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Artificial bee colony algorithm with variable search strategy for continuous optimization

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ABSTRACT

The artificial bee colony (ABC) algorithm is a swarm-based optimization technique proposed for solving continuous optimization problems. The artificial agents of the ABC algorithm use one solution update rule during the search process. To efficiently solve optimization problems with different characteristics, we propose the integration of multiple solution update rules with ABC in this study. The proposed method uses five search strategies and counters to update the solutions. During initialization, each update rule has a constant counter content. During the search process performed by the artificial agents, these counters are used to determine the rule that is selected by the bees. Because the optimization problems and functions have different characteristics, one or more search strategies are selected and are used during the iterations according to the characteristics of the numeric functions in the proposed approach. By using the search strategies and mechanisms proposed in the present study, the artificial agents learn which update rule is more appropriate based on the characteristics of the problem to find better solutions. The performance and accuracy of the proposed method are examined on 28 numerical benchmark functions, and the obtained results are compared with various classical versions of ABC and other nature-inspired optimization algorithms. The experimental results show that the proposed algorithm, integrated and improved with search strategies, outperforms the basic variants and other variants of the ABC algorithm and other methods in terms of solution quality and robustness for most of the experiments.

1. Introduction

In recent years, many swarm intelligence-based heuristic optimization techniques such as the ant colony optimization (ACO) [24,25], particle swarm optimization (PSO) [23,33], artificial bee colony algorithm (ABC) [8], cuckoo search (CS) [45], firefly algorithm (FA) [46], and artificial fish swarm algorithm (AFSA) [44] have been proposed in the literature. These algorithms are generally biologically inspired by the social behaviors of insects, fish or birds. ABC, which is another biologically inspired optimization algorithm and the subject of this study, is based on the foraging and waggle dance behaviors of the honey bee colonies. In the ABC algorithm, there are two types of bees in the hive: employed and unemployed. The unemployed bees are further classified as onlooker and scout. The employed bees collect nectar from the food sources and share the positions of the food sources with the unemployed bees. The onlooker bees search for new food sources based on the information provided by the employed bees. An employed bee becomes a scout bee if a food source cannot be improved

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by the employed or onlooker bees in a predefined and reasonable time. In the ABC algorithm, the positions of the food sources represent a possible solution for the optimization problem, and new food sources are searched by the bees. This information is exchanged among the bees until a termination condition is met.

In ABC, the onlooker and employed bees utilize the same solution updating equation. The solution updating equation of a basic ABC has several issues such as slow achievement of the optimal or near optimal solution (slow convergence) and inefficiency during a local search on the solution space. To overcome these issues, we propose the integration of different search strategies within the setting of the ABC algorithm. To this aim, we present five solution update strategies, and a counter is defined for each strategy in this work. These counters are initialized with a constant integer number, and each strategy has an equal chance of being selected by the employed or onlooker bees. When a strategy is selected by an employed or onlooker bee, its selection opportunity is improved by increasing its counter by one, if the new solution obtained by the selected strategy is better than the previous one. Therefore, the appropriate solution search equation is maintained according to the characteristics of the numerical functions.

The rest of paper is organized as follows. Section 1.1 presents a literature review on the ABC algorithms, and the main contribution of this study is given in Section 1.2. Material and methods (Section 2) gives the basic ABC concept and the proposed search strategies and mechanism for the ABC algorithm. The benchmark functions used in the experiments and an analysis of the update rules is given in Section 3. The performance of the proposed method is also investigated and compared with ABC variants on the benchmark functions in Section 3. The obtained results are discussed in Section 4. Finally, the study is concluded, and future directions for our work are given in Section 5.

1.1. A brief literature review on improvements of ABC

ABC was introduced by Karaboga and was inspired by the foraging and waggle dance behaviors of honey bee colonies [8]. Since its invention in 2005, many ABC variants have been proposed in the literature, more than half of the studies are composed of the bee colony optimization, honey bee mating optimization, bee algorithm or artificial bee colony algorithm, and they provide an improvement or application of the ABC algorithm in the period of 2005 and 2012 [14]. The performance and accuracy of the ABC algorithm was analyzed with the optimizing numerical benchmark functions [4,9,11,12]. Alatas [6] proposed a version of ABC to improve the convergence characteristics and to prevent the ABC from becoming stuck on local solutions. To improve the exploitation ability of the ABC algorithm, Zhu and Kwong [18] added the global best information in the bee population to the solution updating equation in the method called gbest-guided ABC (GABC). Karaboga and Akay [5] defined a new parameter called modification rate (MR) that MR controls regardless of whether a dimension of the problem is updated for the ABC algorithm to increase the convergence rate of the algorithm. Banharnsakun et al. [1] improved the capability of convergence of the ABC to a global optimum by using the best-so-far selection for onlooker bees, and they tested the performance of their method on numerical benchmark functions and image registration. Liu et al. [47] presented a version of the ABC algorithm that was improved by using mutual learning, which tunes the produced candidate food source with the higher fitness between two individuals selected by a mutual learning factor. Gao et al. [38] proposed two ABC-based algorithms that use two update rules of differential evolution (DE) called ABC/Best/1 and ABC/Best/2. The global best-based ABC methods also use chaotic initialization to properly distribute the agents to the search space, and the performance and accuracy of the methods are examined on 26 numerical benchmark functions [38]. To overcome premature convergence and local minima issues, Gao and Liu [39] proposed ABC/Best/1. In ABC/Best/1, Gao and Liu use the update rule of the ABC/Best/1 algorithm for employed bees and the update rule of basic ABC for onlooker bees to reinforce the exploration ability of the method, and they tested the proposed method MABC on 28 numerical benchmark functions. In another study, Gao et al. [40] defined a new update rule based on random solutions while the candidate solution is obtained, and the new rule looks similar to the crossover operator of the GA as is named CABC. In this study, the orthogonal learning strategy is proposed for ABC methods such as basic ABC (OABC), GABC (OGABC), CABC (OCABC), and their accuracies, and performances are examined on numerical benchmark functions and are compared with evolutionary algorithms (EAs), differential evolution variants (DEs) and particle swarm optimization variants (PSOs). Karaboga and Gorkemli [13] proposed a new update rule for onlooker bees in the hive to improve the local search and convergence characteristics of the standard ABC algorithm. Inspired by PSO, Imanian et al. [30] changed the update rule of the basic ABC algorithm to increase the convergence speed of the basic ABC algorithm for solving high dimensional, continuous optimization problems. Wang et al. [20] proposed the MEABC algorithm to improve the local and global search capability of the basic ABC algorithm, and they tested the performance of MEABC on basic, shifted and rotated benchmark functions. In another study, the ABC and bee algorithm are integrated to solve six constrained optimization benchmark problems [21]. Kiran and Findik [28] developed a simple version of the basic ABC algorithm by using direction information regarding the solutions to improve the convergence characteristics of the basic algorithm. Mansouri et al. combined the bisection method with ABC for finding the fixed point of a nonlinear function [31]. Gao et al. proposed two new search equations for the basic ABC algorithm to balance exploration and exploitation on the search space [41].

In addition to modifications and improvements of ABC, ABC has been applied to solve many optimization problems such as the image segmentation [29], synthetic aperture radar image segmentation [26], multi-objective design optimization of laminated composite components [35], in-core fuel management optimization [22], parametric optimization of non-traditional machining processes [34], wireless sensor network routing [16], leaf-constrained minimum spanning tree problem [3], reliability redundancy allocation problems [42], optimum design of geometrically non-linear steel frames [36], training