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RESEARCH ARTICLE

RESEARCH ON PATH CONTROL ALGORITHMS FOR SEARCHING ROBOTS

***Rongrong SUN**

Binzhou University, Binzhou, China

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ABSTRACT

The response ability of ant colony algorithm and Ziegler Nichols method to unit step signal is compared and analyzed. Ant colony algorithm has excellent control ability, such as small overshoot and short steady-state response time. Therefore, ant colony algorithm can be effectively applied to the control of underground search and rescue robot. It is found that the introduction of ant colony algorithm with node activity can solve the problem of premature convergence before the improvement. The control scheme of hardware and software is designed and studied. Through 20 simulation experiments of obstacle avoidance in complex environment, it is found that the improved ant colony algorithm can achieve up to 95% accurate obstacle avoidance rate in the control system, and the average path planning time is 4.4 Ms. It has good search accuracy and control effect, which is of great significance to improve the search and rescue effect.

INTRODUCTION

With the improvement of computer technology and automation control level, underground robots are more and more widely used in coal mine production, such as search and rescue robots, rescue robots, handling robots, etc. They can complete the tasks quickly and accurately through the control system, which is of great significance to improve the safety and production efficiency of coal mines. Generally, most of the underground search and rescue robots use traditional genetic algorithm to complete the tracing operation of fault-free path, and through the iteration of probabilistic mechanism, realize the random search which is not related to the problem domain. However, due to the slow search speed, complex programming and the dependence of operator parameters on experience, this algorithm limits the expansion ability of its work to a certain extent. To solve the above problems, an improved ant colony algorithm with node activity is proposed. By optimizing the heuristic function and path addressing, the convergence speed of path calculation is accelerated, and the feasibility of the algorithm is verified by simulation. According to the characteristics of the algorithm, this paper designs and studies the control system of the underground search and rescue robot to realize the high-efficiency obstacle avoidance ability in complex environment.

Ant colony algorithm control analysis

Algorithmic control principle: Ant colony algorithm (ACO) is a new bionic algorithm. Based on heuristic search, it can optimize controlled objects and targets through feedback of information and distributed computing, and solve the secondary allocation. The implementation of this algorithm requires two conditions: local optimal search and state optimal transition.

***Corresponding author: Rongrong SUN,**
Binzhou University, Binzhou, China.

The ant colony algorithm obtains probabilistic trajectory calculation based on the state transition of ant colony. The probability of system state transition at t moment can be expressed as follows:

$$P_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}^{\alpha}(t)][\eta_{ik}^{\beta}(t)]}{\sum[\tau_{ij}^{\alpha}(t)][\eta_{ik}^{\beta}(t)]} & j\in N_i^k\\ 0 & j\notin N_i^k\end{cases} \quad \text{…………..(1)}$$

Where α represents the role of path information in ant colony state transition. β represents the expected heuristic factor, i.e., the visibility of response path index. $\tau_{ij}(t)$ and $\eta_{ij}(t)$ are Heuristic function.

Ant colony algorithm PID control: The optimization of control parameters based on ant colony algorithm can be verified by the structure of PID controller. Three parameters (proportional coefficient, integral coefficient and differential coefficient) are used to construct a three-dimensional search space. The optimal PID control can be achieved by choosing appropriate parameters. In this paper, the structure of PID control is designed as shown in Fig.1. The input function is $r(t)$ and the output function is $y(t)$.

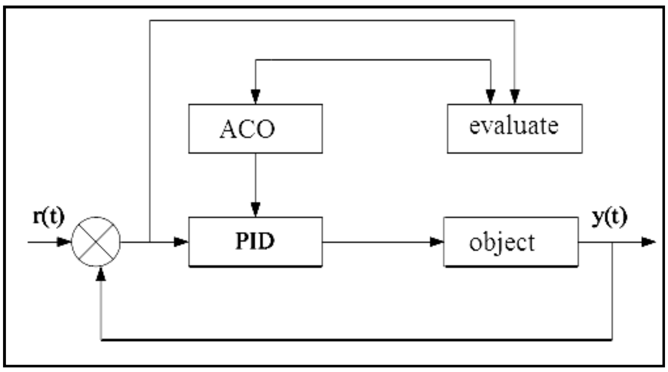

Fig. 1. Principle of ant colony algorithms pid control

In order to verify the good control effect of ant colony algorithm, the paper compares with the PID control of Ziegler Nichols method under the same parameters. Through the numerical simulation of MATLAB, the unit step response curve is obtained as shown in Fig.2. As can be seen from Fig.2, the response curve obtained by ant colony algorithm has a 7% overshoot, which is much less than the 50% overshoot obtained by Ziegler Nichols method, and a shorter steady-state adjustment time. Therefore, the control effect is better. Therefore, the application of ant colony algorithm in the control system of the underground search and rescue robot will obtain good stability and reliability.

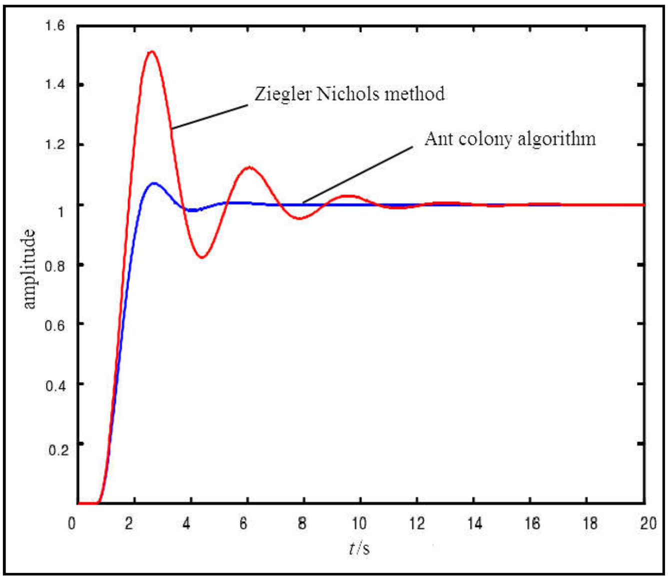

Fig. 2. Amplitude response curve

Path Planning of Search and Rescue Robot

Path planning: In this paper, the path planning of underground search and rescue robot is based on the grid method. Grid method is an advanced modeling method, which is very effective for improving the efficiency of search calculation. This method mainly includes three steps: model building, obstacle analysis and optimal path search. When building the grid model, it is necessary to consider the overall range of motion of the search and rescue robot and reasonably select the grid size of eight directions in space. If the grid is too fine, the search computation will increase exponentially, but it is not conducive to the search operation. After completing the grid model, it is necessary to divide the grid type according to the location of obstacles and other information. Finally, according to the preset constraints, the optimal path search is obtained. The quality of path planning has a key influence on the efficiency and accuracy of search calculation.

Improvement of path algorithms: Using ant colony system algorithm to control underground search and rescue robot can improve the convergence speed and the quality of the optimal solution, but it is easy to produce premature convergence. In order to solve this problem, the node activity is introduced and the algorithm effect is improved on the basis of the Maximum and Minimum Ant Colony System (MMAS). In the control based on MMAS algorithm, if the searching concentration of path information is high at a certain node, the optimal solution of path tracing will be established by positive feedback control. When the searching concentration reaches a stable level, the spatial search will stop. Because of the introduction of node activity, the more the number of nodes, the stronger the searchability of the algorithm, which can reduce the search and calculation of invalid paths, and at the same time reduce the phenomenon of local convergence.

Trajectory simulation: In order to verify the convergence effect of ant colony algorithm with node activity and determine the validity of path space planning with grid method, the convergence of iteration calculation of optimal path length with preset parameters is simulated based on MATLAB [6]. After several iterations, the convergence characteristics of the improved ant colony algorithm are obtained as shown in Fig.3. As can be seen in the figure, after ten iterations, the optimal solution has been found, and the premature convergence of the improved algorithm has been solved. The search efficiency is high and the search speed is very fast. It is feasible to use this algorithm in the control of the underground search and rescue robot.

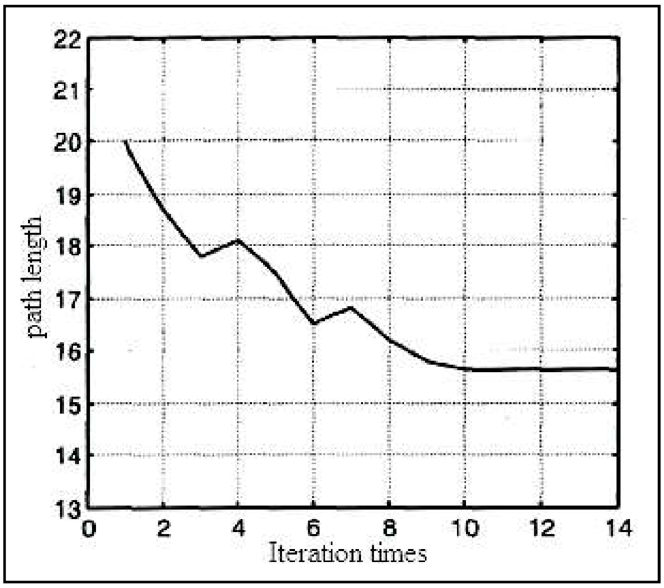

Fig. 3. Convergence of introducing node activity degree

Control System Design

Functional requirements: The internal environment of underground roadway is relatively complex, and the signal is seriously disturbed and absorbed. GPS positioning and navigation technology cannot be used, and there are many flammable gases, dust and other substances. Therefore, this paper adopts hierarchical control for the control system of the underground search and rescue robot, and achieves effective intelligent control mode through hardware design and software control. The main functions of the system are: (1) intelligently adapting to the environment, stably realizing data exchange with the host computer, efficiently completing obstacle-crossing and obstacle-avoiding actions; (2) realizing multi-position and direction search ability. Electronic devices ensure explosion-proof, waterproof and dust-proof capabilities; (3) meeting the requirements of workspace and energy consumption, with good real-time.

Hardware design: The hardware of the search and rescue robot is modular design, which mainly includes monitoring module, sensor module, data acquisition module, data transmission module, mechanism execution module and so on. Real-time communication between modules can be realized.

The frame structure of the module has the characteristics of centralized management and divergence control. In hardware system, the host computer completes remote data exchange through wireless network card, and displays information such as search and rescue trajectory and picture in real time. At the same time, it can generate instructions to complete terminal control. The lower computer chooses embedded industrial control computer, which can not only receive control instructions from the upper computer, but also complete control decisions independently. The intelligent navigation and positioning functions are realized by data acquisition card. The search and rescue path is planned by the preset ant colony algorithm, and the driving of the executing mechanism is controlled. The data acquisition module chooses ADAM-5017 series, which can realize eight-channel programming and collect high-precision data. The types of sensors mainly include: environmental sensing sensors, infrared switches, ultrasonic sensors, position and attitude sensors, gas sensors, carbon monoxide sensors, etc., covering all functional detection. The drive motor adopts brushless DC servo motor, which can meet the complex speed control requirements. The power supply system adopts lithium battery pack and modular output, which can provide real-time early warning.

Software control design: The software control designed in this paper belongs to hybrid system control, including three-layer control strategy. Among them, the first layer is the planning layer, which is selected by human-machine interface parameters to obtain trajectory decision-making and make path planning; the second layer is the coordination layer, whose main function is to obtain planning instructions through path planning; the third layer is the control layer, which inputs the control strategies of the first two layers into the executing mechanism, and feeds back the monitoring parameters to the planning layer. In software control, the application of ant colony algorithm is equivalent to the expression of spatial parameters, which requires three key feedbacks: environmental parameter feedback, model parameter feedback and mechanism parameter feedback. Feedback process can be divided into cognitive layer and perceptual layer. The cognitive layer describes the environmental parameters in the way of dynamic variables. The perceptual layer expands the spatial trajectory through grid modeling to provide optimal decision-making for the system. Because the system needs to achieve accurate search and location in complex environment, sensor data need to be transmitted to the cognitive layer in the way of coordinate information.

System test: In order to study the control effect of ant colony algorithm on the control system of underground search and rescue robot, 100 obstacle avoidance experiments were carried out, and 20 experiments were carried out continuously. The final test results include average speed, average path planning time and accuracy of obstacle avoidance, as shown in Tab.1.

Table 1. Experimental results

Number of experiments	Average operating speed (km/h)	Average path planning time (ms)	Accuracy of obstacle avoidance (%)
20	3.8	4.4	95

From Tab.1, it can be seen that the average path planning time of the underground search and rescue robot under ant colony algorithm is 4.4 ms, which fully meets the time error requirement caused by the change of environmental parameters, and the obstacle avoidance accuracy is up to 95%. This confirms the good search accuracy and control effect of the ant colony algorithm.

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Conclusions

The problem of slow search speed in search and rescue robot control can be effectively solved. Therefore, this paper proposes a control scheme based on ant colony algorithm. Through the analysis of the principle of ant colony algorithm and the research of robot path planning, the search efficiency is obviously improved. On the basis of MAS, the ant colony algorithm of node activity is introduced. The numerical simulation shows that under the control of the improved ant colony algorithm, the convergence speed is faster and the global stability is higher. In addition, the hardware design and software design of the hierarchical control system of the robot have been completed, and the high-efficiency tracing ability of the control system in complex environment has been verified by experimental tests.

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