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Research on robot mobile obstacle avoidance control based on visual information

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Abstract. Robots to detect obstacles and control robots to avoid obstacles has been a key research topic of robot control. In this paper, a scheme of visual information acquisition is proposed. By judging visual information, the visual information is transformed into the information source of path processing. In accordance with the established route, in the process of encountering obstacles, the algorithm real-time adjustment trajectory to meet the purpose of intelligent control of mobile robots. Simulation results show that, through the integration of visual sensing information, the obstacle information is fully obtained, while the real-time and accuracy of the robot movement control is guaranteed.

1 Introduction
As human beings enter the 21st century, with the rapid development of science and technology, robots have been widely applied in various fields. At the same time, users are also demanding more and more intelligent robots. For mobile robots, how to choose and adjust routes in real time and how to avoid obstacles in unknown environment during the course of moving routes will undoubtedly be one of the most urgent problems to be solved[1].

Today, the use of ultrasonic, infrared, stereo vision sensor technology is an important means of detecting obstacles. In the detection of obstacles after the evasion strategy, is currently one of the key topics in the field of robotics. Academia has also conducted a lot of research. For example, [2] uses a neural network-based approach to find the optimal path. Literature [3] uses a comprehensive analysis based on the grid method to search for the shortest path. Literature [4] uses artificial field methods to dynamically adjust Robot's trajectory. For the above methods and means, the stereoscopic vision mode is conducive to real-time monitoring of the unknown environment in the process of robot movement. Therefore, this paper chooses the mode based on visual information to detect obstacles, and on this basis, focuses on the adaptive control of obstacle avoidance strategy and path in the process of robot movement.

2 Convert visual information
The robots need to follow the visual information they collect before proceeding with the obstacles. In order to effectively reduce the size and weight of the robot, this paper uses pinhole camera to collect the surrounding environment information.

According to the pinhole camera imaging principle, we can convert the pixel coordinates of the image plane collected by the camera into three-dimensional coordinates through a certain algorithm, and these three-dimensional coordinates correspond to the coordinate system of the supporting robot[5]. Therefore, assuming that the height of the camera fixed at the robot is H, O_L for the robot coordinate system (X_L, Y_L, Z_L), the lens optical center O_c in the robot coordinate system parameter is (O_{cx}, O_{cy}, O_{cz}), the origin of parameters of image center O_I in camera coordinate system on the Z_c axis. (I_x, I_y) is one of the feature points in the image, and (x_r, y_r) is the point coordinate on the ground in the robot coordinate system.

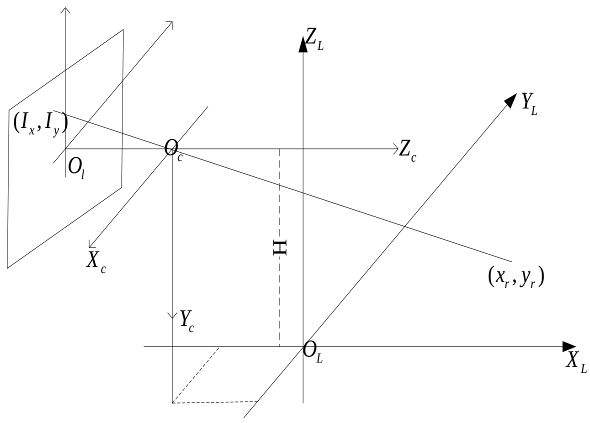

Fig. 1 camera imaging model

Through the imaging principle and the camera's internal and external parameters, the coordinates (I_x, I_y) of the feature points on the ground in the robot coordinate system can be determined by the coordinates (X_L, Y_L) of the points extracted from the image, and further the coordinates Observe the spatial relationship between the object and the object features in the image corresponding to it.

The camera is used to collect the image information. The ideal image should be a digital image with no distortion, noises and clear images. In the general optical imaging system, the image will be greatly distorted away from the optical axis, including barrel distortion and Pincushion distortion.

In the imaging model, the radial distortion and tangential distortion of the optical system are studied. After the corresponding distortion parameters are calibrated by the system, the errors introduced by such distortion can be corrected well.

The image distortion model coefficients are generally defined for the normalized image coordinates of the ideal linear pinhole model. Assuming no distortion normalized image coordinates (x_n, y_n), $r = \sqrt{x_n^2 + y_n^2}$ that the distance from the point of the optical axis to the camera, the distortion δ is used to indicate that the tangential distortion is generally expressed by the following formula

$$\begin{bmatrix} \delta x^{(t)} \\ \delta y^{(t)} \end{bmatrix} = \begin{bmatrix} 2p_1 x_n y_n + p_2(r^2 + 2x_n^2) \\ p_1(r^2 + 2y_n^2 + 2p_2 x_n y_n) \end{bmatrix} \tag{1}$$

The radial distortion generally use the following formula.

$$\begin{bmatrix} \delta x^{(t)} \\ \delta y^{(t)} \end{bmatrix} = \begin{bmatrix} x_n(k_1 r^2 + k_2 r^4 + k_3 r^6 + \dots) \\ y_n(k_1 r^2 + k_2 r^4 + k_3 r^6 + \dots) \end{bmatrix} \tag{2}$$

Where k_i is the coefficient of each order. When the calculation model is different, the calculated number of parameters, the meaning of the parameter values are very different, different calculation model caused by the error is not the same.

3 Vision-based robot obstacle avoidance framework

Vision-based robot obstacle avoidance framework involves two kinds of visual information collection and mobile control system. Frame design principles and ideas can be described as follows:

First of all, through the camera installed on the robot to detect environmental information, and the information sent to the robot's behavior control system for environmental information analysis. At the same time, according to the camera to get the image data to complete the operation of ranging.

Then, the behavioral control system constructs the corresponding two-dimensional map after the received video data is processed by the image processing and the collected traffic information, the obstacle information and the target location. Then use the path planning module to generate a path from the initial point to the target point, and then based on obstacle avoidance algorithm obstacle avoidance behavior control.

When the robot is moving, the control system will use the acquired coordinates, velocity, steering angle and other parameters to guide the robot's movement behavior. Thus summarized as shown in Figure 2 robot obstacle avoidance framework.

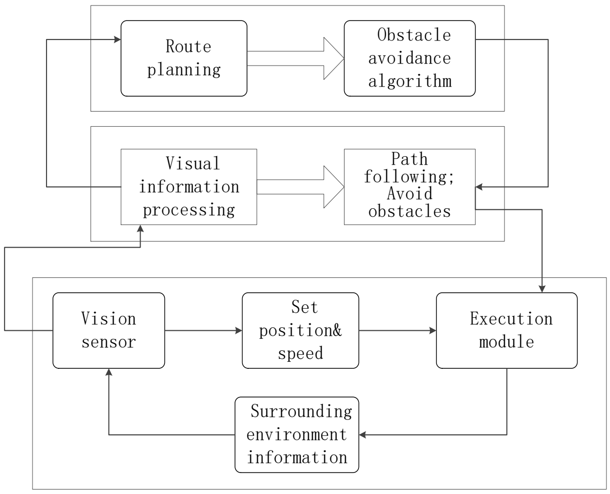

Fig. 2 the frame of robot obstacle avoidance based on vision information

4 Design of Robot Obstacle Avoidance Algorithm

As shown in Fig. 3, a two-dimensional reference coordinate system for the controlled object and the robot to move is established. For convenience of calculation, it is assumed that there is no sliding between the wheel and the ground, and the friction is not counted. XOY is the initial coordinate system. Set the target point coordinate as (x_p, y_p). At any time t, the robot's linear velocity is $v(t)$, then the robot's current position state is $(x(t), y(t), v(t))$.

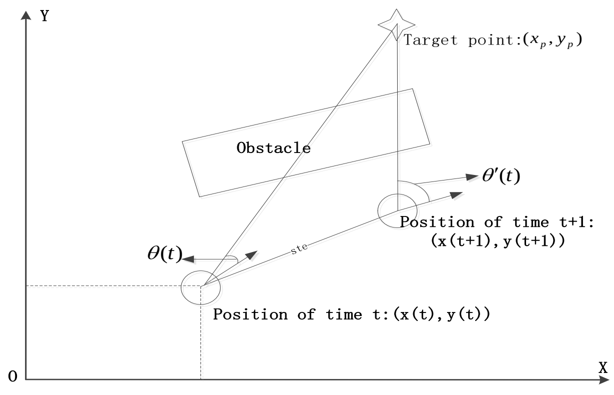

Fig. 3 the representation of parameters in a coordinate system

Assuming that the angle between the current heading and the robot's centroid to the target point is $\theta(t)$ and the steering angle is $\theta'(t)$, the following relationships exist between the parameters:

$$v(t) = \arctan\frac{|\Delta y|}{|\Delta x|} = \frac{|y(t+1) - y(t)|}{|x(t+1) - x(t)|} \tag{3}$$

$$D = \sqrt{(x_p - x(t))^2 + (y_p - y(t))^2} \tag{4}$$

$$\theta(t) = \arctan\frac{|y_p|}{|x_p|} - v(t) \tag{5}$$

After starting from the starting point, the robot moves to the target point according to the established route. During the moving process, if the camera sensor detects no obstacle information or the detected obstacle has a long distance, the angle and the target-robot angle $\theta(t)$ detected by the vision-based azimuth sensor are detected Turn, control the robot to $v(t)$ to move to the target point. During the movement, if the visual sensor detects a closer obstacle, the steering control is performed according to the orientation of the obstacle and the orientation of the target point, and the obstacle is avoided by $v(t)$; the closer the obstacle distance is, The steering angle $\theta'(t)$ the greater the collision to avoid. After escaping from the obstacle, continue to control the robot to the target point according to the angle measured by the azimuth detector $\theta(t+1)$.

The process of using the above obstacle avoidance algorithm during robot movement is given below:

$Step_1$:Determine the current location is not the target point, if it is stopped, otherwise go to the next step.

$Step_2$:Determine whether there is a collision at present, if there is then go to the next step, if not, skip to $step_4$.

$Step_3$:According to this algorithm, the obstacle avoidance algorithm is used to control the robot dynamic obstacle avoidance until it jumps back to $Step_{1.}$

$Step_4$:Move towards the target point and jump back after a decision cycle o jump to $step_1$.

5 Simulation of Obstacle Avoidance Model

In order to simulate, you need to set four types of parameter information. First, set the robot's starting position. The second is to set the robot's target position. Third, set up multiple obstacles. The fourth is to set the obstacle influence distance (when the obstacle and the car distance is greater than this distance, not affected by the obstacle). For ease of presentation, assume that the starting position and the ending position are respectively parallel to the coordinate axis. Two obstacles are respectively set on the upper and lower edges of the connection and an obstacle is set in the middle of the connection.

In accordance with the above design ideas and algorithms, the experiment using MATLAB simulation. From this, the obstacle avoidance trajectory model as shown in Figure 4 is simulated.

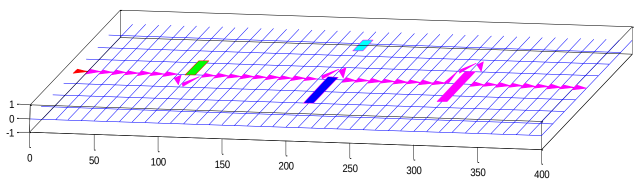

Fig. 4 the trajectory model of robot obstacle avoidance

Similarly, in accordance with the above design ideas set four types of parameter information.

The difference between the first simulation model and the first one is that the starting position and the target position are set on the dividing lines of two axes and are respectively distributed at 45° to the two coordinate axes. Meanwhile, the mobile robot designed in this paper uses two-wheel drive, which is divided into linear motion and circular motion. When the line speeds of the wheels on both sides are the same, the robot drives in a straight line. When the linear speeds of the wheels on both sides are inconsistent, the robot makes a circular motion with a certain radius. According to the algorithm above, the robot obstacle avoidance trajectory model as shown in Fig.5 is simulated.

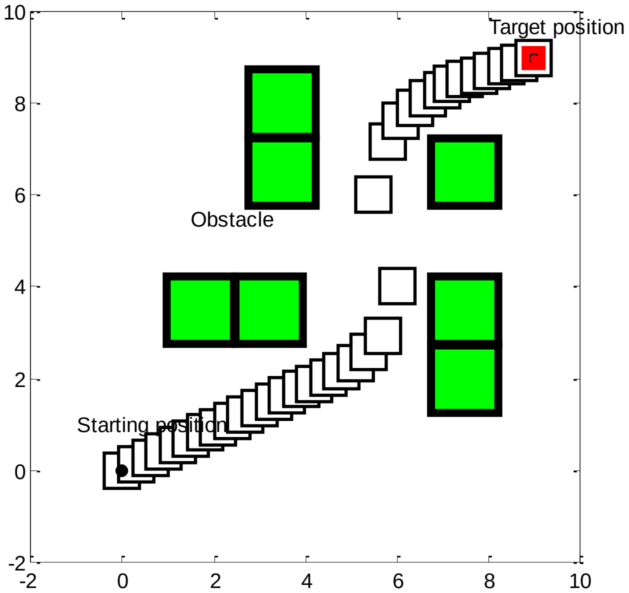

Fig. 5 the trajectory model of robot obstacle avoidance

The simulation model can achieve the purpose of controlling the mobile robot by controlling the moving linear velocity and the directional rotation angle of the mobile robot. Different parameters will produce different results. If the expected result can not be achieved, it may be related to the setting of obstacle influence distance and the inappropriate initial coefficients.

It can be seen from the above model that the robot uses the information collected by the vision sensor to send it to the control center for processing, which realizes the obstacle avoidance in real time. The moving process accords with the expected target. Simulation results show that this algorithm is feasible and the control process of obstacle avoidance has a certain stability.

6 Conclusions

The dynamic environment information perceived by mobile robots is the key to obstacle avoidance. At the same time, the visual sensors need both a sufficiently large detection range and a high acquisition real-time. Therefore, obstacle avoidance in the dynamic environment with static and moving objects is one of the most urgent problems in the robot control process.

This paper discusses the algorithm of obstacle avoidance of a mobile robot in the process of acquiring, using visual environment obstacle information, then according to the direction of movement and obstacle area dynamic obstacle avoidance processing, effectively avoid obstacles and move to goal. However, there are still the problems such as the system real-time, the diversification of the target characteristics, the uncertainty of the road surface in the process of robot control, which need to be further studied in the future.

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