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Strategies for Diversification of Employed Bee Phases in Artificial Bee Colony

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Abstract—Artificial Bee Colony Algorithm (ABC) is a swarm intelligence algorithm inspired by the foraging behavior of honeybees and considered appropriate for function optimization. However, one of the weaknesses of ABC is its slow convergence to the optimal solution. Therefore, we propose an artificial bee colony algorithm that improves the employed bee phase. It is evaluated using a benchmark function.

1. Introduction

Artificial Bee Colony (ABC) has been widely applied to optimization problems in various fields [1]. 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 [2]. ABC can be applied to nonlinear evaluation functions and high-dimensional search spaces, but it is slow to converge to a local solution. In addition, the solution may be biased due to its strong randomness.These could be caused by two factors. In the conventional algorithm, the output of the solution is time-consuming due to the presence of three phases. In addition, the two subsequent phases (onlooker, scout) are executed based on the search results of the employed bee phase. Therefore, the search results of the employed bee phase may significantly affect the later two phases.

So, we propose an ABC that diversifies bee movements in the employed bee phase. Repeat the three phases and add elements of onlooker bee and scout bee movements to the employed bee phase under different conditions. We believe that this will diversify the search for the employed bee phase and improve the overall algorithm.

2. Flow of ABC

ABC has different bee movements in each phase. It also has relatively few parameters to set compared to other swarm intelligence algorithms.
The following is a brief flow chart of ABC.

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Step 1.
Parameter Setting.

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

Step 2.
Initialization and random generation of the initial position of each bee. The position of the i-th bee is x_i.

Step 3.
Employed bee phase.
(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).

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

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

Step 4.

Onlooker Bee Phase.
(i) From Eq. (2), 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}).

$$P_i = \frac{f(x_i)}{\sum_{j=1}^{N} f(x_j)} \tag{2}$$

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

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 (i_{max}) is reached.

Step 7.
Output final solution.

Through these processes, ABC finds the optimal solution.

3. Proposed Method

The proposed method will provide diversity in movement during the employed bee phase. In addition to the traditional ABC movements in the employed bee phase, three types of movements will be introduced. We define these movements as strategies and use three types: cooperation, betrayal, and exploitation [3].

The cooperation strategy aims to reduce randomness, which is both an advantage and a disadvantage of ABC, and aims to enable regular search. The betrayal strategy is based on the movements of the scout bee phase, while the exploitation strategy is based on the movements of the onlooker bee phase. By using the movements of the three phases within the employed bee phase, the goal is to increase the speed of convergence to a solution.

The following is the flow and details of the proposed method.

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. According to the proportion of P_s, all bees are given first arrival, and n number of unique movements are made from them.

$$\begin{cases} n & \text{: Strategy bee count.} \\ P_s & \text{: Percentage of strategies.} \end{cases}$$

Step 2.
The same as ABC. In addition, assign a strategy to every bee with a ratio P_s.

Step 3.
The bee phase used and the application of strategies. Bees that use a strategy will move differently depending on the given strategy. Furthermore, bees that move by strategy do not perform the traditional movements of the bee phase used. Below are the movements of cooperation, betrayal, and exploitation.

(a) Cooperation

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 Eqs. (3) and (4). This determines the new candidate of the bee. In this case, *nearest indices* is the set of indices of the k bees closest to the bee x_i. Evaluate $f(candidate)$ and update the position of the bee i only if there is an improvement in adaptation compared to the original position.

$$average\_position = \frac{1}{k} \sum_{j \in nearest\_indices} (x_j) \tag{3}$$

$$candidate = \frac{x_i + average\_position}{2} \tag{4}$$

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

(b) Betrayal

This strategy prevents convergence by making random jumps when the standard deviation of the adaptivity is stagnant. If the variation in the standard deviation is large, Eq. (1) in the conventional bee search phase is used. When the value of the standard deviation of the adaptivity is less than α, the strategy is considered to have converged and the strategy is activated. The standard deviation of the degree of adaptation is obtained by the following Eq. (5) for each iteration.

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (f(x_i) - \mu)^2} \tag{5}$$

$$\begin{cases} \sigma & \text{: Standard deviation of adaptability.} \\ N & \text{: Total number of bees.} \\ f & \text{: Degree of adaptation.} \\ \mu & \text{: Average value of overall adaptability.} \end{cases}$$

μ is expressed by the following Eq. (6).

$$\mu = \frac{1}{N} \sum_{i=1}^{N} f(x_i) \tag{6}$$

(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 Eqs. (7) and (8).

$$movement\_direction = x_{best} - x_i \tag{7}$$

$$candidate = x_i + \frac{1}{2} \cdot movement\_direction \tag{8}$$

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

Bees to which the strategy is not applied operate in the employed bee phase of the normal ABC algorithm.

Steps 4-7.
The same as ABC.

The above is the main flow of the proposed method, and the operation after the onlooker bee phase in step 4 is similar to that of ABC.

By incorporating elements of onlooker bee and scout bee into the employed bee phase, we aim to improve the overall algorithm by obtaining good solutions with fewer trials.

4. Simulation

4.1. Preparing for the simulation

To verify the performance of the proposed method, simulations are performed using benchmark functions. The four benchmark functions used in this study are listed in Tab. 1. In Tab. 1, D is the number of dimensions. For all functions, the minimum value is 0. The approximate shapes are shown in Figs. 1-4.

In these functions, Rosenbrock and Sphere functions are unimodal functions, while Rastrigin and Ackley functions are multimodal functions. The parameters used are also listed in Tab. 2. By parameter setting, n was set to 25. Therefore, in the proposed method, 25 individuals are executing the strategy moves with a probability of P_s. This number is half of the total number of bees and is a balance with the ABC.

Table 1: Benchmark function.

Function	Name
$\sum_{i=1}^{D-1}\left((1-x_i)^2+100(x_{i+1}-x_i^2)^2\right)$	Rosenbrock Function
$\sum_{i=1}^{D} x_i^2$	Sphere Function
$10D+\sum_{i=1}^{D}\left(x_i^2-10\cos(2\pi x_i)\right)$	Rastrigin Function
$-20\exp\left(-0.2\sqrt{\frac{1}{D}\sum_{i=1}^{D}x_i^2}\right) - \exp\left(\frac{1}{D}\sum_{i=1}^{D}\cos(2\pi x_i)\right)+20+\exp(1)$	Ackley Function

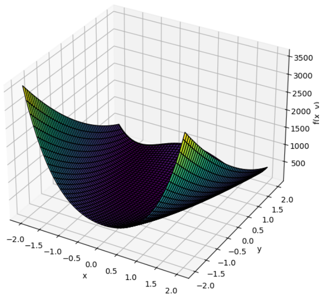

Figure 1: Rosenbrock function.

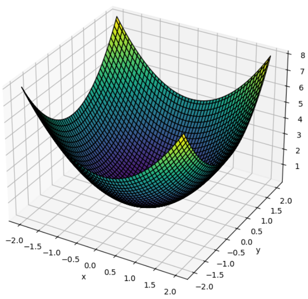

Figure 2: Sphere function.

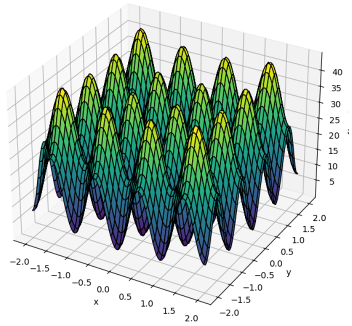

Figure 3: Rastrigin function.

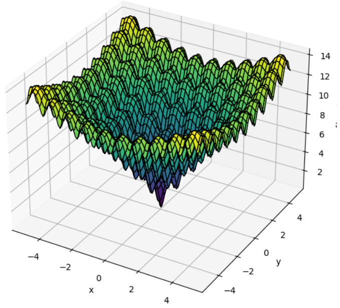

Figure 4: Ackley function.

Table 2: Parameters.

N	50
n	25
t_{max}	100
i_{max}	10000
k	5
α	0.01
P_{s1}=(C , B , E_x)	(0.4 , 0.3 , 0.3)
P_{s2}=(C , B , E_x)	(0.4 , 0.4 , 0.2)
P_{s3}=(C , B , E_x)	(0.5 , 0.5 , 0)
P_{s4}=(C , B , E_x)	(0.5 , 0 , 0.5)
P_{s5}=(C , B , E_x)	(0 , 0.5 , 0.5)
D	50

4.2. Simulation result

Table 3 shows the simulation results of the average and minimum values of ABC and the proposed method on unimodal functions. Tab. 4 shows the simulation results in the multimodal function. As a result, better results than conventional ABC were obtained for all proposed methods (P_s). Here are the simulation times and distribution plots for the proposed method P_{s4}, which obtained better values on average for all functions. Table 5 shows that the proposed method increases the simulation time by 2.4s compared to ABC. This second is 8.25 percent of the conventional ABC.

Figures 5 and 6 show a two-dimensional plot of bees in search in the rastrigin function (D=50). Comparing Figures 5 and 6, bees are more concentrated near the origin in the proposed method, and the minimum value of the rastrigin function is at the origin, indicating that the proposed method is more effective in the search.

Table 3: Simulation results (Unimodal).

	Rosenbrock		Sphere	
	Avg.	Min.	Avg.	Min.
ABC	1.74E+9	1.12E+9	9.18E−8	2.50E−8
P_{s1}	56.65	23.25	5.35E−49	3.67E−101
P_{s2}	79.83	36.24	4.61E−43	1.97E−92
P_{s3}	96.71	14.11	4.50E−22	1.82E−41
P_{s4}	11.79	4.67E−1	8.01E−65	4.53E−110
P_{s5}	75.18	7.73	8.34E−116	5.68E−131

Table 4: Simulation results (Mutimodal).

	Rastrigin		Ackley	
	Avg.	Min.	Avg.	Min.
ABC	621.78	587.78	20.55	20.49
P_{s1}	24.87	18.90	7.44	1.80
P_{s2}	30.61	14.92	8.17	6.58
P_{s3}	29.85	12.94	13.74	9.76
P_{s4}	22.56	13.93	1.47	3.10E−13
P_{s5}	17.10	13.93	20.58	20.52

Table 5: Simulation time (Rastrigin).

	n	output	times[s]
ABC	0	621.78	29.23
Proposed Model(P_{s4})	25	22.56	31.64

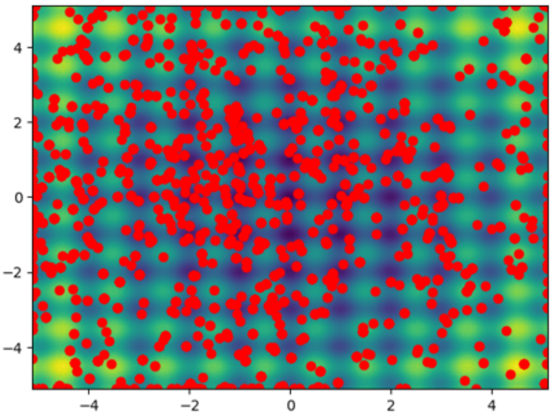

Figure 5: Distribution map (ABC).

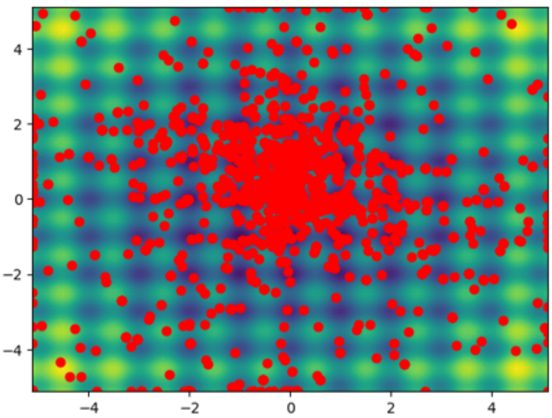

Figure 6: Distribution map (P_{s4}).

5. Conclusions

In this study, we proposed an employed bee phase that incorporates elements of onlooker bee and scout bee. For this purpose, three strategies were set up, P_s were varied, and simulations were performed for four different benchmark functions. The results showed that the proposed method performed better than the conventional method, and the distribution maps confirmed that the proposed method is capable of efficient search. However, the simulation time increased by about 10% with the proposed method. Therefore, reduction of computational cost should be considered. In the future, we plan to apply the proposed method to specific optimization problems such as TSP.

Acknowledgments

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