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Analysis and application research of mobile robot navigation related technologies

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Abstract: With social progress and technological development, mobile robots have played an important role in industries, medical care, safety, home and other fields due to their advantages of saving labor costs, reducing personnel work intensity, and avoiding potential job hazards. Especially in indoor environments, such as industrial indoor operations, warehousing and logistics distribution, indoor safety patrols, and other application scenarios, mobile robots have highlighted inestimable application value. Intelligent mobile robot is an important tool in the field of service and automation, and robot navigation technology is an important technology for intelligent mobile robot to achieve self-positioning, robot mapping and path planning. This paper expounds three technologies of mobile robot navigation mapping: visual mapping and positioning, lidar mapping and positioning, and sensor fusion mapping and positioning. After that, the method of path planning of the mobile robot is analyzed. Finally, the application of intelligent mobile robots in factory automation and supermarket guidance is pointed out, and the development trend of intelligent mobile robots is prospected.

Keywords: intelligent mobile robot, robot navigation, mapping and positioning, path planning.

1. Introduction

In recent years, similar to information technology, microelectronics technology, artificial intelligence technology as a symbol of the development of modern science and technology, has entered a stage of rapid development [1].

Mobile robots are new types of robots that can rely on their own sensors to perceive and understand the external environment, make real-time decisions according to task needs, carry out closed-loop control, operate in an autonomous or semi-autonomous manner, and have certain self-learning and adaptability in known or unknown environments. The application field of mobile robots is very extensive, and there are currently related application directions in service, rescue, agriculture, medical and other fields [2].

The application and development of mobile robots can reduce the cost of human resources, the use of intelligent mobile robots for the transportation of goods in factories or workshops can significantly improve the efficiency of transshipment, and the use of intelligent mobile robots to transport epidemic prevention materials during the epidemic has also reduced the spread of the virus [3].

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Robot navigation technology is an important technical means for intelligent mobile robots to achieve autonomous control and autonomous movement to specific targets in an obstacle environment. In indoor travel, when encountering obstacles obstruction, mobile robots need to detect the surrounding environment and their own state through sensors, carry out mapping and path planning, and find an optimal path. The team of the Robot Industry Technology Research Institute of Anhui Polytechnic University in China broke through the common key technology of multi-axis motion control and scheduling system of mobile robots, and innovatively developed an all-terrain mobile robot with high-precision combined navigation with terrain matching and its operation scheduling system, which realized the autonomous operation of mobile robots in complex situations [4]. Developed countries in robotics represented by the United States, Japan and other countries have carried out in-depth research on robot autonomous navigation technology, and have achieved some results.

The related technologies of robot navigation include mapping and positioning technology, and path planning technology. Among them, mapping and positioning technology includes visual mapping and positioning technology, lidar mapping and positioning technology, sensor fusion mapping and positioning technology, etc. This paper reviews the research status of mobile robot navigation technology from the above three technologies, and further discusses the application prospects and future development trends of mobile robot navigation [5].

2. Related technologies

2.1. Mapping and positioning

Mapping and positioning is the most important aspect of robot navigation, which determines whether the robot can navigate successfully or not. In order to achieve autonomous navigation of an intelligent mobile robot, it is necessary to recognize a variety of environmental information based on multiple sensors: road boundaries, terrain features, obstacles, guides, etc. In driverless car navigation, it is also necessary to recognize traffic signs, typical intersections, and other information. The robot uses environment awareness to determine the reachable and unreachable areas in the forward direction, to determine its relative position in the environment, and to anticipate dynamic obstacle movements, thus providing a basis for local path planning [6].

2.1.1. Visual mapping and positioning. Vision navigation, vision refers to computer vision, computer vision has a rich amount of information, high intelligence, and a variety of advantages, so it has been widely used in recent years in the autonomous navigation of mobile robots, computer navigation technology is the key to complete road sign detection and recognition, obstacles [7]. The knowledge of an autonomous robotic navigation environment is defined in certain early vision systems by a grid in which items in three-dimensional space are projected vertically by volume onto a two-dimensional horizontal plane enabling analysis and exploration of locations concealed from reality. The "Occupancy Map" is another name for this depiction. The Occupancy Map concept was later refined by "Virtual Force Fields" (VFF). The VFF is similar to a "Occupancy Map," except that on the map, each occupied area imposes a repulsive force on the robot, whereas the destination exerts a gravitational force on it. All of these forces interact with one another via vector addition and subtraction to draw the robot away from obstacles and toward the target [8].

The key to map-based navigation is the autonomous robot's localization, and vision-based localization can be separated into four parts.

Obtain sensory information: acquires or digitizes the perceptron, which is the picture acquired by the camera in vision-based autonomous robots.

Detect landmarks: This step is generally a digital image processing process. That is, operations such as edge extraction, image smoothing, filtering, region segmentation, etc. are performed on the basis of different types of images, such as grayscale images, color images, and motion vectors.

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Establish matches between observation and expectation: In this stage, the autonomous robot uses the seen landmarks, which were processed in step 2), to try to match them in the database using some judgment criteria.

Compute position: If the match in step 3) is successful, the autonomous robot must determine its absolute location in the whole navigation space using the exact position of the landmark in the database and the robot's own position relative to the surface.

2.1.2. Lidar mapping and positioning. LIDAR is widely used in robot collision avoidance and environment modelling, because of its long detection distance (tens of meters, even hundreds of meters), high measurement accuracy, and the ability to perform line scan and surface scan. Line scan LIDAR can only obtain a two-dimensional model of the environment, while surface scan LIDAR can obtain a three-dimensional model of the environment [9].

The robot uses sensors (e.g., LiDAR) in an unknown environment to collect depth-of-field data with itself as the origin, a process in which the robot achieves localization (its own pose) and initialization of the global map. The SLAM algorithm generates a new local map and extracts the feature information from the acquired data to match the existing features while the robot is in motion, thus estimating the new pose of the robot. The updated poses allow incremental incorporation of the local map into the global map.

2.1.3. Sensor fusion mapping and positioning (vision+radar). Multi-sensor information fusion is one of the key technologies for mobile robots. Information fusion refers to the integration and processing of environmental information provided by multiple sensors to form a unified representation of the external environment. It not only fuses the complementary information, but also eliminates the redundancy of information, realizes the real-time information and low cost of information, and also can effectively use the multi-sensor based on a more complete and comprehensive depiction and recognition of the measured target, and then make the correct judgment and choice, ensuring the rapidity, accuracy and robustness of robot navigation.

Internal sensors and exterior sensors are the two types of sensors utilized in mobile robots. Internal sensors are utilized to detect the robot system's internal characteristics. Odometers, gyroscopes, magnetic compasses, and optical encoders are among the most common. External sensors are utilized to get information about the environment. Vision sensors, laser range sensors, ultrasonic sensors, infrared sensors, and other types are the most common. Weighted averaging, Bayesian estimation, multi-Bayesian methods, Kalman filtering, D-S evidence inference, fuzzy logic, generative rules, artificial neural networks, and other techniques are extensively employed for multi-sensor information fusion techniques. The weighted average method is an underlying data fusion method that uses a weighted average of redundant data from multiple sensors to produce an estimate that is not statistically optimal. The Bayesian approach is to make probabilistic judgments about events that have not occurred based on known facts, and to make inferences about unknown probabilities from known prior probabilities. D-S evidence inference is an extension of the Bayesian approach, which uses an unstable interval. The prior probability of unknown premises can compensate for the inadequacies of the Bayesian technique. It is especially well suited to dealing with information fusion issues in multi-sensor integrated systems. Using the statistical attributes of the measurement model, Kalman filtering is used to iteratively identify the best fused data estimate in a statistical sense [10]. Artificial neural nets can fuse the information from sensors by certain learning algorithms to obtain the network parameters.

2.2. Path planning

Path planning is an important part and topic of navigation research. The main problems involved in path planning include. 1) Using the infrmation gathered about the mobile robot's surroundings to construct a more realistic model, and then applying some algorithm to discover a collision-free path in the environment space that takes the least time from the beginning state to the destination state; 2) being able to deal with the uncertainties in the environment model and the errors that occur in path tracking, so that the influence of the outside world on the robot is minimized; 3) using the known information to guide the robot's actions, so as to obtain a relatively better behavioral strategies. There are two forms of path planning dependent on the type of information the robot acquires about the environment: global path planning based on a priori information about the environment and local path planning based on sensor input. The former seeks an ideal path based on past environmental knowledge, whereas the latter is unknown or largely unknown, such as when the field environment changes dramatically or unexpected obstacles appear, and the acquired information is insufficient to support the robot's navigation. Information about the size, shape, and location of obstacles must be obtained from the surrounding environment by relying on on-board sensors and reprogrammed online to compute a collision-free path in real time. The following global path planning methods are often used: free-space method, visual graph method, raster method, topology method, etc. In sensor-based local path planning in partially known or unknown situations, the artificial potential field approach, fuzzy logic algorithm, genetic algorithm, and artificial neural network are commonly applied [7]. In recent years, the simulated annealing algorithm, ant colony algorithm, particle swarm algorithm, chaos algorithm, artificial immune algorithm, and heuristic search technique have gained popularity.

3. Application prospect

3.1. Factory automation

In the high-speed production line, the delay of any station will affect the efficiency of the entire line, so the production manager must ensure the efficient and stable supply of materials in each production link. Intelligent mobile robots using robot navigation technology have played a key role in this, and at present, there are several application scenarios of mobile robots in the workshop. For example, to handle materials, mobile robots transport materials to designated areas for storage through navigation, or transport them to the processing place for manual or automatic sorting, and then pull them to the processing point for standby, the whole process is carried out under monitoring, and the operator can flexibly adjust and optimize the equipment operation path to achieve higher efficiency [11].

3.2. Supermarket guidelines

Intelligent mobile robots in shopping malls and supermarkets can help customers to consume conveniently and increase mobile shelves. Through sensor fusion mapping for positioning, the mobile robot breaks the limitation of traditional shelf position fixed and cannot move, and can move autonomously for the crowd to increase exposure. And based on offline flow of people can provide user portraits, including gender, age range, preferences, etc., the support of this data can become an important basis for production and delivery quantification. At present, intelligent mobile robots have been used in many fields such as fresh food and supermarkets, which can record the flow of passengers, the number of people staying and the length of time in the first time, analyze the passenger flow, and provide personalized product display and recommendation [12]. At the same time, the movement path can be continuously optimized based on the robot's position information and the passenger flow statistics of the time series.

4. Conclusion

When the robot goes out of the limited scope and goes to a wider space, navigation becomes a bottleneck technology that restricts the promotion and application of robots in a larger range, and it is also the key technology for intelligent mobile robots to truly realize autonomous control [1] At present, the traditional map representation method is still the most used method for robot mapping. In recent years, algorithms based on artificial intelligence have been widely used in path planning algorithms. [2] It lays the groundwork for the rapid use of intelligent mobile robots in a variety of sectors. With the continued growth and improvement of science and technology, the application possibilities for mobile robots will be broadened in the future. Mobile robot technology for industrial applications will accelerate the

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integration with artificial intelligence, mobile Internet, big data processing and other technologies to create new technologies, products and application models.

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