Research and Implementation of Robot Path Planning Based on Ant Colony Algorithm

Yalong Ji¹, Baichuan Liu²,*

¹School of Computer and Electronic Information, Guangxi university, Nanning, Guangxi, China
²Liuzhou Wuling Automobile Technology Co., Ltd., Liuzhou, Guangxi, China
*email: 75448466@qq.com

Abstract. Intelligent mobile objects (mobile robots) are gradually integrated into People's Daily life, and path planning is the core of this kind of robots. In this article, ant colony algorithm is adopted to plan a global path through all points in the global space based on pheromone changes, so as to solve the practical problem that a robot needs to walk n points at a time and cannot repeat, and its distance is the shortest. Finally, the shortest path is solved based on MATLAB simulation platform.

1. Introduction

As technology comes more and more into people's life, mobile robots are gradually integrated into People's Daily life, such as household sweeping robots[1], shopping guide robots[2], industrial robots, etc. The robot can find a path from start to finish and go through all the points it needs to go through in the workspace according to certain performance indicators, such as the least time spent and the shortest path taken, etc. [3]. Path planning is the core of this kind of robot, and many researchers have been studying the path planning of mobile robots for a long time. According to the degree of the moving object's mastery of the environment, the mobile robot path planning problem includes the following two categories: 1) static global path planning[4], in the condition of known environment information, according to a given starting position and the target position, robot can search out a optimal path, this requires the current environment environment must be mastered and the robot is consistent, and there is no mobile obstacles; 2) Dynamic local path planning[5]. When some environmental information cannot be obtained or moving objects appear in the environment, the robot needs to detect the environmental information by itself and adjust the route to be walked in real time.

Ant colony algorithm was first proposed by Italian scholar Dorigo et al.[6] as an intelligent optimization algorithm to simulate ant foraging behavior. It has good robustness and high adaptability, and has achieved good results in solving problems such as path planning. However, ant colony algorithm is also prone to local optimal solutions and deadlock problems, so many scholars have made improvements and optimization, mainly from pheromone update, search strategies and other intelligent algorithms. In this article, ant colony algorithm is selected from numerous path planning algorithms to solve the practical problem that a robot needs to walk n points at a time and cannot repeat, and its distance is the shortest.

2. Principle of ant colony algorithm

In nature, ants can make the fastest journey from their foraging site to their nest without any...
information. And according to the change of the environment, the new optimal path can be found adaptively. According to biologists, the root cause of ant colony behavior is that as ants search for food, a special kind of substance called pheromones are left behind in their path. Over time, this pheromone is gradually evaporated. Later ants were more likely to choose a path with a higher pheromone concentration. As more ants pass along a path, the pheromone gets thicker and thicker. Later ants are more likely to take this route. When there are more ants in the path, the pheromone gets thicker and attracts more ants. This creates a positive feedback mechanism, in which the colony eventually finds the optimal path.

Ant colony modeling includes the following problems: the modeling of individual ants, pheromone updating mechanism, and the internal mechanism of the entire ant colony.

1) Pheromone updating mechanism:

Pheromones can be updated in two ways. One is evaporation, which means that pheromones decrease at a certain rate along all paths. The other is a pheromone boost, adding pheromones to the path traveled by ants.

2) Modeling problems of ant individuals:

Although a single ant can solve this problem, the optimal or suboptimal solution can be found through cooperation between multiple ants, while ants cooperate with each other through pheromones. The evaporation mechanism of pheromone makes the path search history forgotten to a certain extent and avoids the influence of poor solution in the search of later ants.

3. Proposed and solved robot path planning problems

Now we propose a practical Problem similar to the Traveling Salesman Problem (TSP): there are n points on a map, and a robot needs to walk through n points at one time without repetition. We need to find out what path it takes to make the Traveling distance the shortest.

Ant colony algorithm is adopted to solve this problem, which is described as follows:

Let's say the coordinates of point i are

\[ c_i = (x_i, y_i) \quad i = 1, 2, 3, \ldots n \]  

(1)

The length from point i to point j can be expressed as:

\[ d_{ij} = [(x_i - x_j)^2 + (y_i - y_j)^2]^{1/2} \]  

(2)

Each ant needs to have a tabu list to record the points it has passed through. The first coordinate recorded in the tabu list is the point where the ant started. When all points are added to the tabu list, it indicates that the ant has passed through all points and completed a traversal. Let \( a_{ij}(t) \) be the amount of pheromone between point i and point j, and its value at the initial moment is:

\[ a_{ij}(0) = c \]  

(3)

Where c is a constant.

Assuming that the ant colony completes a tour from t to t+n, the pheromone value on path i to j at t+n can be expressed as follows

\[ a_{ij}(t + n) = (1 - \rho) \times a_{ij}(t) + \Delta a_{ij} \]  

(4)

Where \( \rho \) represents the volatilization ratio of pheromone from time t to time t+n. Then (1-\( \rho \)) represents the proportion of pheromones remaining. The volatility coefficient ranges from 0 to 1.

\( \Delta a_{ij} \) represents the increase of pheromone from time t to time t+n, and its calculation method is as follows:

\[ \Delta a_{ij} = \sum_{k=1}^{m} \Delta a_{ij}^k \]  

(5)

Where \( \Delta a_{ij}^k \) is the pheromone value left between path i to j by the kth ant in this iteration, and the calculation method is as follows (Ant-cycle model):

\[ \Delta a_{ij}^k = \begin{cases} Q, & \text{Ant } k \text{ goes from } i \text{ to } j \text{ on his journey} \\ L_k, & \text{Ant } k \text{ doesn't go from } i \text{ to } j \end{cases} \]  

(6)

Where Q is a positive constant, and \( L_k \) represents the path of ant k in its tour.

The advantage of the Ant-cycle model is that it applies pheromones on the global information...
update path.
At time $t$, the possibility of the $k$th ant going from point $i$ to point $j$ can be calculated in the following way:

$$ \Delta p_{ij}^k(t) = \begin{cases} \left[ a_{ij}(t) \right]^\alpha \left[ \eta_{ij}(t) \right]^{\beta}, & j \in J_k(i) \\ 0, & \text{Other situations} \end{cases} $$  \hspace{1cm} (7)

Where $\eta_{ij}$ is a heuristic factor, and the calculation method is:

$$ \eta_{ij} = \frac{1}{d_{ij}} \hspace{1cm} (8) $$

$\eta_{ij}$ is the expectation of the ant to go from $i$ to $j$. $J_k(i)$ represents the set of points that ant $k$ can choose to go to at point $I$. $\alpha, \beta$ indicate the relative importance of pheromones and expectancy heuristic factors.

From the formula above, we can see that the probability of ant choosing path $i$ to $j$ is proportional to pheromone content and inversely proportional to the distance from $I$ to $J$.

4. Simulation and results
According to the solution proposed above, the flow chart is shown in Figure 1.

![Flow chart](image)

**Fig. 1** Flow chart

Write the code and run it in MATLAB. The results are as follows.
When finally stabilized, the shortest path and length are shown in Figure 2.
The path in blue in this figure is the shortest path to go through the set hash points. This result is the result of stable operation of the algorithm, and is the shortest path of the actual problem.

The curve of iteration times and path length is shown in Figure 3.

This figure shows the curve of path length changing with the number of iterations. With more iterations, the length of the shortest path becomes shorter and shorter until the number of iterations reaches about 20 and the path length reaches the shortest and remains unchanged.
5. Conclusion
In this article, the ant colony algorithm is used to find a fastest path for the robot to go through all the target points. Because the positions of the points used are randomly set by the author, the paths obtained by the same implementation method for different points will not be completely consistent, and the number of iterations tends to be stable will also be different. However, this method can always find a shortest path for the robot to complete all points. At the same time, the method in this paper has universal applicability. When the position of the point that the robot needs to walk through changes in different scenarios, it only needs to modify the coordinates of the point in the algorithm in this paper to get a new shortest path.

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