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An Obstacle Avoidance Method of Soccer Robot Based on Evolutionary Artificial Potential Field

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Abstract

In order to solve the problems that local minimum, path planning in obstacles, and optimizing global obstacle avoidance path, the paper proposed a new obstacle avoidance method. In this method, used the grid method to describe the information of obstacles environment, utilized the evolutionary artificial potential field method to optimize obstacle avoidance path. The simulation results show that the proposed method is feasible and effective.

Keywords: artificial potential field; obstacle avoidance path; soccer robot; genetic algorithm

1. Introduction

Soccer robot obstacle avoidance is searching out a path from starting point to target point among the obstacles in the game environment, and the path must be no collision and optimization. As the game environment is complex, real-time and uncertain, obstacle avoidance problem has become a key of soccer robot in obstacle avoidance path planning.

There are many ways to solve the obstacle avoidance problem of robot soccer; the most commonly used are artificial potential field method [1], grid method [2], genetic algorithm [3], fuzzy methods [4],

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neural network [5], ant swarm algorithm [6] and so on. However, these methods are not perfect that every method has its own advantages and inevitable shortcomings. Among them, the artificial potential field method facilitates real-time control in action layer. Because it is simple and intuitionistic, uses little computation and small data storage space for planning obstacle avoidance paths and the path is smooth and secure. So the artificial potential field has been widely used. Then the artificial potential field method is a local planning method, difficult to plan the global optimal path. Algorithm itself also couldn't solve all local minimum problems. When the obstacle is very close to the target point or the robot on the line between target point and the obstacles, the robot will oscillate in front of the obstacle or be pushed by repulsion. This paper proposed a method used grid method to establish the model and generated an obstacle avoidance path, then optimized line segment path with evolved APF method by genetic algorithm, successfully resolved the problems. Simulation results show the effectiveness of the new method.

2. The traditional artificial potential field

Artificial potential field method was proposed in 1986 by Dr. Khatib, and this method is first used in obstacle avoidance path planning for manipulators, and realized the real time obstacle avoidance. The main idea of APF method is establish attractive force potential field around target point and establish repulsive potential field around obstacles. The two potential fields together formed a new potential field, called artificial potential field. It searches the falling direction of potential function to find a collision-free path which is built from the start point to target point. In the soccer robot game field, two virtual forces are attractive force and repulsive force. The attractive force is generated by target and the repulsive forces are generated by obstacles. The composition of forces makes the robot bypass the obstacles, move to target point.

3. Establish the global path model

Grids method is more widely used in path planning. It divided environment space into several simple areas, called grids. Many scholars use this method to establish environment space model and to solve problems of global path planning, have achieved good research results. Then the potential field is the local path planning method, lack in ability of planning longer path or planning path in multi-obstacle environment. Therefore, the characteristics of grid method that model established simply, many kinds of algorithms can be used to search path and good adaptability for the genetic algorithm and the artificial potential field method have been used in this paper. And using grid method to generate global path, then cutting the path into C section, C pairs of new starting point and new target point appears.

The path planned by grid method is connecting all free grids from the starting point to target point in which one grid corresponds to one node. So the process of connecting free grids should be the process of connecting all nodes from starting point to target point, as shown in Fig. 1. In this paper, the node which had different slope is defined as turning point. The formula for turning point coordinates as follow:

$$tp_i(x,y)\ ,\quad (i=0,1,\cdots,n) \tag{1}$$

In which i is the number of turning points. If i is odd, the section number $C=\frac{i+1}{2}$,else if i is even, $C=\frac{i}{2}+1$. Now the entire path $L=L_1+L_2+\cdots+L_c$ .This path is composed by connecting the original starting point, the original target point and all the even number of turning points, as shown in Fig. 2.

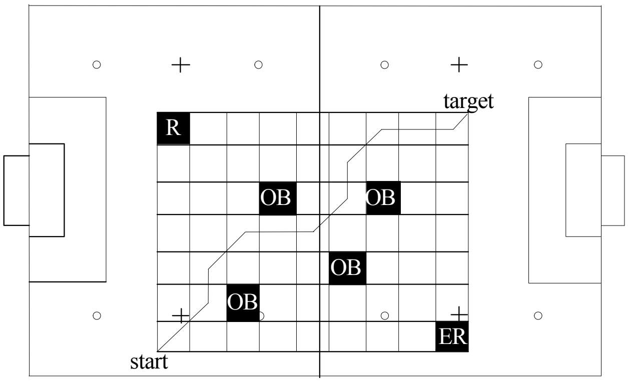

Figure 1: One of global path planned by grid method

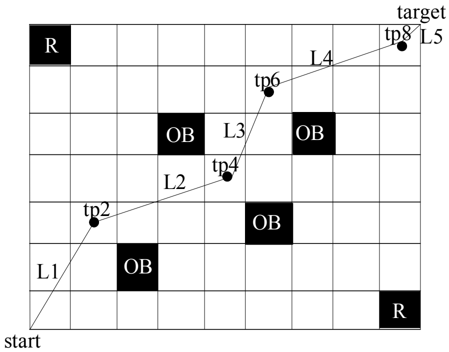

Figure 2: A new global path planned by proved method

4. Using EAPF Method Planning Obstacle Avoidance Path

Grid method can produce many of obstacle avoidance paths from the original starting point to the original target .But only one is the best, most suitable for the robot movement. This paper uses the EAPF method to search the optimal path, realize the obstacle avoidance in global path.

4.1 Design potential function and make its parameters adjustable

Many different potential functions had been described in references [9]. Now the paper presents a common potential field function which is Proportional to distance [10]. In the artificial potential field, the target point attracts the robot and the robot is pushed by repulsion of obstacle. The greater the distance between robot and target point, the larger attraction force, whereas smaller. The smaller distance between robot and obstacles, the greater the repulsion force, whereas larger. Thus, the attractive potential energy is similar with the elastic potential energy, proportional to square of the distance. Repulsive potential energy and electric potential field is very similar, inversely proportional to distance. So attraction function and repulsion function can be written as:

Attraction function：

$$F_{att}(p) = K_a(D_{rt} - R_{rt}) \tag{3}$$

Repulsion function：

$$F_{rep}(p) = \begin{cases} \frac{K_r}{(D_{ro} - R_{ro})^2} - \frac{K_r}{A}, & (D_{ro} \le \rho_m) \\ 0, & (D_{ro} > \rho_m) \end{cases} \tag{4}$$

In which, D_{rt} is the distance between robot and target, R_{rt} is the summation of robot radius and target radius; D_{ro} is the distance between robot and obstacle, R_{ro} is the summation of robot radius and obstacle radius; $A = (\rho_m - R_{ro})^2$, ρ_m is the maximum distance of repulsion. Since ρ_m and R_{ro} are computed before planning, so A is a constant.

Therefore, the formula of the APT composition forces can be written as:

$$F = F_{att}(p) + \sum F_{rep}(p) \tag{5}$$

Obviously, the formula of the potential function included only two adjustable parameters: K_a and K_r .

4.2 Select fitness function of genetic algorithm

It is important to select fitness function when using genetic algorithm to evolve the parameters: K_a and K_r . It affects not only the optimality of obstacle avoidance path, but also affects convergence and stability of the genetic algorithm. So, when selecting fitness function three important factors should be considered. The first is the ability to avoid obstacles. The second is whether the path is the shortest. The third is the path's smoothness. According to these factors, this paper selected the obstacle distance factor, the shortest path factor and the turning factor to design the fitness function.

1) Obstacle distance factor:

$$Fit_{ob}(m) = \sum_{j=1}^{s}\sum_{k=1}^{t} \frac{D_{ob}(m)_{j,k}}{D_{rt}} \tag{6}$$

In which, $Fit_{ob}(m)$ represent the fitness function of the obstacle avoidance path k . $D_{ob}(m)_{j,k}$ represents the distance between turning point j and obstacle k in path m . D_{rt} represents distance between robot and target point. s is the number of turning points. t is the number of obstacle.

In formula (6), the farther distance between robot and obstacle the better fitness.

2) The shortest path factor:

$$Fit_{dis}(m) = \sum_{j=1}^{s-1} \frac{D_{rg}}{D_{dis}(m)_{j,j+1}} \tag{7}$$

In which, $Fit_{dis}(m)$ represents the fitness function, is the sum of distance between all adjacent turning points. $D_{dis}(m)_{j,j+1}$ represents distance between turning point j and the next turning point.

In formula (7), the shorter distance between adjacent turning points the better fitness.

3) Turning angle factor:

$$Fit_{ang}(m) = \sum_{j=1}^{s-1} \frac{1}{angle(m)_{j,j+1}} \tag{8}$$

In which, Fit_{ang} represents the fitness function, is in the sum of turning angles. $angle(m)_{j,j+1}$ represents the angle of turning point j to next turning point.

In formula (8), the smaller angle between adjacent turning points the better fitness.

In summary, the entire fitness function can be written as follow:

$$Fit_0(m) = a \times Fit_{ob}(m) + b \times Fit_{dis}(m) + c \times Fit_{ang}(m) \tag{9}$$

4.3 Evolve the APF parameters by genetic algorithm

Using genetic algorithm to optimize APF parameters K_a and K_r . Chromosome is represented with real numbers.

1) Selection: with roulette wheel selection to select the individuals from the parent generate a new generation of individuals. And copy down the best individual each generation at the same time.

2) Crossover: individuals of new generation mush be paired, and be crossed at the random cross-point Do it this way can produce A pair of new individuals. The cross's probability is P_c . (In this paper, the Value is 0.7);

3) Mutation: each individual of the species would be mutated in accordance with the mutation probability P_m (common value is between 0.01-0.03) within a given range of random variation.

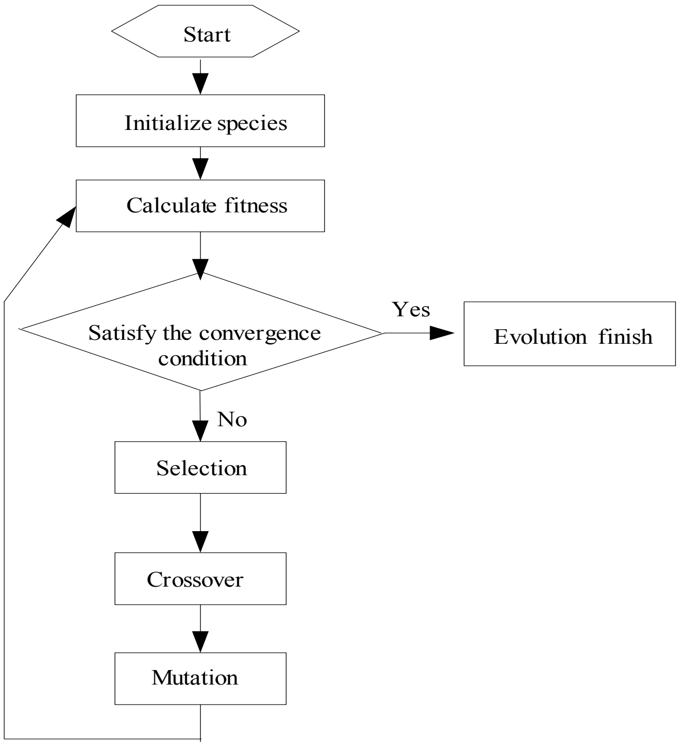

Figure 3: Flow chart of genetic algorithm

According to the response time of platform and game experiences to choose iteration times and values range of each parameter, this paper set a maximum iteration times as the end of condition. The algorithm would be stopped when iteration time is equal to the maximum value.

5. Simulation experiments

Aimed the problem the traditional potential field, such as planning global path difficultly, local minimum, and poor adaptability in more obstacles environment, this paper carried out simulation with the improved method. The simulation result as shown in Fig.4 and Fig.5.

Figure 4: Planning path in more obstacles environment

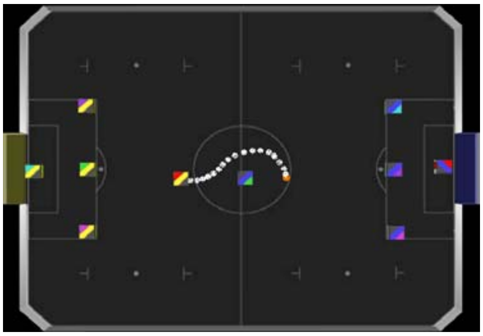

Figure 5: Planning path avoid falling local minimum

6. Conclusion

This paper took MiroSot game system as an research object, want to search for a method which can combine the advantages of several most widely used methods, also can make up for shortcomings of the algorithms. And using the new method, planned an optimal obstacle avoidance path. MiroSot game environment is moderate, Suit grid method to establish model. Therefore, this method using grid model, and then use genetic algorithm to optimize the parameters of the APF function, and finally, use EAPF method to plan obstacle avoidance path.

The simulation results show that the improved APF method is a good solution, had solved the local minimum problem. in obstacles environment, also can plan a smooth global obstacle avoidance path.

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