

Study of Ant colony optimization algorithm in snake-like robot path planning

Li Hongyan

Xi'an University of science and technology
College of electrical and control engineering
xi'an, China
e-mail: lihongyan@xust.edu.cn

Hou Yuanbin

Xi'an University of science and technology
College of electrical and control engineering
xi'an, China
e-mail: houyb@xust.edu.cn

Abstract—the model of the snake-like robot's environment was built by using grid method, Ant colony optimization algorithm based on the genetic mechanism was used to solve the robot path planning, and the optimization strategy was put forward. In order to test the optimized algorithm performance, we designed a simulation program based on MATLAB software. By compared with the ordinary ants colony algorithm, the simulation results show that the optimization algorithm has faster convergence rate, the optimal solution of the characteristics of higher success rate, and also obtain better solutions.

Keywords-snake-like robot; Path planning; Ant colony optimization algorithm; Genetic mechanisms

I. INTRODUCTION

Path planning technology is an important branch in the research field of the snake-like robot, its main content is how to make the robot according to the instruction and environmental information independently choose collision free path, to achieve a given task or goal. For this type of problem solving, many scholars have put forward the method and strategy to solve them^{[1][2][3]}, such as potential field method, genetic algorithm, ant colony algorithm.

Genetic algorithm for solving the shortest path, due to the greatly coding length changes, especially in the large scale problem, complex terrain, invalid path are generated, solving efficiency is poor, so this algorithm can effectively solve problems of relatively small size. In the last century 90's, the ant colony algorithm was proposed by Italy scholars M.Dorigo, V.Maniezzo, A.Coloni etc. has been widely used in more and more fields^{[3][4]}. The basic ant colony algorithm for complex terrain search, the search space is large, complex and prone to ant algorithm into the "trap" phenomenon, and stagnation, early exit from the calculation.

Based on the analysis of the research results and considering the shortcomings of existing algorithms, this paper presents an optimization of a snake-like robot path planning methods. First, we establish the environment model of snake-like robot by using grid method, on the basis of this model; we find the optimal path by using ant colony optimization algorithm. The simulation results show that, this method can effectively avoid the process of optimization algorithm stagnation, particularly suitable

for snake-like robot path planning in complex terrain environment.

II. THE BASIC PRINCIPLE OF ANT COLONY ALGORITHM

Entomologist's study shows that, in the foraging process, ants can be in the absence of any indication to find the shortest path from the nest to a food. From the food back to the nest process will leave behind a secretion, by this way, guide the direction of its own, so that they can find the path back to the caves or food source. Other ants can find companions found with the trajectory of the food location. Ant colony algorithm is a simulation of ant foraging process when looking for the shortest path, optimal path to the destination^{[4][5]}.

Thus, the exchange of information between ants is a positive feedback process, the ant foraging process is a process of searching path. Ant has no visual, can only by relying on the path to walk the release pheromone search path, therefore, ants walk more long, the amount of information released by the smaller. When the later ants come to the path again, a large amount of information, the path selection probability is relatively large, forming a positive feedback mechanism. Pheromone t growing on the shortest path and pheromone t on the other path would be less and less as time went by until it disappears, ant colonies will eventually find the shortest path. When there are obstacles in the path, ants can quickly adapt to the environment to find the optimal path again. Ant colony algorithm is based on the intelligent ant group self organizing foraging behavior to find out a new kind of Intelligent Computing model. However, the basic Ant Colony algorithm for complex terrain search, search space, the algorithms are complex and prone to ants in a "trap" phenomena, and stagnation, early exit from the calculation of^{[5][6]}.

III. THE ESTABLISHMENT OF ENVIRONMENTAL MODEL

The model of their environment must be established before path planning of snake-like robot, this effective description of the robot's workspace is called the environment model. Set the workspace of the robot as a two-dimensional space, and the obstacle sizes and locations are known, and in the course of the movement of the robot, the obstacle size and location are not changed. If a grid contains obstacles, is called the grid barrier grid, on the contrary, called free grid. The obstacle has less than a grid computing as a whole grid, partitioned manipulator

workspace as shown in Figure1. Black grid represents barrier grid in the Figure. Assuming its in the Cartesian coordinates system, so each grid can use Cartesian (x, y) that uniquely identifies. Then the grid according to the order from left to right, from top to bottom, each grid has a number, so that each grid has unique serial number identification. The correspondence is shown in formula 2-1.

$$\begin{cases} X = \text{mod}(L, N) \dots \dots \dots \text{mod}(L, N) \neq 0 \\ X = M \dots \dots \dots \text{mod}(L, N) \neq 0 \\ Y = \text{int}(L / N) \\ L = X + Y * N \end{cases} \quad (2-1)$$

Among them, x indicates that the abscissa; Y represents the vertical axis; L represents a grid number; M represents a two-dimensional spatial line number; N represents a two-dimensional spatial column number, mod represents taking the remainder; int representation of integers.

When the grid model is established, on the model of information encoding, obstacle information serial number 1 indicates that the current grid for obstructions, serial number 0 means that the current grid without obstacles. On the map grid to grid number as an index of an array of structures to store information.

G represents any grid, A represents collection of g, $S = \{b_1, b_2 \dots b_n\} \subseteq A$ represents set of obstacles. For arbitrary two-dimensional terrain, plan aimed at making the robot from an arbitrary starting point g_{begin} safely along a shorter path to any destination g_{end} , $g_{begin}, g_{end} \notin S$ & $g_{begin} \neq g_{end}$



Figure 1. Model for environments by Grid method

IV. ANT COLONY OPTIMIZATION ALGORITHMS FOR PATH PLANNING OF SNAKE-LIKE ROBOT

Snake-like robot is one of the bionic robot branches in recent years. It is different with the traditional robot, the traditional robot using round, leg or tracked mobile, snake like robot can imitate the action of the snake, no limb movement by twisting and stretching of the body, the movement has the advantages of good stability, small cross sectional area, flexible etc.^{[9][10]}. Wireless remote control Snake-like robot has wide application prospect in many fields: such as in radiation, dust, toxic and other battlefield environment, a reconnaissance mission;

find the wounded in the ruins of the earthquake, landslide and after fire; in the narrow space and environmental risk condition detection and dredge pipe etc..

RF wireless remote control system of multi joint robot is divided into three functional parts: PC, handheld remote controller (wireless communication transmission device), hypogynous machine (multi-joint Snake-like robot). Through the RS232 serial port communication between PC and remote controller, through wireless communication between remote control and Snake-like robot. Use the remote host computer and wireless transceiver module nRF905 to realize wireless control of the snake like robot. Use 12864 to achieve human-computer interaction with Chinese font. Wireless remote control system overall diagram as shown in Figure 2 below.

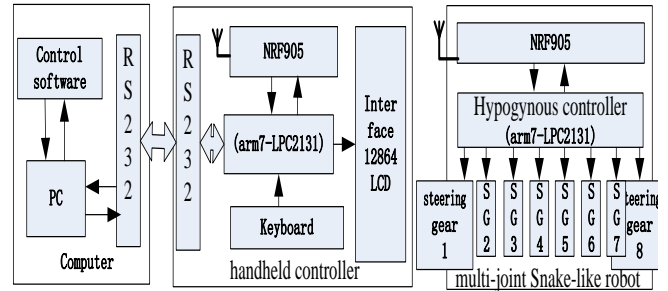


Figure2. multi-joint snake-like robot wireless remote control system block diagram

Due to the snake-like robot is an intelligent agent, which is the foundation of robot path planning algorithm. Robot path planning algorithms, including global and local planning, realized through the combination of the two methods of snake-like robot path planning. In a complex environment, if the computational complexity of the algorithm is too large, may not be an optimal solution.

Genetic algorithm with fast global search capability, but feedback information on the system cannot be used, resulting in low efficiency solution. The ant colony algorithm has the advantages of distributed, parallel, global convergence, but the initial pheromone shortage, resulting in slow convergence speed. In order to overcome the defects of each of the two algorithms, to achieve purpose of complementary advantages, the initial information makes use of genetic algorithm of random search, fast convergence, the problem distribution, then, make full use of parallelism, positive feedback and high solving efficiency characteristics and mechanism of ant colony algorithm. The process of Snake-like robot during walking and ant foraging collaborative optimization path and inter individual pheromone is very similar. So ant colony algorithm optimization is used in the path planning.

Ant colony optimization algorithm for robot path planning can be simply described as: put m Ant on the starting grid g_{begin} , for each Ant make the current grid as Center, if meet obstacles, some ants use visual function selection and move to the next grid, other ants with the path selection strategy to select and move to a grid; if there is no obstacle, the ants use path selection strategy to select and move to the next grid; according to the information of local pheromone renewal rule updating path, when all the ants go to the target grid g_{end} , the iteration of the optimal path, with a certain

probability P_c randomly choose one path crossed with the optimum iteration path, through a calculation comparing the better path, and make global updates to the pheromone on the path^{[7][8]}. Ant Colony optimization algorithm based on genetic mechanism steps are as follows:

Step1: Define the required data structures: $N_x=10$, $N_y=10$, $p=(a_{ij})_{N_x \times N_y}$, in which when a meets $a_{ij}=1$, the grid is an obstacle, when a meets $a_{ij}=0$, the grid is available free space;

Step2: Initialization, set the initial distribution of pheromone. Set Ant at the starting point (the initial grid) g_{begin} , Sets the number of ants for m , And set g_{begin} into the tabu list $tabu_k$ ($k=1,2,\dots,m$), set $\tau_{ij}(0)=\tau_0$, τ_0 as constant, $\tau_{min} < \tau_0 < \tau_{max}$, Set iteration counter $NC=0$, the maximum number of iterations for the $NCMAX$, set $m \leq 4$.

Step3: $\forall k$, Put the current grid g_i as the Center, to determine whether they encounter obstacles, if it is, then goto *Step4*, else goto *Step6*;

Step4: Determines whether the ants is "Visual ants", if it is, then goto *Step5*, Otherwise goto *Step6*;

Step5: Determine the grid on which g_i . With the distance of the obstacle, choose the direction of short distance, if the distance is the same, then determine the corresponding boundary and the target grid obstacle distance and its connections whether through the obstacles, select the corresponding grid g_j to short distance and direction without obstructions across;

Step6: On the basis of the current grid g_i , in accordance with the formula (2-2), and go to the next grid g_j ;

$$j = \begin{cases} \arg \max_{s \in allowed_k} \{ [\tau_{is}]^\alpha [\eta_{is}]^\beta \} & \text{if } q \leq q_0 \\ \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{s \in allowed_k} [\tau_{is}]^\alpha [\eta_{is}]^\beta} & \text{if } q_0 < q \leq q_1 \\ \text{Random}(i) & \text{if } q > q_1 \end{cases} \quad (2-2)$$

Step7: After selection, according to formula (2-3)~(2-4) update the local pheromone.

$$\tau_{ij} = (1 - \xi) [\tau_{ij}(t)] + \xi [\Delta \tau_{ij}^k] \quad (2-3)$$

$$\Delta \tau_{ij}^k = \begin{cases} \frac{A}{d_k} + \frac{B}{d_s} + C \times (a)^{count} & \text{if } kth \text{ uses } edge(i, j) \text{ in its tour} \\ 0 & \text{otherwise} \end{cases} \quad (2-4)$$

Step8: $\forall k$, ($k=1,2,\dots,m$), after the Selection of the grid, check whether all the ants reaches the target grid, If so goto *Step9*, Otherwise, return to *Step3* Start selecting the next grid until all the ants reach the target grid;

Step9: When all of the m ants reaches the target node, calculate the path length L_k of each ant passed by, To elect this iterative optimal path information for this iteration of the host ants and save minimum distance L_{kmin} ;

Step10: Set the crossover probability P_c , Randomly select an Ant, determine whether it has passed the same grid with the optimal ants, if so then goto *Step11*, Otherwise goto *Step10*;

Step11: Generates a random Ant and the iteration optimal Ant passed the same set of grid information SG, Randomly choose a grid from SG as intersection, and perform cross actions;

Step12: determine the crossover operation-calculated path is better than this iterative optimal path or not, if it is, goto *Step13*, Otherwise goto *Step10*;

Step13: update global pheromone of the cross optimal ant according to formula (2-5)~(2-6).

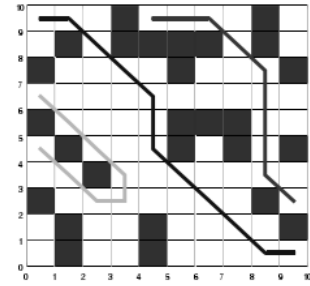
$$\tau_{ij}(t+1) = (1 - \rho) [\tau_{ij}(t)] + \rho [\Delta \tau_{ij}^{gb}] \quad (2-5)$$

$$\Delta \tau_{ij}^{gb} = \begin{cases} \frac{D}{Lk} + \frac{E}{Tk} & \text{if } (ij \in \text{global-best-tour}) \\ 0 & \text{otherwise} \end{cases} \quad (2-6)$$

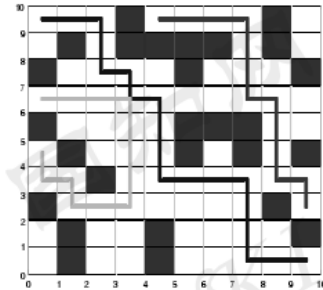
Step14: Add 1 to iterations NC , If it not equal to $NCMAX$, then empty the tabu list, goto *Step2*, Repeat this process until $NC=NCMAX$. The best channel final memory is the optimum path planning.

V. SIMULATION EXPERIMENT OF PATH PLANNING OPTIMIZATION ALGORITHM

To verify the effectiveness of the algorithm, we do a large number of simulation experiments, not only consider the arbitrary obstacles work space, and also consider the complexity of different working space. Simulation diagram in Figure3, Figure4 shows.



a) Path planning based on optimized Ant Colony algorithm



b) Path planning based on Ant Colony algorithm

Figure3. Comparison of two algorithms for path planning

In Figure3, map a) is the simulation of optimized Ant Colony algorithm in environment of 10×10 , use different starting node and the target node, map out the three paths. Map b) is using an ordinary Ant algorithm in the same environment, use different starting node and the target node, and map out the three paths.

Table I is the comparison of the use of optimized ant colony algorithm and ant colony algorithm for path

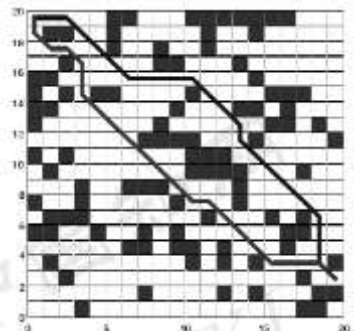
planning, these performance indicators including the path length L, number of turn T, cost function W and achieve optimal iteration solution needs N.

TABLE I. TABLE I COMPARISON OF ANT COLONY OPTIMIZATION ALGORITHM AND ANT COLONY ALGORITHM FOR PATH PLANNING

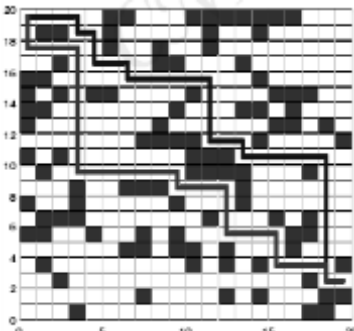
Algorithm	Path number	Path length L	Turn num T	The cost function W	Optimal number of iterations N
Before optimization	1	13.2	10	18	55
After optimization	1	9.08	4	11.45	28
Before optimization	2	18.3	16	27.6	50
After optimization	2	13.962	4	16.323	24
Before optimization	3	13.5	10	18	53
After optimization	3	10.252	3	11.626	27

By comparing the data in the table, we can see that the four performance indicators three paths using the optimized ant colony algorithm obtained are better than the performance of path corresponding to get common ant algorithm.

In Figure4, map a) is the simulation by using optimized Ant Colony algorithm in environment of 20×20 , the same start node and the target node, map out the two paths, one was suboptimal path on the left, and on the right is the best route. Map b) is using Ant algorithm and simulation in the same environment, two paths are also mapped out, the best path on the left, and on the right is the suboptimal path.



a) Path planning based on Ant Colony optimization algorithm



b) Path planning based on Ant Colony algorithm

Figure4. Comparison of two algorithms for path planning in the environment of 20×20

Table II is the comparison of the use of optimized ant colony algorithm and ant colony algorithm for path planning, these performance indicators including the path length L, number of turn T, cost function W and achieve

optimal iteration solution needs N.

TABLE II. COMPARISON OF ANT COLONY OPTIMIZATION ALGORITHM AND ANT COLONY ALGORITHM FOR PATH PLANNING

Algorithm	Path number	Path length L	Number of turns T	Cost function W	Optimal number of iterations N
Before optimization	1	38	22	49.5	105
After optimization	1	26.765	9	33.263	80
Before optimization	2	36	24	50.45	108
After optimization	2	28.621	7	32.412	82

By contrast to the data in the table, we can see the use of optimized Ant Colony algorithm to be two paths of the four performance indicators that are better than those using normal Ant algorithm for path that corresponds to the performance indicators.

VI. CONCLUSION

The model of the snake-like robot's environment was built by using grid method, Ant colony optimization algorithm based on the genetic mechanism was used to solve the robot path planning, and the optimization strategy was put forward: the ant's Visual access to the current position to the destination, pheromone update rule, and path selection policy. These improvements are more consistent with the nature of the behavior of real ants, simulations were compared with normal Ant algorithm, results show that the optimization algorithm has faster convergence rate, the optimal solution of the characteristics of higher success rate, obtain better solutions.

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