

# An Improved Ant Colony for Servo Mechanical Arm Path Planning

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**Abstract:** On account to the restriction of basic ant colony algorithm when the working platform is smaller and the block is approximately the same size as the target, the improved ant colony algorithm is put forward to the path planning of servo mechanical arm. In this paper, the effect of the compartmentalize grid size to path planning speed and accuracy has been discussed. It also presents an improvement of the methods of local and global information updating. Finally, the range of ants' visual field has been enlarged. The experiment results show that the improved ant colony algorithm could find optimized path in shorter time. In terms of achieving functions of avoidance obstacle and the global searching, the proposed algorithm over performs conversional ones.

## Introduction

Currently, most of mechanical arms cannot achieve the desired position when the moving environment changes. The mechanical arm and visual combination can be a good solution to this problem. It dynamically adjusts the motion path of the mechanical arm, hence the arm can accurately reach the designated position.

Ant colony algorithm (ACA) is a new bionic algorithm put forward by Colorni and Dorigoin in 1990s [1,2]. The difficult combinatorial optimization problem is solved through the simulation process of real ants searching for food. It employs the behavior characteristics of ant, and takes advantages of the strong robustness, excellent distributed computer system, ease of combine with other methods[3-5]. In this paper, according to the characteristics of small mechanical arm working platform and the barriers with almost the same size as the target, the ant colony algorithm is improved.

## Solving the path planning problem based-on ant colony algorithm

**Environment modeling.** Let the working space of mechanical arms to be two-dimensional structured space (Notes for RS), the location and size are known, and don't change in the process of mechanical arm movement. Division of RS with the same size grids, given there is no barrier in certain grid sizes range, and then the grid is free one, otherwise is barrier grid. The obstacle space did not significantly reduced, as shown in the operating results

Grid identification utilizes the coordinates and the method of serial alternately:

$$n = x + N_x \times (y - 1) \quad (1)$$

$$\text{Or } \begin{cases} x = (n) \bmod (N_x) \\ y = \text{int}(n / N_x) + 1 \end{cases} \quad (2)$$

Whereby,  $N_x$  is the grid number of each row  $N_x = x_{\max} / Ra$ ,  $\bmod$  denote the remainder of  $n / N_x$ ,  $\text{int}$  denote the integer of  $n / N_x$ .  $x_{\max}$ ,  $y_{\max}$  are the maximum pixels of x and y axis respectively,  $Ra = 30$ pixels.

Let g be any grid in RS, then g (1, 1) sequence number is 1, g (1, 2) sequence number is 2, g (n, 1) sequence number is  $n \times N_x + 1$ . Let  $C = \{1, 2, \dots, s\}$  is a set of grid number.

**Problem definition.** Let  $AS$  be a set of  $g$  in  $RS$ ,  $OS = \{o_1, o_2, \dots, o_s\}$  be a set of obstacles grid, and  $KS = AS \cap \overline{OS}$  be a set of the feasible grid, the initial point of mechanical arms  $g_{begin} \in AS$ ,  $g_{begin} \notin OS$ , be the nest location, the target point  $g_{end} \in AS$ ,  $g_{end} \notin OS$  be food source. The behavior that ants look for food starting from  $g_{begin}$  is the process of finding food source in the range of  $RS$ . Through the ant colony foraging repeatedly and due to the effect of positive feedback information left by the ant, eventually the ant colony find a shortest path around all obstacles.

For the convenience of narration, the following definitions are:

Definition 1:  $ant = \{1, 2, \dots, k, \dots, m\}$  denotes the set of ant,  $k \in ant$ ,  $m$  is total number,  $\tau_{ij}$  denotes the ant residual information in the connection between the grid  $g_j$  and  $g_i$  at moment  $t$ .

Definition 2:  $\forall g \in KS$ ,  $g$  is the feasible node, a set of all possible node is the feasible domain.  $\forall g \in OS$ , Then  $g$  is forbidden node, all the set of forbidden node is forbidden domain.

Definition 3: The distance between arbitrary grids refers to the length of the two grids' connection, denoted by  $d(g_i, g_j)$ ,  $i, j \in C$ , calculation by the formula (3):

$$d(g_i, g_j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3)$$

$$Definition\ 4: \quad BS_i(g_i(x_i, y_i)) = \{g \mid g \in A, d(g, g_i) \leq b\}, \quad i \in C \quad (4)$$

which is the neighborhood of  $g_i$  or the vision domain of ant  $k$  in the  $g_i$ , where  $b$  is the distance of the ant allowed to be run.

$$Definition\ 5: \quad WS_i(g_i(x_i, y_i)) = \{g \mid g \in BS_i(g_i(x_i, y_i)), g \notin OS, i \in C\} \quad (5)$$

it is ant  $k$  in feasible region of  $g_i$  at the moment  $t_i$ , let  $tabu_k = \{P(t_0), P(t_1), \dots, P(t_i)\}$ , and  $t_0 < t_1 < \dots < t_i$  is the set of grid location that ant  $k$  has walked from  $t_0$  to  $t_i$ . In  $t_{i+1}$ ,  $\forall P(t_{i+1}) \in WS_i$  and  $\forall P(t_{i+1}) \notin tabu_k$ , Then  $P(t_{i+1})$  is feasible node of  $t_{i+1}$ . Obviously, the  $tabu_k$  with the ant movement and dynamic change, According to the definition, these positions cannot walk again, Therefore  $tabu_k$  is called tabu list.

Definition 6:  $\eta_i = Q / d(g_i, g_{end})$  is the heuristic function of ant  $k$  select grid  $g_i$ ,  $Q$  is weight coefficient.

## The generation of the problem

**The influence on the system updates local pheromone.** According to the principle of ant colony algorithm path selection[5], ant in the feasible region should has a high level of interest to the point that has more pheromone and reaches the closer target. As shown in fig. 1, in the mechanical arm operation space which gridded in 9 equal, the mechanical arm moves from point A to B. Since point C is the shortest to the target, it has the biggest probability of being chosen. However, there are obstacles in the route from point C to B; the next optimal point is D. although we can look for D from A directly, but it must be passed C according to the original algorithm, and increase the length of the path indirectly. There is more and more information in node C, because of the information update.

So when  $g(tabu_k(n-2), tabu_k(n)) \in WS(g)$ , The table and local information updating as: ( $tabu_k$  Abbreviated as  $t_k$ )

$$t_k(n-1) = t_k(n) \quad (6)$$

$$\tau_{t_k(n-2)t_k(n)}(n+1) = (1-\rho)\tau_{t_k(n-2)t_k(n)}(n) + 2\Delta\tau_{t_k(n-2)t_k(n)}^k \quad (7)$$

$$\tau_{t_k(n-2)t_k(n-1)}(n+1) = (1-\rho)\tau_{t_k(n-2)t_k(n-1)}(n) - \Delta\tau_{t_k(n-2)t_k(n-1)}^k$$

**The influence of global pheromone update to the system.** The feasible region may be empty during the ants path detection, that is, the ant has no path to walk, called "ants die". In original algorithm, the ants are not to be deal with in this case because of the local information update, the path that the dead ants have walked before will also be updated. So the formula of the global information update when the ants die:

$$\tau_{ij}(n+1) = (1 - \lambda)\tau_{ij}(n) - \Delta\tau_{ij}^k \quad (8)$$

## Analysis of Experimental Results

**The influence of local information update on system.** In order to further illustrate the effectiveness of the improved algorithm to the actual system after local information updated, under the setting of parameters, such as the number of ant  $num = 6$ ,  $\alpha = 1$ ,  $\beta = 1$ ,  $\rho = 0.01$ ,  $\lambda = 0.05$ ,  $Q1 = 100$ ,  $Q2 = 100$ , number of loops  $N = 15$  etc (obstacles put random position), For 2 groups of representative experiments, each experiment is the average results of 10 runs. The experimental results in the following table:

Table 1 The comparisons between the former local information and the one updated

	Location 1			Location 2		
	Path length	steps	Time (ms)	Path length	steps	Time (ms)
Unequal improvement	765.110	9	15	765.485	9	16
Unequal improvement	765.110	9	31	765.485	9	16
9 uniform single step planning	462.688	15.4	379.8	182.967	6	203
9 equal single-step length planning	444.831	15.4	339.1	182.967	6	219
9 equal multi-step length planning	507.097	8	903.1	198.685	4.2	552.9
The improved 9 equal multi-step length	450.645	8	765.9	191.154	4.8	542.5
25 equal multi-step length planning	469.898	9.9	7808	200.508	4.1	3972
The improved 25 equal multi-step length	458.593	9.1	7089	200.491	4.1	4001

As can be seen from the table 1, under the same conditions, the result of local information updated whether in path length and planning steps or takes on all has certain improvement. 9 equal to grasp an object of single step planning method generally able to plan the optimal path, and the computation time is short. The mechanical arm movement step number is larger, in the actual operation of the need for the conversion of mechanical arm movement of the shaft angle is larger. 25 equal to grasp an object multi-step planning method although the mechanical arm movement step number is relatively small, but longer time, path length and planning is not necessarily the optimal. 9 equal to grasp an object more time-consuming step planning method is not much, the planning step number less, path length is not optimal, but it with optimal path length maximum difference of ten or twenty a few pixels, the equivalent of about 6-10 mm. So from the various considerations, 9 equal to grasp an object multi step planning method is preferable.

**The influence of the search step length on the system.** Figure 2(a) is the mechanical arm motion path planning curve after local information update improved, Figure 2(b) is the mechanical arm motion path planning curve after the exploration step increased. The experimental results shows that there is only 9 steps in mechanical arm carrying the objects from the initial position to the destination, so greatly reduces the motor's start-stop process.

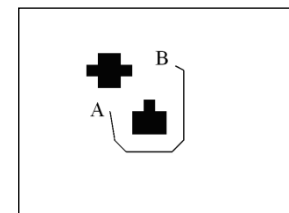
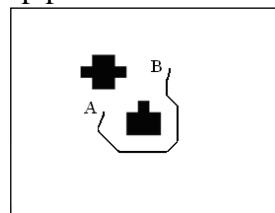
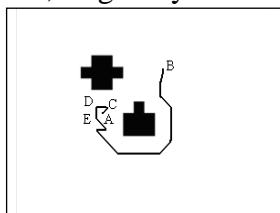


Fig. 1 The effect of changing local information      Fig. 2 The comparison between the search area changed or not

## Conclusion

In this paper, according to the specific circumstances of a practical experimental platform, the

mechanical arm platform is small, the barriers is approximately the same size as the target, for grid tumble of ant colony algorithm, local pheromone updating, search step length and global pheromone updating is discussed and improved. The experiment results shows that the improved ant colony algorithm can find out the excellent mechanical arm movement path in a relatively short period of time, and greatly reduces the mechanical arm start-stop times, improves the global search performance.

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