Information Sciences 417 (2017) 169–185

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

A ranking-based adaptive artificial bee colony algorithm for global numerical optimization

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ARTICLE INFO

Article history:
Received 2 September 2016
Revised 5 July 2017
Accepted 11 July 2017
Available online 12 July 2017

Keywords:
Artificial bee colony algorithm
Adaptive ranking selection
Global numerical optimization

ABSTRACT

The artificial bee colony (ABC) algorithm is a powerful population-based metaheuristic for global numerical optimization and has been shown to compete with other swarm-based algorithms. However, ABC suffers from a slow convergence speed. To address this issue, the natural phenomenon in which good individuals always have good genes and thus should have more opportunities to generate offspring is the inspiration for this paper. We propose a ranking-based adaptive ABC algorithm (ARABC). Specifically, in ARABC, food sources are selected by bees to search, and the parent food sources used in the solution search equation are all chosen based on their rankings. The higher a food source is ranked, the more opportunities it will have to be selected. Moreover, the selection probability of the food source is based on the corresponding ranking, which is adaptively adjusted according to the status of the population evolution. To evaluate the performance of ARABC, we compare ARABC with other ABC variants and state-of-the-art differential evolution and particle swarm optimization algorithms based on a number of benchmark functions. The experimental results show that ARABC is significantly better than the algorithms to which it was compared.

1. Introduction

With the development of science and technology, global optimization problems (GOPs) always arise in almost all science and engineering fields, and optimization techniques have been playing an increasingly important role. However, with an increasing number of real-world optimization problems characterized as non-convex, discontinuous, non-differentiable, multimodal and even dynamic [32,41,44,45], traditional derivative-based methods [18,19] are becoming unavailable or unrealizable. Inspired by natural selection and survival of the fittest, swarm intelligence algorithms [4] such as genetic algorithms (GAs) [49], particle swarm optimization (PSO) [26,39], differential evolution (DE) [8,29,40], and the artificial bee colony algorithm [9,23] have been developed as a branch of derivative-free methods to address these complex problems and have shown excellent performance.

In this paper, we focus on the artificial bee colony algorithm (ABC for short), which is inspired by the intelligent foraging behavior of honey bees and was developed by Karaboga [23] in 2005. The performance of ABC is verified by comparison

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http://dx.doi.org/10.1016/j.ins.2017.07.011

with other evolutionary algorithms (EAs) such as GA, PSO, DE and evolution strategies (ES) [24] on a number of benchmark functions. Due to its simple structure, ease of implementation and outstanding performance, ABC has been quickly applied to solve many practical optimization problems [5].

The core operator of ABC is the solution search equation. In the original ABC, one parent of the solution search equation is randomly selected from the population, and the other is the current target vector. To improve the performance of ABC, Gao et al. [15] design a novel search equation such as the crossover operation of GA (called CABC) without bias toward any search direction, which significantly improves the search ability of ABC. However, the parents in the solution search equation of CABC all are randomly selected from the current population, which may also lead CABC to be useful for exploring the search space but poor at exploitation of the solutions. We are inspired by the natural phenomenon that good individuals always have good genes, and thus they have more opportunities to generate offspring [17]. That is, in EAs, good solutions always contain good information, and thus, they should have more chances to be utilized to generate new solutions (offspring). Therefore, the key issue is how to effectively utilize the good solutions to enhance the exploitation without a loss of exploration. To achieve this goal, some methods in EAs definitively utilize the good solutions proposed. First, in DE, Das et al. [10] exploit the best solution among the neighbors and the current best individual to guide the evolutionary direction (DEGL). Zhang and Sanderson [48] take advantage of the beneficial information from the top $p \times 100\% \times NP$ individuals in the population (JADE). Second, in PSO [26], the personal best solution and the global best solution are collectively used to guide the search. Moreover, in ABC, Zhu and Kwong [50] designed a new search equation exploiting the information of the current best solution to improve the exploitation ability of ABC (GABC). Inspired by DE, Gao et al. [14] designed a new search equation (ABC/best/1), which also exploits the current best solution (IABC). Furthermore, Xiang et al. [46] draw inspiration from PSO and introduce a novel search equation that employs the information of the best solution and other elite solutions (PS-MEABC), and so on.

In this paper, we follow this basic idea and propose a novel ranking-based adaptive artificial bee colony algorithm, ARABC. The idea behind our algorithm is that the higher the ranking a solution obtains, the more opportunities it will have in being chosen to generate new solutions. The major advantages of our approach are listed as follows: 1) Since good solutions are more likely to be selected to produce offspring, our approach is able to enhance ABC's exploitation ability without the loss of the exploration ability; 2) Our approach is easy to implement; 3) Our approach does not increase the overall complexity of ABC significantly. To evaluate the performance of our proposed approach, we compare our approach with state-of-the-art variants of ABC and other state-of-the-art EAs. The comparison results demonstrate that our approach shows promising performance. The contributions of this paper are summarized as follows.

(1) A novel solution search equation is designed for employed bee and onlooker bee, in which the parent food sources are all selected on the basis of their rankings. Moreover, the selection probability of the food source based on its ranking could be adaptively adjusted according to the feedback information of the population evolution.
(2) The food sources also attract the employed bee and onlooker bee for exploitation based on their rankings. In this way, the higher quality food sources are used to promote convergence, and lower quality food sources are employed to maintain population diversity.

The rest of this paper is organized as follows. Section 2 briefly introduces the original ABC and other variants of ABC. In Section 3, we present our ranking-based adaptive ABC in detail. In Section 4, the comprehensive experiments using benchmark functions are conducted, and the experimental results are analyzed. Finally, the conclusion and possible future work are summarized in Section 5.

2. ABC and related work

2.1. Original ABC

ABC, which was proposed by Karaboga [23], is a novel swarm-based stochastic optimization method that simulates the intelligent foraging behavior of honey bees. In ABC, the colony of honey bees includes three groups: employed bees, onlooker bees, and scout bees. The first half of the colony consists of employed bees, and the other half consists of the onlookers. Employed bees are responsible for seeking out better food sources in the vicinity of their previous food sources and passing quality information of the food sources to onlooker bees by dancing. Onlooker bees select good food sources found by employed bees to further search for better food sources. When the quality of a food source is not improved through predetermined cycles (*limit*), the food source is abandoned by its employed bee, and the employed bee becomes a scout and seeks out a new random food source in the vicinity of the hive.

In ABC, the position of a food source denotes a possible solution of the optimization problem, and the nectar amount of each food source denotes the quality (fitness) of the corresponding solution. The number of employed bees (or onlooker bees) equals the number of food sources. The original ABC includes four basic phases: initialization phase, employed bee phase, onlooker bee phase and scout bee phase. In the initialization phase, an initial population $\boldsymbol{P}$ including SN solutions (food source initial position) should be generated, where SN represents the number of food sources (the size of employed bees or onlooker bees). Each initial solution $X_i^0 = (x_{i,1}^0, x_{i,2}^0, \cdots, x_{i,D}^0)$ is produced in the search space randomly as follows:

$$X_{i,j}^0 = x_{L,j} + rand(0,1)(x_{U,j} - x_{L,j}) \tag{1}$$