Artificial Bee Colony Using Strategies

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***Abstract*—Artificial Bee Colony (ABC) is a swarm intelligence algorithm inspired by the foraging behavior of honeybees. In ABC, the search is characterized by a high-dimensional nonlinear evaluation function and a complex search space, where the search tends to be local solution. We propose an artificial bee colony with three search strategies (ABC3SS). Each strategy has different search performance and is evaluated using a benchmark function.**

I. Introduction

Artificial Bee Colony (ABC) has been widely applied to optimization problems in various fields. In this algorithm, three types of roles are set up: employed bees, onlooker bees, and scout bees, and each bee cooperates to search for the optimal solution [1][2].

Artificial bee colony (ABC) algorithms effectively handle nonlinear functions and high-dimensional spaces, but are prone to local optima and solution bias due to randomness. To address this problem, we propose an extended ABC with three search strategies (ABC3SS) inspired by studies on the evolution of cooperative behavior in social systems. In previous research, we incorporate the strategies of cooperation, betrayal, and extortion from the Prisoner's Dilemma game [3]. The extortion strategy, which prioritizes personal gain while enforcing cooperation, is shown to maintain cooperative behavior. By integrating these strategic elements with imitation and desire learning, ABC3SS aims to improve optimization performance and promote cooperative dynamics. Apply this element to ABC.

II. Flow of ABC3SS

The following is a brief flow chart of ABC3SS.

Step 1. Parameter Setting.
Add two new parameters. n is a parameter that sets the number of bees to which the strategy is applied from the total, and P_s is a parameter that indicates the percentage of the total strategy.

$$\begin{cases} N & : \text{Total number of bees.} \\ t_{max} & : \text{Trial limit count.} \\ i_{max} & : \text{Maximum number of iterations.} \\ n & : \text{Strategy bee count.} \\ P_s & : \text{Percentage of strategies.} \end{cases}$$

Step 2.
Initialization and random generation of the initial position of each bee. The position of the i-th bee is x_i. In addition, assign a strategy to every bee with a P_s ratio.

Step 3.
Employed bee phase and application of strategies.
(i) Each bee generates a new candidate solution v_i from its own current position x_i.
(ii) Derive the degree of adaptation f and repeat a number of times in the trial limit count (t_{max}).

These movements are shown as Eq. (1).

$$v_i = x_i + \varphi \cdot (x_i - x_k) \tag{1}$$

$$\begin{cases} \varphi \\ : \text{Uniform random number in the interval } [-1, 1]. \\ x_k \\ : \text{Position of another bee chosen at random.} \end{cases}$$

Bees that use a strategy will move differently depending on the given strategy. Below are the movements of cooperation, betrayal, and exploitation.

(a) Cooperation strategy.
In a cooperative strategy, bees move to the average position of other nearby bees. Specifically, the average position of other bees in the neighborhood of a bee i is computed, and the bee moves to the midpoint of its current position. This movement are shown as Eq. (2) and (3). This determines the new candidate of the bee. In this case, $nearest\ indices$ are the set of indices of the k bees closest to bee x_i.
Evaluate $f(candidate)$ and update the position of bee i only if there is an improvement in adaptation compared to the original position.

$$average\_position = \frac{1}{k} \sum_{j \in nearest\_indices} (x_j) \tag{2}$$

$$candidate = \frac{x_i + average\_position}{2} \tag{3}$$

$$\{ \; k \quad : \text{Number of bees in the vicinity.}$$

(b) Betrayal.
In this strategy, if adaptations are stagnant, they prevent convergence by making random jumps. If the variability in the degree of adaptation is large, the Eq. (1) in the conventional search bee phase is used.
Evaluate f and update the position of bee i only if there is an improvement in adaptation compared to the original position.
The strategy is considered to have converged when the variation in the adaptivity is small, and the strategy is activated when the change in the adaptivity is smaller than α.

(c) Exploitation.

In the exploitation strategy, the bee tries to approach the position of the best adapted bee. This accelerates the progress of the search. Update bee i position if adaptivity improves. These movements are shown as Eq. (4) and (5).

$$movement\_direction = x_{best} - x_i \tag{4}$$

$$candidate = x_i + \frac{1}{2} \cdot movement\_direction \tag{5}$$

$$\{\ x_{best} \quad \text{: Location of the best adapted bee.}$$

Bees to which the strategy is not applied operate in the worker bee phase of the normal ABC algorithm.
Step 4.
Onlooker Bee Phase.
(i) From Eq.(6), randomly selected bees generate v_i and search for solution.
(ii) Derive the degree of adaptation f and repeat the number of times in the trial limit count (t_{max}).

$$P_i = \frac{f(x_i)}{\sum_{j=1}^{N} f(x_j)} \tag{6}$$

$$\begin{cases} f & \text{: Degree of adaptation.} \\ j & \text{: Elements of a Candidate Solution.} \\ N & \text{: Total number of bees.} \end{cases}$$

Step 5.
Scout bee phase.
(i) Update the solution up to the trial limit count (t_{max}). If the solution can be updated, the t_{max} is reset to zero.
(ii) When the t_{max} is reached without updating the solution, the bee is repositioned to a new random position.
Step 6.
Repeat steps 3 through 5 until the maximum number of iterations (t_{max}) is reached.
Step 7.
Output final solution.

III. Simulations

To investigate the performance of ABC3SS, we applied ABC3SS to benchmark functions of dimension 10. The benchmark functions used are shown in Table I and the approximate shapes of the benchmark functions are shown in Figure 1.
In Table I, D is the number of dimensions.

The number of bees is N = 50 and the trial limit is t_{max} = 100. Also, measure the maximum number of iterations i_{max} at 1000, 5000, and 10000. The parameters at the time of the strategy are k = 5 , α = 1.0e-2 and P_s = [0.4 ,0.3 ,0.3]. The strategy bee count (n) is set from 0 to 50 in 5 intervals. When n = 0, the movement is ABC. The average of simulation results with six different seeds is shown. Table II shows the simulation results.
For the Sphere functions, better results were obtained with more trials.

IV. Conclusions

In this study, we proposed an artificial bee colony with three strategies and obtained good results by placing ABC3SS in all functions and setting n to the appropriate parameter. This problem could have been overcome by using a cooperative strategy, which would have reduced the bias in the initial placement. The Sphere function was used as a unimodal function to obtain a minimum value of 0.

Future work includes simulations with only one strategy in order to set the parameters of the strategy. Based on the results, appropriate values of n will be determined and applied to optimization problems such as the Traveling Salesman Problem (TSP).

References

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[2] Dervis Karaboga, Beyza Gorkemli, Celal Ozturk, Nurhan Karaboga. "A comprehensive survey :artificial bee colony (ABC) algorithm and applications", Artificial Intelligence Review, Volume 42 ,pages 21-57, 2014.
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TABLE I: Benchmark function.

Function	**Name**
$\sum_{i=1}^{D} x_i^2$	Sphere Function

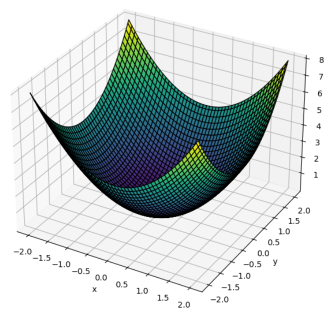

Fig. 1: Sphere function.

TABLE II: Sphere function simulation results.

	i_{max} = 1000	i_{max} = 5000	i_{max} = 10000
0(ABC)	1.772E-40	2.364E-103	5.931E-128
5	1.772E-40	**7.968E-119**	**1.813E-158**
10	**1.408E-40**	**4.088E-201**	**0.0**
15	2.513E-39	**1.771E-193**	**0.0**
20	1.609E-35	**1.427E-199**	**0.0**
25	1.778E-36	**7.281E-197**	**0.0**
30	3.171E-35	**7.281E-197**	**0.0**
35	1.266E-39	**3.164E-176**	**0.0**
40	2.683E-38	**2.32.E-177**	**0.0**
45	3.826E-35	**6.249E-181**	**0.0**
50	1.128E-24	3.920E-45	1.094E-120
Number of good results	1	9	9