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An effective krill herd algorithm with migration operator in biogeography-based optimization

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ABSTRACT

Krill herd (KH) is a novel search heuristic method. To improve its performance, a biogeography-based krill herd (BBKH) algorithm is presented for solving complex optimization tasks. The improvement involves introducing a new krill migration (KM) operator when the krill updating to deal with optimization problems more efficiently. The KM operator emphasizes the exploitation and lets the krill cluster around the best solutions at the later run phase of the search. The effects of these enhancements are tested by various well-defined benchmark functions. Based on the experimental results, this novel BBKH approach performs better than the basic KH and other optimization algorithms.

1. Introduction

Optimization is to select a vector for a function that makes the function reach maximum/minimum. Nowadays, modern intelligent algorithms based on randomness are utilized to solve optimization problems. Up to now, various techniques have been used to cope with these problems. Classification of these techniques can be carried out in many ways. However, in general, a simple way for classifying these techniques is to look at their nature, and they can be generally categorized as two groups: classical methods, and intelligent algorithms. The former follow a rigorous procedure, and for the same input values, they will follow the same path and eventually generate the same solutions. Contrarily, intelligent algorithms are based on randomness, and the final solutions will be different each time you run a program regardless of initial value. However, in most cases, these two types of methods can reach the same values within a given accuracy. Recently, meta-heuristic methods inspired by nature perform efficiently in solving modern complicated global optimization problems. These meta-heuristic methods have been designed according to the principle of the nature for optimization problems, like o reliability problem [1,2], knapsack problem [3], permutation flow shop scheduling [4], system identification [5], airline boarding problem [6], UCAV path planning [7], education [8], and engineering optimization [9,10]. In most cases, these kinds of meta-heuristic methods can always find optimal or near-optimal solutions coming from a population of solutions not individual. After idealizing evolution as an optimization method called genetic algorithms (GAs) [11,12], various techniques have designed for optimization, such as harmony search (HS) [13–15], cuckoo search (CS) [16–19], evolutionary strategy (ES) [20,21], differential evolution (DE) [22–25], imperialist competitive algorithm (ICA) [26], ant colony optimization (ACO) [27], bat algorithm

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(BA) [28], animal migration optimization (AMO) [29], particle swarm optimization (PSO) [30–33], artificial bee colony (ABC) [34], probability-based incremental learning (PBIL) [35], genetic programming (GP) [36], big bang-big crunch algorithm [37–40], biogeography-based optimization (BBO) [41], charged system search (CSS) [42,43], and the KH algorithm [44].

By idealizing the swarm behavior of krill, KH is proposed as a swarm intelligence approach for optimization tasks [44]. For the krill movement, the objective function used in KH is determined by the least distances from food and the highest herd density. The position of the krill consists of three main components. Comparing with other algorithms, one of the advantages of the KH algorithm is that it requires few control variables to regulate.

In general, KH can explore the search space effectively and efficiently but sometimes it may not escape some local optima. Thus, it fails to implement global search fully in a given decision space. For KH, the search in KH is primarily based on random walks; hence, it cannot always converge to a satisfactory solution.

On the other hand, firstly presented by Simon [41], BBO is a novel stochastic global optimizer based on the biogeography theory. BBO has satisfactory global optimization ability, insensitivity for parameters, and simplicity. Therefore, it has attracted much attention from academic research and application.

In the present work, an effective biogeography-based KH (BBKH) method is proposed for the purpose of accelerating convergence speed. In BBKH, firstly, a standard KH is used to cut down the search apace and choose a promising candidate solution set in order to make the search more efficiently. Subsequently, krill migration (KM) operator is combined with the method. It can exploit the search region carefully to find the best solutions for optimization problems. The proposed method is verified on 14 functions. Experiments show that the BBKH method performs better than basic KH and other twelve methods.

The rest of the paper is structured as follows. Reviews on BBO and KH are discussed in Section 2 and Section 3, respectively. The BBKH method is presented in Section 3. Details on BBKH are presented in Section 4. Our method is tested through on functions in Section 5. Finally, Section 6 provides the conclusion and points out the path of the future work.

2. BBO

Firstly proposed by Dan Simon, BBO [41] is a novel meta-heuristic evolution algorithm for optimization problems. It is based on the idealization of the migration of species between islands when searching for more satisfactory places. Each candidate solution is called a "habitat" responding to a HSI and denoted by a d-dimension vector. A population of habitat is initially generated at random in the search space. The quality of habitat is mainly affected by HSI. Low HIS can absorb some useful features from the high HSI. Habitat H in BBO is a vector of NP SIVs. Later migration and mutation operators are implemented to get the final best solution.

The migration operator used in BBO is likely to the ES [21], where many parents cooperate to generate an offspring. In essence, migration is a stochastic operator that updates X_i. The updated probability X_i is related to its immigration rate λ_i and the emigration rate μ_j.

Because mutation operator is not used in our present work, here it is not described in detail. More information about BBO can be referred as in [41].

3. KH algorithm

By idealizing by the swarm behavior of krill, KH [44] is a meta-heuristic optimization approach for solving optimization problems. In KH, the position is mainly affected by three actions [45,46]:

i. movement affected by other krill;
ii. foraging action;
iii. physical diffusion.

In KH, the Lagrangian model [44] is used within predefined search space as Eq. (1).

$$\frac{dX_i}{dt} = N_i + F_i + D_i \tag{1}$$

where N_i is the motion produced by other krill individuals; F_i is the foraging motion, and D_i is the random diffusion of the ith krill individual.

In the first one, its direction, α_i, is decided by the following parts: target effect, local effect, and a repulsive effect. In sum, its definition can be provided below:

$$N_i^{new} = N^{\max}\alpha_i + \omega_n N_i^{old} \tag{2}$$

and $N^{\max}$, ω_n and N_i^{old} are the maximum speed, the inertia weight, the last motion, respectively.

The second one can be approximately calculated by the two components: the food location and its previous experience. For the ith krill, it can be idealized below: