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Robot path planning in unknown environment based on ant colony algorithm

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***Abstract*:** In this paper, we present Ant Colony Optimization Algorithm for path planning to a target for mobile robot in unknown environment. The proposed algorithm allows a mobile robot to navigate through static obstacles, and find the path in order to reach the target without collision. This algorithm provides the robot the possibility to move from the initial position to the final position (target). The proposed path finding strategy is designed in a grid-map form of an unknown environment with static unknown obstacles. The robot moves within the unknown environment by sensing and avoiding the obstacles coming across its way towards the target.

This work provides overviews of swarm intelligence and Ant Colony Optimization applications applied to many fields of our life particularly we will focus in mobile robot routing. Various mechanisms are presented in this paper to demonstrate the useful and wide combination of Ant Colony Optimization. Finally, enhancement to the mechanism is suggested and it is evaluated in MATLAB environment.

Keywords: Ant Colony Optimization (ACO), mobile robot, path planning

I. INTRODUCTION

Today, the robotics become favorite topics of many studies and its applications are applied in various problem of our life. There are many type of robot and they perform many functions. In the conquest of space exploration where they can be used to collect environment data such as rock, soil samples… In medical field, some specialized robots support physicians diagnose and help people with disabilities. Scientists in the world have created special type of robots replace human activities in the particularly dangerous position, for example in case of incidents at nuclear power factory or hygiene robot working in high building…

One of most important tasks in the control of mobile robot is path planning. In environment with obstacles, the role of path planning is to finding the appropriate collision – free path for mobile robot to move from start location to the destination point. There are many methods have been studied and applied in grid-based path planning such as A * (A star) algorithm [1], road map (Voronoi diagram and visibility graphs) [2], artificial potential field [3]…

In robotics field, working environment is divided into three kinds: the totally known, partly known, and total unknown. This paper will focus to total unknown environment, each robot has forage to find the way the target by co-operate with each other.

Ant colony algorithm was invented in 1992 by Marco Dorigo in his doctoral thesis. Since then this algorithm is used in many studies and achieve high performance. Multi ant system has been successfully applied in Travelling Salesman problem (TSP) [4], the Quadratic Assignment problem [5], Vehicle Routing problem [6], etc…

The paper is organized as follow: in the second section the ant colony algorithm is introduced and the next section is discussed about the path planning algorithm realization. In the last section, some result, experiment and conclusion are provided.

II. ANT COLONY ALGORITHM

Ant colony algorithm, based on behavior of real ants, is a nature approach to establish optimization path from ne st to food source, it is a stochastic search algorithm and good effect has been obtained in solving combination op timization, function optimization, system identification, robot path planning, data mining, and network routing a lgorithm.

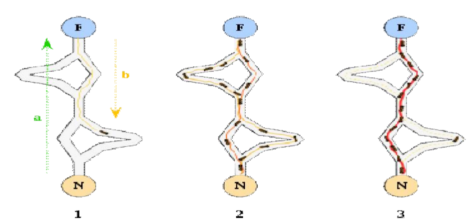


Figure 1: Ant colony foraging food

At the time of beginning, all ants move at random direction to find the way to the destination. Biologist have found by many studies and experiment that ants leave some chemical substance on the route that they have passed, which call "pheromone". Other ants can smell this pheromone, and their path-taking decisions are depended on the amount of pheromone. When subsequent ants sense this trail of pheromone, they will follow the trail with a probability that is proportional to the concentration of pheromone – the higher the concentration, the larger the probability that subsequent ants will follow the trail. The pheromone evaporates at a given rate which means that the strength of pheromone encountered by another ant is a function of the original pheromone strength and the time since the trail was laid.

Besides pheromones are deposited on the foraging path, ants also rely on heuristic information as well. The heuristic information is defined as the inverse of distance between the current point and the next point which ant can be go as show in below equation:

$$\mu_{ij} = \frac{1}{d_{ij}}$$

Therefore, the shorter the distance between two locations is, the better their heuristic information and vice-versa. Following with the intensity of pheromone trails and the heuristic information, the probability of the path which will be chosen by ant can be calculated. This probability is known as the transition probability:

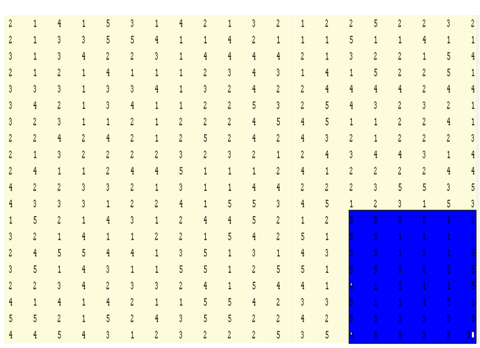
$$P_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}][\mu_i(t)]^{\beta}}{\sum_{J\in Z}[\tau_i(t)]^{\alpha}][\mu_i(t)]^{\beta}} & if\ j \in Z \\ 0 & if\ j \notin Z \end{cases}$$

Where t is the time index, μ_{ij} is the heuristic information, τ_{ij} is the pheromone trail which has been evaporated when the ant move from point i to point j, α, β are the parameter of pheromone function and heuristic function, Z is the set of all moveable point from current point.

III. IMPLEMENTATION OF ANT COLONY ALGORITHM IN ROBOT PATH PLANNING

1. Environment initialization

We will use 20x20 grid model to present the environment of mobile robot. Assume that the space in which a robot moves is a limited region with several obstacles of different size in two – dimensional plane. Assume that the edge of each cell is 1 unit that presents the radius size of scope in which a robot could move freely. Obstacles occupy one or more grids are created by a matrix which each value is distributed from 1 to 5. The value 1 is indicated a cell of obstacles, and the values from 2 to 5 are the free cell.



2	1	4	1	5	3	1	4	2	1	3	2	1	2	2	5	2	2	3	2
2	1	3	3	5	5	4	1	1	4	2	1	1	1	5	1	1	4	1	1
3	1	3	4	2	2	3	1	4	4	4	4	2	1	3	2	2	1	5	4
2	1	2	1	4	1	1	1	2	3	4	3	1	4	1	5	2	2	5	1
3	3	3	1	3	3	4	1	3	2	4	2	2	4	4	4	4	2	4	4
3	4	2	1	3	4	1	1	2	2	5	3	2	5	4	3	2	3	2	1
3	2	3	1	1	2	1	2	2	2	4	5	4	5	1	1	2	2	4	1
2	2	4	2	4	2	1	2	5	2	4	2	4	3	2	1	2	2	2	3
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2	4	1	1	2	4	4	5	1	1	1	2	4	1	2	2	2	2	4	4
4	2	2	3	3	2	1	3	1	1	4	4	2	2	2	3	5	5	3	5
4	3	3	3	1	2	2	4	1	5	5	3	4	5	1	2	3	1	5	3
1	5	2	1	4	3	1	2	4	4	5	2	1	2	5	5	5	5	1	3
3	2	1	4	1	1	2	2	1	5	4	2	5	1	5	5	1	1	1	3
2	4	5	5	4	4	1	3	5	1	3	1	4	3	5	5	1	3	1	5
3	5	1	4	3	1	1	5	5	1	2	5	5	1	5	5	5	5	5	5
2	2	3	4	2	3	3	2	4	1	5	4	4	1	4	1	5	1	1	5
4	1	4	1	4	2	1	1	5	5	4	2	3	3	5	1	1	1	5	1
5	5	2	1	5	2	4	3	5	5	2	2	4	2	5	5	5	5	5	5
4	4	5	4	3	1	2	3	2	2	2	5	3	5	4	5	5	5	5	1

Figure 2: Robot environment matrix

As we can see in the figure 2 the zone near the destination point have high value which is the more attractive for the ant robot. This is the parameter will be used to calculate the cost function in probability transition in next section.

From the matrix in figure 2 the environment for robot path planning will be constructed as figure 3 with the top – left are the starting cell and the bottom – right is the destination cell

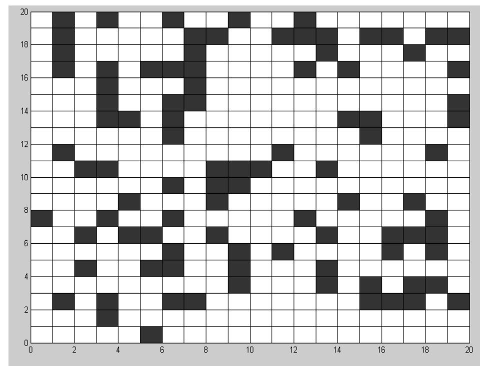

Figure 3: Robot environment

2. Coordinate and mapping

Each cell is assigned by a number from 1 to 400 as figure below which is defined by marking sequentially from left to right, top to bottom.

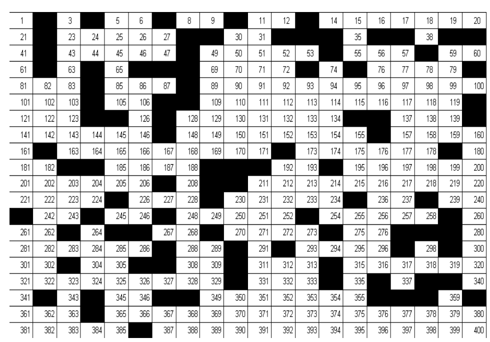

Figure 4: Environment mapping

The mapping relationship between (x_i, y_i) and node number i can be defined by formula:

$$\begin{cases} x_i = mod(i, N) - 0.5 \\ y_i = N - ceil\left(\frac{i}{N}\right) + 0.5 \end{cases}$$

If $x_i = -0.5$ then $x_i = N - 0.5$. Where N is the size of map (N=20), $mod(i, N)$ is function to calculate the remainder value when integral number i divide by N, ceil(x) is function which return the largest integral value of x.

3. Movement Rule

Moveable area for ant robot in each step is chosen from maximum 8 cells around the current cell without obstacles. For example, assume that the current position of robot is cell number 168 then the set of next step are 148, 149, 167, 169, 187, and 188

147	148	149
167	168	169
187	188	189

Figure 5: Moveable area

Each ant robot will chose the next cell to move accordance the visibility of the cell and pheromone intensity. In the initialization state, all ants have no information about environment so they forage to reach the destination by random step.

After that ant robot will go to the next point P_j and J given by:

$$j = \begin{cases} argmax\{[\tau_i(P_i)]^{\alpha}[\mu_i(P_i)]^{\beta}\ [cost(P_i)]^{\gamma}\}, if\ q \le q_0\ , i \in Z \\ J\ ,\ if\ q > q_0 \end{cases}$$

Where q is the random number uniformly distributed between [0, 1], $q_0 \in [0,1]$ is the threshold value set in the initialization, $cost(P_i)$ is the value of cellP_i , γ denotes the relative significance of cost value and J is calculated by:

$$P_J^k(n) = \frac{[\tau_i(P_i)]^{\alpha}[\mu_i(P_i)]^{\beta}\ [cost(P_i)]^{\gamma}}{\sum_{J\in Z}[\tau_i(P_i)]^{\alpha}[\mu_i(P_i)]^{\beta}\ [cost(P_i)]^{\gamma}}$$

Z is the set of moveable area which is discussed above and P_J^k is the transition probability to point J. The heuristic information will be determined as equation below to improve the efficiency and getting better solution:

$$\mu_i = \frac{1}{\sqrt{(x_i - x_e)^2 + (y_i - y_e)^2}}$$

Here i is the next node and e is the destination node.

4. Pheromone Updating Rule

- Localized pheromone update

When the ant has passed the cell P_i, the pheromone will be updated by:

$$\tau_i(n+1) = (1-\rho)\tau_i(n) + \rho\tau_0$$

- Global update:

After all ants reached the target, the pheromone will be refreshed and update by equation below:

$$\tau_i(n+1) = (1-\ \rho)\tau_i(n) + \Delta\tau_i(n)$$

$$\Delta\tau_i(n+1) = (1-\rho)\Delta\tau_i(n) + Q/\min\ (L_k)$$

Where $0 < \rho < 1$ is the erased rate of pheromone and τ_0 is the initial value of pheromone

IV. EXPERIMENT AND RESULT

The algorithm has been simulated by MATLAB language by Intel Pentium IV with Core2Dual 1.8 GHZ, 1Gigabytes memory running in WindowXp environment. This experiment we use a map with 20x20 grid and all operations were done by 10 ant robots. All parameters have been using for simulation $\alpha = 0.5$, $\beta = 5, \gamma = 0.5, q_0 = 0.5$, $\rho = 0.1$, number iteration is 50 and initialization value of pheromone is 1. The figure below is the result when ant robot using basic algorithm, the length of minimal path is 31.5563 (28 cells

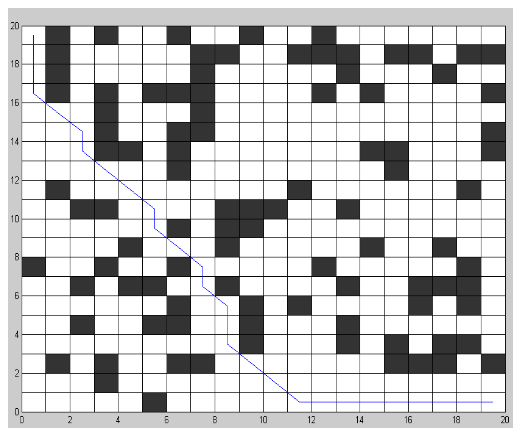

Figure 6: Basic algorithm result

And the result with improved ant colony algorithm with minimal length is 29.779 (25 cells)

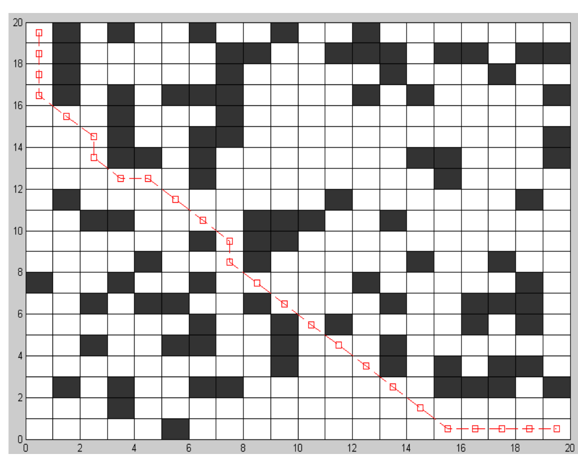

Figure 7: Improved algorithm result

V. CONCLUSION

In this paper, ant colony optimization is presented detail to provide an efficient method for solving robot path planning problem. Ant colony optimization is a meta-heuristic in which a colony of artificial ants cooperates in finding good solutions to difficult discrete optimization problems. Cooperation is a key design component of ACO algorithms: The choice is to allocate the computational resources to a set of relatively simple agents (artificial ants) that communicate indirectly, that is, by indirect communication mediated by the environment.

The application of ACO is particularly interesting for: (1) NP – hard problem, which cannot be efficiently solved by most traditional algorithms; (2) Dynamic shortest path problem in which some properties of the problem's graph representation change over time concurrently with the optimization process; and (3) problems in which the computational architecture is spatially distributed. The key elements are cost value and improved heuristic function, the robot path planning scheme has been simulated using MATLAB language to solve efficiently the Ant Colony Algorithm using two-dimension grid model with static obstacles in order to make the robot's environment.

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