Research on Path Planning Algorithm of Binocular Vision Positioning Mobile Robot

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Keywords: Mobile Robots; Image Processing; Path Planning

Abstract: With the rapid development of computer and automatic control engineering in like, mobile robots have been widely used in various fields of social life. Based on this, this paper puts forward a system design scheme of mobile robot path planning and obstacle avoidance, which realizes the path planning and automatic obstacle avoidance function of mobile robot autonomous travel. Describe in detail how to use stereo vision to detect the environment. The global path planning method and the local path planning method are combined, and the path planning method based on the combination of the behavior-based behavior planning and the deliberate behavior planning is adopted. The global path planner uses the A* algorithm to generate the sub-target node sequence reaching the target point. Using the fuzzy control algorithm, a series of control rules are designed, and the control rules table is obtained by reasoning. By inquiring the table, the information of the mobile robot can be obtained, which effectively avoids obstacles and realizes the path planning of the mobile robot.

1. Introduction

Mobile robot is a comprehensive product of many disciplines such as information technology, electronic technology, microprocessor, mechanization and artificial intelligence. It has a high degree of electromechanical integration and is one of the most advanced fields of scientific research at present [1]. The main functional requirement is to collect, sense and analyze the external environment through its own sensors, so as to realize autonomous travel to the target under the condition of obstacles and complete some specific tasks [2]. Machine vision is often used to replace artificial vision in some dangerous working environments that are not suitable for manual operation or in situations where artificial vision is difficult to meet the requirements. In some applications such as architectural planning and urban transportation, most obstacles can be approximated as simple polygons, in which case the global optimal path can be found by calculation [3]. The stereoscopic perception process of binocular stereo vision is very similar to the process of human visual perception. It directly simulates the way human eyes handle scenes. It is simple and reliable, and has great application prospects. This technology has been valued by scholars in various fields [4]. From the original mechanical structure that can only move to intelligent machine, from repetitive work that can only move simply to human work that can be engaged in a variety of complex and dangerous tasks, this paper focuses on the path planning and obstacle avoidance of the binocular vision-based mobile robot designed by us in autonomous travel. This paper also introduces our research work and achievements in this field.

2. Path Planning Method

2.1. Global path planning method

The global path planner uses a grid map to describe the environment model and uses the A* method for path planning. Since the local path planner has the function of avoiding dynamic obstacles, the grid granularity can be larger to reduce the storage space of the system and A* method search space. Among them, the monocular defocusing distance is calculated by the degree

  DOI: 10.25236/scmc.2019.026

of blurring of the image boundary in multiple different defocus states [5]. If the image blur degree is too serious, the boundary of different objects in the environment cannot be distinguished, which makes the further object separation and extraction process much more difficult. A* Search target point is set as the coordinate of robot target point position in grid coordinate system. In grid coordinate system, A* method generates a target sequence sub-node from initial point to target point. The task of path planning is to find a collision-free path in an unknown environment with obstacles according to certain criteria [6]. The planned path should be optimal or sub-optimal. The initial position of the target should be given in the initial frame, and the continuous input should be made in the non-initial frame according to the target position of the previous frame. The motion model uses the temporal and spatial correlation of continuous frames to predict the target location area, and collects candidate samples in the prediction area to provide data for subsequent target tracking steps.

In the study of the best priority search, the most widely known form is called A* search. Its basic idea is that it evaluates a node by combining the cost g(n) to reach the node and the cost h(n) from the node to the target node:

$$f(n) = g(n) + h(n) \tag{1}$$

m and n are the projection points of the space point h in the left and right cameras, respectively. d is the distance from the target point h to the camera, ie the depth value. According to the principle of similar triangles, there are formulas:

$$d = bf(m+n) \tag{2}$$

Using similarity as a measurement standard, the region with the highest template matching degree is selected as the target. The system uses European distance as the measurement standard. The Euclidean distance between the pattern sample vectors x and y is defined as:

$$D(x, y) = \|X - Y\| = \sqrt{\sum_{i-1}^{n} (x_i - y_i)^2} \tag{3}$$

The A* method only generates sub-target node sequences, and the path points generated by the A* method need to be smoothly optimized. In order to avoid obstacles of mobile robots, the collected environmental information must be analyzed to separate the background, road surface and objects in the image, and to distinguish obstacles and objects [7]. Moreover, the high-pass filtering and Gaussian filtering operations are included in the implementation of the shadow elimination algorithm. Therefore, in the process of filtering pre-processing, the median filtering is used to smooth the image, which solves some of the isolated noise and further edge extraction. In this paper, the improved artificial potential field method is used to plan the local path between the target sequence points, so that the whole motion track of the robot appears smooth and achieves the purpose of real-time obstacle avoidance.

2.2. Local path planning method

During the movement of the robot, not all obstacles around it will affect the robot. For example, the angle between the direction of the robot motion may affect the motion of the robot. There are a large amount of discrete noise from the left and right images obtained from binocular vision. In order to preserve the image information to the greatest extent and extract the target object from the complex background [8]. However, in the process of robot movement, the surrounding environment is constantly changing, so the factors that affect the image capturing effect are complex, diverse and constantly changing. Classical image processing methods are difficult to achieve high-precision segmentation and extraction effect. Other obstacles will not generate repulsive potential field to the robot. This method can effectively let the robot quickly pass through the obstacle group and reduce the local minimum point generated by the potential field method [9]. The user can easily remove the good cutoff of the unneeded modules without affecting the work of other modules. Make each pixel point judge according to the color and position correlation matching score when matching, and achieve better detection effect. A stable background model cannot be established when the camera moves or the scene changes greatly. In this case, automatic initialization will require other detection modules to complete.

Gaussian filtering is a kind of linear smoothing filtering method that selects template weights according to the shape of Gaussian function. Gaussian smoothing filtering has a good effect on removing noise that obeys normal distribution. The formula of the two-dimensional Gaussian function is:

$$h(i, j) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{i^2+j^2}{2\sigma^2}} \tag{4}$$

The amount of computation of the two-dimensional Gaussian filter increases linearly with the width of the filter template rather than squared. These properties make it particularly useful in early image processing, indicating that Gaussian smoothing filters are very efficient low-pass filters in both the spatial and frequency domains. The essence of spatial Gauss smoothing filtering is weighted mean filtering method, which can be expressed as follows:

$$S_{\mathrm{j}} = \frac{1}{\sum_{i=1}^{n}(S_r)}, (0 < (S_{\mathrm{j}}) \le 1) \tag{5}$$

According to the potential field method, only the current force direction of the robot can be obtained. The arc motion planning strategy proposes a method that enables the robot to move along the smooth trajectory in the direction of the force field to the desired target point. In order to extract obstacles and objects from video images, the system combines a series of classical image processing algorithms to separate the outlet, background, obstacles and objects. However, in natural light, objects will produce shadows at the bottom or other surface, and the shadows of close objects may intersect with each other. Therefore, in the process of image segmentation, objects with shadows intersect can not be extracted separately. The robot can effectively bypass the trap area, not only can recognize the path in the similar obstacle group, but also can avoid oscillation in the vicinity of the obstacle group, at the same time, there will be no oscillation phenomenon in the narrow channel [10]. Effective path is the trajectory that connects the starting point to the ending point and can avoid obstacles in the environment. The accuracy of searching is the most important index to evaluate the system's excellence. The feature recognition method of mobile robot obtains the position of the target and the robot in the image coordinate system separately, then obtains the position information of the robot and the target in the world coordinate system by monocular measurement, and receives the obstacle position sent by the mobile robot synthetically, which can realize the map construction in two-dimensional plane.

3. Research on Path Planning of Mobile Robot Based on Binocular Vision Positioning

Path recognition is one of the techniques of mobile robot path planning. Due to the dynamic change and unpredictability of the environment, the path planning algorithm is complex and computationally intensive, which seriously affects the path planning effect. Therefore, the robot can quickly perceive continuous in the environment. The path is the key to determining the pros and cons of its algorithm. When the image is translated, the regional moment and the boundary moment have better invariance; when the image is rotated and scaled, the regional moment maintains a good invariance, while the boundary moment changes greatly. The region of interest image is extracted from the corresponding region of the original image acquired by the robot in real time, and the extracted local image is filled, edge detected and obstacle extracted, so that obstacle information on the corridor road surface can be obtained simply, accurately and quickly. Perception of environment is very important, and vision is an important perception ability of robots. The research goal of robot vision is to make the robot system have the ability to recognize three-dimensional environmental information through two-dimensional images. The main reason is that there are many pixels available for calculating the regional moments. When the image changes, only the boundary pixels will change, so the calculation of the boundary moments will fluctuate greatly. It can be seen that the calculation results of regional moments are better than those of boundary moments.

The basic principle of the algorithm is to extract and track the feature path in the image, and calculate the coordinates of the uncalibrated feature (feature path) in the world coordinate system according to the known position and pose of the robot. The pose of the robot is calculated by using the coordinates of the calibrated feature in the image coordinate system corresponding to the new observed pose, thereby forming a recursive relationship between the feature coordinates and the robot pose calculation. Figure 1 below shows the robot coordinate system model.

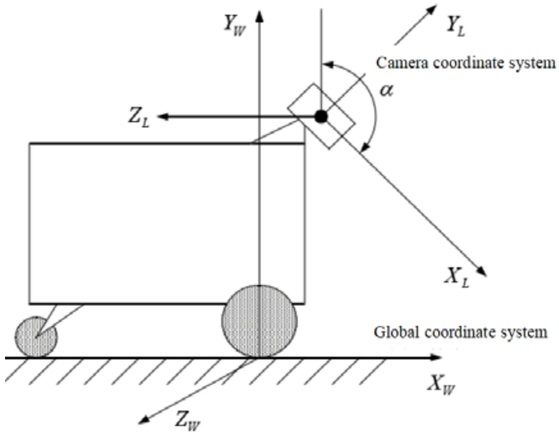

Fig.1. Robot coordinate system model

The direction of motion of the robot at any position in space is specified by the direction of the total field strength synthesized by the repulsive field of the obstacle and the gravitational field of the target point. The gravitational potential field function is:

$$\sigma = \sqrt{\ln(1+\frac{v_r}{m^2})} \tag{6}$$

Its value is determined according to the specific situation between the obstacle and the target point, and should generally be less than half of the distance between each obstacle and the minimum distance between the target point and each obstacle. When the robot does not reach the target point, the repulsive force of the obstacle to it is:

$$\mu = \ln(\frac{m^2}{\sqrt{v_r + m^2}}) \tag{7}$$

As the robot approaches the target, the first term r is close to zero, and the second term k pushes the force of the robot toward the target to zoom close to a constant:

$$T_r = \frac{1}{N}\sum_{i=i_0}^{k} r_i r_i^T \tag{8}$$

In order to achieve the purpose of identification, some intelligent algorithms use the method of comparing the standard object with the object to be discriminated, and complete the recognition by judging their similarity, such as online or offline sample learning of the neural network, and completing the ability to recognize the neural network through training. We use the artificial potential field method to plan the path of mobile robots. In order to eliminate the local minimum phenomenon of the method, we propose a corresponding solution. The parallax calculation is completed by calculating the matching point of the target point in the right camera image by the template matching method. The template matching algorithm is implemented by scanning the template in the image to be matched and finding the position with the largest local similarity. The selection of the similarity criterion is the key to template matching. If this hypothesis is not valid, it will indicate that the robot is too close to the dangerous area and the planning fails. Under this assumption, for visual-based path planning, the road information in the whole visual field space can be deduced according to the sampling characteristics in a small range. Camera internal parameters are intrinsic geometric and optical characteristics of the camera, while camera external parameters describe the camera's position and attitude in the world coordinate system. The block segmentation of the image and the inner pixel representation of the obstacle area are realized. Finally, the contour information of the obstacle is accurately extracted by edge detection to complete the outer boundary representation of the obstacle.

Figure 2 shows the error curve of the algorithm. during initial positioning, the x and y axes have the largest error because the initial position of the robot is not necessarily on the navigation path. the algorithm starts by finding the path to be tracked. Therefore, the error between the robot pose and the estimated pose is large. As the algorithm runs, the effective features of matching become more and more, and the error will become smaller and smaller.

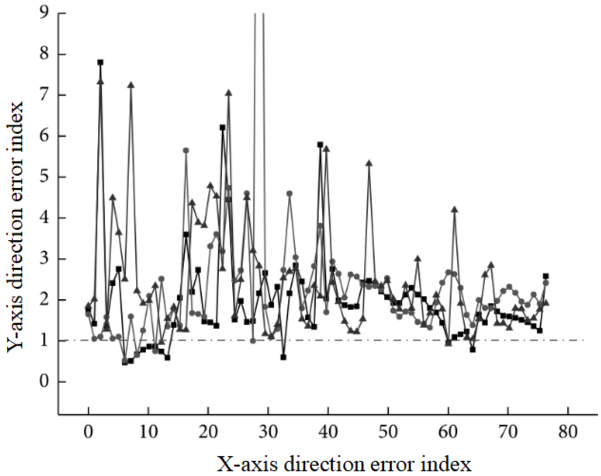

Fig.2. Robot motion trajectory error

The image is a reflection of the natural scene, and its perception is generally continuous, which is an analog image. Since the computer can only receive and process digital signals, it is necessary to sample and quantize the analog images, convert them into digital images, and then process them by a computer. The stereo calibration of the binocular camera is to obtain the spatial position transformation relationship of the left and right cameras. The solution process needs to use the internal and external parameters obtained separately for the left and right camera calibration. Because if the area of the target object calculated by the camera changes with the distance between the target and the camera, this algorithm can only be used when the camera does not move and the distance between the target object and the camera does not change very much, it has limitations. In the topology map, nodes represent key positions with symbolic significance, and paths between nodes represent connection relationships between these important positions, such as corridor channels, etc.

The motion space of the robot is two-dimensional. To reach the target, the robot needs to continuously move towards the target. The motion process of the robot is regarded as a kind of motion in a virtual artificial force field. It can generate an analog electrical signal proportional to the received electromagnetic energy. The other is a digital device, whose function is to convert the above-mentioned analog electrical signals into digital forms. The algorithm has high real-time performance and can greatly improve the accuracy and speed of tracking and positioning. In addition, an area minimum difference method for tracking and locating targets is also studied. When the obstacle is close, the mobile robot makes a reasonable decision according to the distribution of the obstacle and the target orientation, and advances toward the target while ensuring obstacle avoidance. When the obstacle is far away, the target orientation plays a major controlling role, and the mobile robot constantly changes the heading and advances toward the target.

4. Conclusion

This paper proposes a system framework for mobile robot path planning and obstacle avoidance system. The design scheme of each module of the system is introduced in detail, and the experimental results after system implementation are given. The force control strategy based on the cross-section contour of the force sensor coordinate system is used to track the surface of the workpiece. Based on the spatial position of the contact point during the precise measurement and tracking process, a direct least squares fit is performed on the elliptical tracking trajectory. The robot kinematics model is constructed. The odometer mainly gives the relative pose in the robot motion through the cumulative measurement, and the external sensor can realize the description of the external environment by sensing and measuring the surrounding environment of the robot. When the scale of the obstacle is equivalent to that of the mobile robot (for example, when the robot moves in a room), the shape and volume of the mobile robot should be considered, and its shortest path planning algorithm is quite different from the above algorithm. According to the environmental brightness information; The algorithm of seed filling and morphological operation is used to process the image after shadow elimination to complete obstacle detection and ground feasible region acquisition. The structure and electromechanical control system of binocular vision wheeled robot are designed, and the communication module between the two computers is applied and improved, so that the robot can locate and track the target object autonomously with good real-time performance.

References

[1] Wang X, He L, Zhao T. Mobile Robot for SLAM Research Based on Lidar and Binocular Vision Fusion. Chinese Journal of Sensors and Actuators, 2018, 31(3):394-399.

[2] Li, Jing. Binocular vision measurement method for relative position and attitude based on dual-quaternion. Journal of Modern Optics, 2017, 64(18):1846-1853.

[3] Santos E M, Chang Y, Alvarez T L. Comparison of symmetrical prism adaptation to asymmetrical prism adaptation in those with normal binocular vision. Vision Research, 2018, 149:59-65.

[4] Xu G, Chen J, Li X. 3D Reconstruction of Binocular Vision Using Distance Objective Generated from Two Pairs of Skew Projection Lines. IEEE Access, 2017, PP(99):1-1.

[5] Gao Y, Li J, Li J. Modeling the convergence accommodation of stereo vision for binocular endoscopy. The International Journal of Medical Robotics and Computer Assisted Surgery, 2017:e1866.

[6] Song M, Ou Z, Castellanos E. Exploring Vision-Based Techniques for Outdoor Positioning Systems: A Feasibility Study. IEEE Transactions on Mobile Computing, 2017:1-1.

[7] Ingenhoff D, Fuhrer T. Positioning and differentiation by using brand personality attributes. Corporate Communications: An International Journal, 2010, 15(1):83-101.

[8] Dickmanns E D. Developing the Sense of Vision for Autonomous Road Vehicles at UniBwM. Computer, 2017, 50(12):24-31.

[9] Nagarajan P, Saravana P S. GA-based camera calibration for vision-assisted robotic assembly system. Iet Computer Vision, 2017, 11(1):50-59.

[10] Bai L, Yang X, Gao H. Corner Point-Based Coarse-Fine Method for Surface-Mount Component Positioning. IEEE Transactions on Industrial Informatics, 2017:1-1.