Research on Unmanned Vehicle Path Planning based on Improved Artificial Potential Field Method

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Abstract: Path planning is one of the most important tasks in unmanned vehicle navigation system. Artificial potential field method has been widely used in real-time obstacle avoidance trajectory control due to its advantages of simple structure, less computation and strong robustness. However, it also has the problems of local minimum point and unreachable target. Aiming at this defect of artificial potential field method in unmanned vehicle path planning, the gravitational potential field function and repulsive potential field function were improved, and the effectiveness of the algorithm is verified by simulation experiments.

1 INTRODUCTION

Unmanned vehicle is of great significance in alleviating road congestion, reducing traffic accidents and reducing driver fatigue. In the unmanned vehicle system, path planning is the basis of intelligent vehicle navigation and control. For the problem of path planning, many algorithms are proposed, such as genetic algorithm, ant colony algorithm, particle swarm optimization, neural network algorithm and so on. These algorithms play a positive role in the research of path planning, but they also have arithmetic. The method is complex and computationally expensive, and it is inefficient for path planning (H. Liu, J. Mao 2013; L.Yin, Y. X. Yin, 2009; D. Q. Shi, E. G. Collins, D. Dunlap, 2008). The artificial potential field method has the advantages of simple structure, small calculation and easy control. Therefore, it has been widely used in real-time obstacle avoidance. However, the traditional artificial potential field method has the following shortcomings: 1) no path can be found between two obstacles close to each other; 2) there is oscillation problem in front of obstacles; 3) When there are obstacles near the target point, it can not reach the target point; 4) there is a local minimum (C. L. Liu, 2012; J. Y. Zhang, T. Liu, 2007; X. X. Liang, et.al, 2018; J. Y. Zhang, et.al, 2006).

Aiming at the problem of target unreachability and local minimum point in the path planning of unmanned vehicle, this paper studies it.

2 ARTIFICIAL POTENTIAL FIELD METHOD

Artificial potential field method (C. L. Liu, 2012) was proposed by Khatib in 1986. The basic idea is to regard the motion of the unmanned vehicle as a kind of motion in the virtual artificial force field. The target point produces gravitation to the unmanned vehicle, while the obstacle produces repulsion to the unmanned vehicle. The unmanned vehicle avoids the obstacle and moves to the target point under the combined force of gravitation and repulsion.

Note $U_{att}(x)$ as gravitational potential field function, the traditional function of it is usually taken as follows

$$U_{att}(x) = \frac{1}{2}\xi\rho^2(x, x_g) \tag{1}$$

In the formula, ξ represents the gravitational potential field coefficient, x represents the current position of the unmanned vehicle, x_g represents the

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position of the target point, and $\rho(x, x_g)$ represents the distance between the position of the unmanned vehicle and the position of the target point. From this function, it can be seen that the larger the distance between the unmanned vehicle and the target point, the stronger the gravitational potential field function and the greater the gravitation.

Note $U_{rep}(x)$ as repulsive potential field function, the traditional function of it is usually taken as follows:

$$U_{rep}(x) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho(x, x_o)} - \frac{1}{\rho_0}\right)^2, & \rho(x, x_o) < \rho_0 \\ 0, & \rho(x, x_o) \geq \rho_0 \end{cases} \quad (2)$$

In the formula, η represents the repulsive potential field coefficient, $\rho(x, x_o)$ represents the distance between the current position of the unmanned vehicle and the position of the obstacle, and ρ_0 represents the repulsive force acting distance of the obstacle. From this function, the smaller the distance between the unmanned vehicle and the obstacle, the stronger the repulsive potential field and the greater the repulsion.

Note $U(x)$ as the potential field of the position which the unmanned vehicle locates, it is taken as follows

$$U(x) = U_{att}(x) + U_{rep}(x)$$

Note $F_{att}(x), F_{rep}(x), F(x)$ as gravitation, repulsion and resultant force of the unmanned vehicle respectively.

$$F(x) = F_{att}(x) + F_{rep}(x) = -\nabla U_{att}(x) - \nabla U_{rep}(x)$$

The unmanned vehicle moves to the target point under the resultant force.

3 IMPROVEMENT OF ARTIFICIAL POTENTIAL FIELD METHOD

Aiming at the problems of the artificial potential field method in the path planning of unmanned vehicle, the algorithm is improved.

3.1 Target Unreachable Problem and Solution

If there are obstacles near the target point, the unmanned vehicle moves closer to the target point and closer to the obstacle at the same time. According to the definition of the gravitational potential field and the repulsive potential field function mentioned above, in the process of moving to the target point, the gravitation will be smaller and smaller, while the repulsion will be larger and larger. When the repulsion is greater than the gravitation, the unmanned vehicle will not continue to move towards the target point, which will lead to the problem of not reaching the target point. Therefore, the repulsive potential field function is improved by introducing the power of distance factor between unmanned vehicle and target point.

$$U_{rep}(x) = \begin{cases} \frac{\rho^2(x, x_g)}{2}\eta\left(\frac{1}{\rho(x, x_o)} - \frac{1}{\rho_0}\right)^2, & \rho(x, x_o) < \rho_0 \\ 0, & \rho(x, x_o) \geq \rho_0 \end{cases} \quad (3)$$

Formula (3) shows that the repulsion will be greatly reduced when the unmanned vehicle moves towards the target point, and the repulsive potential field will be the smallest at the target point. Thus, it is ensured that he local minimum point only toccurs at point x_g and the unreachable problem can be avoided.

3.2 Local Minimum Point Problem and Solutions

In the process of driving, when the gravitation and repulsion of the unmanned vehicle are the same and the direction is opposite, the resultant force of the unmanned vehicle is 0, and the unmanned vehicle cannot continue to move forward, thus causing the local minimum point problem.

In order to avoid this problem, when the unmanned vehicle enters the local minimum point, the direction of gravitational potential field can be changed artificially, so that the force at the point becomes unbalanced, so as to help the unmanned vehicle find the next moving point.

The gravitational potential field function is modified as follows

$$U_{att}(x) = \frac{1}{2}\xi\rho^2(x, x_g)\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \quad (4)$$

In the formula (4), the variable θ represents the angle of the change of the gravitational potential field direction.

Because of the random angle θ, the direction of the oscillating potential field can be selected randomly to ensure the operation of the oscillating potential field, so that the unmanned vehicle can jump out of the current point, and then the path planning is carried out according to the artificial potential field method function (1). If the unmanned vehicle falls into the local minimum state again, the gravitational potential field function is switched from function (1) to (4). Then it goes down in turn until the unmanned vehicle avoids all the local minimum points in the driving process and reaches the target point.

4 SIMULATION VERIFICATION

In order to verify the effectiveness of the improved artificial potential field method, the simulation experiment is carried out through software MATLAB. For the convenience of discussion, the size and shape of unmanned vehicles and obstacles are treated as a particle.

In the simulation, the starting point is (0, 0), (9.7, 9.7) is the target point. Obstacles are represented by small circles, target points are represented by triangles, the gain coefficients of gravitation and repulsion are 5 and 1 respectively, and the deviation angle is 30 degrees. The results of path planning are shown in the figure.

Aiming at the obstacles near the target point and the repulsion is greater than gravitation, the path planning curves of the traditional artificial potential field method and the improved artificial potential field method are given in Fig.1 and Fig.2 respectively. The simulation results show that the improved artificial potential field method can effectively avoid the problem that the unmanned vehicle cannot reach the target point.

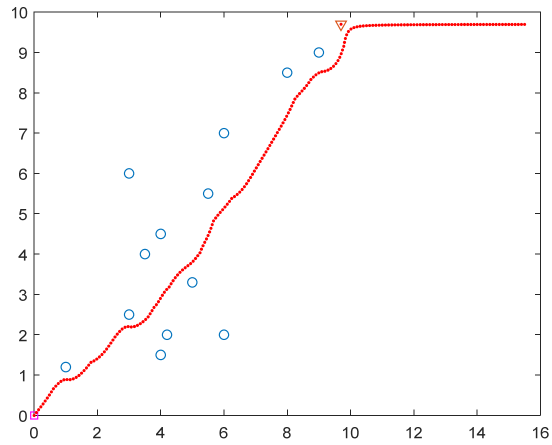

Figure 1. Traditional artificial potential field method.

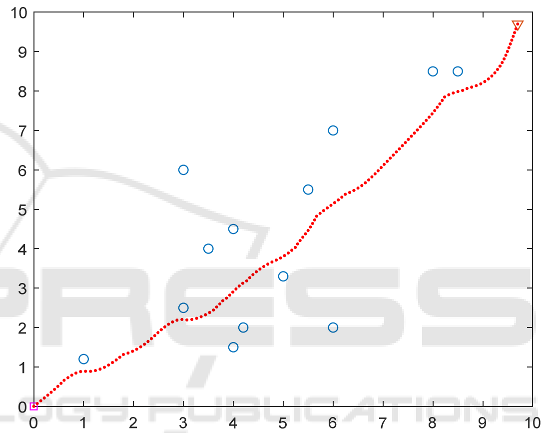

Figure 2. Improvement of artificial potential field method.

Aiming at the problem of local minimum, the path planning curves of traditional artificial potential field method and improved artificial potential field method are given in Fig.3 and Fig.4. The simulation results show that the improved artificial potential field method can effectively avoid the problem of local minimum.

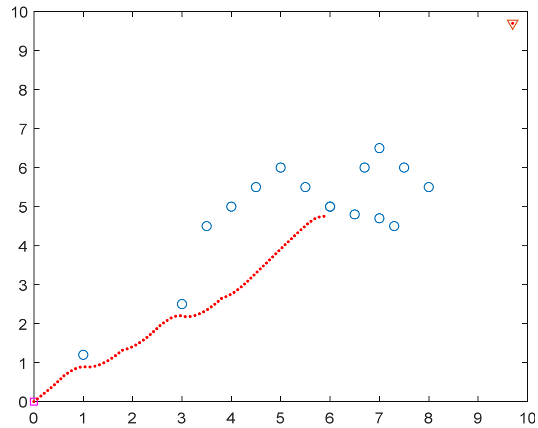

Figure 3. Traditional artificial potential field method.

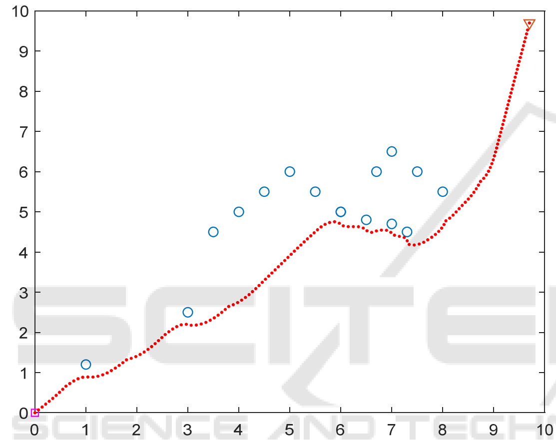

Figure 4. Improvement of artificial potential field method.

5 CONCLUSION

The artificial potential field method may cause local minimum and unreachable problems in path planning. To solve this problem, the gravitational potential field function and repulsive potential field function are improved. The feasibility of this method is verified by simulation. However, it does not consider whether the planned path is the optimal path and whether the planned path is smooth, etc. These problems need further study.

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