Research on Artificial Bee Colony Algorithm Based on Homogenization Logistic Mapping

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Abstract. Aiming at the defects of artificial bee colony algorithm with poor performance and slow optimization efficiency, this paper puts forward an artificial bee colony algorithm that initializes honey sources by homogenizing chaotic mapping. First, a homogenization logistic mapping model is constructed, and the frequency distribution and information entropy are analyzed. Second, during the initial honey stage, a homogenization logistic map is introduced to continuously iterate to generate a feasible global uniform distribution with a feasible solution. Finally, by evaluating the optimal solution for different characteristic functions, it is shown that the algorithm achieves the improvement of convergence performance, optimal solution accuracy, optimization efficiency and stability under the condition of limited bee colonies.

Keywords: Homogenization logistic mapping; Convergence performance.

1. Introduction
Artificial bee colony algorithm (ABC), which has the advantages of low implementation difficulty, low time complexity, less parameter control, robustness of the algorithm, global optimization and local search for each iteration [1]. However, the convergence speed of the algorithm itself becomes slower when the optimization process approaches the global optimum, the optimization accuracy and population diversity also decrease, and there is a possibility of falling into a local optimum [2].

With the deepening of people's understanding of this algorithm, the theoretical research and practical application of artificial bee colony algorithm have also increased year by year. For example: Zhang Yisen introduced mutation operators to improve the search equations of the artificial bee colony algorithm, thereby improving the convergence speed and local optimization ability of the algorithm [3]. Sally proposes a hybrid genetic artificial bee colony algorithm that optimizes spectrum utilization by introducing genetic operators to increase detection probability [4].

Based on the analysis of the biological behavior of honeybees and the factors that influence their activities, this paper proposes a method to improve the algorithm of artificial honeybee colony to improve the efficiency of mutual cooperation. By introducing a homogenization logistic chaotic map, the honey source distribution tends to be uniformly distributed globally. And comparison with existing algorithms from the convergence curve and the convergence value, it is found that the algorithm has achieved improvements in convergence performance and optimization efficiency. It ensures the reliability and stability of the optimal solution.

2. Construction and Analysis of a Homogenization Logistic Mapping Model
First, in order to introduce a homogenization Logistic mapping to initialize the algorithm, so that the initial honey sources tend to be globally uniformly distributed and related, the map construction and main characteristics are analyzed first. The Logistic mapping expression is as
in (1).

\[ x_{n+1} = \mu x_n (1 - x_n) \]  

Among them, \( \mu \in [0, 4] \), \( x_n \in [0, 1] \), when \( 3.57 < \mu \leq 4 \), the Logistic mapping is in a chaotic state [5]. In response to the requirement that the iterative value of the chaotic map be uniformly distributed throughout the interval, when \( \mu = 4 \), the method of mathematically deriving the probability density of Logistic mapping is used to derive the random variable function. According to the definition of homogeneous distribution, if the probability density function of random variable \( y \) satisfies the homogeneous distribution, the following equation can be obtained:

\[ y = \frac{2 \arcsin (\sqrt{y})}{\pi} + C. \]  

Among them, \( C \) is a constant term in the solution after solving the differential equation, and \( C = 0 \) in this paper. Then substitute Eq. (1) into Eq. (2), so the random variable function \( Y \) that obeys the homogeneous distribution in the interval \([0, 1]\) is:

\[
\begin{align*}
    x_{n+1} &= 4x_n(1 - x_n), \quad 0 \leq x_n \leq 1 \\
    y_n &= x_{n+1} \\
    y_{n+1} &= \frac{2}{\pi} \arcsin(\sqrt{y_n}), \quad 0 \leq y_n \leq 1
\end{align*}
\]

Figure 1. Logistic mapping frequency

Figure 2. Homogenization Logistic mapping frequency

The sequence generated by the Logistic chaotic mapping in Fig.1 presents a U-shaped distribution of the boundary bimodal, the chaotic sequence generated by the homogenization Logistic mapping shown in Fig.2 is approximately a straight line distribution. It is a uniformly distributed sequence, and its random distribution is more prominent.

Finally, the information entropy is used to further analyze the uniformity of the three functions. Information entropy is used as a characteristic parameter to measure the degree of chaos in the sequence. It is used to represent the average uncertainty of the simulated signal [6]. The paper calculates the number of running times \( N = 50,000 \) and the number of different range intervals \( M \). The information entropy of the three functions is obtained. The results are shown in Tab.1 below.

| Number of intervals | Rand function | Logistic mapping | Homogenization Logistic mapping | Maximum information entropy |
|---------------------|---------------|------------------|---------------------------------|----------------------------|
| 10                  | 3.2839        | 3.1458           | 3.3189                          | 3.3219                     |
| 100                 | 6.5383        | 6.3436           | 6.6352                          | 6.6439                     |
| 200                 | 7.5167        | 7.3254           | 7.6335                          | 7.6439                     |
| 400                 | 8.4937        | 8.3117           | 8.6316                          | 8.6439                     |
| 600                 | 9.0648        | 8.8903           | 9.2154                          | 9.2288                     |
The results in Tab.1 show that by setting different statistical intervals M for calculation, the information entropy of the Rand function and the homogenization Logistic mapping are closer to the maximum information entropy. By contrast, the iterative values generated by the homogenization Logistic mapping are more uniform, and the ideal results are obtained.

3. Homogenization Logistic Artificial Bee Colony Algorithm

To sum up, the HLABC (Homogenization Logistic Artificial Bee Colony Algorithm) in this paper mainly uses the homogenization Logistic mapping to improve the distribution of the initial honey source, making it more random and uniform.

Step1: Initialize the population parameters in the algorithm, the number of iterations (Cycle=1000), the number of bee colonies (NP=100), the number of honey collections (Limit=300), and the initial value of chaotic mapping($X_0=0.715$).

Step2: Use the homogenization Logistic mapping to generate 30-dimensional different trajectory sequences, and obtain the uniform initial honey source $Y_i$ through formula (3).

Step3: Within the set number of iterations, the two values before and after the feasible solution are subtracted as a neighborhood, the initial nectar source vector is recorded as $\text{Fail (i)} = 0$, and save the numerical results of same nectar source (the value of fitness) obtained from the bees, that is, the new neighborhood search formula is: $\text{new}_Y^j = Y^j_i + \text{rand}() (Y^j_{i+1} - Y^j_{i-1})$.

Step4: The bees search according to the neighborhood near the nectar source determined by Step3 formula, and calculates a new fitness value $F (V_i)$.

Step5: If $F (V_i) > F (Y_i)$, then $Y_i = V_i$, $\text{Fail (i)} = 0$; otherwise, $\text{Fail (i)} = \text{Fail (i)} + 1$.

Step6: The scout bee selects the honey source according to the calculated selection probability $p_i(t)$, searches again near the neighborhood according to Step4, calculates the adaptive value $F (V_i)$ that generates a new solution, and then proceeds to Step5 for judgment.

Step7: If $\text{Fail (i)} > \text{Limit}$, then the bees will be transformed into the scout bee, and a new solution $F (V_i)$ will be replaced to the honey source according to the chaotic of the homogenization Logistic mapping.

Step8: Keep the optimal nectar source obtained from all current bee colony searches, and save the optimal solution obtained under the set criteria.

Step9: Update the optimal fitness value obtained from each iteration, determine whether the maximum iteration times and maximum acquisition times of the termination conditions are met, and save the movement process of all bee colony optimization positions, otherwise go to Step2 and continue to initialize the honey source.

4. Experimental Simulation

This paper selects 4 standard test functions: $f_1$: Sphere, $f_2$: Rastrigin, $f_3$: Shubert, $f_4$: Hansen, and compare HLABC (Homogenization Logistic Artificial Bee Colony Algorithm) with LABC (Logistic Artificial Bee Colony Algorithm) and SABC (Standard Artificial Bee Colony Algorithm). The comparison graph of convergence curve is shown in a to d in Fig.3. The abscissa is the number of iterations, the upper limit is set to 200. The ordinate represents the average fitness value of 30 experiments.
To sum up, \( f_1 \) is a nonlinear symmetric single-mode function, used to test the accuracy of the algorithm. \( f_2 \) is a complex multimode function, used to test whether the algorithm can find the optimal solution in the global. \( f_3 \) and \( f_4 \) are multimodal functions, used to test the accuracy and speed of convergence. As can be seen from Fig. 3, for the four test functions, compared with LABC and SABC, HLABC can converge to a fixed accuracy with the least number of iterations, and has the highest convergence accuracy.

### 5. Calculation Results and Numerical Analysis

About the optimization capability of the HLABC, this paper uses four indicators and references the theoretical values to fully verify the global search performance of the three algorithms through simulation. The performance comparison of SABC, LABC and HLABC is shown in Tab.2.

| function | algorithm | reference | optimal value | worst value | mean value | variance |
|----------|-----------|-----------|---------------|-------------|------------|----------|
| \( f_1 \) | SABC      | 0         | 2.6202E-13    | 1.0301E-10  | 9.5059E-12 | 4.7543E-22 |
|          | LABC      | 3.4029E-13| 5.8750E-11    | 8.6674E-12  | 1.5697E-22 |          |
|          | HLABC     |           | 2.8826E-16    | 7.7493E-16  | 5.4014E-16 | 1.2214E-32 |
| \( f_2 \) | SABC      | 0         | 3.2797E-07    | 6.3748E-04  | 6.2375E-05 | 2.2223E-08 |
|          | LABC      |           | 4.4334E-07    | 2.7062E-04  | 2.8248E-05 | 4.1271E-09 |
|          | HLABC     |           | 0.0000E+00    | 0.0000E+00  | 0.0000E+00 | 0.0000E+00 |
| \( f_3 \) | SABC      | -24.062   | -2.4062E+01   | -2.3776E+01 | -2.3924E+01| 9.4277E-03 |
|          | LABC      |           | -2.4054E+01   | -2.3810E+01 | -2.3962E+01| 6.5480E-03 |
|          | HLABC     |           | -2.4062E+01   | -2.4056E+01 | -2.4060E+01| 2.7607E-05 |
| \( f_4 \) | SABC      | -176.54   | -1.7643E+02   | -1.7330E+02 | -1.7570E+02| 5.7740E-01 |
|          | LABC      |           | -1.7644E+02   | -1.7343E+02 | -1.7526E+02| 6.8193E-01 |
|          | HLABC     |           | -1.7654E+02   | -1.7648E+02 | -1.7651E+02| 2.0767E-03 |

According to the results in Tab.2, for \( f_1 \), HLABC has better accuracy than LABC and SABC. For \( f_2 \), HLABC has a strong global search capability, can accurately and quickly converge to the extreme value position, and has better stability. For \( f_3 \) and \( f_4 \), the convergence speed, convergence accuracy, and stability of HLABC are significantly better, and extreme points can be accurately found. It can be seen that the HLABC is higher in optimization performance and optimization efficiency than the other two algorithms.

### 6. Summary

Homogenization Logistic Artificial Bee Colony Algorithm, by introducing homogenization logistic mapping to initialize the honey source, the feasible solution tends to be uniformly distributed globally, and then perform experimental simulation with 4 test functions with different characteristics. As a result,
it is found that HLABC Compared with LABC and SABC, the optimal solution accuracy and optimization efficiency are significantly improved.

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