SLIDING CONTROL METHOD OF MARINE ECOLOGICAL PROTECTION ROBOT

by

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In order to solve the problem of low control accuracy of the marine ecological protection robot in the route planning process during positioning, a new sliding control method is proposed. First, obtain the position information of the marine ecological protection robot, use the dynamic information measurement method to process the dynamic information, and extract the position tracking information. According to the needs of dynamic positioning and target path tracking, combined with the robot sliding control method, the global positioning of the marine ecological protection robot is designed. Experiments show that this method has high positioning accuracy for marine ecological protection robots, small positioning errors, good obstacle avoidance performance and strong dynamic positioning control capabilities.

Key words*: dynamic positioning, marine ecological protection robot, sliding control*

Introduction

Underwater robots are the main tools for humans to understand the ocean, develop the ocean, and use the ocean. An important development direction in the future is to achieve the information interaction and autonomous collaborative operation of multiple underwater robots, to overcome the short working time and small working range of manned deep submersibles [1]. For this reason, many scholars have carried out research on this problem. Wei and Jin [2] proposed a method of tracking and controlling mobile robot trajectory under the influence of sliding and sideslip. The unknown non-linearity in the system is approached by a fuzzy system. With the compensation of side-slip interference factors, the Lyapunov function is used to derive the adaptive law of fuzzy parameters, and the adaptive fuzzy controller based on dynamics is designed. In the kinematics part, the inverse kinematics controller is designed to process the error between the actual position and the expected position of the mobile robot to obtain the expected speed of the mobile robot. Jiang et al. [3] proposed a data-driven wheeled mobile robot control method. This method studies the coordinated control of the left and right wheel drive control system for a wheeled mobile robot with two front wheels independently driving the rear wheel as a universal wheel structure. Based on the decoupling con-

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trol strategy of the subspace identification method, a dual-input dual-output system is decomposed into two mutually coupled single-input single-output systems, and the controller is designed directly using the measured input and output data information. However, the positioning accuracy of the aforementioned two methods is not high, and the positioning error is large.

In response to the previous problems to this end, this paper designs an underwater robot experimental platform system with functions such as control, communication, and positioning, and studies the positioning accuracy and path planning of the underwater robot in the experimental system. In view of the previous problems, this paper proposes a sliding control method of marine ecological protection robot based on dynamic positioning, firstly, using gyroscope and rangefinder as information sensor of marine ecological protection robot, collecting the position information of marine ecological protection robot, using dynamic information measurement method to measure the location information of marine ecological protection robot, extracting the position and pose tracking information of marine ecological protection robot, then tracking and identifying the dynamic positioning robot according to the environmental perception of marine ecological protection field, and the accelerated global positioning design of marine ecological protection robot combined with robot sliding control method [4]. Finally, the performance of this method in improving the positioning accuracy of marine ecological protection robot is demonstrated by simulation [5].

Information acquisition and robot pose information feature extraction

Sensing information collection of marine ecological protection robots

The marine ecological protection robot's sensor system mainly includes the sensors and depth gauges required for the attitude angle, and uses them to obtain the attitude angle and depth in the water, respectively.

The integrated three-axis gyroscope and three-axis accelerometer save a lot of packaging space. The output of each axis is composed of two registers of high 8-bit and low 8-bit. By reading sequentially, the initial value of the attitude can be obtained. Its serial transmission bit rate can reach 100 kbit per seconds in standard mode, and it can reach 3.4 Mbit per seconds at the highest speed.

Because the yaw angle is mainly used underwater, a magnetometer is needed to repair the gyroscope drift. The magnetometer used in this article is Honeywell's HMC5883L magnetometer. It is a highly integrated module with a very small volume. It can sense the geomagnetic vector to obtain the angle between the carrier and north. The attitude information of the determining carrier is widely used in the fields of magnetic field detection, communication and navigation due to its low price. The HMC5883L is equipped with Honeywell's patented integrated circuit, the control accuracy of the compass can reach 1~2°. It has the characteristics of high axial sensitivity and high linear accuracy. It decomposes a vector of geomagnetism into components in three directions. The three components obtained will be used to repair the deviation in the attitude solution.

The position and position parameter information of marine ecological protection robot were collected by fusion sensing technology, the position information of marine ecological protection robot was analyzed, the position information of marine ecological protection robot was collected by using gyroscope and rangefinder as marine ecological protection robot information sensor, and the position information of marine ecological protection robot was measured by dynamic measurement method.

Feature extraction of position and posture information of robot

Wireless data communication is used between the host computer and the robot to achieve two-way data sharing and real-time stable data transmission. The flowchart of the communication between the host computer and the NRF sends information. Similarly, the NRF uses the same mode for the host computer to send information. The communication process is mainly based on the global visual positioning to obtain the global position co-ordinates in real time, sending co-ordinates to the underwater robot, and at the same time, sending the self-attitude angle information obtained by the underwater robot to the upper computer.

In order to ensure the effective transmission of co-ordinate information and attitude information, relevant communication protocols must be designed. In this paper, the protocol frames are self-made, and the rules of the information are divided into two categories, sending mode and receiving mode:

– *In the sending mode*: The upper computer sends the co-ordinates to the underwater robot. The frame header uses AAAA as the middle 16-bit function word command, and the frame end ends with 0D.
– *In the receiving mode*: The underwater robot returns the real-time attitude angle to the host computer, and the frame header uses AAAF the middle is a 16-bit function word command, and the end of the frame ends with 0D.

After the data frame is specified, if the normal communication mode is used, the transmission and reception modes need to be switched continuously. Therefore, this article uses its advanced function to carry user data using response packets, which can realize two-way transmission of data in real time, eliminating frequent switching, and thereby making communication more convenient.

Marine ecological protection robot positioning optimization

Dynamic tracking and identification of marine ecological protection robot

On the basis of completing the marine ecological protection robot experimental platform system, using existing research algorithms, it is easy to find a path for the robot to reach the target point, and it can be completely guaranteed to be safe and meet certain performance requirements, such as the shortest distance and collision-free path. But the global environment has the problem that the information is not completely known or the environment information is incomplete, or even the environment is completely unknown. Therefore, path planning can only be performed based on the robot's predicted and prior information. Therefore, in this chapter, an improved ant colony algorithm is designed to plan the optimal path for the underwater robot. At the same time, the optimal path planning method provides a guarantee for the autonomous movement of the underwater robot. The complexity of the underwater environment is of great significance for the study of complex paths.

The path planning of marine ecological protection robots not only allows each marine ecological protection robot to find one of the aforementioned optimal paths, but also requires that the path designed for the underwater robot does not occur with other static or dynamic obstacles during movement contact and collision, try to keep the original desired direction to reach the target point, and need to adjust in real time to find a path that meets the requirements according to the continuous change of the environmental information in the water. At the same time, in order to better verify the reliability and practicability of the platform, the underwater robot has a certain learning ability in path planning, and realizes the stable operation of marine ecological protection robots.

Based on the position information of marine ecological protection robot using gyroscope and rangefinder as the information sensor of marine ecological protection robot [6], the positioning optimization design of marine ecological protection robot is carried out, the position and posture tracking information of marine ecological protection robot is extracted, the dynamic positioning and robot tracking identification are carried out according to the environmental perception of marine ecological protection site, and the GPS trajectory map of marine ecological environment fusion tracking and positioning plan of marine ecological protection robot is constructed.

Marine ecological protection robot obstacle avoidance and positioning output

According to the environmental perception of marine ecological protection site, dynamic positioning and robot tracking recognition are carried out [7]. The state measurement equation of the spatial position of the moving path is analyzed in combination with the robot sliding control method:

$$X_{k+1} = \Phi_{k+1,k} X_{k+1} + G_{k+1,k} U_k + \Gamma_{k+1,k} \eta_k \tag{1}$$

$$\Phi_{k+1,k} = HX_{k+1} + V_{k+1} \tag{2}$$

where $\Phi_{k+1,k}$ is the spatial distribution quadrant of the robot motion path, $X_{k+1} = [\varepsilon_{k+1} \quad W_{k+1}^1 \quad W_{k+1}^2 \quad W_{k+1}^3]^T$ is $k + 1$ time marine ecological protection robot moving path information acquisition weight coefficient [8], $G_{k+1,k}$ – the kinetic energy of the robot's motion pat, U_k – the movement potential energy of the robot, $\Gamma_{k+1,1}$ – the co-ordinate vector when the robot is moving, η_k – the speed vector when the mobile robot moves, H – the constraint matrix when the mobile robot moves, and V_{k+1} – the control parameter of the robot motion path information. When each element of the path distribution tends to be infinite, the azimuth deviation generated by the marine ecological protection robot under the real-time regulation of the continuous path is:

$$KL = \sum_{i=1}^{m+a} \frac{1}{N} \ln \frac{1}{Nw_d^i(H)} + \sum_{i=1}^{N-m-a} \frac{1}{N} \ln \frac{1}{N} \ln \frac{1}{Nw_d^i(H)} + 0 \tag{3}$$

$$\sum_{i=1}^{m} n_i = \sum_{i=1}^{N} = N \tag{4}$$

where m is the external force matrix, a – the external force and force that the marine ecological protection robot receives during the process of moving along a straight line, N – the ground rolling friction coefficient of the marine ecological protection robot, w_d^i – the weighted vector of the path information of the marine ecological protection robot, and n_i – the variable parameter of the marine ecological protection robot.

In Cartesian space, the estimation range is subjected to particle scattering points, and the marine environment is perceived by adaptive adjustment of mechanical driving parameters, and the moving path planning of marine ecological protection robot is carried out in intelligent spatial scheduling system:

$$\mathbf{q}_1 = [q_1, \cdots, q_7]^N \equiv [\theta_4, \cdots, \theta_{10}]^N \tag{5}$$

Using the linear parameter adjustment method of the dynamics, the position measurement of the robot is estimated, and the iterative expression is obtained:

$$P_{ij}(k) = \frac{\left[l_j(k) - l_i(k)\right]\eta_{ij}(k)}{\sum\limits_{j \in N_i(k)} \left[l_j(k) - l_i(k)\right]\eta_{ij}(k)} \tag{6}$$

where

$$j \in N_i(k), N_i(k) = \left\{\left\|x_j(k) - x_i(k)\right\| < r_d(k)\right\} \tag{7}$$

The $\eta_{ij}(k)$ is the regression coefficient of the robot's precise position estimation, $l_j(k)$ – the control parameter for robot position measurement, and $l_i(k)$ – the variable control parameter of the robot position measurement. According to the observational modified odometer increment information, the robot's physical information parameter measurement tracking is carried out in the space of 6 DoF [9]. Based on the adaptive pose tracking method, the inverse Jacobian matrix of robot positioning is obtained:

$$^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -d_i s\alpha_{i-1} \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & d_i c\alpha_{i-1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}$$

where s denotes the sine of taking the angle θ and c denotes the cosine of taking the angle θ. Add a rotation error in the initial motion trajectory plane, combined with SLAM algorithm to achieve obstacle avoidance and positioning of marine ecological protection robot [10].

Simulation experiment and result analysis

Experiment of realizing a marine ecological protection robot to a target point in an obstacle-free underwater environment. While using the improved ant colony method to achieve the semi-circle movement of the underwater robot, the direction angle also changed from –180° to 0°. The sampling points in the experiment include the starting point and end point of the underwater robot during the operation, and several tangent points of the underwater robot at the semicircle tangent. This verifies that the underwater robot can effectively complete the path planning when there are no obstacles [11].

The experimental platform adds two adjacent obstacles. When the robot meets the obstacles, the optimal path is bypassed to reach the target point through the designed algorithm. In this set of experiments, due to the closeness of the obstacles, only two obstacles can be chosen to bypass.

From the previous experimental results, it can be seen that the improved algorithm proposed in this paper can achieve effective path planning and avoid obstacles for marine ecological protection robots, ensure that underwater robots reach the target point in different environments, overcome the slow initial convergence of the ant colony algorithm, and are extremely easy. At the same time, it can be verified that the underwater global positioning platform can obtain the accurate underwater robot position and pose angle in real time, which proves the feasibility of the algorithm [12].

In order to test the application performance of this method in realizing the intelligent positioning of marine ecological protection robot, the marine ecological protection robot used in the experiment is ARJDLH type robot, the marine ecological protection robot information sensor is marine ecological environment rangefinder (SICKLMS111), In order to ensure the accuracy of the experiment, MATLAB7 is selected as the simulation design platform in this article, the algorithm is designed with MATLAB7, and the sampling time interval of marine ecological environment sensing information of marine ecological protection robot is 0.24 seconds. If the control parameter $q = 4$, $b_2 = b_{-2} = 1$, $b_1 = b_{-1} = 2$, $b_0 = 0$, the flexible control moment of the robot is $M_p = 1.6 \cdot 10^4$ kg, and the rotational inertia is 1.585 KN. The map spatial distribution of the constructed marine ecological protection robot is shown in tab. 1.

Table 1. Spatial distribution of marine ecological conservation robots

Guidepost	Probability Center	Measured center	Error spacing
1	(–43, 43)	(–7, 14)	4.35
2	(23.4, 21.7)	(15, 15.4)	5.45
3	(32, 45)	(24, 120)	5.32
4	(147.6, 356.7)	(15, 146)	5.36
5	(4, –4.6)	(112, –34)	6.56
6	(12.1, 13.4)	(33.1, 14.4)	5.43

According to the previous simulation environment and parameter setting, the positioning design of marine ecological protection robot is carried out, and the position information of marine ecological protection robot is collected by using marine ecological protection robot information sensor. In the open source robot platform CARMEN, the information collection result is shown in fig. 1.

Taking the marine ecological environment sensing information of the marine ecological protection robot as the input, the position and posture tracking information of the marine ecological protection robot is extracted, and the dynamic positioning and the tracking identification of the robot are carried out according to the environmental perception of the marine ecological protection site, and the result of the estimation of the robot's altitude is shown in fig. 2.

According to the results of the robot's navigation level calculation, the positioning of the marine ecological protection robot is carried out, and the real track and the positioning track output of the marine ecological protection robot are obtained as shown in fig. 3.

The analysis fig. 3 shows that the trajectory tracking ability of the marine ecological protection robot using this method is strong, the positioning error is small, and the positioning error of the different methods is tested. The comparison results are shown in tab. 2.

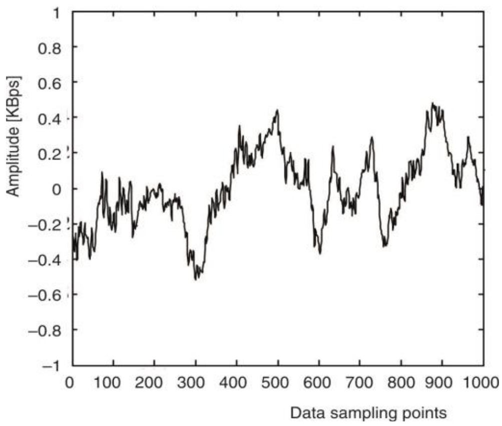

Figure 1. Marine ecological environment sensing information acquisition results of marine ecological protection robot

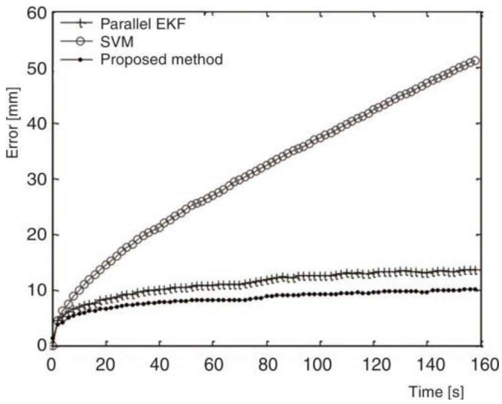

Figure 2. Estimated results of the robot's aerial projection

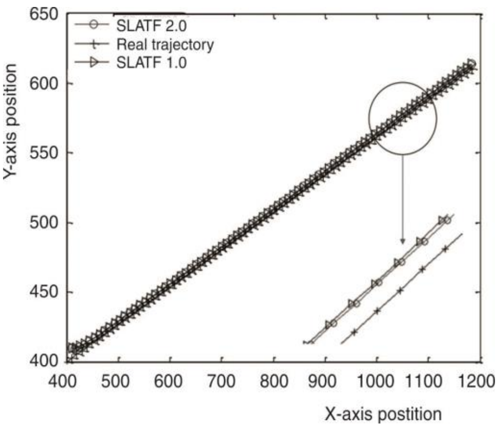

Figure 3. Real trajectory and positioning trajectory output of marine ecological protection robot

The analysis tab. 2 shows that the obstacle avoidance performance of the marine ecological protection robot in this paper is better and the dynamic positioning control ability of the robot is stronger and has good application value.

Conclusions

This paper mainly designs 2-D path planning algorithms. Since underwater is a 3-D environment, it is necessary to further improve the algorithm to realize path planning in 3-D environment. At the same time, only the path planning of a single marine ecological protection robot is considered in the article. In a complex system, multiple underwater robots need to co-operate to complete the task. This involves the information interaction and autonomous collaborative control of multiple marine ecological protection robots.

Table 2. Comparison of positioning errors

Iterations	Proposed method	Fuzzy PID	Adaptive inversion integral
100	0.054	0.265	0.176
200	0.042	0.1434	0.165
300	0.016	0.076	0.076
400	0.004	0.054	0.065

The intelligent control design of marine ecological protection robot, combined with obstacle avoidance control and map planning method of marine ecological protection robot, improve the intelligent positioning control ability of marine ecological protection robot, this paper proposes a sliding control method of marine ecological protection robot based on dynamic positioning, using gyroscope and rangefinder as the information sensor of marine ecological protection robot, collecting the position information of marine ecological protection robot, using dynamic information measurement method to measure the location information of marine ecological protection robot, extracting the position tracking information of marine ecological protection robot, carrying out dynamic positioning and tracking of robot according to the field environment perception of marine ecological protection, combining with robot control method to design the global positioning of marine ecological protection robot, improving the measurement and positioning ability of marine ecological protection robot under the dynamic environment protection robot. The research shows that the method has high stability and low positioning error, which improves the marine information perception of marine ecological protection robot. However, in the sliding control method of marine ecological protection robots, due to the complex operating environment of underwater robots and the high noise of underwater acoustic signals, filtering technology is extremely important in the motion control system of underwater robots. In view of the impact of this issue, I hope that future research will focus on this aspect.

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