Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 6.017

IJCSMC, Vol. 6, Issue. 7, July 2017, pg.114 – 120

Improved Artificial Potential Field Based Ant Colony Optimization for Path Planning

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Abstract- Path planning field for mobile robot is an important problem that involves finding free path from initial position to goal position .in this paper we introduce an improved artificial potential field based on ant colony optimization .which can obtain additional attractive force to prevent artificial potential field from local minimum .and use ant colony optimization to determine the location of goal in the environment .we develop ant colony optimization to optimize planned path .we do not use the pheromone in all the path from initial position to goal position. We use pheromone in the goal position only. After that the proposed algorithm applied in a laptop computing equipped with 1.80GHz Intel core CPU, 2.5GB memory with 2014 MATLAB in Windows 8.1 Operating System. The simulation results confirm that the proposed algorithm could always find shortest path in less time. The comparison between ant colony optimization and genetic algorithm was also made in this paper.

Keyword: path planning, ant colony optimization, artificial potential field, motion planning, multi robot.

I. INTRODUCTION

In the last few decades, robotic scientists have investigated on service mobile robots which could be able to operate within human-robot coexistent environments to execute different complex works, such as transportation of heavy objects, surveillance, rescue, and guiding people in exhibitions and museums. Autonomous mobile robot path planning or navigation is one of the most important applications for robot control systems and has attracted remarkable attention from number of researchers. We can classify the method for solving the problem based on the environment into two types: known environment and unknown environment. And each of these two kinds could be divided into static and dynamic environment. In the known environment the robot know all the information about the environment before it start to move. the algorithms are suitable to solve the problem of path planning for example artificial potential field [1],the Visibility Graph [2],Voronoi diagrams[3],The Grid method [4], the cell decomposition [5]. in unknown environment the robot does not have any information about the environment .in this state the robot must be solve the problem of path planning by the sensor or the few information its available about the environment. A lot of researchers introduced important investigation results for examples genetic algorithm(GA)[6], ant colony optimization (ACO)[7], Fuzzy Logic [8], Neural Networks (NN)[9], particle swarm optimization(PSO) [10].but these algorithms can't reach an optimal solution separately in complex environment . In this paper we introduce a new efficient approach for mobile robot motion planning .we use two algorithms to solve the problem of path planning: artificial potential field(APF) and ant colony optimization .Ant colony optimization (ACO) is used to increase the attractive force .the pheromone information generated from ACO is used to prevent (APF) from falling into local minimum. The remainder of this paper is structured as follows. In section 2 displays ant colony optimization. Section 3 displays artificial potential field. In section 4 displays the proposed algorithm. Section 5 discusses the simulation and result for this paper and finally 6 the conclusion for this paper.

II. ANT COLONY OPTIMIZATION

Ant Colony Optimization is a meta-heuristic for solving problems which need optimization. The idea of Ant colony Optimization was taking from the natural behaviour of ants in finding their short road from their living place (nest) to food. The unique feature in the ant colony is that, it finds the shortest path from the nest to the food resource without any direct communication between the ants. This is the basic idea of swarm intelligence that is noted not only in ants, it can be noted in birds, fishes, etc. The communication between the ants is based on the amount of the pheromone through their path. The difference in the amount of pheromone putted in the path taken by ants will shows the quality of the route selected to reach the food. [11]

A. *Improved ant colony optimization*

Original ant colony optimization (ACO) contains some limitations, such as occupy long time, getting into local minimum if the size of the problem is large. In original ant colony (ACO), the amount of pheromone of all elements are same started. So all the solutions are started blindly in the beginning of evolution phase, and it would occupy a long time to find a short path from many paths. So we should improve the ACO. We don’t need to put the pheromone in all the length of the path. We want to increase the attractive force to prevent the (APF) from local minimum. Therefore the robot moves in the environment to explore the entire environment because the robots don't have any information about the environment and determine the goal and obstacles locations by the pheromone putting in the position of the goal and the obstacles only. Amount the pheromone differ between the goals and obstacles location. Amount of pheromone in the goals location is very much while in the obstacles locations is little.

III. ARTIFICIAL POTENTIAL FIELD

APF mainly contains from two force vectors, caused by the obstacles and goals positions. The goal position generate the attractive forces to attract the robot to the goal while the obstacle position generate repulsive force to repel the robot from the obstacle .sum of these forces is controlling on the movement of the robot. [12]

A. *Attractive and repulsive force*

In artificial potential field, the goal position has attractive force on robots, and when the distance between the robots and goals increases, the attractive force increases. Position of robots in its work space referred to as $q = [x\ y]^T$. The attractive field created by the goal is given by:

$$U_{att} = \frac{1}{2}(q - q_g)^2 = \frac{1}{2} k p^2{}_{goal}(q) \qquad (1)$$

Where k is a positive coefficient for APF, $q_g = (x_g, y_g)^T$ is the location of goal. $P_{goal}(q) = // q - q_g //$ Is the distance from the location of robot to the position of goal. The attractive force is calculated by the negative gradient of the attractive potential and given the following form:

$$F_{att}(q) = -\nabla U_{att}(q) = -\frac{1}{2} k \nabla p^2{}_{goal}(q) = -k(q - q_g) \qquad (2)$$

$F_{att}(q)$ is a vector directed toward q_g with magnitude linearly related to the distance from q to q_g. The repulsive force has the form:

$$U_{rep}(q)=\begin{cases}\frac{1}{2}\eta\left(\frac{1}{p(q)}-\frac{1}{p_0}\right)^2 & , p(q)\le p_0\\ 0 & , p(q,q_{ob})\ge p_0\end{cases} \qquad (3)$$

Where η is a positive scaling factor, let $q_0=(x_0,y_0)$ be unique configuration in obstacle closest to q. $p(q)=\|q-q_0\|$ is the shortest distance between robot and obstacle. p_0 is the largest impact distance of single obstacle. The repulsive force is calculated by the negative gradient of the repulsive potential and given the following form:

$$F_{rep}(q)=-\nabla U_{rep}(q)=\begin{cases}\eta\left(\frac{1}{p(q)}-\frac{1}{p_0}\right)\left(\frac{1}{p^2(q)}\right)\nabla p(q) & , p(q)\le p_0\\ 0 & , p(q)\ge p_0\end{cases} \qquad (4)$$

The total artificial force is calculated:

$$F(q)=F_{att}+F_{rep} \qquad (5)$$

Where $F(q)$ is artificial force, F_{att} is attractive force and F_{rep} is repulsive force. When the environment has multi obstacles, the total repulsive potential field is the sum of all obstacles' repulsive potential field. The total potential field can be expressed as:

$$F(q)=F_{att}(q)+\sum_{i-1}^{n}F_{rep}(q) \qquad (6)$$

Where n: is the number of obstacle

IV. THE PROPOSED ALGORITHM

This paper improved artificial potential field by using the pheromone that generated from ant colony optimization (ACO) as additional force to increase the attractive forces that attract the robot which the robot will not fall into local minimum .the work of ant colony optimization is exploring all the environment when it find the goal the robot put pheromone in the goal location (the amount of pheromone is very much)while putting the little pheromone in obstacles location when it find obstacles . The pheromone amount in obstacle location is very little and does not affect at the total forces .the total attractive force that it attracts the robot is:

$$TF_{att}=F_{att}+F_p \qquad (7)$$

Where TF_{att} is the total attractive force, F_{att} is attractive force that generate from goal position, F_p is the pheromone force. Now each robot is driving by the composition of three forces:

$$F_t=TF_{att}+F_{rep} \qquad (8)$$

Where F_t the total force is driving the robots, TF_{att} is the total attractive force, F_{rep} repulsive force. The entire algorithm of our proposed method is as follow:

1. Select one robot randomly from multi robot.
2. The robot moves in the environment to explore the environment.
3. When it find goal, it puts the pheromone in the goal location.
4. When it finds obstacles, it puts the pheromone in the obstacles location but the amount of pheromone is very little.
5. Repeat until exploration the entire environment is finishing.

6. Compute the artificial potential force at current configuration under our proposed improved artificial potential field.
7. Move all robots to the environment.
8. Each robot has repulsive force with other robot to avoid the collision.
9. Each robot reaches to the goal without any collision with obstacles.

The robot is starting the movement from the first point of the environment to explore the environment according to the path planned by global planner .when it find goals in the path of robot it put some pheromone in the location of goals. The amount of pheromone in the location of goals is very much .When the robot finds the obstacle in the environment; it also put the pheromone in the location of obstacles. The amount of pheromone in the location of obstacle is little. In this paper are used multi robot, multi obstacle and one goal. The goal of the paper at first exploration the entire environment after that each robot must be reaches to the goal in the environment and avoids the collision with obstacles.

V. SIMULATION AND THE RESULT

Some simulation experiments are carried out for validing the proposed algorithm using MATLAB. We used ant colony optimization to explore the environment by one robot. The environment is setting as square which shown in Fig.1. The paper has used different types of environments. Some environments were simple (number of obstacles is few and size of the environment is small). And some of them were very complex (number obstacles is too many and size of the environment is big). When the robot find goal it puts the green box in the location of goal and when it finds the obstacles it put the red box in the location of obstacles .Fig. 2 shows that:

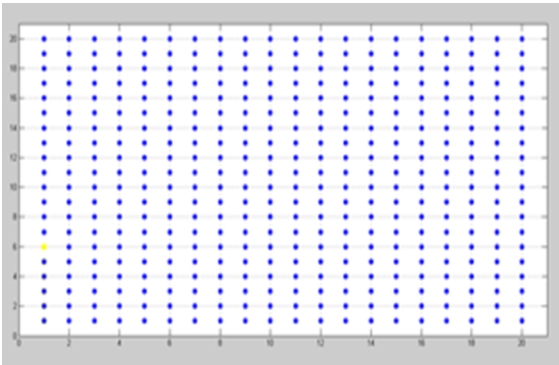

Fig. 1 Simulation environment

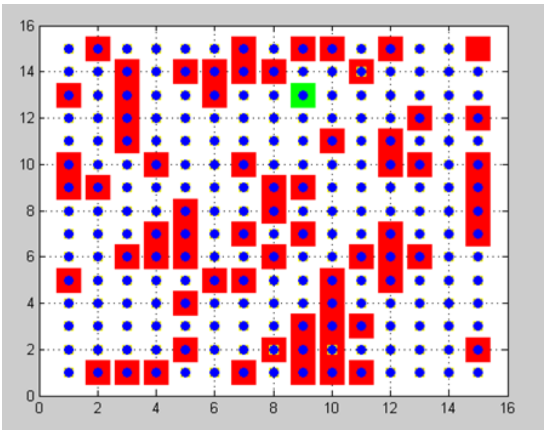

Fig. 2 exploration the environment 15*15

After that the robots calculate the (APF) and start to move to the goal. The simulation results shown in the figures, the green box and red box represent the goal and the obstacles position respectively, the red line represents the path of the robot to reach to the goal .Fig.3 to Fig.5 display the path of robot to reach the goal in different environments.

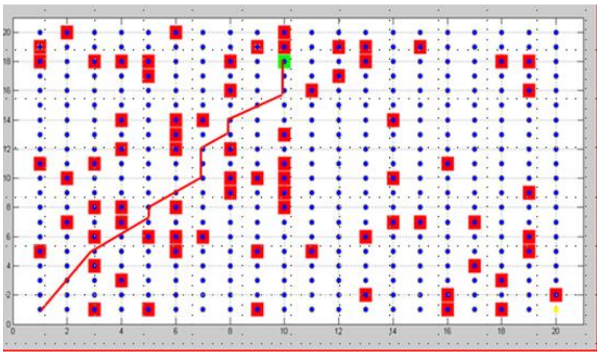

Fig. 3 displays path of robot in environment 20*20

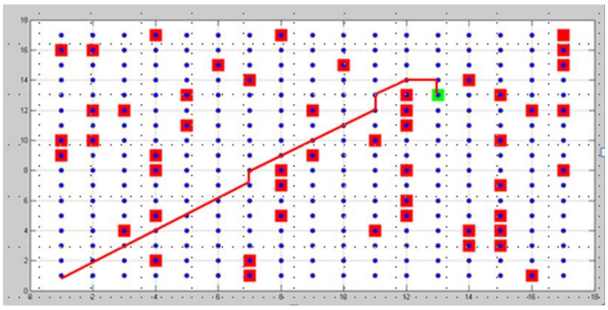

Fig. 4 displays path of robot in environment 18*18

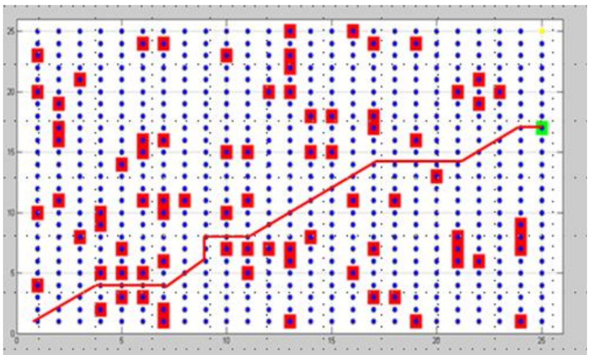

Fig. 5 displays path of robot in environment 25*25

Then we used three robots all of them are moving at the same time without collision between each other. Each robot must be reach to the goal in the environment. In Fig.6 black box represents the first robot, Purple box represents the second robot and Turquoise box represents the third robot.

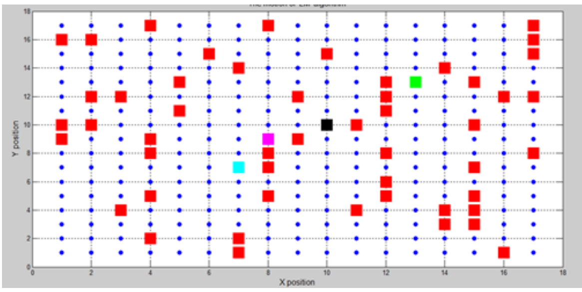

Fig. 6 movement of multi robot

TABLE I

THE RESULTS OF PROPOSED ALGORITHM

	Environment		
	18*18 No. obstacles :70	20*20 No. obstacles:78	25*25 No. obstacles:80
Time (s)	15.9125	17.6281	26.6541
Distance (m)	24	29	33

"Table I" represents the results for the proposed algorithm. We also compare the performance of the proposed algorithm and that of GA in [13].we use the same environment that they used with GA. From "Table II", we can see that the performance of the proposed work better than the GA in the time and distance.

TABLE II

COMPARISON BETWEEN THE PROPOSED ALGORITHM AND GA

		Distance (m)	Time (s)
The proposed algorithm	18*18 No. obstacles :78	16.7541	25
	25*25 No.obstacles:80	26.6541	33
	15*15 No. obstacles :70	13.9082	19
GA	Iteration 20	374.47	30.86
	Iteration 10	238.84	33.77
	Iteration 5	148.99	34.79
	Iteration 4	111.37	36.95

VI. CONCLUSION

Path planning problem is one of the most important robotic problems for mobile robot to accomplish given tasks. An improved artificial potential field ant colony optimization was proposed to obtain shortest path in less time without local minimum in unknown and static environment. Additional attractive force are utilized to eliminate local minimum caused by traditional APF when the composition of attractive force and repulsive force becomes zero. Exploration problem was solved by using the pheromone to determine the goal and obstacles position. This algorithm has been successfully applied through the MATLAB program without any problem. The paper tested the algorithm on a simple environments and complex environment. We use the environment with 3 robots, number of obstacles and one goal. The last work, the paper compares the performance of the proposed algorithm and that of GA. we see that the performance of the proposed work overmatches that of GA obviously as shown in "Table II".

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