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Modified global best artificial bee colony for constrained optimization problems ☆

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ABSTRACT

Artificial Bee Colony (ABC) is one of the most popular nature inspired optimization algorithms. Recently, a variant of ABC, Gbest-guided ABC (GABC) was proposed. GABC was verified to perform better than ABC, in terms of efficiency and reliability. In the position update process of GABC, Gbest (the best individual in the swarm) individual influences the movement of the swarm. This movement may create a cluster around the Gbest individual which further leads to the premature convergence, particularly for constrained optimization problems. This paper presents a modification in GABC for constrained optimization problems. GABC is modified in both employed and onlooker bee phases by incorporating the concept of fitness probability based individual movement. The modified GABC is tested over 20 constrained benchmark problems and applied to solve 3 engineering design problems. Optimal power flow problem has also been solved using modified GABC to check the efficiency of the proposed algorithm.

1. Introduction

Problems in various fields, like economics, engineering design, structural optimization are modeled as constrained optimization problems. Due to the presence of constraints, usually, the problem becomes difficult to solve. A general form of a constrained optimization problem (in minimization case) is:

$$\begin{aligned} \underset{\vec{x}}{\text{minimize}} \quad & f(\vec{x}), \\ \text{subject to} \quad & g_j(\vec{x}) \le 0, \quad \forall j = 1, 2, \ldots q \\ & h_j(\vec{x}) = 0, \quad \forall j = 1, 2, \ldots r \end{aligned} \tag{1}$$

Here, f($\vec{x}$) is the objective function defined on a search space $\mathbb{S}$. $\vec{x} = (x_1, \ldots, x_n) \in \mathbb{S} \subset \mathbb{R}^n$ is a n-dimensional vector bounded by its lower and upper limits i.e. $l_i \le x_i \le u_i, \forall i = 1, 2, \ldots n$. R^n is the n-dimensional field of real numbers, $g(\vec{x})$ is the set of q inequality constraints and $h(\vec{x})$ is the set of r equality constraints. The solution of problem (1) is a vector $\vec{x}$ defined in the search space $\mathbb{S}$ that minimizes f($\vec{x}$) such that the set of given equality and inequality constraints are satisfied.

Many traditional, mostly deterministic optimization methods are available in the literature to solve the constrained optimization problems. For solving real world constrained optimization problems, deterministic methods like generalized reduced gradient methods [1], sequential quadratic programming methods [2] etc. require many mathematical conditions, e.g.

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convexity, continuity or differentiability to be satisfied. A real world problem rarely follows all required conditions. In this scenario, deterministic methods become infeasible to solve a real world problem, in their original form.

On the contrary, nature-inspired optimization algorithms have merits over deterministic methods, such as derivative free mechanism, having higher ability to avoid local optima, flexible in terms of the applicability, and being simple for implementation.

Therefore nature-inspired optimization algorithms like, particle swarm optimization (PSO) [3], differential evolution (DE) [4] and artificial bee colony (ABC) [5] are preferred to solve such complex constrained optimization problems.

Several new variants of these algorithms are developed in order to make their performance more powerful over constrained optimization problems. In this context, we observe artificial bee colony (ABC) which was invented by Karaboga et al. [6] and is inspired by the foraging behavior of honey bees. Similar to other swarm based optimization algorithms, ABC possesses a swarm of candidate solutions, which are the food sources of honey bees. The nectar amount (or quality) of food source represents fitness. There are three categories of honey bees in the hive with respect to their work assignments, namely employed bees, onlooker bees and scout bees. Employed and onlooker bees collect nectar from the food sources. The bee associated to abandoned food source becomes scout bee. The scout bee searches new food sources in different directions and creates fluctuations in the search process. Thus the search space is exploited by the onlooker and employed bees, while the exploration of the search space is done by scout bees.

The dominance of random components in the position update strategy of ABC tends to explore the search space at the expense of the possibility of skipping true solution. Researchers are continuously trying to establish a proper trade-off between the exploitation and exploration capabilities to improve the performance of ABC algorithm.

To improve the exploitation property of search space, Gao et al. [7] proposed a new search strategy called ABC/best/1, associated with a novel chaotic initialization technique. In this search strategy, solution updates itself in the neighborhood of the previous best solution. To improve the convergence characteristics of ABC, Banharnsakun et al. [8] proposed a modified search equation for onlooker bees. In this equation, onlooker bees follow the direction of the best-so-far solution in a biased way, instead of a randomly selected neighbor one. Li et al. [9] improved the search process of ABC by using best-so-far solution, inertia weight, and acceleration coefficients. In this ABC model, a pool of different search equations is used to produce multiple new solutions, in which the best one is selected by the greedy approach. Alatas [10] proposed chaotic ABC, in which the parameter adaptation of ABC is done by chaotic maps and scout bee uses the chaotic search to explore new regions of search space. To improve the exploitation ability of ABC, Gao et al. [11] used Powell's method as a local search tool. Karaboga and Gorkemli [12] introduced a more accurate behavior of onlooker bees to improve the local search ability of ABC. Kiran et al. [13] used five search strategies and counters for updating the solutions of ABC. Sharma et al. [14] introduced Levy flight random walk inspired search strategy as a local search to improve the exploitation ability of ABC.

To solve constrained optimization problems, Karaboga and Akay [15] proposed a new variant of ABC, namely Modified ABC (MABC) in which the selection scheme of ABC is replaced by Debs selection rules [16]. Mezura-Montes et al. [5] proposed elitist artificial bee colony. In the proposed approach, equality constraints are controlled by dynamic tolerance mechanism to promote the exploration of search space. Bravejic et al. [17] presented an improved version of ABC, in which the very first swarm of candidate solutions is initialized randomly, after that all further swarms contain the best solution of their previous swarm. Mezura-Montes et al. [18] presented a novel algorithm in which the exploitation of search space is done in the vicinity of the best solution of the current swarm and constraints are handled by ϵ- constrained approach. In order to improve the efficiency of ABC in constrained search space, Brajevic [19] proposed a crossover-based ABC in which dynamic tolerance is used to handle the equality constraints and improved boundary constraint-handling method is employed.

In 2010, Zhu and Kwong [20] proposed an improved ABC algorithm, namely Gbest-guided ABC (GABC) in which Gbest (the best individual in the swarm) is incorporated into the position update equation to improve the exploitation ability of the search space. Since all the solutions which are going to be updated, move towards the Gbest solution, there is enough chance to trap in local optima. On the other hand, the performance of GABC is not good enough to establish its competitiveness to solve the constrained optimization problems.

To overcome this deficiency of GABC and make it efficient for constrained optimization problems, a new variant of GABC namely, Modified GABC (MGABC) is introduced.

Rest of the paper is organized as follows. Section 2 describes the standard ABC. A brief description of MGABC is introduced in Section 3. Section 4 describes the properties of considered benchmark functions, adopted experimental setting, constraint handling and experiment results with a comparative study. In Section 5 optimal power flow problem with three different objective functions has been solved by MGABC to verify its applicability for solving the real world problems. Finally, the conclusion is given in Section 6.

2. Standard ABC

Artificial bee colony algorithm is inspired from forging behavior of honey bees. In ABC, the position of a food source corresponds to a possible solution to the optimization problem and the quality (nectar amount) of each food source represents its fitness of the associated solution.

Initially, ABC generates a uniformly distributed initial swarm of SN food sources (potential solutions), where the dimension of each food source x_i $(i = 1, 2, \ldots SN)$ is D, which is equal to the number of variables in the optimization problem. Each

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