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Path Planning for Robot based on Chaotic Artificial Potential Field Method

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Abstract. Robot path planning in unknown environments is one of the hot research topics in the field of robot control. Aiming at the shortcomings of traditional artificial potential field methods, we propose a new path planning for Robot based on chaotic artificial potential field method. The path planning adopts the potential function as the objective function and introduces the robot direction of movement as the control variables, which combines the improved artificial potential field method with chaotic optimization algorithm. Simulations have been carried out and the results demonstrate that the superior practicality and high efficiency of the proposed method.

1. Introduction

The path planning for Robot under unknown environments is referred to search an optimal or sub-optimal path which is a safe collision-free path from the starting point to the objective point [1]. It generally falls into global planning and local planning [2]. The global planning includes: visibility graphic method, tangent graphic method, penalty function method and enumeration algorithm etc [3]. The local planning mainly includes: artificial potential field method, fuzzy logical method, genetic algorithm, simulated annealing algorithm and ant colony optimization etc [4]. The artificial potential field method is frequently used in local path planner. It has the advantages of simple structure, less computation and good capabilities of obstacle avoidance except for local optimum and shaking before obstacles etc. Aiming at the above, combining improved artificial potential method with chaotic optimization algorithm, the path planning for robot based on chaotic artificial potential field method is presented. It effectively solves the path planning for robot under unknown environments.

2. Improved artificial potential method

Artificial potential field method is frequently used in local path planner, the principle of which is that robot is regarded as the particle in Virtual Force Field and its movement controlled by resultant forces which is composed of repulsive force from obstacles and attractive force from the objective point. The path generated by the artificial potential field method is generally smooth and safe [5], but this method has local optimum etc.

2.1. Repulsive force potential function.

The repulsive force from obstacles acts on robot in virtual force field. Potential function used in the algorithm is shown as (1):

$$U_{rep}(x)=\begin{cases}0.5\eta\left[\dfrac{1}{\rho(x,x_0)}-\dfrac{1}{\rho_0}\right]^2\rho^2(x,x_g) & \rho(x,x_0)\le\rho_0\\ 0 & \rho(x,x_0)>\rho_0\end{cases} \quad (1)$$

In (1), η is repulsive force coefficient; $\rho(x,x_0)$ is the shortest distance between robot and obstacles; $\rho(x,x_g)$ is relative distance between robot and the objective point; ρ_0 is the constant, within ρ_0 the repulsive force from obstacles acts on robot but no repulsive force beyond ρ_0. The repulsive force is negative gradient of its potential function accordingly as shown in (2):

$$F_{rep}=\begin{cases}F_{rep1}+F_{rep2} & \rho(x,x_0)\le\rho_0\\ 0 & \rho(x,x_0)>\rho_0\end{cases} \quad (2)$$

$$\left\|F_{rep1}\right\|=\eta\left[\frac{1}{\rho(x,x_0)}-\frac{1}{\rho_0}\right]\left[\frac{\rho^2(x,x_g)}{\rho^2(x,x_0)}\right] \quad (3)$$

$$\left\|F_{rep2}\right\|=\eta\left[\frac{1}{\rho(x,x_0)}-\frac{1}{\rho_0}\right]^2\rho(x,x_g) \quad (4)$$

In 2, F_{rep1} and F_{rep2} stand for two components forces of F_{rep}, The direction of $F\ rep1$ is pointing from the obstacles to robot and the direction of $F\ rep2$ is pointing from robot to the objective point.

2.2. Attractive force potential function

The attractive force from the object point acts on robot in potential field. Potential function being used in the algorithm is shown (5):

$$U_{att}(x)=0.5\kappa\rho^2(x,x_g) \quad (5)$$

In (5), κ is attractive force coefficient; $\rho(x,x_g)$ is relative distance between robot and the object point. Attractive force is negative gradient of its potential function, the direction of which is pointing at the object point with corresponding attractive force as shown in (6):

$$F_{att}=-\kappa\rho(x,x_g) \quad (6)$$

In conclusion, the resultant force is shown as (7):

$$F=F_{rep}+F_{att} \quad (7)$$

2.3 Variable repulsive force coefficient

Because traditional artificial potential field method is that all obstacles has the same repulsive effect, η of all obstacles is the same. According to the rule of the movement for robot, obstacles in the direction of movement have greater repulsive force than ones in the other direction. The idea is introduced to artificial potential field method and η is redefined as shown in (8):

$$\eta_V=\eta|\sin\beta\sin\alpha+\cos\beta\cos\alpha| \quad (8)$$

In (8), α is the direction angle (that is the angle between the direction of movement for robot and Y axis) and β is the direction angle of obstacles (that is the angle between position of obstacles and Y axis) and η is the constant repulsive force coefficient. The variable repulsive force coefficient is introduced and the (9) is shown.

$$F_{rep}=\eta_V F_{rep}/\ \eta \quad (9)$$

Computing the repulsive force by using the above method can weaken repulsive forces of obstacles for robot except for directions of movement and reduce shaking in the process of movement.

3. Chaotic artificial potential field method

Chaos is a universal phenomenon in nonlinear system. Chaos phenomenon has stochastic property, ergodicity and regularity. In the optimization area, the ergodic property can be used as an optimization mechanism to escape from local optimums[6]. Chaos has been a kind of novel global optimization technique. People pay much attention to the research of the optimization method based on the chaotic search [7]. By improving the method or combining it with other methods, such as simulated annedling, genetic algorithm, artificial potential field method. The optimization performance has been improved greatly.

When chaotic optimization algorithm is chosen, dynamical systems that generate chaotic variables should be first selected, the following Logistic system is frequently used in all kinds of established system [8].

$$X_{n+1} = \mu X_n(1 - X_n) \tag{10}$$

In (10), μ is control parameter ($0 \leq \mu \leq 4$, $X \in [0,1]$). When μ goes to 4, the system is in chaos state. The ergodic property can be used to escape from local optimums.

Based on a research of artificial potential field method and chaotic optimization algorithm, chaotic optimization algorithm is applied to improved artificial potential field method and the path planning for Robot based on chaotic artificial potential field method is proposed. Potential function is the objective function and control parameter is the direction of movement for robot in the algorithm. Based on the path planning of chaotic artificial potential field method, chaotic optimization algorithm is applied to compute the direction of next step for robot and decides next sub-target point and so on. The path planning for local optimums is implemented in real time.

4. Simulation experiment

Simulation environments is the grid map generated by simulation soft with the measurements of 30 by 20. In the figure S point is the starting point and G point is the objective point. Black grids are obstacles and these are the regions where robot can't pass through. Robot can pass in white grid regions. Simulation experiment parameter is shown as follows: ρ_0 is 15, K is 2 and η is 10. The step size is 1 for robot. The simulation results are shown from figure 1 to figure 3.

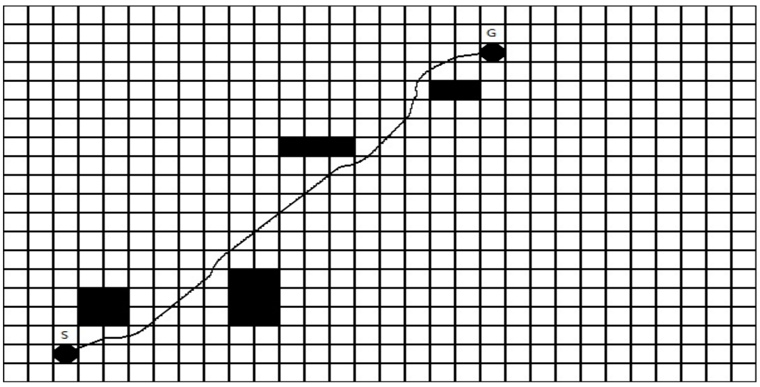

Figure 1. Conditions with approaching to the starting point and objective point for obstacles.

When obstacle is adjacent to the starting and objective point, the algorithm is applied on the path planning for robot to avoid the obstacles in figure 1. The robot can well avoid the obstacle and no shaking when the obstacle is close to the starting point. There are no conditions that t obstacles push away the robot that can't get to the objective point when it is close to the objective one. The algorithm has good ability of obstacles avoidance for other obstacles.

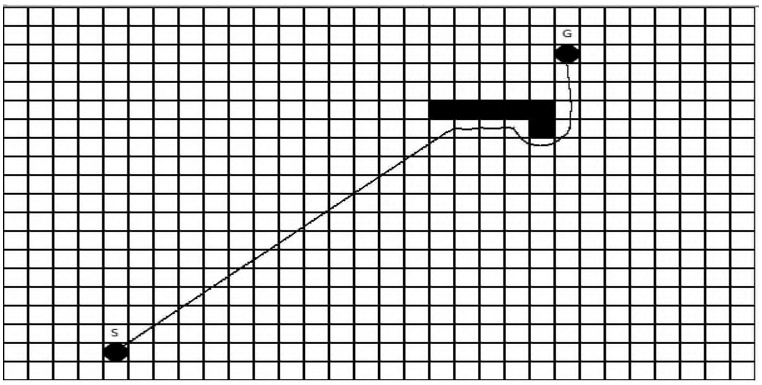

Figure 2. Condition with local optimums

The algorithm is applied on the path planning for robot to avoid the obstacles when there are easily local minimums in condition with the concave-shaped obstacles in figure 2. The robot can avoid well the obstacles, no shaking and no unattainable targets. Local optimums in traditional artificial potential field method are solved in the algorithm.

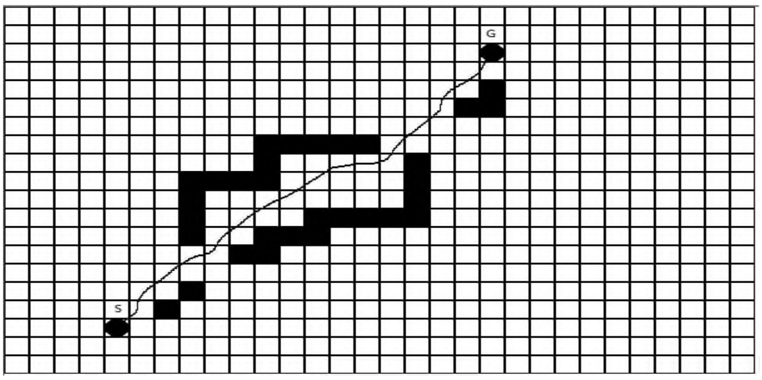

Figure 3. Conditions with one or more closer obstacles.

In figure 3 the algorithm is applied on the path planning for robot to avoid the obstacles in conditions with one or more closer obstacles. The robot doesn't bypass the obstacles but to pass between them. The problem that robot can't find the path in condition with near the obstacles in traditional artificial potential field method are solved in the algorithm.

5. Conclusions

Combining the improved artificial potential field method with chaotic optimization algorithm, the path planning for Robot based on chaotic artificial potential field method is proposed in this paper. The best path planned by the algorithm is more real and more effective obstacles avoidance under unknown environment. According to the simulations results, local optimums in traditional artificial potential field method are solved in the algorithm. Robot can find the path to avoid the obstacles between the closer obstacles and the path is more smooth and practical.

References

[1] Shi C and Sun H 2005 *Robot* **27** 152.
[2] Latombe JC 1991 *Robot Motion Planning* (Boston: Kluwer Academic).
[3] Ouyang Y X and Yang S G 2014 *Control Engineering of China* **21** 134.
[4] Ge S S and Cui Y J 2000 *IEEE. Trans. Rob. Autom* **5** 615.
[5] Hu Y and Zhang Q 2012 *Adv. Mater. Res.* **562** 937.
[6] Strogatz S H 2001 *Nolin. Dyn. Chaos* (Boulder: Westview).
[7] Li B and Jiang W 1997 *Contr. Theor. Appl.* **14** 613.
[8] Jovanovic V 2000 *Int. J. Numer. Mesh. Engng* **48** 137.