The Wolf pack assignment rule based on ant colony algorithm and the path planning of scout ants in complex raster diagram

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Abstract. The traditional ant colony algorithm based on raster algorithm has slow searching speed and convergence speed in the problem of robot path planning, and it is easy to fall into the problem of local optimal. In order to solve this problem, an improved ant colony algorithm based on Wolf distribution rules and reconnaissance ant strategy is proposed, which can adjust the pheromone coefficient adaptively and obtain a more suitable proportion of pheromone allocation. Experiments show that this algorithm is superior to the traditional ant colony algorithm in terms of optimal path searching speed, quality and convergence speed in simple and complex environments.

1. Introduction
Path planning has been a popular project, from belongs to one of the important contents of the research in the field of mobile robot, and the existing mature technology available at the moment, the mobile robot by using the mobile robot to achieve some of the more dangerous for people to work, so the path planning for mobile robots, is particularly important. At home and abroad scholars have proposed many kinds of intelligent algorithm, such as fireworks algorithm [1], randomness, the characteristics of the locality and the explosive, but because of its core is the explosion radius, non-linear, more suitable for the numerical instead of the path, the particle swarm algorithm [2], and easy to implement, fast convergence rate, adjusting parameters less, but for discrete optimization problem, and easy to fall into local optimum, artificial potential field method [3], the mathematical description is clear, operation quickly, small amount of calculation, but easy to fall into local minimum value, easy to collision with obstacles. Only analyzing ant colony algorithm [4]. The ant colony algorithm originated in the 1990 s, the Italian scholars Dorigo, Mzniezzo and others in the process of research of ants foraging, found that ants in the foraging process releases a pheromone (a chemical), walk through the pheromone attached on the route of the past, at the same time, every ant has a special senses, sensory can help them to collect the pheromone information on the road, and tend to walk along the path pheromone is strongest, over time, and path of the shortest path pheromone concentration will be more and more high, Eventually all ants will follow this path. According to the intelligent behavior of ant colony foraging, they proposed ant colony algorithm, which has been widely used as a heuristic search algorithm in combinatorial optimization problems and path planning problems. It has strong robustness and searchability, but it is also prone to fall into local optimal problems. So how do you get out of optimality, how do you reduce the search time of the ant colony, how fast do you converge.
2. Principle of traditional ant colony algorithm

In the original ant colony algorithm [5], at time T, the probability of ant K moving from one palisade to another is determined by formula (1):

\[ p_{ik}(t) = \frac{\tau_{ik}(t)^{\eta} \eta_{ik}(t)}{\sum_{s \in \text{allowed}} \tau_{is}(t)^{\eta} \eta_{is}(t)}, \quad s \in \text{allowed} \]
\[ 0, \quad s \notin \text{allowed} \]

Where, \( \eta_i \) is the weight of the heuristic function, means the next grid map node that can be selected, \( s \) is the ant colony pheromone concentration function, \( d_{ij} \) is the distance heuristic function, \( d_{ij} \) is the Euclidean distance between the grid map that the robot needs to choose and the terminal grid map, its formula is as follows:

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

After the completion of the first iteration of ant colony algorithm, the original pheromone will disappear with time, and then the pheromone of this round of iteration will be added on the path, so its pheromone iteration formula is as follows:

\[ \tau_{ij}(t + 1) = (1 - \rho) \tau_{ij}(t) + \Delta \tau_{ij}(t) \]

\[ \tau_{ij}(t) = \sum_{k=1}^{m} \Delta \tau_{ijk}(t) \]

\[ \Delta \tau_{ij}(t) = \begin{cases} Q & \text{The ant K goes through a path (i, j).} \\ \frac{Q}{L_k} & \text{others} \end{cases} \]

3. Model Establishment

- According to the criteria of raster-based rapid path planning for robots [6], the task movement area of robots is divided into a 20*20 raster map. The initial sequence of cells is 1, from left to right, top to bottom, from 1 to 2 to 3 all the way to 400. The robot starts from the starting point, Grid 1, and reaches the target point, grid 400, as a successful pathfinding. In the grid map, the white areas represent the feasible areas, the black areas represent the obstacle areas, and the obstacle area is to avoid the collision between the robot and the obstacle, one to one mapping according to the physical scale. And the obstacle margin is expanded, so that the obstacle can fill a grid, Leave enough margin to allow the robot to change direction and move. Rules of robot movement: When moving in the white area, the robot can walk at will except that it cannot move backwards. The spot area indicates obstacles and the robot cannot pass, so it needs to change direction to move towards the white area. The ordinal number of the raster diagram is shown in formula (7):

\[ D = x + (j-1) * M \]

Where D is the ordinal number of coordinates, x, y and M are the horizontal and vertical coordinates and the number of columns in the grid column respectively, and the specific appearance is shown in Figure 1:
Algorithm improvement and process

After the simulation of the most basic ant colony algorithm, it is found that the most basic ant colony algorithm is better at finding the optimal path when there are fewer roadblocks, and can always find the optimal solution within a certain iteration. However, on the more complex roadblock map, the ability of finding the optimal path is greatly reduced, and it is very easy to fall into the local optimal solution.

Ant colony algorithm in a complex grid diagram above as the main disadvantages of walking - random walk on the map, the number of iterations spurt, the algorithm convergence rate is reduced, and easy to fall into local optimum, in order to avoid the shortcoming of slow convergence, introducing wolves allocation strategy to update the ant colony algorithm, the distribution of the wolves rule: capture food priority assigned to the strongest of the Wolf, and the Wolf can only be assigned to the rest of the weak, will eventually be starved to death, and based on ant colony of division of labor cooperation, introduce monitoring ant colony [7], an improved ant colony optimization mathematical model expression as shown in formula (8):

$$
\tau_{ij}^* = \rho \tau_{ij}^{t-1} + \Delta^{\text{max}}\tau + \Delta^{\text{new}}\tau_{ij} - \Delta^{\text{min}}\tau_{ij} \\
\Delta^{\text{new}}\tau = \begin{cases} 
(\min / \max) \times (Q / L_{\text{min}}), & \text{if there is an optimal route this time} \\
0, & \text{if there is no optimal route this time} 
\end{cases} \\
\Delta^{\text{max}}\tau = \begin{cases} 
(1 - \rho) \times (Q / L_{\text{max}}), & L_{\text{max}} \text{ belongs to the global optimal route} \\
0, & L_{\text{max}} \text{ does not exist} 
\end{cases} \\
\Delta^{\text{min}}\tau = \begin{cases} 
s \times (Q / L_{\text{min}}), & L_{\text{min}} \text{ is the longest path of this iteration} \\
0, & L_{\text{min}} \text{ non-existent} 
\end{cases}
$$

(8) (9) (10) (11)

In the above equation, is the minimum path of this iteration [8], Sn is the number of shortest paths of this iteration, and Sall is the number of paths that reach the end point of this iteration. Is the longest path of this iteration, and z is the number of the longest paths of this iteration. As global iterative least path for pheromone updating formula, according to the polymorphism of ant colony, will be divided into one ant scouts, the shortest path, by its record global, as formula (9) is the current iteration of the shortest path pheromone update, according to certain proportion formula (10) is a global shortest route to record and to update a certain proportion, the formula (11) is the longest path for a certain percentage cuts the pheromone.

Pheromone volatilization factor for the performance of ant colony algorithm has a very important role, in order to avoid the early stage of the ant colony algorithm convergence speed too fast, trapped in local optimal solution, the need for volatile coefficient changes [9] information, references to [10] of mobile robot path planning based on improved ant colony algorithm, by combining the wolves and polymorphic ant colony can know, pheromones if previous volatile, easy to fall into local optimum, namely find is suboptimal solution of the path, and unable to find the optimal path, if the early stage of the pheromone volatilization too slow, and will bring the algorithm convergence rate is reduced, between the above situation, modify the pheromone update strategy is as follows:
\[ \rho(t+1) = \frac{T}{T+t} + e^{-\rho(t)} \]  \tag{12} 

T is the total number of iterations, and T is the current iteration number, in order to make the first ant colony strong global search ability, give a larger value, volatile factors makes the preliminary pheromone concentration for ant colony optimization ability of random search path is higher, and with the increase of the number of iterations, the global optimal path pheromone of gradually increase, make the most of the ant colony to global convergence, the shortest path algorithm to speed up the convergence speed. The specific flow chart and steps are as follows:

Step 1: Use grid method to model the obstacle
Step 2: Initialize the parameters, set the starting and ending positions, set the number of iterations and the number of ants.
Step 3: Start M ant search, through the roulette method to choose the path.
Step 4: Determine whether the next round iteration is over, and if it is, store the path of each ant this time
Step 5: Select the longest and shortest paths for this iteration and store them.
Step 6: Compare the shortest path to the previous round and replace it if it is shorter
Step 7: Update the pheromone according to equation (8) -(12) above, and start the next iteration.
Step 8: Determine whether the iteration is over, and output the optimal solution if it is.

5. Experimental results and analysis

The algorithm in this paper was compared with the literatures [11] and the traditional ant colony algorithm, and MATLABR2019A was used as the simulation tool to carry out simulation experiments on the complex and simple 20*20 raster map. The number of ants was set as 50, the maximum number of iterations was 100, $\alpha$ is 1.5, $\beta$ is 6 and $\rho$ is 0.9. The parameters of the three algorithms were the same, and 10 experiments were conducted to select the one with the optimal path for comparison.

Figure 2: 20*20 raster Simple Path simulation of traditional ant colony algorithm

Figure 3: shows the simple path simulation of ant colony algorithm in raster diagram [11]
Figure 4: shows the simple path simulation of ant colony algorithm in this paper.

Figure 5: shows the total comparison of simple paths.

Figure 6: shows the complex path simulation of the traditional ant colony algorithm.
Figure 7: shows the complex path simulation of ant colony algorithm in literature [2]

Figure 8: shows the complex path simulation of ant colony algorithm in this paper

Figure 9: shows the total comparison of complex paths
Table 1

| Algorithm                             | Shortest path | Number of convergent iterations | Average calculating time |
|--------------------------------------|---------------|---------------------------------|--------------------------|
| Traditional ant colony algorithm     | 30.095        | 40                              | 7.086s                   |
| Literature [2] ant colony algorithm  | 29.869        | 20                              | 5.482s                   |
| This paper, ant colony algorithm     | 28.0416       | 20                              | 5.082s                   |

Table 2

| Algorithm                             | Shortest path | Number of convergent iterations | Average calculating time |
|--------------------------------------|---------------|---------------------------------|--------------------------|
| Traditional ant colony algorithm     | 63.845        | 75                              | 8.565s                   |
| Literature [2] ant colony algorithm  | 66.0122       | 20                              | 7.623s                   |
| This paper, ant colony algorithm     | 52.768        | 20                              | 6.320s                   |

A conclusion can be drawn from the comparison in Table 1: In the raster diagram of simple environment, the ant colony algorithm in this paper has the fastest convergence speed, and the shortest path obtained is also the shortest among the three algorithms.

The comparison of Table 2 shows that the iteration speed of this paper is greatly improved compared with the traditional ant colony algorithm, and the shortest path obtained is also shorter than that in the literature [11].

6. Conclusion

In order to optimize the traditional ant colony algorithm in the optimization of complex map ability, through the distribution of food and the wolves combined ant colony system of division of labor cooperation, to make the ant colony optimization to find the optimal path, at the same time and with the number of iterations and the adaptive mechanism of the volatile coefficient of change, reduce the search time of ant colony, to speed up the convergence speed, improve the global search ability of the ant colony, avoid the ant on the same path into the possibility of deadlock. The ant colony algorithm in this paper greatly enhances the ability of searching the optimal path on the complex raster map and reduces a lot of search time and iteration times.

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