Research on Unmanned Vehicle Path Planning based on Improved Bat Algorithm

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Abstract：Vehicle driving technology has developed in the direction of informatization and intelligence, and the research hotspot is unmanned driving and path planning [1]. This paper proposes an improved bat algorithm (Improved Bat Algorithm, IBA). First, a weighted speed update mechanism is introduced in BA, so that with the increase of the number of iterations, the speed changes adaptively to avoid the algorithm falling into local extreme values prematurely. Then, in the subsequent iterations, the quadratic differential change mechanism is used to maintain the diversity of the bat population; and under the static road network, the optimal route is planned through the MATLAB simulation experiment, which verifies that the IBA algorithm has better performance.

Keywords: Unmanned vehicle; Path planning; Bat algorithm.

I. INTRODUCTION

The unmanned vehicle path planning problem studied in this paper is superior to the effective path obtained by the traditional basic optimization algorithm in terms of time or path length [2]. The ability of the bat population to explore globally and locally determines the efficiency of the bat algorithm to find the global optimal solution. In order to achieve a proper balance between global exploration and local development, the probability of bat population falling into local extrema is reduced, and the optimization accuracy is improved. So a weight parameter is introduced in the standard velocity update formula. Through the weighted speed update strategy, as the number of iterations increases, the speed of the bat changes adaptively, avoiding the local overdevelopment of the algorithm.As the number of iterations of the algorithm increases, individual bats will gather, and the loudness of the bat population will gradually decrease and tend to 0, which will reduce the overall convergence speed and optimization accuracy of the algorithm. Therefore, the quadratic differential change mechanism is further integrated to maintain the diversity of the population, thereby further improving the global exploration and local development capabilities of the algorithm.

II. Path Planning Based on Bat Algorithm

The bat algorithm has strong adaptability to the environment, strong global search ability and fast convergence speed[3].

A. BA Algorithm

The bionic principle of BA thought: at the initial positiony_i, there is a bat individual i., searching in space. Once the target location has been explored, the individual bats will move to the target point. Update its own sound frequency f_i, sound A_0, flight speed v_i and pulse firing rate R_i during flight[4]. When the number of iterations is t, the pulse firing frequency, velocity and position update the bat population using equation (1)(2)(3):

$$f_i = f_{min} + \xi(f_{max} - f_{min}) \tag{1}$$

$$v_i^{t+1} = v_i^t + (y_i^t - y^*)f_i \tag{2}$$

$$y_i^{t+1} = y_i^t + v_i^{t+1} \tag{3}$$

It can be seen from equations (1), (2) and (3) that the product of the difference between the minimum pulse firing rate f_{min} and the maximum firing rate f_{max} and the random value ξ obeying a uniform distribution on [0,1] , and superimpose the minimum pulse rate f_{min} to

2473-3636/22/$31.00 ©2022 IEEE
DOI 10.1109/DCABES57229.2022.00067

get the sound frequency f_i of bat i.

The current frequency f_i is multiplied by the difference between the position y_i^t of the bat individual i under the current number of iterations and the current global optimal solution y^*, and the velocity v_i^t of the bat population is superimposed to update the i-th bat in the next iteration.speed v_i^{t+1}.

The updated position y_i^{t+1} of the i-th bat is obtained by superimposing the position y_i^{t+1} of the bat individual i with the updated velocity v_i^{t+1} under the current number of iterations

When the bat population enters the local search, in order to improve the optimization performance of the bat individual, the position update formula will be as shown in Equation (4):

$$y_{new} = y_{old} + \lambda A^t \quad (4)$$

With the iterative operation of the algorithm, the sound wave intensity A_i^{t+1} and the pulse emission frequency R_i^{t+1}emitted by the individual bats are updated by formula (5) (6):

$$A_i^{t+1} = \eta A_i^t \quad (5)$$

$$R_i^{t+1} = R_i^0[1 - \exp(-\beta \cdot t)] \quad (6)$$

Where η is the loudness attenuation coefficient, the value is $0 < \eta < 1$, β is the pulse emission frequency enhancement coefficient is constant, and generally greater than 0; R_i^0 is the initial pulse firing rate of the bat population, and the value generally approaches 0. From equations (5) and (6), it can be seen that with the increase of the number of iterations, the loudness of the bat population decreases continuously and gradually approaches 0, while the pulse firing rate increases continuously and remains at [0,1] within the range[5].

B. Improvement of BA Algorithm

In the iterative process, different bat individuals use the same speed update strategy to move. If the speed update step is larger, it may cause the bat individuals to deviate from the global optimal solution. If the speed update range is small, it may cause the algorithm to fall into a local minimum prematurely and reduce the optimization accuracy. In order to achieve a proper balance between global exploration and local development, the probability of bat population falling into local extreme value is reduced, and the optimization accuracy is improved[6].

A weight parameter is introduced in the velocity update formula of standard BA, and this velocity weight factor helps to maintain a balance between global exploration and local exploitation[7][8].

Because the main idea of this weight is to get how much the current speed is affected by the previous speed, a logarithmic decreasing speed weight parameter w is used, which helps to improve the convergence speed of the algorithm. The calculation formula of the speed weight parameter w is as formula (7):

$$w = w_{max} + (w_{max} - w_{min}) * log_{10}(c + 10 * t/T_{max}) \quad (7)$$

In the above formula, w_{min} is the initial minimum weight, w_{max} is the initial maximum weight. c is a constant, generally taking the value 1. t is the current number of iterations and T_{max} is the maximum number of iterations. Therefore, the improved speed update formula is as formula (8):

$$v_i^t = w * v_i^{t-1} + (y_i^t - y^*)f_{i1} + (y_i^t - k)f_{i2} \quad (8)$$

The parameter k is the minimum of four random values, and k helps to increase the diversity of the population, so as to balance the development ability of the global search and the local depth mining ability more effectively, and improve the performance of the global breadth exploration.

C. Differential Variation Mechanism

As the iteration goes on, the individual bat will get closer and closer to the local extremum, causing the bat population to repeat the search at this location.This chapter integrates the secondary differential evolution (DE) mutation mechanism into the BA algorithm. By introducing the evolutionary process of mutation, crossover, and selection, the excellent offspring are retained to search in the entire solution space, and the diversity of the population is enhanced to ensure that the algorithm is in the later stage of iteration. It has the ability to jump out of local extreme values, which further improves the optimization accuracy[9].

(1) Two methods of differential evolution mechanism

1) Random vector difference method

$$y_i(t+1) = y_i(t) + P(y_a - y_b) \quad (9)$$

In the formula, when the number of iterations is t, two different individuals y_a and y_b that are different from the current individual y_i are randomly selected,Multiply the difference between the distances of the two individuals by the amplification factor P and superimpose the current individual position to obtain the updated position value after differential evolution. where P is a random value on [0,2].

2) Optimal solution random vector difference method

$$y_i(t+1) = y_{best}(t) + P(y_a - y_b) \quad (10)$$

(2) Basic process of differential evolution algorithm

Differential evolution has strong search ability. The algorithm steps of simple differential evolution can be described as follows:

1) Initialize the population size N, the maximum number of iterations T_{max}, the crossover probability P_c and the amplification factor F

2) Calculate the fitness value according to the fitness function.

3) Three individuals are randomly selected from the population, and the differential mutation operation is performed according to formula (9) or (10) to generate offspring.

4) Crossover operation。

$$y_i^j(t+1) = \begin{cases} y_i^j(t+1), rand \geq P_c \\ y_i^j, rand < P_c \end{cases} \quad P_c \in [0,1] \quad (11)$$

5) Greedy selection operation.

6) Whether the optimal solution is found or T_{max} is reached, If so, output the result, otherwise, repeat the above steps.

The global difference mutation strategy is added during the global search; the local difference strategy is added to the local search cycle.

D. Implementation of Improved Bat Algorithm (IBA)

The standard test function Rosenbrock Function is selected as the fitness function of IBA path planning, as shown in formula (12):

$$F_t(x) = \sum_{i=1}^{d-1}[100\left(x_{i+1} - x_i^2\right)^2 + (x_i - 1)^2)] \quad (12)$$

1) Initialize the population size N, the speed of the bat v_i the initial position y_i, the initial loudness of the bat A_i^0, the pulse emission frequency R_i^0 and the maximum number of iterations T_{max} of the algorithm.

2) According to formula (12), the fitness value of the bat population is arranged, and the current optimal solution is recorded as y_i.

3) Use (1), (8), (3) to update the frequency, speed and position of the bat population, perform differential and mutation operations on the current individual according to formula (9) (11), and select the current outstanding individual y_i to enter the next generation.

4) Generate a random number $rand$, If $rand > R_i$, a local solution y^* is generated according to formula (4), the current individual is differentiated and crossed according to formula (10) (11), and the excellent individual y_i is selected to enter the next generation.

5) If $rand < A^t$ & $f(y_i) < f(y^*)$, update the current optimal solution to y^*, and update the loudness A^t and pulse emission frequency R_i^t according to equation (5) (6).

6) According to the fitness function, keep the current optimal value y_i.

7) Whether the number of iterations reaches T_{max} or the global optimal solution is obtained, if so, output the result; otherwise, repeat the above steps.

III. SIMULATION EXPERIMENT

In the MATLAB simulation experiment, multiple obstacles are randomly set, and the geometric representation is used to construct the environment map under the constraints of the starting point, the target point and the known obstacles. IBA and BA use the same software and hardware experimental environment and run independently for 30 times. The following are some parameter settings for the experiment.

(1) The starting point position S(0,0), the target point position T(700,700);

(2) Obstacle setting: The three-dimensional arc body represents the obstacle that cannot be crossed;

(3) Set the number of bat populations to $N = 200$;

(4) The maximum frequency is $f_{max} = 0.5$, and the minimum frequency is $f_{min} = 0$;

(5) Maximum loudness is $R_{max} = 1$;

(6) The maximum number of iterations is $T_{max} = 100$;

(7) The initial variation factor F_0 and the hybridization parameter C_0 are both 0.5;;

(8) Inertia weight is $w = 0.8$。

Simulation comparison experiments are shown in Figures 1 and 2. The comparison between the fitness value and the number of iterations of the two algorithm plans is shown in Table 2.

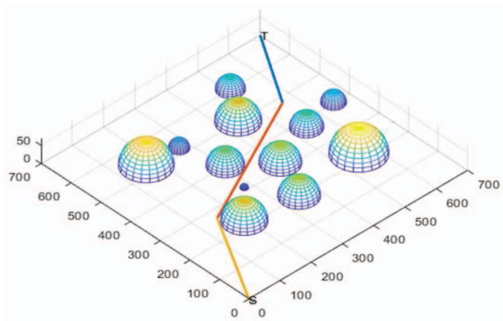

Figure 1. Path optimization graph of BA algorithm

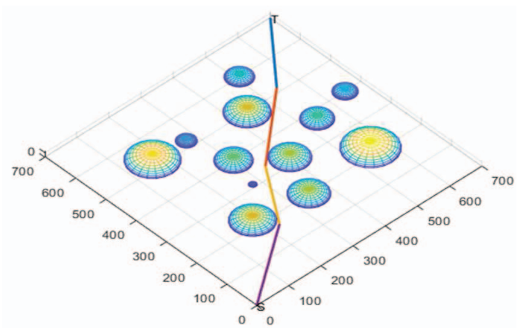

Figure 2. Path optimization graph of IBA algorithm

TABLE I. Comparison of path lengths planned by two algorithms

algorithm	worst	optimal	average
BA	1503.837	1241.486	1201.029
IBA	1391.438	1003.341	1106.662

TABLE 2. The fitness value and the number of iterations planned by the two algorithms

algorithm	adaptability	iteration
BA	0.038611	95
IBA	1.603E-08	10

As can be seen from Figure 1, Figure 2 and Table 1, the path obtained by the BA algorithm has a larger steering angle and a longer path, while the path obtained by the IBA algorithm is basically a straight line from the starting point to the target. It can be seen from Table 2 that the fitness value obtained by the BA algorithm is 0.038611, and the optimal solution is obtained when the iteration reaches about 95 generations, and the convergence speed is relatively slow. However, the number of iterations of the IBA algorithm is about 10, and the final fitness value is 1.603E-08, which is close to the minimum extreme value of the objective function of 0.

IV. CONCLUSION

The weighted speed update factor is introduced into the BA algorithm, which effectively solves the problems of low optimization accuracy, slow convergence speed, and prematurely falling into local extreme values. The IBA algorithm that introduces the differential mutation mechanism better maintains the diversity of the population, has better performance, and has a shorter planned path. And by analyzing the simulation experiments of the BA algorithm and the IBA algorithm under the same constraints, it is concluded that the IBA algorithm has certain feasibility and effectiveness in the path planning of unmanned vehicles.

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