Control Method of Multi Joint Snake Like Manipulator Based on Hybrid Fish Swarm Ant Colony Algorithm

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Abstract. In the control process of multi joint snake like manipulator, the traditional control method is easily affected by the interference of multi link communication signal, and its overall control stability is poor. Therefore, a control method of multi joint snake like manipulator based on hybrid fish swarm ant colony algorithm is proposed. The hybrid fish swarm ant colony algorithm is used to update pheromone, so as to select the optimal motion path of the manipulator, and design the transmission control to ensure the normal communication and signal stability of each joint of the manipulator. On this basis, the control rules of the manipulator are designed for the selected path of the manipulator to achieve the goal of real-time control of the manipulator. The experimental results show that: the control method based on hybrid fish swarm ant colony algorithm has high control signal transmission efficiency, reliable convergence value, and its overall stability has been improved.

Keywords: Ant colony algorithm · Multi joint · Snake like manipulator · Control method

1 Introduction

Snakes are widely distributed in nature, and can be seen in a variety of environments. From land to sea, from forest to desert, their special appendage free movement has strong environmental adaptability [1]. If this kind of motion ability can be applied in robot, it will be a great breakthrough. Most of the commonly used robot movements are wheeled or foot walking. Although they have been developed for a long time, their movement ability is still limited and their ability to adapt to the terrain is limited. Due to the strong adaptability of snake like motion, it can be predicted that snake like robot will have broad application prospects in exploration, dangerous environment operation, on-site inspection and reconnaissance.

In addition to the special environment and terrain adaptability, snake like robots are often composed of a large number of repetitive segments, with many redundant structures. Different segments can backup each other, and their scalability and reliability are greatly improved. Therefore, in some areas with high reliability requirements, such as

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military, aerospace and so on, NASA has been developing snake like robots Application of space robot in the field of research [2, 3].

Snake like robot has many useful characteristics, but at the same time, these characteristics also bring many problems, so snake like robot attracts numerous researchers to explore. Among these problems, how the snake like robot, or snake, moves is the most basic one. Different from the motion of wheeled or walking robots, their motion is obvious and easy to understand. When the wheels turn or the feet push, the robot moves [4]. The movement of snake like robot is not so obvious, it uses the overall deformation of the body to achieve movement, rather than wheels or feet.

The research of snake like robot in China is later than that in foreign countries. In 1999, Shanghai Jiaotong University published the first prototype of snake like robot in China. Since then, some research on motion theory has been carried out. In 2001, the University of national defense science and technology also published a prototype snake like robot [5]. South China University of technology has also carried out research on snake like robots. They mainly focus on the theoretical research on the application of snake like robots in bridge cable detection, and have carried out a lot of simulation on snake like robots [6]. At present, Shenyang Automation Research Institute of Chinese Academy of Sciences has the most abundant research achievements in the field of snake like robot in China. They not only carried out in-depth research in theory, but also published a number of prototypes.

For the control of snake like manipulator, the current common methods are vision based manipulator control and neural network-based manipulator control. Ai et al. [7] proposed design of manipulator target positioning system based on monocular vision. Obtain the image of the lock target in real time through monocular optical imaging, and combine the image analysis algorithm to calculate the target space position and the relative position of the target and the robot arm. Using OPC communication technology, the target space position information is transmitted to the robot arm control module and control the movement of the robotic arm to achieve the target grab. Li et al. [8] proposed research on robot trajectory control algorithms based on BP neural network and ant colony algorithm. Establish the manipulator motion trajectory model, and then use the neural network algorithm to train the main parameters of the manipulator, and then compare the output predicted motion trajectory with the manipulator's expected motion trajectory in order to solve the optimal parameters that are closer to the expectations. These two control methods have the problem of poor stability in the actual application process, which is mainly affected by the unstable communication between the joints.

In this case, a multi joint snake like manipulator control method based on hybrid fish swarm ant colony algorithm is proposed to solve the problems existing in the traditional control method. The hybrid fish school-ant colony algorithm is used to update the pheromone during the movement of the robotic arm. In this process, the optimal motion path of the robotic arm is selected. The path data is transmitted to the data receiver of the robotic arm to realize the real-time control of the robotic arm. In this process, the hybrid fish school-ant colony algorithm ensures the stability of data transmission.

2 Control Design of Multi Joint Snake Like Manipulator Based on Hybrid Fish Swarm Ant Colony Algorithm

2.1 Update Pheromone

In the basic ant colony algorithm, the calculation of transition probability depends heavily on the updating of pheromone. Different pheromone updating strategies will affect the search behavior of ants, thus improving the performance of the algorithm. In the basic ant colony algorithm, the pheromone update strategy makes the premature convergence behavior of the search mode more likely to occur, and the feasible solution cannot be quickly concentrated near the optimal solution, which inevitably reduces the quality and convergence speed of obtaining the optimal solution [9, 10]. In this paper, a new pheromone updating strategy is proposed in the hybrid intelligent algorithm, which can better avoid the algorithm falling into the local optimal solution prematurely.

In order to reflect that the pheromone secreted in nature is a kind of biological material, which will be gradually reduced in the air. Therefore, the concept of pheromone volatilization coefficient P is introduced, that is, the concentration of pheromone secreted by individual ants will gradually decrease with time according to some natural law. When the ant colony K finishes one cycle, it volatilizes the pheromones on all paths according to the volatilization coefficient p, and then updates the pheromone concentration according to Formula (1).

$$\sigma_{ij}(t+1) = (1-p)\sigma_{ij}(t) \tag{1}$$

Then according to formula (1), pheromone updating is completed for all the global paths of the manipulator.

$$\sigma_{ij}(t+1) = (1-p)\sigma_{ij}(t) + \Delta\sigma_{ij}(t) \tag{2}$$

$$\Delta\sigma_{ij}(t) = p \times f(L_{best}) \tag{3}$$

The formula L_{best} represents the optimal feasible solution obtained by all ants so far in this cycle. The proposed pheromone updating strategy can gradually evaporate the interference of the poor initial solution on the optimal global path, and gradually strengthen the influence of pheromone on the optimal global path as the algorithm continuously iterates. In the process of pheromone iterative updating, if the amount of pheromone trajectories of one point on each selected point is significantly higher than that of other points, when using the above method to update pheromone, the search stagnation phenomenon is very likely to occur, and the feasible solution is often locally optimal. In order to avoid this phenomenon, this paper proposes an update strategy which directly depends on the pheromone trajectory and heuristic information to influence the probability of selecting the next solution element. The heuristic information is constant in the whole process of the algorithm, which is determined according to the actual problem. Therefore, by limiting the amount of pheromone update trajectories, the effect of affecting the solution elements can be achieved, and avoid that ants may move along part of the same path, but will not move along the same path.

The calculation method is as follows: select the appropriate pheromone trajectory boundary, for all pheromone $\sigma_{ij}(t)$ in the path, The following rules must be followed.

$$\sigma_{ij}(t) \in [\sigma_{\min}, \sigma_{\max}] \tag{4}$$

In formula (4), if $\sigma_{ij}(t) > \sigma_{\max}$, then upper limit is taken as the amount of pheromone, and need to conform to formula (5).

$$\sigma_{ij}(t) = \sigma_{\max} \tag{5}$$

In formula (5), if $\sigma_{ij}(t) < \sigma_{\min}$, set $\sigma_{ij}(t) = \sigma_{\min}$. Consider that the algorithm updates pheromones on a single path, the maximum pheromone amount is $\frac{1}{L_{best}}$, where the symbol $\frac{1}{L_{best}}$ represents the path length of the corresponding global optimal solution or iterative optimal solution. Therefore, according to the following strategy $\sigma_{\min}$ and $\sigma_{\max}$ is dynamically updated until a better feasible solution is found.

Before the first generation solution is produced, $\sigma_{\min}$ and $\sigma_{\max}$ are calculated by the following formula:

$$\sigma_{\min} = \frac{\sigma_{\max}}{20} \tag{6}$$

$$\sigma_{\max} = \frac{1}{2(1-p)} \cdot \frac{1}{L_{best}} \tag{7}$$

When the pheromone in the path is updated,$\sigma_{\min}$ still determined $\sigma_{\max}$ by formula (6) and formula (7)

$$\sigma_{\max} = \frac{1}{2(1-p)} \cdot \frac{1}{L_{best}} + \frac{1}{L_{best}} \tag{8}$$

The convergence condition of the algorithm is that if there is only one solution element at each selection point, the information amount of the other solution elements is $\sigma_{\min}$, while the information amount of the other solution elements is $\sigma_{\max}$. Therefore, in the process of solving the algorithm, it is necessary to select the solution element with the largest amount of pheromone trajectory each time to obtain the optimal solution of the manipulator motion.

2.2 Signal Transmission Control Design

The serpentine robot's head and body are directly connected with the remote control by wireless communication. The wireless module uses the NRF24L01 wireless transmission module which has become the modular structure. When using this module to communicate, users do not need to participate in the communication process, as long as the module is programmed configuration, data can be transparently transmitted. NRF24L01 is a 2.4 GHz wireless communication chip produced by NORDIC. It is modulated by FSK and integrated with NORDIC's own Enhanced Short Burst protocol. The module in the NRF24L01 chip with an antenna, the terminal and other peripherals, through the SPI communication mode and SCM communication, very convenient to use.

With the support of wireless transmission technology, remote control is used to control the robot arm. The remote controller is used to display the state of the serpentine robot and realize the manipulation of the robot. Including power supply module, voltage monitoring module, indicator light, touch screen, wireless communication module and SWD download port.

Touch screen: using STM32 development board with ALIENTEK TFTLCD module, which belongs to the resistive touch screen, is currently the most used in the market type. Status Indicator LED: For convenience of observation, all of them are high-brightness direct insertion LEDs, which are red, blue and green respectively.

Voltage monitoring module: In all circuits are set up a power monitoring module to avoid the battery voltage is too low and damage the battery, monitoring module includes sampling circuit and buzzer alarm circuit. Because the requirement is not high, the voltage of 8.4V power supply is divided by a simple resistance voltage divider, and then the sampling voltage is converted to AD by STM32. The snake-like robot adopts a partial voltage resistor with resistance of 20 K and 30 K and accuracy of 1%, so the sampling voltage is 8.4 V * 2/5 = 3.36 V. When the power supply voltage is lower than 7.2 V, the sampling voltage is lower than 2.88 V, the buzzer alarms. Buzzer module: In order to reduce the size of the circuit board, the passive buzzer is used, the size is only 5 mm * 5 mm * 2 mm. The difference between active buzzer and passive buzzer lies in whether it integrates oscillation circuit, so the passive buzzer should output PWM signal in MCU and control the buzzer by amplifying triode S9012, which is different from conventional buzzer control. SWD debug mode: J-LINK V8 and STM32 both support JTAG debug and SWD debug, so two debug modes can be used, but SWD only needs two IO, occupies less resources and volume than JTAG, so SWD debug mode is used. When using the J-LINK V8 downloader, the STM32 ground and 3.3 V need to be connected to the J-LINK V8 ground and 3.3 V, so only four wires are required for SWD downloads, including two IO pins (SWDCLK, SWDIO) and 3.3V and GND. Power module: This module is responsible for the power supply of the whole remote control, because the remote control has two kinds of power demand, 3.3 V and 5 V, so the power module is divided into 3.3V voltage regulator and 5V voltage regulator part, because the power is not big, so all use ASM 1117 series linear voltage regulator chip, linear voltage regulator compared with DC-DC voltage regulator is generally small, input voltage and output voltage can be very close, use ASM 1117–3.3 and 1117–ASM 5.0 regulator chip, 8.4 V power supply voltage to 3.3 V supply MCU, 5.0 V supply touch screen. The transmission control part guarantees the reliable completion of data stream transmission between the segments, and the object it transmits is a segment of byte stream. The hardware base of this module is STM32. To ensure reliable transmission, the sender must be able to receive the authenticated frame sent by the receiver after sending the data frame. Therefore, each segment must be duplex with the forward and backward communication, and each segment needs two transmission control systems, one for the first segment and the other for the second segment.

2.3 Motion Control Design of Manipulator

Motion control is responsible for direct control of the steering gear and updating of motion parameters. The core is to record the state of motion, which determines the current implementation of the motion.

The steering gear used in the motion control part is MG995. The steering gear has 3 control wires, two of which are power and ground wires, and one is signal wire. The control signal of the steering gear is a square wave with a period of 20ms, which has a certain requirement on duty ratio. The steering gear of the MG995 rotates in the range of –90° to 90°, and its high level time length y (unit us) is related to the angle x as follows:

$$y = \frac{100}{9}x + 1500 \tag{9}$$

Each segment has two actuators to control, that is, STM32 chip output two square waves, using STM32 chip timer 3 to complete, timer 3 can output up to four square waves with the same period. Timer configuration, the use of timer 3 channel 3 and channel 4, the working mode is PWM 1 mode, in this mode, when the timer count value is less than the comparison register, the output high level, less than the comparison register output low level.

Because the system clock is 16 MHz, so as long as the timer set to 15, you can reach 16 min, the unit of time is lus, then set the timer 3 count value to 19999, so the timing cycle is 20,000 times, the length of time is just 20 ms, to set the steering angle, just take the required angle into the Type 7 to calculate the length of time, the calculation results into the corresponding comparison register.

Motion parameter updating, especially in interrupt process, only includes the updating of direct parameter time and rotation angle, because these two parameters need to be calculated in real time, and the updating period is 20 ms. The first is the update of the time parameter t. In fact, there are only three kinds of motion: sinusoidal motion, lateral rolling motion, fixed at a certain angle, and only the first two kinds of motion that need time parameter. Since the update period here is 20 ms, you will need to increase the time by 20 ms per cycle. In addition, there is a special parameter: reverse, reverse instructions, in order to achieve this function, the need for another time reverse growth, that is, 20 per cycle to reduce 20 growth. Then there's the angle update. From the structure, it can be seen that none of the parameters recorded the current angle, which is caused by two reasons: first, the angle needs to be updated in real time with a period of 20 ms, and it is meaningless to record different angles in each period; second, the comparison register corresponding to the query rudder can be used to infer the current angle. Thus, the multi-joint serpentine manipulator control method based on hybrid fish-ant colony algorithm is designed.

3 Experimental Study on Multi-joint Serpentine Manipulator Control Based on Hybrid Fish-Ant Colony Algorithm

In order to verify the performance of the proposed multi-joint snake-shaped manipulator control method based on the hybrid fish-ant colony algorithm, the DDC controller is tested, and the input signal is simulated by MATLAB software according to a certain time sequence.

3.1 Experimental Preparation

In the experiment, the serpentine manipulator is tested by the driving end. The overall structure of the driving end is shown in Fig. 1.

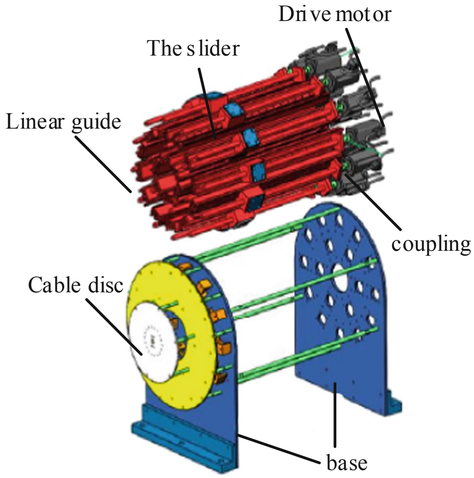


Fig. 1. Structure diagram of drive end

On this basis, the MATLAB software is used to simulate the signal, and the input signal timing requirements are shown in Fig. 2.

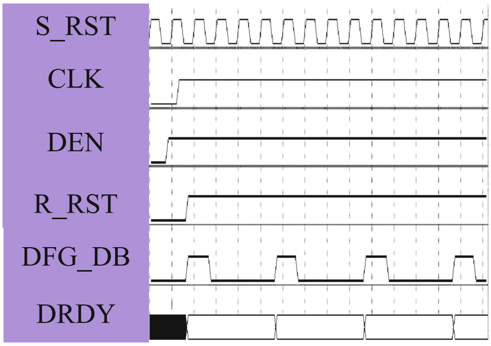


Fig. 2. Input signal timing design

In order to better verify the control of multi joint snake like manipulator, the experimental parameters are set. The carrier frequency of the input signal is set to 5 MHz. The modulation signal frequency is set to 120 kHz. The initial value of the accumulator is set to 0 dB. The total amount of data is 10–50T.

In the same experimental environment, the control of multi joint snake like manipulator is realized through many tests. In addition, compared with the traditional control method of multi joint snake like manipulator, its signal processing speed is tested under the interference of different amount of data.

3.2 Experimental Results and Analysis of Control Signal Processing Rate

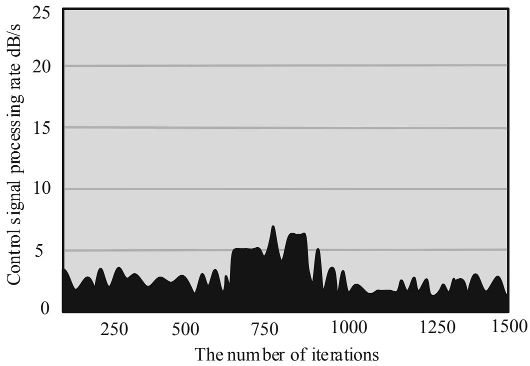
Based on the above experimental preparation content, the signal processing rate of different manipulator control methods is verified. In the experiment, the manipulator control method based on neural network, vision and the manipulator control method based on hybrid fish ant colony are used to control the manipulator to do the same action. The experimental results are output by MATLAB software. The specific experimental results are as follows This is shown in Fig. 3.

When the number of iterations based on the neural network is very low, it can be seen that with the increase of the number of iterations in the control chart, only the peak of 5dB / s can be seen. Experimental results show that when the number of iterations is increased to 750, the signal processing speed is always maintained at a high level. To sum up, the robot control method based on hybrid fish swarm ant colony algorithm has higher control signal processing speed.

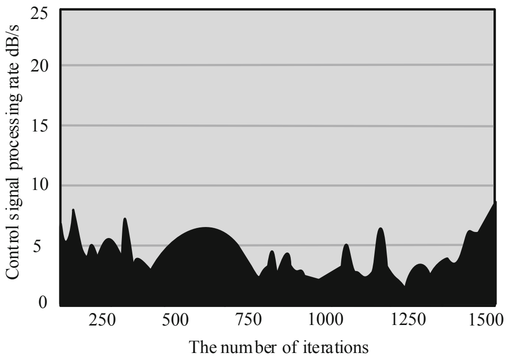
3.3 Simulation Results and Analysis

Based on the control process of the manipulator in the above experiment, the output of the change of the convergence value in the control process is taken as the experimental result of the second experiment, and the stability of the control method of the manipulator is compared and analyzed according to the change of the convergence value.

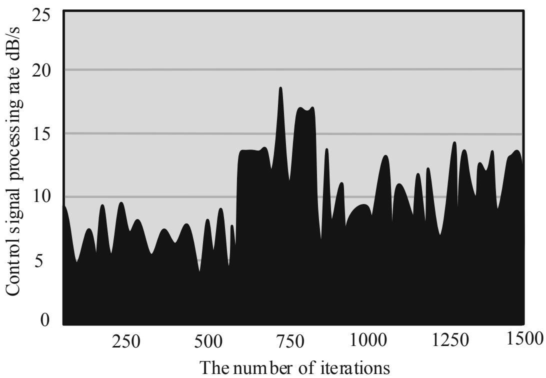
From the data in Table 1, it can be seen that with the increase of the number of iterations, the convergence values of each manipulator control method are increasing, but the longitudinal observation analysis shows that the designed manipulator control method based on hybrid fish swarm ant colony algorithm has the lowest convergence value and the smallest change. The convergence value is as low as 0.036. Combined with the experimental results of control signal processing rate, the stability of the control method based on hybrid fish swarm ant colony algorithm is better than the traditional control method.



(a) Experimental results of manipulator control method based on Neural Network



(b) Experimental results of robot arm control method based on vision



(c) Experimental results of manipulator control method based on hybrid fish swarm ant colony algorithm

Fig. 3. Experimental results of signal processing rate controlled by different manipulator control methods.

Table 1. Experimental results of different manipulator control methods

	Control method of snake like manipulator based on Neural Network	Control method of snake like manipulator based on vision	Snake like manipulator control method based on hybrid fish swarm ant colony algorithm
Iterations	500	500	500
Convergence value	0.926	0.648	0.036
Iterations	1000	1000	1000
Convergence value	2.064	1.395	0.051
Iterations	1500	1500	1500
Convergence value	3.135	2.361	0.097

4 Conclusion

The progress of science and technology, the innovation of technology and the trend of social development put forward new challenges and requirements for the mechanical design at this stage. In this context, this paper focuses on the research and discussion of multi joint snake like manipulator. With the support of the original relevant data and literature, a control method of multi joint snake like manipulator based on hybrid fish swarm ant colony algorithm is proposed. After the method design is completed, the effectiveness of the proposed control method is verified by a number of comparative experiments with traditional control methods The reliability and stability of the control method, to a certain extent, solve the problems faced by the traditional manipulator control method. However, due to the limitations of personal ability and energy, coupled with the manipulator control is a more complex problem, there will inevitably be some deficiencies in the research, in the future research will start from the deficiencies in this paper in-depth research and analysis. Subsequent research can be conducted from the aspect of the control accuracy of the robotic arm.

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