

## **A novel hybrid bat algorithm based on tent map and mutation operator**

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Standard bat algorithm is easy to fall into local optimum to handle complex functions with high- dimension. This paper proposes a hybrid chaotic mutation bat algorithm handling local convergence. The chaotic variables and mutation operator are introduced to bat algorithm to enhance its global search ability. The simulation experimental results based on typical test functions show that the improved algorithm can effectively improve the global optimization ability of the bat algorithm and significantly improve the accuracy of the algorithm optimization and convergence efficiency.

*Keywords:* Bat Algorithm; Local Optimum; Tent Map; Genetic Algorithm; Mutation Operator.

### **1. Introduction**

As is known to all, bat has amazing echo-location ability to avoid all kinds of obstacles in a completely dark environment and successfully catch food. Bats use short of wide band frequency modulation signal measuring target distance. The inter specific change of echolocation acoustic frequency is different. The higher the frequency is, the smaller the prey is. And the lower the frequency is, the greater the prey is. In the process of closing to the target, bats increase their echolocation pulse repetition frequency, so as to get more target information.

According to the mechanism of the bats' precise positioning in a complex environment, Yang proposed a new type of bionic swarm intelligence algorithm-bat algorithm [1, 2]. In essence, the bat algorithm is a random optimization algorithm using the principle of bat echolocation evolved predation, the algorithm is a local search algorithm [3], a small amount of calculation, the applicable scope is wide, but is easy to fall into local optimum late, prone to premature convergence and slow post convergence speed and so on.

Aiming at the shortcomings of the algorithm, this paper puts forward a new hybrid bat algorithm based on chaotic mapping [4-6] and genetic variation[7]. The chaotic variables generated by tent mapping function are introduced into the

bat algorithm, replacing some parameters of the bat algorithm with chaotic sequence, increase the search ability. The mutation operator algorithm is introduced to the algorithm to improve late convergence speed and local search ability.

## 2. A Novel Hybrid Bat Algorithm

### 2.1. Chaotic search

Chaos is a deterministic, random-like process found in non-linear, dynamical system, which is non-period, non-converging and bounded[9]. Chaos optimization [10] is to use the randomness, ergodicity, universality and sensitivity to the initial value of chaos movement to improve the efficiency of the stochastic optimization algorithm. The basic idea is through some kind of mapping rules to map variables to be optimized within the range of the chaos variable space, and then give full play to the characteristics of chaotic variables to search again, the search results finally transformed into linear optimization.

Chaos movement widely exists in many nonlinear dynamic systems. Wherein the Logistic map[3] is the most common chaotic mapping, it is simple but can well embodies the essence of the nonlinear phenomena. Tent map not only can achieve the same optimal results, but also has better uniformity traversal and optimization efficiency[5]. The mathematical expression of tent mapping is:

$$x_{k+1} = \begin{cases} 2x_k & 0 \leq x_k \leq 1/2 \\ 2(1-x_k) & 1/2 < x_k \leq 1 \end{cases} \quad (1)$$

Theoretical study shows that the Tent map can be expressed as the following form after Bernoulli profit shift conversion:

$$x_{k+1} = (2x_k) \bmod 1 \quad (2)$$

Tent map is as shown below:

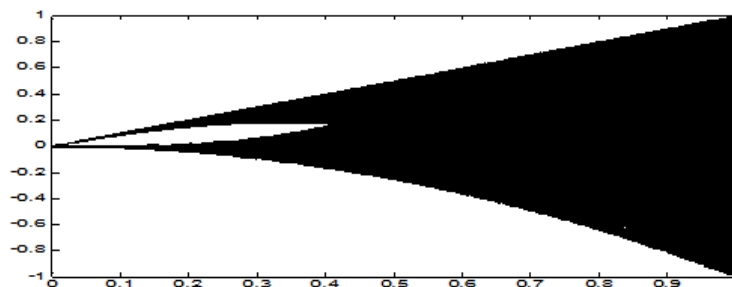


Fig. 1 Tent mapping

According to the usage of chaotic sequence, there are three ways for the bat algorithm to be combined with chaotic sequence: one is to first use the bat algorithm, and then the chaotic sequence is adopted to search for local solutions. The second is to replace one or more parameters of the basic bat algorithm using chaotic sequence, such as inertial factor, the random number, learning factor, etc. Third, the initial individual of the bat algorithm is generated with chaotic sequence.

The first method can indirectly improve the local search ability of the bat algorithm; The second method is mainly to enhance the global search ability of the bat algorithm; When the search range is very wide and the number of groups is not very big, the third way is very difficult to make initial individual evenly distributed in the search space, and could not reach the purpose of uniform distribution only by generating initial population with chaotic sequence, so there is no essential difference between this method and the method of randomly generated initial population.

Since the bat algorithm belongs to the local search algorithm, it can ensure the local convergence, but cannot guarantee the global convergence, therefore should focus on promoting its global search ability, which uses chaotic sequence to replace one or more parameters of the bat algorithm, so that the effect should be better than other two methods. This paper tries to replace inertia weight and search pulse frequency range [  $f_{min}$ , ] of the bat algorithm with chaotic sequence.

## 2.2. Genetic mutation operator

The global search ability of the improved bat algorithm based on tenting mapping has improved so much, can rapidly converge to a more optimal solution, but the spending time from the better solution to the optimal solution of convergence is not stable, so we must find new solutions.

Genetic algorithm is a kind of random search optimization method evolved with reference to the biological genetic evolution law. Due to its probability optimization strategy is used, thus automatically guide and obtain the optimization search space, adaptively adjust the search direction. Mutation operator is a basic operator in genetic algorithm, has significant local search ability, its basic content is to change certain genes value of the individual in the group. On the basis of different individual coding representation methods, divided into real value mutation and binary mutation. Introducing the mutation operator in genetic algorithm mainly has two main effects: one is to make the genetic algorithm has local random search ability. When genetic algorithm

closes to the neighborhood of optimal solution, using the local random search ability of mutation operator can accelerate convergence to the optimal solution. The second is to make the genetic algorithm maintain the population diversity, to prevent premature convergence.

Based on the above consideration and the fact that the optimization capability of mutation operator is strong, when convergence to a certain range, the best individual is mutated to speed up late local optimization. Mutation is as follows:

$$x_{id}^{k+1} = x_{id}^{k+1} + c * N(0,1) \quad (3)$$

$$c = \min([b_1 - a_1], [b_2 - a_2], \dots, [b_n - a_n]) \quad (4)$$

According to the following formula to calculate the current iteration mutation rate:

$$p_m(k) = p_{m,min} + \frac{p_{m,max} - p_{m,min}}{NC\_MAX} \times Iteration \quad (5)$$

### 2.3. The description of improved bat algorithm

According to the above analysis, this paper proposes an improved hybrid bat algorithm to get rid of local extreme value, by using chaos search in conjunction with genetic mutation, can not only promote global optimization ability, but also accelerate the late local convergence efficiency. The steps are as follows:

Step 1. First initialize the basic parameters, including bats number  $m$ , the inertia weight  $\omega_{max}$  and  $\omega_{min}$ , search pulse frequency range  $[f_{min}, f_{max}]$ , maximum pulse frequency , biggest pulse sound intensity  $A$ , sound intensity

attenuation coefficient , frequency increase coefficient , chaotic mapping

iterations , the maximum number of iterations MaxT epsilon or search accuracy .

Step 2. According to the formula (1), replace the inertia weight and search pulse frequency of bat algorithm with chaotic sequence, map it to the interval  $[0,1]$  of tent equation domain, and then use tent equations to generate chaotic sequences iteratively, put produced points in chaotic sequence back to the original space by inverse mapping. The points can be obtained by chaotic sequence after tent mapping.

Step 3. The positions  $x_i(i = 1, 2, \dots)$  of the bats individual are random initialized, find out individuals which are in the best position of current group.

Step 4. Initialize the search pulse frequency  $f_i$ , calculate the bat flying speed.

Step 5. Generate a random number rand1, if  $\text{rand1} < p_n$ , randomly disturb the bats in the best position, in place of the current position of the bat individual with the position after disturbance; Otherwise, update the space position of bats individual I.

Step 6. Generate a random number rand2, if  $\text{rand2} < p_n$ , and current position improved, move to the location of the updated.

Step 7. If updated location of bats is better than the current best position, update pulse frequency and pulse sound intensity.

Step 8. After updating the speed and location, if random number  $\text{rand} < p_n$ , then variation factor is joined in the bat algorithm and the mutation operation is carried out according to formula (3), (4).

Step 9. When meet the search accuracy or maximum number of search, go to step 10, otherwise turn to step 3, for the next search.

Step 10. Output global extreme points and the best individual values.

### 3. Experiment Results

To verify the effect of the proposed new hybrid bat algorithm, we use several standard test functions which are commonly used in the field of intelligent optimization algorithms in experiment, these four functions are complex nonlinear multimodal function, exist a large number of local minima, can effectively detect global search performance from multiple angles.

#### 3.1. The typical standard test functions

This paper selects the following four typical standard test functions [11]:

(1) Branin function

$$f_1(x) = \left(x_2 - \frac{5}{4\pi^2}x_1^2 + \frac{5}{\pi}x_1 - 6\right)^2 + 10\left(1 - \frac{1}{8\pi}\right)\cos(x_1) + 10 \quad (6)$$

Search space is  $[-5, 5]$ , the global optimal value is 0.397887.

(2) Griewank function

$$f_2(x) = \frac{\sum_{i=1}^P x_i^2}{4000} - \prod_{i=1}^P \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1 \quad (7)$$

Search space is  $[-600, 600]$ , the global optimal value is 0.

(3) Rastrigin function

$$f_3(x) = \sum_{i=1}^P [x_i^2 - 10\cos(2\pi x_i) + 10] \quad (8)$$

Search space is  $[-5.12, 5.12]$ , the global optimal value is 0.

(4) Shubert function

$$f_4(x) = \sum_{i=1}^5 i \cdot \cos((i+1)x_1 + i) \cdot \sum_{j=1}^5 j \cdot \cos((j+1)x_2 + j) \quad (9)$$

Search space is  $[-10, 10]$ , the global optimal value is -186.7309.

### 3.2. Optimization results and analysis

Optimization results areas shown in Fig. 2~5 respectively. Wherein, the CPSO represents chaos particle swarm optimization, BA represents the standard bat algorithm, CMBA represents the proposed new hybrid algorithm based on chaotic mutation.

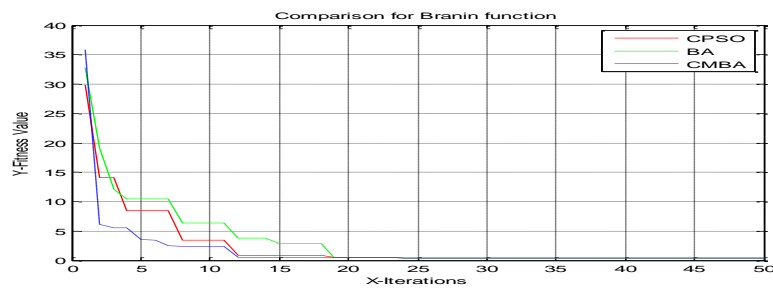


Fig. 2 Branin function test optimization curve

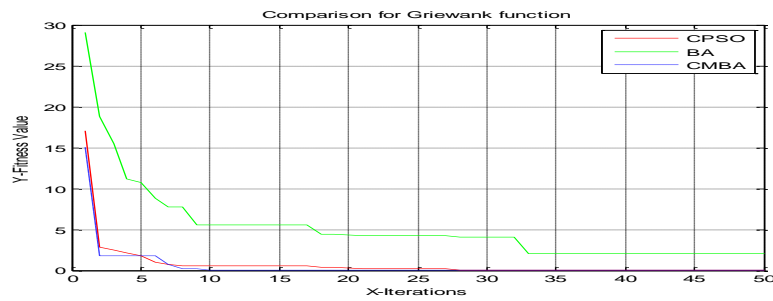


Fig. 3 Griewank function test optimization curve

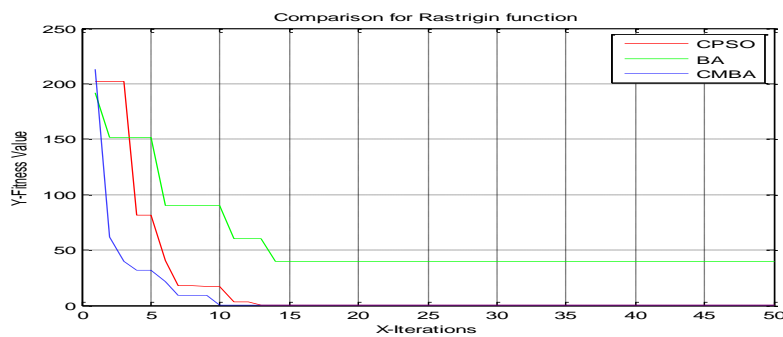


Fig. 4 Rastrigin function test optimization curve

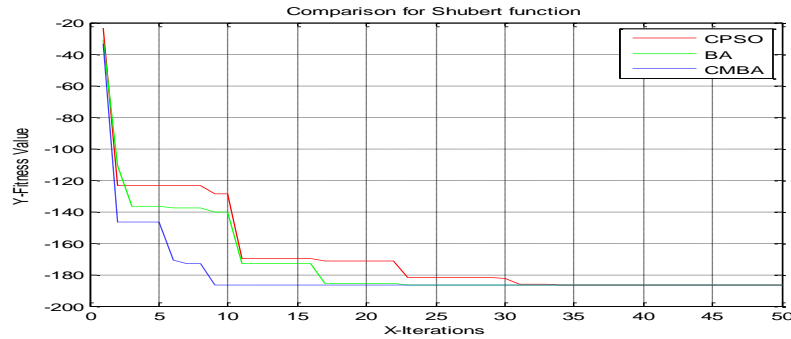


Fig. 5 Shubert function test optimization curve

As you can see from the above optimization curves, compared with the standard bat algorithm, chaos particle swarm optimization are significantly better than the standard bat algorithm on other three test functions in addition to the Shubert function. The proposed new hybrid bat algorithm converges to the optimal solution in different dimensions of test space. The optimization precision and convergence speed of the improved bat algorithm are better than the standard bat algorithm and chaos particle swarm optimization algorithm, showing good global optimization performance and higher robustness.

#### 4. Conclusion

Based on the fact that the optimization process of standard bat algorithm is easy to fall into local optimum and late slow convergence speed, this paper puts forward a new hybrid algorithm to get rid of local extreme. The tent map and genetic mutation operator is joined into the bat algorithm. The simulation experiments of standard test functions show that the proposed algorithm significantly improved optimization performance of the bat algorithm, its improvement ideas can be used for reference for other swarm intelligence algorithms.

Although the chaotic motion has ergodicity in a certain range, but it is more sensitive to initial value, some states may require a longer time to reach. If the global optimal value just appears on these states, the search time will be very long. Next, we will try a parallel search strategy, starting from different groups of initial points for parallel computing, in order to reduce the sensitive dependence on initial conditions, and further speed up the search.

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