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An adaptive artificial bee colony algorithm for global optimization

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ABSTRACT

Artificial bee colony algorithm (ABC) is a recently introduced swarm based meta-heuristic algorithm. ABC mimics the foraging behavior of honey bee swarms. Original ABC algorithm is known to have a poor exploitation performance. To remedy this problem, this paper proposes an adaptive artificial bee colony algorithm (AABC), which employs six different search rules that have been successfully used in the literature. Therefore, the AABC benefits from the use of different search and information sharing techniques within an overall search process. A probabilistic selection is applied to determine the search rule to be used in generating a candidate solution. The probability of selecting a given search rule is further updated according to its prior performance using the roulette wheel technique. Moreover, a memory length is introduced corresponding to the maximum number of moves to reset selection probabilities. Experiments are conducted using well-known benchmark problems with varying dimensionality to compare AABC with other efficient ABC variants. Computational results reveal that the proposed AABC outperforms other novel ABC variants.

1. Introduction

Swarm Intelligence (SI) based algorithms have been widely used by researchers to solve global optimization problems [1]. SI simulates the collective behavior of groups of simple agents like colonies of ants, flocks of birds, swarm of bees, and so on [2]. Some examples of SI based algorithms are: artificial bee colony algorithm (ABC) [3], ant colony optimization [4], particle swarm optimization (PSO) [5], firefly algorithm [6] and bacterial foraging algorithm [7]. A global optimization problem can be defined as follows:

$$\min/\max\ F(\boldsymbol{x}) = f(x_1, x_2, \ldots, x_n), \quad \boldsymbol{x} \in X \tag{1}$$

where $X \subseteq R^n$ denotes the search space with n dimensions, $\boldsymbol{x} = (x_1, x_2, \ldots, x_n) \in R^n$ is the decision vector. $f : X \to R$ is a real valued continuous nonlinear objective function, which is responsible for mapping n dimensional space to one dimensional objective function value $F(\boldsymbol{x})$ and n is the number of variables.

The ABC is a biologically inspired population-based meta-heuristic algorithm that mimics the foraging behavior of honey bee swarms [8]. Due to its simplicity and ease of application, the ABC has been widely used to solve both continuous and discrete optimization problems since its invention [9]. Karaboga et al. [10,11] analyzed the performance of ABC by comparing it to other

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novel evolutionary algorithms on well-known benchmark problems. Results showed that, ABC is superior to other meta-heuristic algorithms such as genetic algorithm (GA), differential evolution (DE) and PSO, on most of the instances.

A well-designed swarm based algorithm should manage the tradeoff between exploration and exploitation successfully. However, it has been shown that ABC tends to suffer poor exploitation performance on complex problems [12–14]. To improve the exploitation performance of ABC, many researchers have focused on the search rule as it controls the tradeoff between exploration and exploitation. Therefore, various new search strategies, mostly inspired from PSO and DE, have been proposed in the literature. Zhu and Kwong [15] proposed a global-best guided ABC, which utilizes the global best individual's information within the search rule similar to PSO. Inspired by DE, Gao and Liu introduced a modified version of the ABC in which ABC/best/1 and ABC/Rand/1 were employed as local search rules [14]. Li et al. [16] presented an improved version of ABC (IABC) in which the best-so-far information, inertial weight and acceleration coefficient are used when employing local search. Furthermore, Kang et al. [17] described the Rosenbrock ABC, which combines Rosenbrock's rotational method with the original ABC. To improve exploration, Alatas [12] employed chaotic maps for initialization and chaotic searches within a search strategy. Gao et al. [18] proposed a new search rule in which the Powell's method is used. Xu et al. [19] described a new ABC (NABC) that employs a modified version of the DE/best/1 strategy. Akay and Karaboga [20] introduced a modified version of the ABC in which frequency of perturbation is controlled adaptively and the ratio of variance operator was introduced. Bansal et al. [21] integrated a new local search phase to the algorithm, which uses the best individual's information. Xiang and An [22] introduced a new combinatorial search rule and chaotic search technique so as to improve the performance of the ABC. Liao et al. [23] proposed a detailed experimental analysis and comparison of an ABC variant with different search rules. Qui et al. [24] presented a modified ABC, which employed a current-to-best/1 strategy in the differential evolution algorithm. Banharnsakun et al. [13] described best-so-far selection in ABC where the best feasible solutions found so far are used globally among the entire population. Biswas et al. [25] presented migratory multi swarm ABC where sub population of swarms employ different search strategies. Gao et al. [26] introduced two new search rules for onlooker and employed bee phases and a new robust comparison technique for candidate solutions. Xiang et al. [27] hybridized DE and ABC with a new search strategy inspired from g-best guided ABC. Furthermore, ABC has been successfully applied to solve combinatorial optimization problems, such as production scheduling [28, 29], vehicle routing [30], location-allocation problem [31] and many others [32–36]. Readers can refer to Karaboga et al. [9] for an extensive literature review of the ABC and its applications.

In related literature, integrating adaptation mechanisms into swarm-based algorithms is one of the most widely used techniques to improve the performance. To mention a few studies, Brest et al. [37] proposed a self-adaptive DE (jDE) in which control parameters *CR* and *F* are adjusted adaptively. Qin et al. [38] presented DE algorithm (SaDE) that updates the control parameters and adaptively selects the search strategy between rand/1/bin and best/1/bin according to their success. Zhan et al. [39] proposed an adaptive particle swarm optimization (APSO) where adaptive adjustment is applied for the inertia weight, acceleration coefficient and other algorithmic parameters according to the evolutionary states. In addition, evolutionary states were determined by using population diversity with fuzzy classification. As mentioned before, most of these studies involve adaptation mechanisms for an algorithm's control parameters. Unlike most of the papers in literature, this study presents an adaptation mechanism for search strategies in which a sustainable exploration/exploitation balance is achieved effortlessly. To the best of our knowledge, this study is the first in literature that integrates adaptive search selection mechanism into ABC.

This study presents an adaptive ABC (AABC) in which a new adaptive search strategy selection (ASSEL) mechanism is introduced. The main contribution of this study is to adaptively use various search strategies with different exploration and exploitation abilities in a single overall search process within ABC. The search strategy in ASSEL, that is used to generate candidate solutions, is adaptively updated according to its prior performance. For the success of a meta-heuristic algorithm, it is crucial to use different search approaches in different phases of the search process. Therefore, a memory length is introduced corresponding to an upper value for the cycle number to reset the selection probabilities. Experiments are conducted using well-known benchmark problems with varying dimensionality to compare AABC with other efficient ABC variants introduced in literature. Computational results show that AABC achieves a superior performance to other novel ABC variants.

The remainder of this paper is organized as follows: Section 2 presents the traditional ABC; Section 3 introduces the proposed AABC; the computational experiments and results are presented in Section 4 and finally Section 5 concludes the paper.

2. Artificial bee colony algorithm

The ABC is a population-based meta-heuristics algorithm that mimics the foraging behavior of honey bee swarms. The ABC classifies bees in a colony into three main groups: employed bees, onlooker bees and scout bees. Employed bees are responsible for exploiting the food sources and sharing the information about these food sources. Onlooker bees wait in the hive and take the food source information from employed bees to make a decision on further exploiting the food source. Scout bees randomly search the environment to find a new food source.

In the ABC, each candidate solution to the problem is associated with a food source and is represented by an n-dimensional real-coded vector. The quality of a solution corresponds to the amount of nectar on that food source, and a single employed bee explores each food source. In other words, the number of employed bees is equal to the number of food sources. The colony is equally divided into employed and onlooker bees. If a given food source cannot be improved for a predetermined number of tries, then it is abandoned and the employed bee associated to that food source becomes a scout. In the ABC, the employed and onlooker bees are responsible for exploitation, whereas the scout bees handle exploration.