



Artificial bee colony algorithm with distribution-based update rule



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ABSTRACT

In last decades, lots of nature-inspired optimization algorithms are developed and presented to the literature for solving optimization problems. Generally, these optimization algorithms can be grouped into two categories: evolutionary algorithms and swarm intelligence methods. Evolutionary methods try to improve the candidate solutions (chromosomes) using evolutionary operators such as crossover, mutation. The methods in swarm intelligence category use differential position update rules for obtaining new candidate solutions. The popularity of the swarm intelligence methods has grown since 1990s due to their simplicity, easy adaptation to the problem and effectiveness in solving the nonlinear optimization problems. One of the popular members of swarm intelligence algorithms is artificial bee colony (ABC) algorithm which simulates the intelligent behaviors of real honey bees and uses differential position update rule. When food sources which present possible solutions for the optimization problems gather on the similar points within the search space, differential position update rule can cause a stagnation behavior in the algorithm during the search process. In this paper, a distribution-based solution update rule is proposed for the basic ABC algorithm instead of differential update rule to overcome stagnation behavior of the algorithm. Distribution-based update rule uses the mean and standard deviation of the selected two food sources to obtain a new candidate solution without using any differential-based processes. This approach is therefore prevents the stagnation in the population. The proposed approach is tested on 18 benchmark functions with different characteristics and compared with the basic variants of ABC algorithm and some nature-inspired methods. The experimental results show that the proposed approach produces acceptable and comparable solutions for the numeric problems.

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1. Introduction

In recent years, many swarm intelligence algorithms have been presented for solving nonlinear optimization problems to the literature. Particle swarm optimization (PSO) is inspired by social behaviors of birds or fishes [1]. Ant colony optimization (ACO) algorithm is developed by simulating the behavior of real ants between nest and food sources [2]. Artificial bee colony algorithm (ABC) [3] which is one of swarm intelligence algorithm simulates two intelligent behavior of real honey bee colony. First behavior is to search nectar around the hive, and the second is to share position information of food sources around the hive. These behaviors are collectively performed by employed, onlooker and scout bees of the algorithm. In ABC algorithm, each food source position represents a possible solution for the optimization problem. While searching food sources around the hive, a differential position update rule is used by employed, onlooker and scout bees in the ABC algorithm. This rule has caused stagnation in the population during

the search process. Due to the stagnation in the population, new candidate solutions those are different from the actual solutions cannot be produced, and therefore, the search process stops. In order to overcome this issue in ABC algorithm, a distribution-based update rule is developed being inspired by vortex search algorithm [4]. The proposed update rule uses the actual and neighbor solutions in ABC algorithm in order to produce a new candidate solution. The mean and standard deviation of two solutions are obtained, and new candidate solution is produced by normal distribution.

This paper is organized as follows: Section 1 introduces the study and presents a brief literature review and main contribution of the paper. In Section 2, material and methods are explained and the proposed update rule and algorithm are detailed. The experimental studies and comparisons are given in Section 3. The obtained results are discussed in Section 4. The study is finally concluded and future directions are presented in Section 5.

1.1. A brief literature review on improvements of ABC

The ABC algorithm has been developed by Karaboğa [3] for solving continuous optimization problem. The performance of ABC

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algorithm has been examined on optimizing numerical benchmark functions [5–8]. Being inspired by the update rule of PSO, Zhu and Kwong [9] proposed a variant of ABC algorithm to improve exploitation ability of the method. Alatas [10] developed chaotic ABC algorithm to improve global search ability of the method. Karaboga and Akay [11] added a new control parameter named as modification rate (MR) to the algorithm, which MR parameter is used to control perturbation of ABC algorithm. Banharnsakun [12] introduced best-so-far selection for onlooker bees of ABC to improve convergence capability of ABC algorithm, and Kiran and Findik [13] proposed a directed ABC algorithm for the same purpose. Kiran and Gündüz [14] used crossover operator for sharing information between onlooker and employed bees. Gao et al. [15] proposed an ABC variant named as MABC by inspiring solution update rule of differential evolution (DE) algorithm. Similar to MABC, Gao et al. [16] developed ABC/Best/1 and ABC/Best/2 algorithms with chaotic system and opposition-based learning strategy by modifying DE update rules. In another study, Gao et al. [17] introduced a new update rule for ABC, and orthogonal learning strategy is combined with ABC in the same study. Gao et al. [18] developed new search equations to adjust exploration and exploitation capability of the ABC algorithm. In a different approach for ABC algorithm, Das et al. [19] proposed a learning routine based on fitness and proximity stimuli, and they tested the method on standard benchmark functions. In another study, Kiran et al. proposed an integration of update rules for ABC algorithm and they analyzed the performance of proposed method on solving the numeric functions [20]. In addition, a comprehensive literature review on ABC algorithm and its applications published can be found in 2013 [21] and 2014 [22]. Das et al. [23] suggested another approach for global optimization in their study. The authors implement optic flow of information in honeybees to ABC algorithm, and try to enhance performance of the ABC algorithm using this implementation with saccadic flight strategy. To improve global capability of the basic ABC algorithm, some modified versions of the basic method were proposed for solving continuous optimization problems [24,25]. Besides improvements of ABC, The ABC algorithm has been applied to solve a huge number problems such as designing digital IIR filters [26], to estimate electricity energy demand [27], image processing and clustering [28,29], dynamic deployment of wireless sensor networks [30], neural network training [31,32], to optimal filter design [33] and antenna array design [34].

The most of the studies based on ABC in the literature aims to develop the differential update rule for ABC in order to improve local or global search capability of ABC or in order to increase convergence speed of ABC. Differential search has caused the stagnation and all the artificial agents in the method gather on a point. Therefore, the new candidate solution could not be obtained by using subtraction after a point. Apart from these studies and by inspiring vortex search algorithm [4], this paper proposes a new update rule based on distribution.

1.2. Main contribution of the study

This paper proposes a new update rule mechanism instead of traditional differential update rule of ABC. The new update solution update mechanism prevents stagnation of the population, because there is no differential update mechanism in the new proposed approach. Unlike the other methods, the search in new method is carried out down to the wire of search process of the algorithm. By utilizing distribution-based update rule for ABC, the stagnation situation in the population is prevented, because new candidate solution can be produced even if all agents are on the same point.

1.3. Stagnation in bee population of ABC algorithm

Stagnation in the populations of swarm intelligence methods corresponds to similarity of the candidate solutions to the parent solutions in the population [35–37]. The diversity in the population is kept up to date during the search process to overcome stagnation issue in the population. Different-based update rules propose for basic ABC algorithm and its versions can cause degradation of the diversity in the population, and the bee population can show stagnation behavior. To cope with this issue in the bee population of ABC algorithm, a distribution-based update rule is proposed and the proposed approach is detailed below.

2. Material and methods

This section explains the material, which is test suite to be used for analyzing and comparing the performance of the proposed approach with the traditional ABC variants. The methods those are standard ABC algorithm and proposed search mechanism and algorithm are also detailed in this section.

2.1. Benchmark functions used in experiments

In order to validate and analyze the performance of the proposed method, well-known numeric benchmark functions are collected from the literature [7–9,20]. These functions are given in Table 1.

These functions have some characteristics such as unimodality, multimodality, separable and non-separable. Unimodal functions have only one local optimum and it is the global optimum. This type of functions can be used for analyzing the intensification capability of the methods. Multimodal functions have more than one local optimum and one or more of the local optimums can be global optimum. Besides intensification capability, this type of functions can also be used the exploration capability of the algorithms. Separable functions can be written as the sum of n -functions of one variable but non-separable functions cannot be reformulated by being used this formulation, because there is an interrelation among the variables of the non-separable functions [8,20]. The dimensionality of a function can be an issue for the optimization methods, and to solve low dimensional functions is easier than the high dimensional functions, because the search space is expanded exponentially by depending on the dimensionality [8,20,38].

In this study, the performance of the proposed approach is examined on numeric functions given in Table 1 and obtained results are compared with the basic ABC algorithm. The dimension for the functions is set to 30 and 60 for first and second comparisons, respectively.

2.2. Standard ABC algorithm

The real honey bees try to discover the food sources within the colony area in nature. Different types of the honey bees are employed to accomplish this process in order to sustain the life cycle of the colony. ABC algorithm is inspired from intelligent behavior of these real honey bees in nature [7]. By this inspiration of foraging in nature, ABC algorithm tries to find the optimal solutions for the optimization problems. This inspiration uncovers three types of artificial bee group namely employed, onlooker and scout bees [3].

The employed bees in the hive are assigned to find the food sources and share the information with onlooker bees. During the search process, employed bees evaluate new food sources in their neighborhood. When a food source quality is better than the old one, employed bee memorizes this source as its primary source and make the following search process within this new food sources neighborhood. Then the information is shared with

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