2018 11th International Conference on Intelligent Computation Technology and Automation

A Robot Obstacle Avoidance Method Based on Improved Genetic Algorithm

MAO Lin[1],JI Xiaoming[2],QIN Fei[2]
1. Department of Agricaltural Information of Jiangsu Agri-animal Husbandry Vocational College, Taizhou, 225300,China
2. College of Management Science and Engineering, Anhui University of Technology, Maanshan,243002, China
mljsahvc@foxmail.com

***Abstract*—In order to improve the space obstacle avoidance ability of the robot and realize the optimal kinematics planning and design of the robot, a robot obstacle avoidance method is proposed based on improved genetic algorithm (GA), a robot space obstacle avoidance model based on genetic evolutionary adaptive guidance control is constructed. The constraint parameter model of obstacle avoidance control of robot is constructed, and the trajectory of space obstacle avoidance is described as the global optimization problem of genetic evolution. The pheromone released in genetic evolution is used as the guiding rule of space obstacle avoidance control of robot. The mechanical parameters of obstacle avoidance motion and trajectory tracking control parameters are obtained, and the control equations and dynamics equations of robot obstacle avoidance are constructed. The pheromones are broadcast according to the global optimization control rules of genetic evolution. The robot is driven to realize the space path optimization planning and to improve the obstacle avoidance algorithm. The simulation results show that the proposed algorithm is effective in avoiding obstacles, it can effectively avoid obstacles and improve the control performance of the robot.**

Keywords- improved genetic algorithm; evolution; robot; obstacle avoidance; control; global optimization

I INTRODUCTION

Robot is the product of modern industry and high development of information technology. Robot is controlled automatically by artificial intelligence operation, instead of human being to carry out the corresponding difficulty operation. Now, robot in the field, polar science, space exploration and underwater exploration have important application value. The working environment of robot is relatively complex[1]. In the course of path planning and walking of robot, there is a lot of interference from obstacles. However, the robot cannot avoid obstacles by observing them through the eyes like human beings. It is necessary to design the corresponding obstacle avoidance algorithm to realize the intelligent control and operation of the robot. Space obstacle avoidance is an important subject in robot kinematics. The research of robot obstacle avoidance algorithm has been paid attention by many experts and scholars[2].

Obstacle avoidance is one of the most basic and key functions in robot technology. It aims to ensure that the robot does not collide and avoid excessive aging and falling off of the structure. The core of obstacle avoidance technology includes sensor selection and planning algorithm selection. Different sensors have different characteristics and principles, and different algorithms require different time and space complexity[3]. The research of robot obstacle avoidance has been studied by many scholars at home and abroad, but on the basis of these studies, it is still of great significance to further discuss and compare the advantages and disadvantages of each method. This paper will enumerate and analyze the common methods of robot obstacle avoidance, compare and analyze the merits and demerits of each method in each case, so as to provide a reference for the future application. In general, robotics is an interdisciplinary fusion that combines the latest research results in electronic circuits, automation control, computer technology, mechanical dynamics and bionics, symbolizing the latest advances in science and technology. It is the embodiment of a country's high-tech and economic strength. Therefore, many big countries in Europe and America regard robot technology as the first advanced science and technology planning task in the 21st century[4].

This paper focuses on the problem of obstacle avoidance and path location of robot in the room. Due to the complexity of obstacle interference factors, it is difficult to plan obstacle avoidance path for robot moving indoors. The traditional obstacle avoidance algorithm adopts genetic evolutionary binocular visual dynamic tracking technique. In the case of irregular distribution of indoor obstacle areas, the obstacle avoidance performance is poor. In reference [5], a robot space obstacle avoidance algorithm based on genetic evolution is proposed. By using genetic evolution and dynamics theory, the position and attitude of the corresponding robot are calculated by genetic evolution method. The obstacle avoidance behavior control of robot is realized, but the obstacle avoidance effect is not good under the condition of nonlinear distribution of indoor obstacle. In reference [6], a reinforcement learning method based on neural network is proposed to realize obstacle avoidance localization of robot in space. Using the control method of obstacle avoidance formation, the whole effect is paid attention to in the course of obstacle avoidance, but the reliability effect of this algorithm on space obstacle avoidance of robot is not good[7]. In order to solve the above problems, this paper proposes a space obstacle avoidance algorithm based on genetic evolutionary adaptive guidance control. Firstly, the behavior space of the robot is modeled, then the mechanical parameters of the robot's indoor obstacle avoidance are analyzed, and the control equation and dynamic equation of the robot's space obstacle avoidance

978-1-5386-8308-8/18/$31.00 ©2018 IEEE
DOI 10.1109/ICICTA.2018.00081

are constructed. Genetic algorithm is used for obstacle avoidance index and pheromone fuzzy logic is introduced to improve obstacle avoidance algorithm. The simulation results show the superiority of this method in improving the performance of robot obstacle avoidance.

II INDOOR MOTION ENVIRONMENT MODEL AND PARAMETER DESCRIPTION OF ROBOTS

A.Robot indoor motion environment model

The first step in automatic obstacle avoidance is to enable the robot to perceive its surroundings. Generally speaking, we need to provide the robot with the parameters of the surrounding environment through the sensor. For example, the size, shape and position of obstacles. At present, there are a variety of sensors used in obstacle avoidance, and their characteristics and scope of application are also different. According to different principles, can be divided into: ultrasonic sensor, infrared sensor, laser sensor and vision sensor. In order to study the space obstacle avoidance algorithm of the robot, the indoor motion environment of the robot is first studied[8]. In this paper, the robot is a six-degree-of-freedom 6R industrial robot, and the robot entity diagram is shown in figure 1.

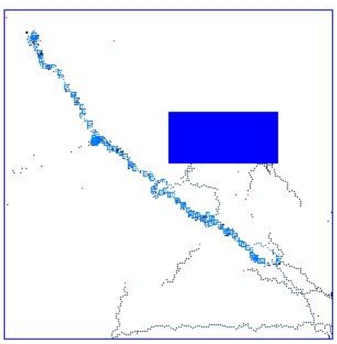

Figure 1. Research object model and obstacle avoidance environment of robot

The indoor environment is the classroom, the position of the indoor space in the right-angle coordinate system is $p^0 = (p_x^0, p_y^0, p_z^0)^{\mathrm{T}}$. the initial position of the robot is given as $\boldsymbol{T}_6^0$, the position of the robot in the right-angle coordinate system is $p^0 = (p_x^0, p_y^0, p_z^0)^{\mathrm{T}}$. The starting point of the robot is ${}_6^0\boldsymbol{T}_0, {}_6^0\boldsymbol{T}_1, \cdots, {}_6^0\boldsymbol{T}_n$, only the end of the robot is considered. Based on the attitude of the actuator at the beginning and the end, the variation matrix of the robot motion is calculated as $P_0, P_1, P_2, \cdots, P_n$. In the course of the robot walking, the robot linkage system can be regarded as an open motion chain, and the joint variables of the robot are q_0 , q_1 , q_2 , $\cdots$, q_n and $\{q(t), \dot{q}(t), \ddot{q}(t)\}$. Given the initial pose of the robot $\boldsymbol{T}_6^0$ and the indoor obstacle point $\boldsymbol{T}_6^1, \boldsymbol{T}_6^2, \cdots, \boldsymbol{T}_6^{m-1}$, the vector equation of the robot's trajectory in the world coordinate system is described as follows:

$$Z_c \begin{bmatrix} U \\ V \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{f}{d_x} & 0 & U_0 & 0 \\ 0 & \frac{f}{d_y} & V_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & T \\ O^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \quad (1)$$

In the upper formula, the two-dimensional image coordinates of indoor obstacle points are transformed into three-dimensional world coordinate coordinates, and the robot motion space can be abstracted by an organic evolution process of macro and micro, and the space coordinates of robot motion trajectory can be abstracted. For the virtual world of genetic population, the environmental information such as obstacles of robot is described as a quantum genetic pheromone[9]. According to the type of pheromone in the environment, the pheromone parameters of the robot's indoor moving environment are obtained as:

$$pheromone(x, y) = (kind, capability) \quad (2)$$

The joint variable of the given robot is q_i^0 , q_i^1 , q_i^2 , $\cdots$, $q_i^m (i = 1, 2, \cdots, 6)$, and the two-dimensional obstacle avoidance behavior space is V_2 :

$$V_2 = \{p(x, y) \mid x \in (0, width), y \in (0, height), x, y \in N\} \quad (3)$$

According to the above formula, the obstacle space of robot motion can be subdivided into $t_1, t_2, \cdots, t_n$. In the absence of obstacles, the obstacle avoidance problem can be described as the rules of quantum searching for target points and moving. Based on the above analysis, the indoor motion and obstacle avoidance environment of the robot are constructed.

B.Description of mechanical parameters and trajectory tracking control parameters of obstacle avoidance robot

The obstacle avoidance process of robot is a continuous process, which requires the robot to have certain precision in the whole process of obstacle avoidance. By the above setting of obstacle avoidance environment and the description of behavior space, the obstacle avoidance of robot is realized, the mechanical parameters of obstacle avoidance and trajectory tracking control parameters are required to set the initial position $\boldsymbol{T}_6^0$ and pose of the robot and sit at right angle. In the position of $p^0 = (p_x^0, p_y^0, p_z^0)^{\mathrm{T}}$, the distance of the robot's moving chain in the room is $\mathrm{T_0, U_0, V_0}$. the robot moves in a straight line along the obstacle to another point. In the right angle coordinate system, the robot's motion trajectory is described as the global finding of genetic evolution[10]. Optimal problem, the pheromone released in genetic evolution is used as the guidance rule of robot space obstacle avoidance control, and the foraging movement rule first determines the initial position of the robot $\boldsymbol{T}_6^1$ and the rotation angle

T_1, U_1, V_1 . The size $p^1 = (p_x^1, p_y^1, p_z^1)^T$ of pheromone concentration in *capability* is calculated, if *state*=0, indicates that the population is looking for food and halves the pheromone between the first and last two points, then the pose increment of each obstacle interval is:

$$\begin{rcases} \Delta x = (p_x^1 - p_x^0)/n \\ \Delta y = (p_y^1 - p_y^0)/n \\ \Delta z = (p_z^1 - p_z^0)/n \end{rcases} ; \begin{rcases} \Delta T = (T_1 - T_0)/n \\ \Delta U = (U_1 - U_0)/n \\ \Delta V = (V_1 - V_0)/n \end{rcases} \quad (4)$$

According to formula (4), the angle of moving towards more pheromones is obtained as x_i, y_i, z_i , $T_i, U_i, V_i (i = 1, 2, \cdots, 6)$. According to the obstacle avoidance algorithm, the control robot runs to any position in space, and the control equation and dynamic equation of the robot space obstacle avoidance are obtained as:

$$^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -d_i s\alpha_{i-1} \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & d_i c\alpha_{i-1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

In the formula, the positioning error of the end effector of the human end is represented, *c* represents the feedback coefficient of the robot obstacle avoidance parameter, and each link conversion is multiplied to obtain a transformation matrix of the obstacle avoidance control:

$$^0_6T = {}^0_1T\,{}^1_2T\,{}^2_3T\,{}^3_4T\,{}^4_5T\,{}^5_6T \quad (6)$$

All the subdivision points are substituted into the kinematics and dynamics equations of the robot, and the mechanical parameters of the robot obstacle avoidance and the trajectory tracking control parameters are obtained[11], and the pheromone is broadcast according to the global optimization control rules of genetic evolution, so as to drive the robot. The robot realizes space path optimization planning to ensure that the end effector moves along the predetermined trajectory to avoid obstacles.

III IMPROVED DESIGN AND IMPLEMENTATION OF OBSTACLE AVOIDANCE ALGORITHM

On the basis of setting the mechanical parameters of obstacle avoidance motion and trajectory tracking control parameters, the improved obstacle avoidance algorithm is designed. The obstacle avoidance path rules for indoor robot are complicated by obstacles[12]. The traditional obstacle avoidance algorithm uses genetic evolution binocular visual dynamic tracking technology, and the obstacle avoidance performance is not good when the indoor obstacle area is distributed irregularly. In order to overcome the shortcomings of traditional algorithms, this paper proposes a robot space obstacle avoidance algorithm based on genetic evolutionary adaptive guidance control[13]. Genetic evolution algorithm is used to control robot obstacle avoidance. Genetic optimization algorithm adopts adaptive dynamic neighborhood decision to realize resampling and local resampling of robot behavior parameters[14]. When *VR* is greater than 1, whether the current obstacle points and the trajectory of the robot determined by the genetic evolution movement rule are blocked by the obstacles, the quantum residuals of the robot without detours are calculated, and the robot movement is obtained. The genetic evolutionary adaptive guidance control equations of azimuth are expressed as follows:

$$\begin{cases} H_0 : \tilde{x}(t) = \tilde{w}(t) \\ H_1 : \tilde{x}(t) = \sqrt{E_t}\tilde{f}(t-\lambda)\tilde{b}_D(t-\frac{\lambda}{2}) + \tilde{w}(t) \end{cases} \quad 0 \le t \le T \quad (7)$$

In the upper formula, $\tilde{w}(t)$ is a statistically independent zero-mean complex white Gaussian process, which represents the obstacle pheromone interference in the indoor movement of the robot. It is constructed based on genetic evolutionary adaptive guidance control and combines the path loss characteristics of outliers. Under pheromone guidance and mutation, a new individual is generated according to the quantum amplitude of quantum chromosome, and the measurement error of obstacle avoidance point of robot is obtained as follows:

$$l = \frac{1}{N_0}\int_{T_i}^{T_f}\int_{T_i}^{T_f} \tilde{x}(t)\tilde{h}(t,u)\tilde{x}(u)dudt \quad (8)$$

Under genetic evolutionary adaptive guidance control, the obstacle avoidance path control problem of robot is generally represented by a multi-information fusion model of *N* decision variables:

$$\begin{aligned} \min \quad & F(x) = (f_1(x), f_2(x), \dots, f_m(x))^T \\ s.t. \quad & g_i \le 0, \quad i = 1,2,\dots,q \\ & h_j = 0, \quad j = 1,2,\dots,p \end{aligned} \quad (9)$$

Assuming that the guidance error of pheromone in the fuzzy logic control unit of indoor robot at *T* moment is a random sample characterized by $E[M_B] = 1$:

$$\eta = \frac{a}{a+b+c} \cdot \frac{E[M_A] + E[M_B]}{E[V_A] + E[V_B]} \quad (10)$$

According to the above behavior rules, the measurement equations of the robot in the virtual world of genetic evolution space are expressed as follows:

$$E[M_A] = E[V_A] = \sum_{i=0}^{\infty} i(1-p)^i p = \frac{1-p}{p} \quad (11)$$

If the solution found by the robot in the course of walking is superior to the iterative optimal solution, then the robot can avoid obstacles in space[15].

IV SIMULATION AND EXPERIMENTAL ANALYSIS OF OBSTACLE AVOIDANCE FOR ROBOT

In order to the performance of this algorithm in the realization of robot space obstacle avoidance, simulation experiments are carried out, and the simulation scene of robot indoor behavior trajectory is designed with NetLogo simulation software. The robot is a six-degree-of-freedom 6R industrial robot. The robot is equipped with a positioning sensor for sensing ranging information, indoor environment information and other experimental environments. The host computer used in the experiment is Pentium (R) D CPU 2.80 GHz 2.79 GHz, 2.00 GB memory. In the experiment, the coordinate information of the environment robot walking sign is set up, including the indoor location sign, the probability center of the obstacle occurrence, and the two-dimensional plane of the robot's indoor motion 300. The simulation scene of the robot's simultaneous location and path offset correction is designed. In the two-dimensional plane of the simulation 300, the starting point of the robot's motion in the room is [20,20], [250,230]. Firstly, the behavior space of the robot is modeled by mathematics, and then the mechanical parameters of the robot's indoor obstacle avoidance motion are analyzed, and the results are obtained. The behavior quantum number m=100, the pheromone evolution factor $\alpha = 1$, the expected heuristic factor $\rho = 0.3$, the pheromone volatilization coefficient $Q = 1$, the robot obstacle avoidance path planning pheromone increase strength H=0.21, there are 6 rectangular obstacles, robot The behavioral map in the room is 300×300 pixels in size and a unit of length in pixels. The simulation environment of the robot is shown in figure 2.

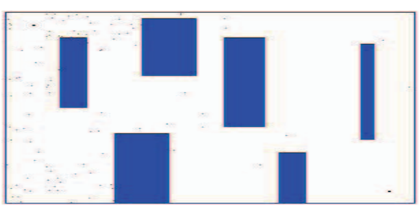

Figure 2. Simulation working environment of the robot

According to the above experimental environment and parameter description, the robot obstacle avoidance trajectory simulation is carried out. The simulation results are shown in figure 3. It can be seen from the diagram that the robot can avoid obstacles in space by using the algorithm in this paper. The robot can avoid obstacles effectively and realize the shortest and best walking distance.

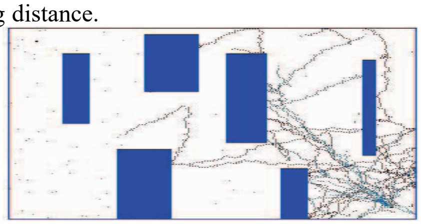

Figure 3. Simulation of obstacle avoidance trajectory of robot

In order to quantitatively analyze and compare the superiority of this algorithm, on the basis of the same obstacle and environment setting, the running time of the robot from the indoor starting point to the end is taken as the test parameter, under the different experiment times. The test results of the method and the traditional algorithm are shown in figure 4. It can be seen from the diagram that by using the algorithm in this paper, the robot can avoid obstacles by optimizing the trajectory, which saves the robot's time to reach its destination, and shows the superiority of the algorithm in this paper.

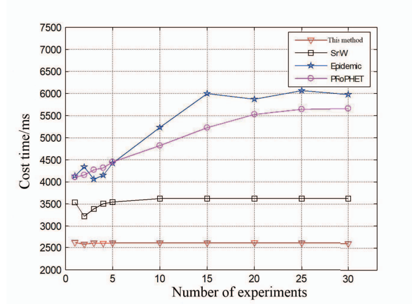

Figure 4. Performance comparison of obstacle avoidance algorithm

V CONCLUSIONS

In this paper, a robot obstacle avoidance method is proposed based on improved genetic algorithm (GA), a robot space obstacle avoidance model based on genetic evolutionary adaptive guidance control is constructed. The constraint parameter model of obstacle avoidance control of robot is constructed, and the trajectory of space obstacle avoidance is described as the global optimization problem of genetic evolution. The pheromone released in genetic evolution is used as the guiding rule of space obstacle avoidance control of robot. The mechanical parameters of obstacle avoidance motion and trajectory tracking control parameters are obtained, and the control equations and dynamics equations of robot obstacle avoidance are constructed. The pheromones are broadcast according to the global optimization control rules of genetic evolution. The robot is driven to realize the space path optimization planning and to improve the obstacle avoidance algorithm. The simulation results show that the proposed algorithm is effective in avoiding obstacles, it can effectively avoid obstacles and improve the control performance of the robot. This method has good application value in obstacle avoidance and optimal control of robot.

REFERENCES

[1] Zhang J M, Sun C Y, Zhang R M, et al., (2015). Adaptive sliding mode control for re-entry attitude of near space hypersonic vehicle based on backstepping design.IEEE/CAA Journal of Automatic Sinica, 2(1), pp.94-101.

[2] PENG Cheng, BAI Yue, QIAO Guanyu, (2018). Static Anti-windup Compensation Control of Yaw Movement for a Coaxial Eight-Rotor UAV. ROBOT, 40(2), pp. 240-248.

[3] SHI Ruidong, ZHANG Xiuli, YAO Yan'an, (2018). A CPG-Based Control Method for the Multi-Mode Locomotion of a Desert Spider Robot. ROBOT, 40(2), pp. 146-157.

[4] Gao Q, Wang Z L, Hu W J, et al., (2015). Gait simulation of snake robot based on CPG method. Journal of System Simulation, 27(6), pp. 1374-1380.
[5] Zhang X L, Gong J Q, Yao Y A.,(2016). Effects of head and tail as swinging appendages on the dynamic walking performance of a quadruped robot. Robotica, 34(12), pp. 2878-2891.
[6] Tunc L T, Shaw J, (2016). Experimental study on investigation of dynamics of hexapod robot for mobile machining. International Journal of Advanced Manufacturing Technology, 84(5-8), pp. 817-830.
[7] Wang Z L, Gao Q, Zhao H Y, (2017). CPG-inspired locomotion control for a snake robot basing on nonlinear oscillators. Journal of Intelligent and Robotic Systems, 85(2), pp. 209-227.
[8] Yoon W K, Goshozono T, Kawabe M K, et al.,(2004). Model-Based space robot teleoperation of ETS-VII manipulqator.IEEE Transactions on Robotics and Automation, 20(3), pp.602-612.
[9] WANG Jungang, TANG Lei, GU Guoying, ZHU Xiangyang, (2018). Tip-following Path Planning and Its Performance Analysis for Hyper-redundant Manipulators. Journal of Mechanical Engineering, 54(3), pp. 18-25.
[10] Tang L,Wang J,Zheng Y,et al., (2017). Design of a cable-driven hyper-redundant robot with experimental validation. The International Journal of Advanced Robotic Systems,2017,14(5), pp.1-12.
[11] Liu J C, Chen N, Yu X,(2014). Modified two-degrees-of-freedom internal model control for non-square systems with multiple time delays. J of Harbin Institute of Technology, 2014, 21(2), pp. 122-128.
[12] BAO Shuting, SUN Liping, ZHENG Xiaoyao, et al., (2018). Density peaks clustering algorithm based on shared near neighbors similarity. Journal of Computer Applications, 38(6), pp. 1601-1607.
[13] WU Huijun, SHEN Jianjian, CHENG Chuntian, et al., (2015). Coordination Method of Regional and Provincial Grids for Short-term Peak Shaving Operation Among Hybrid Energy Sources. Proceedings of the CSEE, 35(11), pp.2743-2755.
[14] Liu Jing,Luo Xianjue, (2012). Short-term optimal environmental economic hydrothermal scheduling based on handling complicated constraints of multi-chain cascaded hydropower station. Proceedings of the CSEE, 32(14), pp. 27-35.
[15] LIU Kai, ZHU Ji-hong, YU Bo, (2013). Longitudinal control of aircraft with thrust vectoring using robust dynamic inversion. Control and Decision, 28(7), pp.1113-1116.