Trajectory Stability Control of the lidar tracking robot Based on Improved Particle Swarm Filter Algorithm

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Abstract. Aiming to improve the accuracy of path planning and autonomous positioning of the lidar tracking robot, the accurate tracking control of its moving trajectory is achieved. The trajectory of the lidar tracking robot is affected by the map location offset error, which leads to the low control accuracy. An improved particle swarm filter (PSO) algorithm is proposed to control the trajectory of a lidar tracking robot. The motion environment model of the lidar tracking robot is simulated and constructed, and the space coordinates of the lidar tracking robot are abstracted into the virtual world of particle swarm filter population. The tracking map grid model of the lidar tracking robot is obtained, and the target point is found by Particle Swarm filter evolution and the remote command control is carried out. An integral term of tracking error is designed on the synovial surface of the lidar tracking robot. The simulation results show that the algorithm is used to track the trajectory of the lidar tracking robot. The path offset correction ability is good and the control is stable.

1. Introduction
The lidar tracking robot is a machine that automatically controls and executes instructions. It is the product of a combination of mechanical control, computer and intelligent bionics. As the greatest artificial intelligence technology since the Industrial Revolution, lidar tracking robot has important application value in the fields of industry, scientific research, military, agriculture, construction and so on. The lidar tracking robot consists of a control unit, a driving device and a sensing device [1]. According to the command signal issued by the control system, according to the set position, speed and acceleration, perform related environmental operations and external information awareness. Among them, the control system of the lidar tracking robot and the core of laser radar tracking robot system, the control system of laser radar tracking robot can be divided into point control, continuous trajectory control and force (torque) control. In the course of walking and working, the lidar tracking robot needs to track and control the trajectory of the robot effectively, so as to improve the accuracy of path planning and autonomous positioning of the lidar tracking robot. At the same time, it is the key to improve the obstacle avoidance ability of the lidar tracking robot. It is an important branch of the subject of the lidar tracking robot to study the trajectory constant stability control method of the lidar tracking robot. The related algorithms have been paid attention to by many experts in the field of laser radar tracking robot control[2].

The research of the traditional trajectory constant stability control algorithm of the lidar tracking robot is mainly divided into path offset correction and path tracking control algorithm based on particle filter motion rigid trajectory decomposition and trajectory constant stability control algorithm based on particle swarm filter evolution algorithm. Among them, the control algorithm of the lidar
tracking robot based on particle swarm filter algorithm is more commonly used. In reference [3], a reinforcement learning algorithm based on neural network is proposed and applied to the trajectory correction and tracking control of the lidar tracking robot. And it is applied in the obstacle avoidance of the lidar tracking robot. Based on the reinforcement learning algorithm of neural network and the intelligent control structure, it is applied to the path and trajectory constant stability control of the mobile lidar tracking robot. The algorithm takes the lidar tracking robot as the model, which has some guiding significance, but the model is not detailed enough, which cannot completely reflect the simultaneous localization and path planning characteristics of the lidar tracking robot, and the tracking control performance is not good. In reference [4], an algorithm for simultaneous localization and map creation of the lidar tracking robot based on particle filter is proposed, and the pose model of the lidar tracking robot and the creation of map of surrounding environment are obtained. The trajectory constant stability control of the lidar tracking robot is realized, but the calculation accuracy of the algorithm is not high, and the implementation is more complex, so the application value is not good. Based on the design of integrated synovium control for lidar tracking robot, the multitree hybrid particle swarm filter evolutionary method is used to track the moving trajectory of the lidar tracking robot. The trajectory control of the lidar tracking robot based on multi-information fusion improves the control precision, but the convergence performance of the algorithm is not good, and the local optimization ability and search speed need to be improved [5]. It is concluded that the trajectory of the lidar tracking robot is affected by the map location offset error and is a multivariable nonlinear control system. The conventional PSO algorithm is used to control the steady state tracking error in the boundary layer.

To solve the above problems, an improved PSO algorithm is proposed to control the trajectory of the lidar tracking robot. Firstly, the motion environment model and parameter setting of the lidar tracking robot are constructed. The improved particle swarm filter evolutionary algorithm is used to improve the trajectory constant stability control algorithm of the lidar tracking robot. The simulation results show the superiority of the proposed algorithm in improving the accuracy and performance of the lidar tracking robot.

2. Design of Moving Environment Model and Parameter System of the Lidar Tracking Robot

2.1 Design of dynamic environment model for lidar tracking robot

In this paper, the motion environment model of the lidar tracking robot is simulated and constructed. Particle swarm filter algorithm is used to control the trajectory of the lidar tracking robot. The evolutionary theory of particle swarm filter comes from the micro world. According to the wave-particle duality of microparticles, such as molecules, nuclei and electrons, the motion of microparticles shows certain deterministic laws in the macro world and follows the statistical probability. The simulation of the bionic control particle swarm filter evolutionary model of the lidar tracking robot was first developed by Wilenskyas based on NetLogo software[6]. This paper is used to simulate the modeling and simulation of quantum particle swarm filter evolution system in micro field. By using the bottom-up Agent modeling method, the space coordinates of the lidar tracking robot are abstracted into the virtual world of the particle swarm filter population, and the map grid model of the lidar tracking robot is obtained as shown in figure 1.
Figure 1. Map grid model for trajectory tracking of the lidar tracking robot

In the map grid model of the lidar tracking robot in figure 1, the moving space of the lidar tracking robot can be represented by a plane rectangular coordinate system with organic connection between macro and micro [7]. The path optimization and trajectory tracking control of the lidar tracking robot are generally represented by a multi-information fusion model of a decision variable:

\[
\text{min } F(x) = (f_1(x), f_2(x), ..., f_m(x))^T
\]

\[\text{s.t. } g_i \leq 0, \quad i = 1, 2, ..., q\]

\[h_j = 0, \quad j = 1, 2, ..., p\]

It can be seen that the lidar tracking robot itself is a nonlinear system, which needs to linearize the control equation of the lidar tracking robot. In a small range of angles, it is used in the constant stability control of the trajectory of the lidar tracking robot. Assuming that \(\sin \theta = \theta, \cos \theta = 1\), \(J_{yy}\) is the moment of inertia of the human body around the vertical axis (Y axis) of the lidar tracking machine, and its value is also related to \(\theta\), several constraints for the constant stability control of the trajectory of the lidar tracking robot are obtained as follows:

\[X_{ai} = R \times \theta_{ai}\]

\[X_{ao} = R \times \theta_{ao}\]

\[X_r = X_{ao} + L \sin \theta\]

\[X_r = \theta \cdot L \cos \theta + X_{ao}\]

Considering the nonlinear characteristics and uncertainty of the model, the two-bit motion space \(V_2\) of the lidar tracking robot is obtained:

\[V_2 = \{p(x, y)\} \in (0, width), y \in (0, height), x, y \in N\]

Where, \(width \times height\) is the domain of coordinates, because the computer can only deal with discrete information, so the environment of the lidar tracking robot motion is also a nonlinear coupled discrete control system. Combined with figure 1, the lidar can be obtained. The moving trajectory of tracking robot is a grid composed of \(height\)-line \(width\) column. Each grid can be described by \(p(x, y)\). With the above description, the dynamic environment model of the lidar tracking robot is obtained, which is the lidar tracking robot track. The design of trace constant stability control algorithm provides the model basis [8].

2.2 Description of the constant stability control parameters of the lidar tracking robot

On the basis of constructing the map grid model of the lidar tracking robot, the environment parameter model of trajectory constant stability control of laser radar tracking robot is analyzed. According to the classical particle swarm filter algorithm, the laser tracking robot is controlled by laser. In the path planning of radar tracking robot, the particle swarm filter evolution is used to find the target point and carry out remote command control. The sensor collects a certain amount of external data, analyzes and
controls the information characteristics, and falsely\cite{9}. Let the attitude quantization feature of the fuzzy logic control unit control system of mobile lidar tracking robot be \( N \) random samples at the \( t \) moment:

\[
\eta = \frac{a}{a+b+c} \cdot \frac{E[M_t]+E[M_{t+1}]}{E[V_x]+E[V_y]} \tag{7}
\]

The trajectory control equations of the lidar tracking robot and lidar tracking robot are expressed in discrete form, and the zero potential energy surface of \( t = 0,1,\cdots,k \) is selected as two excitations for the evolution measurement value of particle swarm filter corresponding to \( Z_k = \{z_0, z_1, \cdots, z_k\} \). The kinetic energy \( T \) of the lidar tracking robot control system is:

\[
T = \frac{1}{2} M_x X_x^2 + \frac{1}{2} M_x X_y^2 + \frac{1}{2} J_{\theta_1} \dot{\theta}_1^2 + \frac{1}{2} J_{\theta_2} \dot{\theta}_2^2 + \frac{1}{2} J_{\theta_3} \dot{\theta}_3^2 + \frac{1}{2} M_{\phi} (\dot{\theta}_1 \cos \phi + X_{\phi})^2 + (\dot{\theta}_1 \cos \phi \dot{\phi} - \dot{\theta}_3)^2
\tag{8}
\]

Where, \( x_k \) is used to express the displacement of the center of the chassis tracking robot by lidar, that is \( \{x_k, y_k, \theta_k\} \). According to the constraint conditions, the motion state parameters of the lidar tracking robot are described as follows:

\[
x_k = f\{x_{k-1}, u_{k-1}, w_{k-1}\} \tag{9}
\]

Where, \( u_k \) is expressed as the moment of inertia of the human body passing through the center of mass and parallel to the \( Z \) axis by the lidar tracking machine. The measurement error in the process is expressed by \( w_k \). The measurement equations of the constant stability control parameters of the lidar tracking robot are as follows:

\[
E[M_t] = E[V_x] = \sum_{i=0}^{n} \eta_i (1 - p) \frac{1 - p}{p} \tag{10}
\]

On the basis of the description of the parameters of the trajectory constant stability control of the lidar tracking robot, the data foundation is provided for the trajectory constant stability control of the laser radar tracking robot.

3.ALGORITHM IMPROVEMENT DESIGN AND IMPLEMENTATION

On the basis of the space environment design and parameter setting of the lidar tracking robot, the trajectory constant stability control design of the laser radar tracking robot is carried out. According to the above analysis, the laser radar tracking machine can be seen. The human trajectory is affected by the migration error of map location. The trajectory control system of the lidar tracking robot is a multivariable nonlinear control system\cite{10}. In this paper, an improved particle swarm optimization algorithm is proposed. A constant stability control algorithm for lidar tracking robot, the expression of mobile azimuth confidence of the lidar tracking robot is obtained as follows:

\[
P(Y) = \frac{\exp\left(-p \sum_{i=0}^{n} V_i(Y)\right)}{\sum_{Y} \exp\left(-p \sum_{i=0}^{n} V_i(Y)\right)} \tag{11}
\]

According to Bayesian Theorem, in order to satisfy the matching condition of particle swarm filter algorithm and the error caused by parameter perturbation, it is necessary to track the mobile trajectory of the lidar tracking robot in order to satisfy the matching condition of PSO algorithm and the error caused by parameter perturbation. Synovial surface designs an integral term for tracking errors, the trajectory tracking control of the lidar tracking robot system is carried out under the action of the control law. The recursive expression of the confidence degree of the lidar tracking robot moving azimuth is obtained as follows:

\[
P(x_k, |x_{k-1}, |\alpha, \beta) = \prod_{i=0}^{n} a_i \frac{1}{2 \pi \sigma_i^2} \exp \left( -\frac{(x_k - \mu_i)^2}{2 \sigma_i^2} \right). \tag{12}
\]
The trajectory of the lidar tracking robot generates new individuals according to the quantum amplitude of the quantum chromosome, and carries out quantum coding. The measured data \( AS \) is independent of its previous measurement value \( z_i \), and is only related to \( z_{i-1} \), that is:

\[
g(x_i, y_i | \mu_k, \sigma_i^2) = \prod_{i=1}^k \alpha_i \frac{1}{\sqrt{2\pi\sigma_i^2}} \exp\left\{-\frac{(x_i - \mu_i)^2}{2\sigma_i^2}\right\} \quad (13)
\]

Then

\[
P(y_{i_k} | x_{z_i}, \theta, \beta) = \prod_{i=1}^k w(d_i) P_i(y_i | x_{z_i}, \theta, \beta) = \prod_{i=1}^k w(d_i) \prod_{j=1}^{z_i} \frac{\alpha_i}{Z(\beta)} \sqrt{2\pi\sigma_i^2} \exp\left[-\frac{\sum_{j=1}^{z_i} (y_j - \mu_{ij})^2}{2\sigma_i^2} + \sum_{j=1}^{z_i} \sum_{j=1}^{y_j} \right] \quad (14)
\]

The control law of the trajectory constant stability control of the lidar tracking robot is obtained as follows:

\[
u = \nu_{eqx} + \nu_{eq\theta} + \nu_{sw} \quad (15)
\]

The control errors of the whole system are as follows:

\[
P(x_{s_j}, y_{sw} | \Theta) = \prod_{x_i \in m} \prod_{k=1}^X \alpha_k g(x_{ij}, y_{ij} | \mu_k, \sigma_k^2) \quad (16)
\]

It can be seen from the above analysis that the improved particle swarm optimization evolutionary algorithm overcomes the shortcomings of conventional sliding mode control in moving trajectory control with high error and no stability. According to the above algorithm design, an improved motion tracking control algorithm for lidar tracking robot based on particle swarm filter evolution is proposed.

4. SIMULATION EXPERIMENT AND RESULT ANALYSIS

Aiming to test the performance of this algorithm in the realization of the trajectory constant stability control of the lidar tracking robot, the simulation experiment is carried out. The host computer used in this experiment is Pentium (R) D CPU 2.80GH, 2.79GHz, 2.00GB memory. The simulation scene of the lidar tracking robot is in a 2D plane of 300 ~ 300. The model of robot and position tracking sensor is shown in figure 2.

Figure 2. Robot physical diagram

Based on the simulation field of the lidar tracking robot motion space shown in figure 2, the grid structure of the lidar tracking robot motion space is constructed, and the trajectory constant stability control is carried out. In the simulation time, the approximate shortest path between the starting point and the end point of particle swarm filter evolutionary coordinates is obtained. The parameters are selected according to the Wilensky model, that is, the environmental scale is 100x100, the particle swarm filter evolution number is 120, and the Ticks representation is obtained. Time units, the time spent by the labeling model to find the shortest path, and different methods are used to obtain the trajectory tracking position distribution of the lidar tracking robot in the evolutionary control process of PSO, as shown in Fig. 3.
It can be seen from the results of the diagram that the path offset correction ability is better and the performance accuracy and convergence of path tracking control are better when using the control algorithm in this paper to control the trajectory of the lidar tracking robot with constant stability.

5. CONCLUSIONS

The trajectory of the lidar tracking robot is affected by the map location offset error, which leads to the low control accuracy. An improved particle swarm filter algorithm is proposed to control the trajectory of a lidar tracking robot in this paper. The motion environment model of the lidar tracking robot is simulated and constructed, and the space coordinates of the lidar tracking robot are abstracted into the virtual world of particle swarm filter population. The tracking map grid model of the lidar tracking robot is obtained, and the target point is found by Particle Swarm filter evolution and the remote command control is carried out. An integral term of tracking error is designed on the synovial surface of the lidar tracking robot. The simulation results show that the algorithm is used to track the trajectory of the lidar tracking robot. The path offset correction ability is good and the control is stable. This method has good application value in the optimization control of robot.

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