Research on Path Planning of Mobile Robot Based on Immune Genetic Algorithm

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Abstract
The purpose of this paper is to research on the path planning of mobile robot based on immune genetic algorithm. In this paper, a nonlinear kinematic model is established and the input and output linearization is carried out. In this paper, the motion control law of a dual vision dual differential drive robot is designed. The kinematics model of the binocular vision dual differential drive robot is complex, and the transient kinematics model is established only. The principle of immune genetic control is introduced, and the immune genetic control law of the front and back drive module is designed respectively. The results of digital simulation and experiment show that the hybrid control law can smooth the deviation state and synchronize the posture deviation, so that the mobile robot can track the straight line and the arc guide track accurately and stably. The experiment result shows the proposed method can fulfil the engineering requirements in path planning of mobile robot.

Keywords: Path planning, Mobile robot, Immune genetic algorithm

1. Introduction

With the wide use of mobile robots, the type and application environment are expanding from the indoor environment to the outdoor environment. For autonomous mobile robot in outdoor working environment, including driverless vehicle, better environment awareness and scene understanding ability is a necessary condition for autonomous navigation to complete its action task. Body recognition of complex outdoor road environment has become one of the hotspots of mobile robot research. For unmanned vehicles, the biggest challenge comes from environmental perception, which is the most basic part of self-driving technology. Because of the outdoor road environment is complex and changeable, autonomous mobile robot for environment information is not stable, it is difficult to identify the road robot and objects, especially in the changing environment of lighting, pedestrians, traffic jams, and Suburban Park Road No lane rural road pavement markings or D, there is no better pavement and obvious edge. In a complex environment, how to identify and understand the content of the road scene in real time is a challenging research topic. Outdoor road structure can be divided into structured roads (highways, urban roads), quasi-structure (suburban roads, parks) and non-structural roads (rural roads, off-road environment). Whether unmanned vehicles can accurately perceive the surrounding environment information of vehicles in various road environments is related to the safety of self-driving, pedestrians and other vehicles. Because of the diversity and complexity of the road environment, the development of perceptual technology has not reached enough security at present, so there is still a lot of work to be done (Liang, 2015; Wu, 2015).

Robotics combines many disciplines, such as mechanics, electronics, sensors, computers, artificial intelligence and so on. It covers many advanced technologies, represents the highest achievement of electromechanical integration, and is one of the most active areas of technology development. In recent years, more and more attention has been paid to the research and development of robot technology. Robots are divided into underwater, ground, flight and space robots. In driving, it can be divided into wheeled, tracked and legged mobile robots (including humanoid robots).

Mobile robot is an important branch of the field of robot research. A mobile robot is a comprehensive system of environmental awareness, dynamic decision-making and planning, behavior control and a variety of functions. It emphasizes the characteristics of “mobile”, perceives the environment and its own state through sensors, and achieves the goal of autonomous motion in the obstacle environment, and then completes certain operations. Wheeled mobile robot is the most widely used mobile robot. Wheeled mobile robot is reliable and reliable, stable operation, high energy efficiency, and relatively simple structure and control which is widely used in the fields of scientific research, military, industrial, civil and other fields (Montiel, 2015).

In this paper, the motion control of a dual vision dual differential drive robot is studied. Because of the complexity of the kinematics model of the binocular vision dual differential drive robot, the traditional immune genetic control method is adopted in this paper. Aiming at the difficulty of parameter selection in immune genetic control, this paper combines the established approximate model with fuzzy reasoning method, and designs fuzzy reasoning immune genetic parameter model fuzzy self-correcting method.

2. Robot kinematics model
Dual differential drive robot binocular vision two CCD cameras installed in the drive module, rather than the body, so the binocular vision control target dual differential drive robot can be regarded as two of the two wheeled differential drive robots in coordination constraints, respectively in the wire with the ground tracking. Therefore, the problem of this chapter is the problem of multi robot cooperative motion based on path tracking, which has aroused wide attention of scholars at home and abroad. Figure 1 shows the binocular vision dual differential drive robot model.

![Figure 1 Binocular vision dual differential drive robot model](image)

Input-output linearization is a common design method for nonlinear control system. The core idea is to continue to deduce the output variable until the control variable appears. This method is widely used in single input and single output control system. The application of the multi input and multi output control system is relatively small.

The speed of the front drive module centre A is (Montiel, 2015; Mo, 2015):

\[ v_f = v \]  

The speed of the rear drive module centre B is:

\[ v_r = \frac{v_f \cos \theta_f}{\cos \theta_r} \]  

(1) is a certain value, in order to achieve the coordination of the front and rear drive modules, the centre speed of the rear drive module will satisfy the formula (2), the robot is actually running in the control cycle of the initial operation time will meet this collaboration constraints.

For unmanned vehicles, the biggest challenge comes from environmental perception, which is the most basic part of self-driving technology. Because of the outdoor road environment is complex and changeable, autonomous mobile robot for environment information is not stable, it is difficult to identify the road robot and objects, especially in the changing environment of lighting, pedestrians, traffic jams, and Suburban Park Road no lane rural road pavement markings or D, there is no better pavement and obvious edge.

(k + 1) T moment before the drive module attitude angle deviation (Zhu, 2015; Li, 2016):

\[ e_{\phi}^{f}(k + 1) = e_{\phi}^{f}(k) + w_{\phi}^{f}(k)T \]  

We can get the former model of attitude deviation of the drive module:

\[ e_{\phi}^{f}(k + 1) = e_{\phi}^{f}(k) - \frac{2\Delta v_f(k)}{W}T \]  

Moment angle deviation of the drive module after the moment (k + 1) T:

\[ e_{\phi}^{r}(k + 1) = e_{\phi}^{r}(k) - \frac{2\Delta v_r(k)}{W}T \]  

(k + 1) T time before the drive module distance deviation:

\[ e_{\delta}^{f}(k + 1) = e_{\delta}^{f}(k) + v \sin(e_{\phi}^{f}(k)) \]  

In summary, in the control cycle T is small enough, you can get the approximate kinematic model:
Consider the control system, it is available to show:

\[
\begin{align*}
\dot{e}_\alpha(k+1) &= e_\alpha(k) - \frac{2\Delta v_f(k)}{T} \\
\dot{e}_\delta(k+1) &= e_\delta(k) + v\sin(e_\alpha(k)) \\
\dot{e}_\omega(k+1) &= e_\omega(k) - \frac{2\Delta v_r(k)}{W} \\
\dot{e}_d(k+1) &= e_d(k) + \frac{v\cos\theta_f(k)}{\cos(\theta_f(k))}\sin(e_\alpha(k))T
\end{align*}
\]  

\[(k>0) \quad (7)\]

Consider the control system, it is available to show:

\[
\begin{align*}
h_1(x) &= [e(\theta) \ 0 \ 0 \ 0] \\
h_2(x) &= [0 \ e(d) \ 0 \ 0] \\
f(x) &= \begin{bmatrix}
\frac{v}{l} (\cos \theta_f - \sin \theta_f \tan \theta_f) \\
\frac{v}{l} \cos(e(\theta)) (\sin \theta_f + \cos \theta_f \tan \theta_f) + v \cos \theta_f \sin(e(\theta)) \\
-\frac{v}{L} (\cos \theta_f - \sin \theta_f \tan \theta_f) \\
-\frac{v}{L} (\sin \theta_f - \cos \theta_f \tan \theta_f)
\end{bmatrix} \\
g_1(x) &= [0 \ 0 \ -\frac{2}{W} \ 0]^T \\
g_2(x) &= [0 \ 0 \ 0 \ -\frac{2}{W}]^T
\end{align*}
\]

3. Hybrid control law based on immune genetic control

The immune genetic control method needs three parameters. The system is mainly composed of immune genetic controller and controlled object. The immune genetic controller is used as the control deviation according to the difference between the target output and the actual output, and then the final control is achieved through the linear combination of the ratio deviation and integral and differential links. The proportional coefficient \(k_p\) has a proportional control effect on the deviation signal, and the deviation signal is reduced at the fastest speed. If the value of \(k_p\) is too small, the response sensitivity to the deviation is low and the value of \(k_p\) is too large, and the system will oscillate and become unstable. The integral coefficient \(k_i\) is to eliminate the system’s steady-state error, that is, to eliminate the system in the steady state of the actual output and target output difference. \(k_i\) value is too large, then eliminate the steady-state error is slow, the effect is not obvious, but the value of \(k_i\) is too small to increase the system oscillation, and even the system instability. The differential coefficient \(k_d\) effect is mainly to improve the system stability and dynamic response performance, that is, the differential coefficient \(k_d\) can predict the future output, thereby reducing the overshoot (Min, 2015; Chen, 2016; Li, 2016).

Because the method does not depend on the control of immune genetic model, and the design is simple, so it has been widely used in industrial process control, but the immune genetic control parameters selection is difficult, now many industrial occasions or by using the method of immune genetic control parameters. But considering some complex control systems, it is difficult to get control parameters. Therefore, many scholars combine immune genetic control with some control methods.

For the first deviation state (attitude angle deviation 0), taking the above distance deviation as an example, we need to change the attitude angle deviation to achieve the reduction of the distance deviation, that is, to enter the third kind of deviation state. For the second deviations (distance deviation is 0), we need to reduce the attitude angle deviation, but as the driving module continues to move forward, we enter fourth kinds of deviations.
For third kinds of deviations (attitude angle deviation and distance deviation), we set threshold to determine whether we should increase the attitude angle to accelerate the correction of distance deviation or reduce the attitude angle deviation to achieve two kinds of simultaneous correction.

For the fourth deviations (attitude angle deviation and distance deviation and number), taking the above attitude angle deviation and distance deviation as an example, we first change the attitude angle from positive to negative direction, so as to reduce the distance deviation, and then input third kinds of deviation states.

It can be seen that the third kind of deviation state is the ideal deviation state of third kinds of deviation states. If we can’t adjust the attitude deviation in time, the deviation degree deviation is more and more important, and even there may be a problem. In the vision of CCD camera, guide wire is used. Figure 2 shows the control law flow chart.

In the process of small deviation state control, we adopt immune genetic control with different deviations and immune genetic control with distance deviation. The immune genetic control of the deviations depends on the deviation range of the attitude deviation. If the 1 degree deviation of the attitude deviation is equal to the 2mm of the distance deviation, that is, the attitude deviation is two times larger than the attitude angle deviation, and then the immune genetic control method using distance deviation is adopted. Otherwise, the control method of attitude deviation is adopted in the immune genetics.

Control for large deviation state, summed up the four kinds of error correction strategies, the first and fourth bias state, you should adjust the distance deviation as soon as possible, so the use of immune genetic distance deviation control method, second kinds of deviation, the distance deviation is 0, only the attitude angle deviation, attitude angle deviation should be adjusted as soon as possible. So the immune genetic control method of attitude angle deviation.

In the large deviations, the first class, the second class and the fourth class of deviations, adopt the immune genetic control method, which is similar to the control method under the small deviation state. There is no more introductions here. At the same time, the control methods of the first, second and fourth types of deviations are also used to convert to the third type of deviation state. The following detailed descriptions of third control methods for deviations are described in detail.

First of all, this paper defines the distance deviation time coefficient \( t \), that is, to maintain the current state and drive module speed difference control is 0, the distance deviation into 0 required times. The distance deviation time coefficient \( t_f \) of the front drive module is:

\[
t_f = \left| \frac{\epsilon_{fd}}{\sqrt{\sin \epsilon_{f\theta}}} \right|
\]

(9)
The distance coefficient of the rear drive module is:

\[
t_r = \frac{e_{rd} \cos \theta_r}{v \sin e_{fd} \cos \theta_r}
\]

(10)

When \( t > 0.7 \), that is, the distance deviation is reduced to 0 for more than 7 cycles (the control period of this control system is 0.1s), then the distance deviation is not very fast, choose to continue to increase the attitude angle deviation \( \Theta \) to speed up the deviation from the deviation, this time using the distance deviation of the immune genetic control can achieve this effect.

When \( 0 < t < 0.5 \), that is, the distance deviation is reduced to 0 for more than one cycle is less than 5 cycles, then the distance deviation of the reduction rate is fast enough.

When \( 0.5 \leq t \leq 0.7 \), this interval is designed as a buffer, the speed difference control is designed to 0, which can avoid the control system oscillation, when the speed difference control is 0, the distance deviation continues to decrease, it will enter \( 0.1 < t < 0.5 \).

4. Simulation and verification

In order to verify the feasibility of the design of the dual vision dual differential drive robot control law, this paper uses Matlab software to carry out digital simulation analysis.

For the correction effect of the predecessor Module shown in Fig. 3, the initial deviation state is in the fourth deviation state of the large deviation state, the attitude angle deviation and the distance deviation are all positive, and the distance deviation increases. The distance deviation immune genetic control method changes the attitude angle deviation to the negative value. Step 6, the attitude angle deviation becomes a negative value. When entering the third deviations, the distance deviation decreases, that is, the deceleration rate is very low, and the attitude angle deviation continues to increase to negative growth. The distance from the deviation is reduced. In step 9, the attitude angle deviation and the distance deviation begin to decrease synchronously. Step 13, the speed difference control is 0, the attitude angle deviation is constant and the distance deviation maintains the current deceleration rate constant. Step 18, enter the small deviation state and compare the relative size of the two deviations, choose the use of attitude angle deviation immune genetic control or distance bias immune genetic control. The simulation results have achieved the tracking precision.

![Figure. 3 Drive module attitude angle deviation and distance deviation](image-url)

The correction effect is shown in Figure 4 the rear wheel drive module, the starting time deviation is in the state of third deviation state large deviation state, speed difference control of 0, attitude angle deviation constant distance deviation keep current deceleration rate constant in step 2, attitude angle deviation and distance deviation start synchronized decline. Step 4, the degree of control is 0. Step 5, into a small deviation state. The simulation results have achieved the tracking precision.

The angle values of the drive modules before and after the experiment are shown in Fig. The mobile robot is transformed from the linear path with a large distance deviation. The deviation state is transformed into the exponential stability control by the deviation intelligent transformation evaluation function method. After several cycles of exponential stability control, the tracking accuracy of the straight path is up to \( |e(\theta)| < 2^\circ\), \( |e(d)| < 7\text{mm} \). When the transition from the straight path to the curved path changes, the attitude deviation and the distance deviation of the moving robot are rapidly increasing, and the motion control unit is switched to the
deviation intelligent transformation evaluation function method. The tracking accuracy of the circular path is kept at $|\| < 12^\circ, |e(d)| < 20 \text{mm}$.

The experimental results of the binocular vision dual differential drive robot are shown in Figure 6. In order to quantitatively analyze the effect of path tracking experiment, the Matlab software is used to map the data in the upper monitoring software in the form of graphics.

![Figure 4. Front and rear drive module control](image)

![Figure 5. Results of path tracking experiment of binocular vision double differential drive robot](image)

![Figure 6. Front and rear drive module distance deviation](image)
In the 0 ~ 30s stage, the robot is in the straight line of figure 5.5, the tracking accuracy of the distance difference of the front drive module is 8mm, the tracking accuracy of the attitude angle deviation is 5 degrees, the tracking accuracy is 17mm for the rear drive module, and the tracking accuracy of the attitude angle deviation is 5 degrees. At the stage of 30 to 145 s, the robot has been in the arc section of figure 5.5, and the attitude deviation and distance of the front and rear driving modules are different. In 60 ~ 75s, the radius of curvature radius and the opposite arc is very small, the phase distance deviation reached 60mm, attitude angle deviation reaches 30 DEG 145s, after entering the line before and after the distance between the driver module of 10mm, the deviation angle tracking accuracy is 5 degrees for distance deviation, attitude angle and speed deviation differential control, rear drive module in time precursor lags behind in relation to, the driver module after the driver module.

5. Conclusion

With the rapid development of computer, control and AI technology, the application of two wheel differential drive mobile robots is more and more extensive, and the degree of intelligence is higher and higher. Aiming at the path tracking problem of dual differential drive mobile robot, a two input and two output nonlinear kinematic models are established, and the input output linearization is carried out. In this paper, the motion control law of a dual visual dual differential drive robot is designed. The results of digital simulation and experiment show that the hybrid control law can smooth the deviation state and synchronize the posture deviation, so that the mobile patient can track the straight line and the arc rail accurately and stably.

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References