# Robot Motion Planning Based on Improved Artificial Potential Field

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***Abstract*—The path planning is one of the key technologies of mobile robot field, which is also the one of the key technologies of intelligent robotics. As the mobile robot path planning is one of the most important and basic problem, path planning of robot has solved the robot movement question in the environment. This paper studies the method of robot path planning-artificial potential field method, which is the most mature, the most stable. In the traditional research of the robot path planning, the target is stationary, but in this paper research object is the mobile robot. So the traditional artificial potential field method is not adapted to this paper. This paper puts forward an improved artificial potential field method based on the traditional artificial potential field method , which can make the robots avoid obstacles while locate and track dynamic target. Finally, the simulation experiment shows the effectiveness of the improved artificial potential field method.**

***Keywords- Mobile Robot, Artificial Potential Field, Robot Path Planning***

## I. INTRODUCTION

Artificial potential field method was firstly used in robot path planning in 1986[1].It was pointed out by Khatib, and it was a kind of virtual force method. Knatib made Operational Space Formulation as the theory basis, derived and extended by it, put forward the method of artificial potential field, established potential field function in the simple environment and expounded its concrete realization forms and application[2]. The basic thought of artificial potential field method is: Construct virtual gravitational field for target position and virtual repulsion field for obstacles. The gravitational pulls attract robot to move to the target, and repulsion field holds back robot to obstacles, so the robot moves to the target under the two forces[3].

## II. MODEL OF TRADITIONAL ARTIFICAIL POTENTIAL FIELD METHOD

To illustrate, in traditional artificial potential field method, this paper assumes that the robot is a particle, and the environment is a two-dimensional space. The current position of robot can be expressed as $q = [x, y]^T$, and target location can be expressed as $q_{goal} = [x_{goal}, y_{goal}]^T$.

Gravitational field function of traditional artificial potential field method of can be expressed as follows:

$$U_{att}(q) = \frac{1}{2}\xi\rho^m\left(q, q_{goal}\right) \tag{1}$$

$\xi$ is the direct proportion coefficient of the gravitational field, and $\rho\left(q, q_{goal}\right) = \left\|q - q_{goal}\right\|$ is the distance between the robot current position and target location, and $m = 1$ or 2. Gravity can be gained by the negative gradient, and it can be expressed as follows:

负梯度表示下降的方向
m=2时的结果

$$\vec{F}_{att(q)} = -\nabla U_{att}(q) = \xi\left(q - q_{goal}\right) \tag{2}$$

The value of this function will become smaller as the robot close to target point. When the robot reaches its destination, which gravity is zero, and the value of the function becomes 0.It is according with the actual situation. Repulsive force field function is expressed as follows:

$$U_{rep}(q) = \begin{cases} \frac{1}{2}\varepsilon\left[\frac{1}{\rho(q, q_{obs})} - \frac{1}{\rho_0}\right]^2, & if\ \rho(q, q_{obs}) \le \rho_0 \\ 0, & if\ \rho(q, q_{obs}) \le \rho_0 \end{cases} \tag{3}$$

$\varepsilon$ is direct proportion coefficient of the repulsive force field, and $\rho\left(q, q_{obs}\right)$ is minimum distance between current robot position and the surface of the obstacles. $q_{obs}$ is obstacles coordinate that is the shortest distance which is the surface of an obstruction to the robot ,and $\rho_0$ is distance which can be affected by repulsion of obstacles surface. And beyond the distance, the robot is not influenced by repulsion of the obstacles. This paper can be obtained corresponding repulsion field function by the negative gradient:

$$\vec{F}_{rep} = -\nabla_{rep}(q) = \begin{cases} \varepsilon\left(\frac{1}{\rho(q,q_{obs})} - \frac{1}{\rho_0}\right)\frac{1}{\rho^2(q,q_{obs})}, & if\ \rho(q,q_{obs}) \le \rho_0 \\ 0, & if\ \rho(q,q_{obs}) > \rho_0 \end{cases} \quad (4)$$

According to the principle of artificial potential field method, sum of the total force of gravity and repulsion of the robot is expressed as follows:

$$\overrightarrow{F_{sum}} = \overrightarrow{F_{att}} + \overrightarrow{F_{rep}} \quad (5)$$

## III. New Gravitational Field Function Based on Dynamic Target

In traditional artificial potential field method, the target is static, but in this paper prey (namely target) is dynamic, so the traditional artificial potential field of gravitational field function is not suitable for this discussion. So this paper puts forward a new gravitational field function based on target is dynamic.

In dynamic environment, the problem of mobile robot path planning is to plan and control the robot in an ideal way to track the target from initial points, and avoid obstacles while moving. In order to simplify the analysis, this paper does the following assumption:

Assumption 1: robot is a particle, and its position $q$ and velocity $v$ are known;

Assumption 2: target robot's position $q_{tar}$ and velocity $v_{tar}$ are known, and $|v_{tar}| < v_{max}$.

Usually, the gravitational field is defined a function that is only related the distance between robot and target, and target is defined a fixed particle in the space. But when the target is moving, the traditional potential field function cannot be used in the situation. It needs to define a new gravitational field function to suit the situation.

$$U_{att(q,v)} = \alpha_q \left\| q_{tar}(t) - q(t) \right\|^m + \alpha_v \left\| v_{tar}(t) - v(t) \right\|^n \quad (6)$$

Among (6), $q(t)$ and $q_{tar}(t)$ correspond with the position of capture robots and moving target robot, $v(t)$ and $v_{tar}(t)$ are velocity vector of capture robots and moving target robot in the time of $t$. $\|q_{tar}(t) - q(t)\|$ is Euclid distance of capture robots and the moving target robot in the time of $t$. $\|v_{tar}(t) - v(t)\|$ is relative value speed of capture robots and the moving target robot in the time of $t$. $\alpha_q$ and $\alpha_v$ are direct proportion coefficient, and $m$ and $n$ are positive constant.

From the formula (6), it can been seen that gravitational field function $U_{att}(q,v)$ becomes 0, if and only if the relative distance and velocity between capture robots and target robot both equal to the minimum value, namely 0. With relative distance or relative speed between robots and the target robot increasing, the gravitational function $U_{att}(q,v)$ increases.

If $\alpha_v = 0$, $m = 2$, new gravitational field function will degenerate into the form of quadratic of traditional gravitational field function :

$$U_{att}(q, v) = U_{att}(q) = \alpha_p \left\| q_{tar}(t) - q(t) \right\|^2 \quad (7)$$

Formula (7) does not include information of the relative speed of the robot and target robot. Accordingly, the gravitational pull of traditional gravitational field function is only defined as relative to the position of negative gradient direction, and is irrelevant with relative speed of the robots and target robot.

$$F_{att}(q) = -\nabla U_{att}(q) = -\frac{\partial U_{att}(q)}{\partial q} \quad (8)$$

New gravitational field function is a function related to the position and speed. Therefore, corresponding gravity should be defined negative gradient direction that is related to position and speed:

$$\overrightarrow{F_{att}}(q,v) = -\nabla U_{att}(q,v) = -\nabla_q U_{att}(q,v) - \nabla U_{att}(q,v) \quad (9)$$

Among them:

$$\nabla_p U_{att}(q,v) = \frac{\partial U_{att}(q,v)}{\partial q} \quad (10)$$

$$\nabla_v U_{att}(q,v) = \frac{\partial U_{att}(q,v)}{\partial v} \quad (11)$$

The value of $m$ and $n$ are significant to the new gravitational field function in formula (6), and different selection has different effects to the gravitational function, so we must choose reasonable values of $m$ and $n$ .This paper discusses the parameters selection as follows.

When $0 < m < 1, q = q_{tar}$, gravitational field function $U_{att}(q, v)$ cannot differential; when $0 < n \le 1$, $v = v_{tar}$, gravitational field function $U_{att}(q, v)$ cannot differential. In the construction of gravitational field function of the moving target, we can make application divided into two kinds, one kind can be called "soft capture", and the other is called "hard capture”.”Soft capture" is that the robot arrives the given location and the speed rate of robot becomes same as the target. "Hard stalking" is that the robot considers how to reach the target only moving ( $q = q_{tar}$ ) without considering relative speed.

When $q \neq q_{tar}$, $v \neq v_{tar}$, make formula (6) into the formula (9), may have:

$$F_{att}(q,v) = F_{att1}(q) + F_{att2}(v) \tag{12}$$

Among them:

$$F_{att1}(q) = m\alpha_q \left\| q_{tar}(t) - q(t) \right\|^{m-1} n_{RT} \tag{13}$$

$$F_{att2}(v) = n\alpha_v \left\| v_{tar}(t) - v(t) \right\|^{n-1} n_{VRT} \tag{14}$$

$n_{RT}$ is unit vector that is from the robot to target robot, and $n_{VRT}$ is unit vector of relative speed to capture robots and the target robot. The gravity of the gravitational field and the relationship of the position and velocity of the robots and the target are shown as figure 1. Gravity $F_{att}$ consists of two components: the first component $F_{att1}(q)$ attracts robot to move to the target, and shorten the distance between target and robot; the second component $F_{att2}(v)$ pulls robot to move at the same rate.

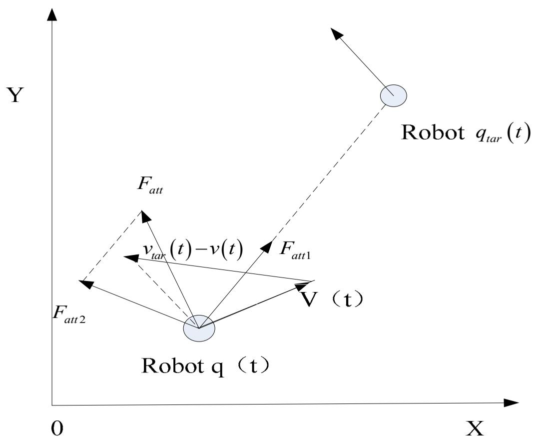


Fig. 1. Gravity of new gravitational field in 2d space

From the formula (8) and formula (9) can be seen, when the robot close to the target, $\left\| q_{tar}(t) - q(t) \right\|$ is also close to zero, namely $F_{att1}(q)$ is close to zero; when speed of robot close to target, $F_{att2}(v)$ is close to zero. When capture robot catch target, the robot moves at the same rate, and gravity of gravitational field is zero, so capture robots can move with the target robot. For "soft stalking" problem choice of $m$ and $n$ is essential. There are no such constraints in "hard stalking”.

## IV. Improved Type Artificially Potential Field Method Simulation Experiment

In order to validate effectiveness of improved type artificially potential field method, this paper uses the Visual C++ 6.0 and Matlab7.1 to make simulation experiment. There are many obstacles existing in the simulation environment, obstacles are given by artificial setting. Through set starting point of capture robot (green dot) and dynamic target (black dot) and the trajectory, we can verify the feasibility of algorithm. In the simulations, the robot is circular omni-directional mobile robots, and cycle of investigation of robot is greater than sport cycle. Robot relies on its own sensor to detect environmental only, and its detection range is five times as the robot radius. Single robot avoiding obstacles to capture mobile target in a given environment are shown as follows.

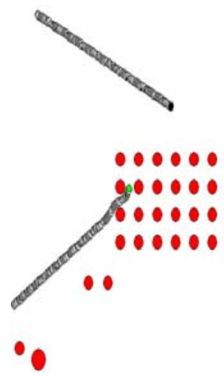

Fig. 2. The Capture Robot Passes through Obstacles

Robot (green dot) starts from the initial point (artificial), avoiding obstacles, movine to the target robot (black dot) under comprehensive force of the improved artificial potential field method.

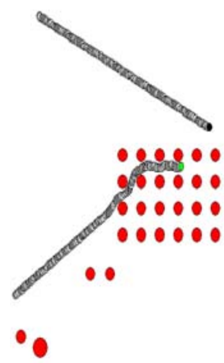

Fig. 3. Detect the Intrusion Robot

Robot found target robot.Because this paper introduce velocity vector to new gravitational field of the improved artificial potential field method, the new gravity produced by the gravitational field guides robot to track a moving target robot.

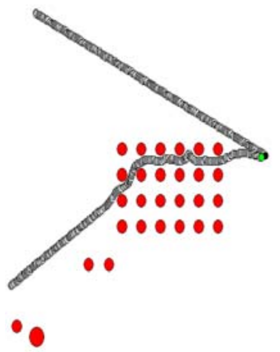

Fig. 4. Capture Robot Catches the Intrusion Robot

With closing target robot, repulsion and gravity are decreasing. When the robot captures the target robot, the resultant force is zero. And the robot rounds up moving target robot successfully.

## V. CONCLUSION

This paper researches for robot path planning, and studies the artificial potential field method which is more mature. Because of the traditional artificial potential field method cannot adapt to dynamic environment, this paper puts forward an improved artificial potential field method, which introduces velocity vector to artificial potential field method. And the improved artificial potential method can make accurately locate and track dynamic target. Finally, through the simulation experiments, this paper proves that the improved artificial potential field method can effectively guide robot to avoid obstacles and reach the target location, and achieved good control effect.

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