Path Planning of Mobile Robot Based on Bacterial Foraging Algorithm and Artificial Potential Field Method

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Abstract. Based on the artificial potential field algorithm and bacterial foraging algorithm, research method for obstacle avoidance and path planning of the mobile robot. Firstly, analysis method of bacterial foraging three operations: trends, replication, migration, establishment of bacterial foraging algorithm process; secondly establish the bacterial foraging algorithm model; and then analyze the artificial potential field algorithm and bacterial foraging the advantage and disadvantage of the algorithm, proposed a new hybrid algorithm has the global search ability and fast convergence. Using artificial potential field and bacterial foraging method on mobile robot global path planning and then compared with the mixture algorithm, based on the simulation results, the global path planning of mobile robot Simulation results show the feasibility and effectiveness of the hybrid algorithm.

Introduction
Path planning of mobile robot in unknown environment is unknown given the robot initial position and target location, according to the strategy in which the robot does not collide obstacles under the condition of the shortest time to reach the target position. According to the environment information can be a local path planning for robot path planning division of environmental information known to the global path planning and the environment the local information is unknown or known [1]. This is the path planning of mobile robot based on improved genetic algorithm, simulated annealing algorithm with random moving rule set update function of temperature, speed up the convergence rate. But the algorithm does not consider the obstacle avoidance in dynamic environment. Literature [2] proposed a global path planning method for mobile robot based on particle swarm optimization. This method is simple, the algorithm complexity is low, but it is easy to appear the phenomenon of ion degradation, which will fall into the local optimal value.

Aiming at the defects in the current path planning algorithm in the dynamic environment of existence, put forward a kind of artificial potential field and bacterial foraging algorithm of path planning algorithm based on artificial potential field method. The advantages are less calculation, good real-time performance, simple structure, easy to fall into local optimal solution but the deadlock phenomenon. The bacterial foraging algorithm in bacteria with a certain probability to migrate to new regions of the space, the search direction will be random transform, which can improve the global search ability of bacteria. In this paper using the bacterial foraging method of global path planning in static obstacles in the environment of the robot; at the same time, the use of artificial potential field method of dynamic environment in the avoidance of the robot Local path planning is carried out, and the algorithm is used to find the optimal path of the robot obstacle avoidance.

Bacterial Foraging Algorithm (BFO)

Basic Principles Of BFO
BFO is based on swarm optimization model of intelligent performance of Escherichia coli in the feeding process is put forward, as a result of the group search strategy based on, through cooperation...
and competition among individuals to achieve optimization, so to improve the parallel processing ability of the BFO algorithm, to enhance the search efficiency. In the BFO algorithm, the model will be the first encoding optimization problem, and defines the result for the optimization problem (fitness function) the corresponding search bacteria in state space (energy). The solving process for specific problems as follows: the initial solution group, plan evaluation function value, using iterative optimization the influence and interaction mechanism of the group, through the cycle of chemotaxis, migration and reproduction, the three major operators to obtain optimal or near optimal solutions, bacteria first gravitaxis to another state of motion; and then use the copy operation to the survival of the fittest; finally the migration operation after iterative calculation, and ultimately achieve After moving the target to find the optimal solution.

Basic Operation Of BFO

Directional Operation

In biology, the movement of bacteria in the move to the target or avoid harmful substances is called chemotactic behavior. Chemotaxis of bacteria contain two kinds of forms: walk and walk. The rotation is when the bacteria have relatively good environment (such as accessibility) is along the last time the direction to move forward; rotation is when the bacteria encounter bad environment in search of food in the process (for example, encounter many complex obstacles and random selection) is rotating in a new direction, through the exchange of the above two kinds of movement, and ultimately avoid obstacles in the process of walking to reach the target. Chemotactic operation can guarantee the bacteria in the whole solution To search the solution space, bacteria first selects a random direction, and then go to a free unit step, the calculation of the new position of fitness, if the fitness value is greater than the preset value, along the direction to walk forward, if less than a preset value need to choose a direction of rotation. Bacteria tend to operation according to the formula (1) to replace the new position:

\[ P(i, j+1, k, l) = P(i, j, k, l) + C(i)\phi(i) \]  

\[ \phi(i) = \frac{\Delta(i)}{\sqrt{\Delta^2(i)\Delta(i)}} \]  

Among them: \( P(i, j, k, l) \) represents the bacterial \( i \) in the first \( j \) directional operation, the first \( k \) copy operation and the \( l \) migration operation after the new node location. \( C(i) \) represents a unit step in which a bacterium performs a directional operation; \( \theta(i) \) indicates that the bacteria are rotated to adjust the selected unit step vector. \( \Delta(i) \) is Random vector.

If the fitness value of the rotation is improved, the travel is carried out in the direction of rotation until the fitness value is not improved or the preset maximum number of movement steps \( N_s \) is reached.

The fitness based on the bacterial induction mechanism \( J_{cc} \) is expressed as follows:

\[ J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{S} J_{cin}^{i}(\theta, \theta^{i}(j,k,l)) \]

\[ = \sum_{i=1}^{S} [-d_{attract}\exp(-\omega_{attract} \sum_{m=1}^{D} (\theta_{m} - \theta^{i}_{m})^2)] + \sum_{i=1}^{S} [h_{repellant}\exp(-\omega_{repellant} \sum_{m=1}^{D} (\theta_{m} - \theta^{i}_{m})^2)] \]  

Among them: \( P(j,k,l) = \{\theta^{i}(j,k,l)|i = 1,2,\cdots,S\} \) is Bacterial flora, \( d_{attract} \) is Gravitational depth, \( \omega_{attract} \) is Gravitational width, \( h_{repellant} \) is Repulsive height, \( \omega_{repellant} \) is Repulsive width.

After the introduction of the bacterial sensing mechanism, the adaptability of bacteria \( J_{cc} \) must be superimposed on the perception of bacteria.
Copy Operation

In the bacterial chemotaxis cycle is completed, that bacteria completed a life cycle activities, so as to reproduce. In the algorithm, the definition of energy for reproduction of bacteria bacteria in complete chemotaxis period all fitness and high energy, bacteria get copies of the opportunity, the low energy elimination of bacteria off. In order to ensure the population size is constant and the simplified algorithm operation, high definition of half the energy of bacterial replication, alternative energy and low eliminated bacteria. Therefore, in the BFO copy number scale operator to set the general bacteria even.

Migration Operation

The migration operation is when the bacteria living environment changes, will cause the bacteria to another area of the migration phenomenon or collective death phenomenon. When foraging area food less, bacteria migrate to another area; suddenly when the ambient temperature is too high or too low may kill the region the bacteria flora will move to another area. The migration operation simulation survival phenomenon of bacteria.

Migration operations can be described as: Given a migration probability $P_{ed}$, In the course of bacterial migration, A random number Rand in a region will be produced. If Rand $< P_{ed}$, to meet the individual conditions of migration, extinction, and randomly generated a new individual to replace the current individual; equivalent to the realization of the random migration effect. Otherwise, the individual keep unchanged, and turn to the next individual, until all individuals are traversing the end. Migration operation can make the algorithm into a local optimal solution, and then find the global the optimal solution.

Artificial Field Method

Artificial potential field method is a kind of virtual force method, its basic idea is to move the robot in the environment as a kind of movement in the field force. The concrete method is as follows: Firstly, a potential field $U$ is constructed in the moving environment of the robot. The potential field is composed of two parts: one is the gravitational field $U_{att}$ generated by the target point, and as the distance between the target point and the robot increases The gravitational increase is monotonically increasing in the direction of the robot and the target point and pointing to the target point; the other is the repulsive potential field $U_{rep}$ generated by the obstacle. When the robot is in the obstacle, it has a maximum value. The distance between the robot and the obstacle increases monotonically, and the direction is the obstacle and the robot is connected to the obstacle. The whole potential field $U$ in the robot movement space is the vector of the gravitational field and the repulsive field. The direction of the force of the repulsive force and the gravitational force is the direction of motion of the robot.

Artificial potential field method has the characteristics of simple structure and real-time control, so it is widely used in real-time obstacle avoidance and smooth trajectory control.

The classical artificial potential method uses the idea of constructing the gravitational potential $U_{att}$ at the target location and constructing the repulsive field $U_{rep}$ around the obstacle. The corresponding planning of the path $q$ represents the position of the mobile robot in space. The gravitational potential field can be expressed as a quadratic function:

$$U_{att}(X) = \frac{1}{2} k \rho^2(X, X_g)$$

Where $K$ is the proportional position gain coefficient, $X$, $X_g$ represent the position of the robot and the target in space. $\rho(X, X_g) = \|X_g - X\|$ is the distance between the robot and the target point, the
direction of gravity is the connection between the robot and the target point, and the robot points to the
target point.
The Gravitational field is:
\[ F_{\text{attr}}(X) = -\nabla U_{\text{attr}}(X) \] (5)
\[ F_{\text{attr}}(X) = k(X_g - X) \] (6)
The repulsive potential field can be expressed as a function of two times:
\[ U_{\text{rep}}(x) = \begin{cases} 
\frac{1}{2} \left[ \frac{1}{\rho(x, x_i)} - \frac{1}{\rho_o} \right] & \rho(x, x_i) \leq \rho_o \\
0 & \rho(x, x_i) > \rho_o 
\end{cases} \] (7)
Which \( \eta \) is Repulsive potential field constant, \( X \) indicates the current position of the robot; \( X \) indicates the position of the obstacle; \( \rho_o \) is the distance of the force field; the distance from the
robot to the obstacle.
The repulsive force and attractive force can be obtained from the above potential field function:
\[ F_{\text{rep}}(X) = -\nabla U_{\text{rep}}(X) = k(X_g - X) \] (8)
\[ F_{\text{rep}}(X) = -U_{\text{rep}}(X) = \begin{cases} 
\frac{1}{2} \left[ \frac{1}{\rho(x, x_i)} - \frac{1}{\rho_o} \right] & \rho(x, x_i) \leq \rho_o \\
0 & \rho(x, x_i) > \rho_o 
\end{cases} \] (9)
\[ U(X) = U_{\text{attr}}(X) + U_{\text{rep}}(X) \] (10)
\[ F(X) = F_{\text{attr}}(X) + F_{\text{rep}}(X) \] (11)

**Hybrid Algorithm Steps**
The advantages of the basic BFO algorithm is able to find the global optimal solution. The
convergence speed is slow, suitable for global path planning. The advantages of the artificial potential
field method is local obstacle avoidance, suitable for local path planning. Through analyzing the
characteristics of the two algorithms, a hybrid path optimization method is proposed. The hybrid
algorithm is as follows:
Step 1: To initialize the parameters of the BFO algorithm (including the number of migration, the
number of times, the number of times, the probability of migration, the number of bacteria, the
number of bacteria, etc.);
Step 2: Through the BFO algorithm for global target search, bacteria from the starting point
through the trend, copy, move the three operations to find the path to reach the target point
Step 3: Two local path planning using artificial potential field method. If the path is a straight line,
the target point is that local robot global target, the robot will be a starting and ending point and the
target point of global gravitational field. If the path for the draw line, will be divided into line analysis
a plurality of line segments, the robot will be local target point and end point point for local target
attraction field.
Step 4: When the iterative requirements can be met when the end of the program, this time will find
the global optimal solution.

**Simulation Analysis**
In order to verify the feasibility of the hybrid algorithm in the hybrid path planning of the robot, the
simulation is carried out in matlab:
The number of bacteria \( S = 40 \), the gravitational depth (the number of attractants), the gravitational width (the rate of release of the attractant) \( d_{\text{attrac}} = 0.05 \), the repulsive height (the number of repressants) \( w_{\text{attrac}} = 0.05 \), the repulsive force (the rate of repelling agent release) \( h_{\text{repellant}} = 0.05 \), Repulsion width (velocity of repulsion release) \( w_{\text{repellant}} = 0.05 \), the number of copies The probability of migration \( s_r = 0.5s \). Migration probability of bacteria \( P_{\text{ed}} = 0.25 \). Figure 1 shows the simulation diagram of using the artificial foraging method. The simulation diagram of the bacteria foraging algorithm is shown in Figure 3. The robot path planning using the hybrid algorithm is shown in Figures 2 and 4.

Figure 1 is the use of artificial potential field path planning emerged into the local extremum problem; this is because the robot is in a certain point of the potential field of attraction and repulsion are equal, the robot will fall into the local minimum. Figure 2 is a hybrid algorithm combined with BFO algorithm and the artificial potential field method to solve in the problem of local extremum, the method of bacterial foraging chemotaxis operator is introduced into the artificial potential field method, the bacteria turn and move, random change in the direction of motion and the moving step to bacteria to expand the search space and to jump out of local optimal value. In addition, the migration operation, judging by the individual is the probability of bacterial migration Whether to reach the migration conditions, so as to determine whether the diffusion into the search space, thus greatly reducing the probability of falling into local minima. Figure 3 is a bacterial foraging robot used to find a method to avoid obstacles in the global path; Figure 4 is a global path robot using hybrid algorithm is obtained, by comparing Figure 3 and Figure 4 is very intuitive to see the hybrid algorithm is faster than the path of bacterial foraging, find the shorter path to find the fast convergence path algorithm is shorter because the bacterial foraging algorithm in the trend direction of operation in the field after overturning direction by the bacteria in this position by the decision, so after overturning The direction is changed from random to fixed to the local target point, which reduces the search time and shortens the search path.
Summary

The simulation results show that the hybrid algorithm can find the optimal path, and the convergence speed of algorithm has faster convergence speed than the basic bacterial foraging; artificial potential field method basically is likely to encounter obstacles will fall into the local loop, and the hybrid algorithm will not fall into dead circulation, avoid the local optimum the area, and can avoid the dynamic obstacles. By the improved hybrid algorithm for path planning of robot under dynamic environment is feasible and effective.

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References


