Research on Robot path Planning algorithm based on Biological heuristic Machine Learning algorithm

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Abstract. In order to solve the problem that mobile robot is trapped in local convergence and cannot achieve path optimization in ant colony algorithm path planning, an improved variable step size ant colony algorithm is proposed to achieve path optimization with less convergence iterations. According to the relevant characteristics of the application of ant colony algorithm in path planning, the pheromone allocation is optimized, the influence of local pheromone content on the algorithm is reduced, the ant colony is prevented from falling into local optimization when searching the path, and the weight factor is added to the transfer probability formula. improve the probability of the mobile robot moving towards the end point, effectively reduce the number of convergence iterations of the ant colony, and change the mobile robot's mobile step size. So that it can move freely without collision within 360°, and the path length can be effectively shortened. The simulation results show that in a simple environment, the convergence iteration times and optimal path length of the improved variable step size ant colony algorithm are 2 and 28.042 m, respectively, and the convergence iteration times and optimal path length of the traditional ant colony algorithm are 25 and 29.213 m, respectively. In the complex environment, the convergence iteration times and optimal path length of the improved variable step size ant colony algorithm are 2 and 43.9602m respectively, and the convergence iteration times and optimal path length of the improved potential field ant colony algorithm are 16 and 45.1127m, respectively. Simulation results verify the effectiveness and superiority of the improved variable step size ant colony algorithm.

Keywords: variable step size, ant colony algorithm, pheromone, path planning.

1. Introduction
Path planning has always been one of the key technologies in the field of mobile robot. Its main purpose is to find an optimal safe collision-free path from the starting point to the end point in a given environment. Path optimal evaluation is mainly manifested in the length of the path, the speed of algorithm convergence, the safe distance between the robot and obstacles and so on. The common methods of path planning for mobile robot are artificial potential field method [1], particle swarm optimization algorithm [2], A* algorithm [3], genetic algorithm [4], ant colony algorithm [5-7] and so on. However, these existing algorithms are limited to eight neighborhood movements that can be carried
out in the moving direction of the mobile robot, that is, each step of the mobile robot can only move to the next adjacent grid. However, there are serious problems in the actual path planning of the mobile robot, because the search of the mobile robot in the complex environment should be mobile in 360° direction, not limited to 8 directions, so that the search path can be optimal.

In order to avoid the easy local convergence of ant colony algorithm and achieve the shortest path, an adaptive variable step size method is proposed in this paper. The algorithm improves the traditional ant colony algorithm and adaptively adjusts the step size by using the nodes between obstacles and obstacles to ensure that the path is smooth while avoiding deadlock. The weight factor is added to the mobile robot transfer probability formula to effectively improve the convergence speed of the algorithm, improve the pheromone allocation mode, and optimize the shortest path pheromone. Avoid the problem of weak search ability of mobile robot in the initial stage of the algorithm, and minimize the number of convergence iterations of the algorithm while realizing the shortest path.

2. The algorithm used in this paper

2.1. Traditional ant colony algorithm
Ant colony algorithm is a kind of swarm intelligence algorithm designed based on the characteristics of ants' foraging behavior. Ants will secrete different amounts of pheromones according to the length of the foraging process. The shorter the path from the starting point to the end point, the more pheromones the ants secrete, and the greater the probability for the ants to choose this path, thus forming a positive feedback process. After iteration, the ants gradually find a shorter path.

2.2. Path Planning of improved Ant Colony algorithm
In order to improve the global search ability of the algorithm and increase the probability of the mobile robot selecting nodes closer to the end point, an induction factor δ is introduced to improve the convergence speed of the algorithm. The improved transition probability formula is as follows:

\[
p_{ij}^{\delta} = \begin{cases} 
\frac{[\tau_{ij}(t)]^{\alpha} [\eta_{ij}]^{\beta}}{\sum_{k \in \Delta(N-tau_{ij})} [\tau_{ik}(t)]^{\alpha} [\eta_{ik}]^{\beta}}, j \in (N - tau_{ij}) \\
0, \text{ else}
\end{cases}
\]

\[\delta = \frac{d_{ij} \cdot d_{ij}}{(d_{ij} + d_{ij})^{2}}\]

\[d_{ix} = \sqrt{(x - c)^2 + (y - 0.5)^2}\]

In the formula: \(d_{ix}\) characterizes the distance from node I to the end point; \(d_{ij}\) represents the distance between node I and the next arriving node j. When the node j is closer to the straight line connected between the current node I and the end point and closer to the end point, the value of \(\delta\) will increase, and the probability of being selected will be increased, thus the convergence speed will be improved.

2.3. Improve the algorithm flow
In this paper, the improved variable step size ant colony algorithm for mobile robot path planning steps are as follows. The main contents are as follows:

1) the grid method is used to model the running environment of mobile robot and initialize the relevant parameters.
2) establish the adjacency matrix, use the improved variable step size ant colony algorithm to find out the set where ants can reach the next position in any position, and initialize the adjacency matrix.
3) set the starting point and end point coordinates, and establish a heuristic information matrix.
4) initialize the route and taboo list and other related parameters.
5) calculate the creeping probability of the ant from the current node to the next node, establish the probability distribution, and use the formula to select the next node.
6) Local pheromone updating is carried out according to formula.
7) update the path length, taboo list and other related parameters.
8) according to the different path length, different pheromone concentrations are allocated, the upper and lower limits of pheromones are limited, and the global pheromones are updated according to formul.
9) find out the shortest path of each generation, compare it, and output the shortest path as the global optimal path.

3. Algorithm simulation comparison

In order to verify the effectiveness of the improved variable step size ant colony algorithm, simulation experiments are carried out in MATLABR2018a. The computer operating system is Windows10 64 bit, CPU is i3-3227U, main frequency is 1.9GHz, memory is 6G. The simulation environment is divided into simple environment and complex environment.

In the ant colony algorithm, there are four main parameters that affect the performance: the parameter $\alpha$ which characterizes the importance of pheromone, the parameter $\beta$ that characterizes the importance of heuristic factors, the evaporation coefficient of pheromone $\rho$, and the increasing intensity coefficient $Q$ of pheromone. After many experiments, this paper selects $\alpha = 0.747$, $\beta = 0.747$, $\rho = 0.3$, and sets the size of each grid as $1m \times 1m$.

3.1. Algorithm simulation comparison

The path planning simulation experiments of the improved algorithm and the traditional algorithm are carried out under the grid model with a simple environment of $20m \times 20m$. The crawling path of the mobile robot in the traditional ant colony algorithm is shown in figure 1, and the path length is 29.213m. The crawling mode is single-step crawling, and the path is slightly longer. The crawling path of the mobile robot in the improved algorithm is shown in figure 2, the path length is 28.042m, and the crawling mode is variable step size. Compared with the traditional ant colony algorithm, the optimal path found by the improved algorithm is shorter than the traditional ant colony algorithm. The convergence iterative curve of the mobile robot in the traditional ant colony algorithm is shown in figure 3, and the number of iterations is 25. Obviously, the path length of the traditional ant colony algorithm is very unstable at the beginning of the iteration. The convergence iterative curve of the mobile robot in the improved algorithm is shown in figure 4. The number of iterations is 2, that is, the mobile robot has reached a stable state after 2 convergences. Compared with the traditional ant colony algorithm, the convergence speed of the improved algorithm in this paper is greatly improved.

![Figure 1. Path Planning of traditional Ant Colony algorithm](image1)

![Figure 2. Improved Ant Colony algorithm path Planning](image2)
3.2. Complex environment simulation experiment

In order to further verify the reliability of the algorithm, simulation experiments are carried out in a complex environment with a scale of $30\text{m} \times 30\text{m}$, and the raster map is consistent with the reference [8-9]. Compared with the literature [9-8] algorithm, the path length of the improved algorithm is reduced by 2.6% and 0.007% respectively, and the number of convergence iterations is reduced by 87.5% and 66.7%, respectively. The experimental results show that in the complex environment, the improved algorithm still has a fast ability to search the optimal path, and the convergence speed of the algorithm is much better than that of the other two algorithms, which effectively shortens the convergence iteration times of the mobile robot. The path planning of the improved ant colony algorithm is shown in figure 3, the convergence curve is shown in figure 3, and the experimental data are shown in Table 1.

Table 1. Comparison of algorithms in complex Environment

| Arithmetic                                      | Optimal path length / m | Number of convergent iterations |
|-------------------------------------------------|-------------------------|---------------------------------|
| Arithmetic 1                                     | 45.1127                 | 16                              |
| Arithmetic 2                                     | 43.9634                 | 6                               |
| Improved variable step size Ant Colony algorithm | 43.9602                 | 2                               |
4. Conclusion

In view of the deficiency of traditional ant colony algorithm in path planning, an improved variable step size ant colony algorithm is proposed in this paper. According to the order of the optimal path of each iteration, the algorithm redistributes the pheromone and sets the upper and lower limits of the pheromone to reduce the effect of pheromone concentration on the optimal path. The induction factor is introduced into the state transition probability formula to guide the mobile robot to move towards the end point and improve the convergence iteration times of the mobile robot. Considering the practical application of the mobile robot, the moving direction of the mobile robot is adjusted to any collision-free movement in the 360° direction, and the mobile robot will adaptively adjust the step size according to the surrounding node of the obstacle and greatly reduce the optimal path length. On the one hand, the search range of the mobile robot is improved due to the step size, on the other hand, the search activity domain of the mobile robot is expanded.

The results show that the algorithm has the least number of convergence iterations, the shortest optimal path length and the strongest global optimization ability.

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