeping robots, it is expensive and inconvenient for daily maintenance.

Visual SLAM is according to the camera to obtain its own position, according to the camera type is divided into monocular camera and binocular camera. Most robots use monocular cameras because they have only one camera, a simple structure, low price and low power consumption. However, the monocular camera has scale uncertainty, and there is an error between the measured data and the real situation [6]. Binocular cameras can estimate the image depth using pictures from two different angles captured from an object [7] . Binocular camera not only has low cost, but also makes up for the error caused by monocular camera, but its calibration is more complex, high-power consumption, and requires more computing resources. RGB-D camera is a combination of color head and depth head, with high measurement accuracy, less computing resource consumption and strong real-time performance. It is vulnerable to the influence of solar light and is more suitable for indoor environment.

SLAM fused with multiple sensors can improve localization accuracy and robustness. Our common methods of multi-sensor fusion include lidar and IMU fusion, which provides the current and estimated pose of the robot, and also provides information about point cloud distortion to optimize positioning and mapping. When encountering a sensor leading to measurement distortion in fast motion, Gentil et al propose a probabilistic framework to repair the distorted generated in the laser scan [8].

The lidar and the camera merge to obtain more accurate pose information by converting the acquired point cloud into a camera coordinate system. J Li and others. use the fusion of lidar and camera multi-sensors to generate point cloud information acquisition semantic map, to solve higher level of scene interaction and improve the efficiency of positioning and mapping. Lidar can solve the weakness of camera [9].

Fusing the camera and IMU, there will be a time offset between the two data streams [10]. Li et al. uses the method based on the extended Kalman filter, which includes the time offset between the two data streams [11]. RGB-D camera and IMU multiple sensors to improve the efficiency of data acquisition in an indoor environment with a large amount of occlusion [12]. How to effectively couple multiple sensors, improve accuracy and robustness is the direction to be explored in the future.

Table 1lists the characteristics of the three SLAM species.

Table 1. The characteristics of SLAM.

The species of the SLAM	Characteristics
Laser SLAM	Less calculation, higher accuracy, little influence by illumination,but it does not collect the complex environment information very well.

Table 1. (continued)

Visual SLAM	Less cost, higher measurement accuracy, it can measure more complex environment, but the amount of calculation is large, easy to be affected by the outdoor light.
Multi-sensor fusion of SLAM	Combined with a variety of sensors, reduce the limitations of the sensor, high accuracy, but the amount of calculation is large, high cost, not easy to daily maintenance.

3. Dead-reckoning

The method can calculate its position without environmental information, but the errors will gradually accumulate. There are many methods to correct the cumulative error of the dead reckoning, such as the optimal estimation method, combining UWB, the fusion map matching method, etc. In the dead reckoning, Liu Shengkai et al. compared the experimental results of combining a single IMU sensor and multiple IMU sensors, and the calculation results after data fusion of multiple sensors are more in line with the actual situation [13]. Dead reckoning can achieve positioning in a short time. If in a long time of navigation work, the cumulative error will increase and eventually lead to inaccurate positioning.

4. Environmental map matching and positioning technology

Environmental map matching and positioning technology is to obtain the local environmental information around the body through sensors, and then match with the stored global map, so as to obtain its own location. The methods commonly used in drawing are grid method, topological method and geometric method.

Raster method is to build a map model with the same size of the required environment, using the same size grid to partition. In a grid, the robot is set to 0 and the place with obstacles as 1, so a matching map model is built. The raster method can make the map model clearer, but requires a lot of storage and more errors. Zhao Jiang et al. establishes a feature grid by extracting features, because the number of grids required to search and identify becomes reduced, which can solve the algorithm problem caused by the excessive number of grids [14].

Topological method is to divide the environmental space into three spaces with consistent topological characteristics, free activity space, incomplete movable space and non-active space. The algorithmic complexity of topological method will increase with the increase of obstacles, so it is difficult to apply in complex indoor environments. McCammon et al. proposed two algorithms for spatial topological planning. The first is to collect information hotspots by layers, and the second is to spatially decompose the topological features of information to optimize the performance of the traditional algorithm [15].

The feature map established by the geometric method is represented by the geometric features of the environmental space, usually combined with GPS, UWB, lidar, etc., but it is not completely applicable to indoor sweeping robots, and the cost should be taken into account.

5. Beacon-based positioning technology

The beacon-based positioning technique relies on the known beacons around the sensor measurements for positioning. This technique can be divided into the triangulation survey and the trilateration survey. Triangulation survey needs to calculate the position of the unknown point through the known position of the three nodes, which is the direction method and the Angle measurement method to measure and calculate, while the trilateration survey is similar, as shown in figure 1.

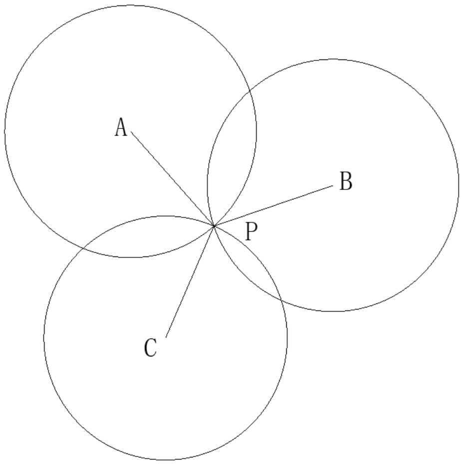

Figure 1. Tripartite measurement. Known three-point coordinates of A, B, C, the coordinatesof P are found by the distance from the unknown point P.

When the sensor receives and transmits signals, resulting in positioning error, and the least squares method is usually used to reduce the error. However, selecting only three beacon points will also increase the algorithm error of the least squares method. Therefore, Liu Wu and other candidates will match the acquired beacon sequence with the best beacon combination, and select the optimal node combination to solve the position of the unknown point [16]. However, once there is more serious information interference, local accurate information cannot be obtained and this optimization method cannot be used.

6. Conclusion

Even though the current indoor positioning technology has been quite mature, the positioning technology that can be well applied to the sweeping robot is very limited. In daily life, it will still encounter problems such as repeated cleaning, lost, unable to locate the charging pile and so on. There are many methods to improve the positioning technology of sweeping robots, such as the combination of multiple sensors or algorithms. This paper proposes that the following five aspects are an ideal sweeping robot needs to have, with high positioning accuracy, high efficiency, low power consumption, low cost, to ensure the cleanliness of the sweeping robot.

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