Information Sciences 274 (2014) 17–34

Contents lists available at ScienceDirect

Information Sciences

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

Chaotic Krill Herd algorithm

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ARTICLE INFO

Article history:
Received 20 August 2012
Received in revised form 26 September 2013
Accepted 10 February 2014
Available online 3 March 2014

Keywords:
Global optimization problem
Krill Herd
Chaotic maps
Multimodal function

ABSTRACT

Recently, Gandomi and Alavi proposed a meta-heuristic optimization algorithm, called Krill Herd (KH). This paper introduces the chaos theory into the KH optimization process with the aim of accelerating its global convergence speed. Various chaotic maps are considered in the proposed chaotic KH (CKH) method to adjust the three main movements of the krill in the optimization process. Several test problems are utilized to evaluate the performance of CKH. The results show that the performance of CKH, with an appropriate chaotic map, is better than or comparable with the KH and other robust optimization approaches.

1. Introduction

The process of optimization is essentially the choice of a vector within a search space. The selected vector can maximize/minimize an objective function to provide the best solution. Generally, modern intelligent approaches are used to deal with these types of optimization problems. Such optimization approaches can be categorized into two groups in view of their natures: (1) deterministic, and (2) random intelligent approaches. The deterministic approaches using gradient have a strict step. They produce the identical solution if its initial starting values are the same with each other when solving the same problem. Contrary to the deterministic approaches, gradient-free stochastic algorithms are based on random walks. Therefore, the optimization process cannot be repeated under any conditions. However, in most cases, both of them are capable of finding the same final optimal solutions [44]. Recently, nature-inspired meta-heuristic algorithms show a powerful and efficient performance for dealing with high-dimension nonlinear optimization problems [12,53].

To some extent, all meta-heuristic approaches manage to make a trade-off between intensification (local search) and randomization (global search) [50]. These robust nature-inspired meta-heuristic approaches are utilized to tackle NP-hard problems such as task-resource assignment. They can fully exploit the useful information of the whole population to find optimal solutions. Up to now, significant research has been done on evolution theory. The process of evolution is idealized as a kind of gradient-free method, called genetic algorithms (GAs) [6,18,55]. Since then various nature-inspired meta-heuristic approaches have been proposed such as evolutionary strategy (ES) [1,2], particle swarm optimization (PSO) [27,28,40,56], ant colony optimization (ACO) [4], differential evolution (DE) [10,19,38], firefly algorithm (FA) [7], biogeography-based optimization (BBO) [29,37], cuckoo search (CS) [9,49], probability-based incremental learning (PBIL) [36], big bang–big

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1 URL: http://www.gozips.uakron.edu/~ag72.

http://dx.doi.org/10.1016/j.ins.2014.02.123
0020-0255/

crunch algorithm [5,23,25,26], harmony search (HS) [15,17,47], charged system search (CSS) [24], animal migration optimization (AMO) [31], teaching–learning-based optimization (TLBO) [3,35], bat algorithm (BA) [11,52], and the KH method [8]. In fact, KH is a new kind of swarm intelligence optimization approach inspired by the herding behavior of krill [8]. In KH, the objective function for the krill movement is decided by the distances of each krill from density of the krill swarm and food. The position for each krill is made up of three parts: (i) movement induced by other individuals (ii) foraging motion, and (iii) physical diffusion. The crucial advantage of KH algorithm is its simplicity, making KH implement easily and lending itself to parallel computation [44].

In general, KH lends itself strongly to exploitation. However, it cannot always implement global search well. Thus, in some cases, KH fails to find global optimal solution. The search strategy used in basic KH is mainly based on random walks. Thus, it cannot always deal with the problem successfully [45]. Different strategies have been added to the basic KH method [43,45] with the aim of improving its performance [45].

With the development of the nonlinear dynamics, chaos concept has been widely considered in various applications [34]. In this context, one of the most famous applications is the introduction of chaos theory into the optimization methods [48]. Up to now, the chaos theory has been successfully combined with several meta-heuristic optimization methods [13]. Some major efforts in this area includes hybridizing chaotic sequences with memetic differential evolution algorithm [22], FA [13], gravitational search algorithm [20], imperialist competitive algorithm [41], charged system search [33,42], PSO [14,46], and GAs [21].

In the present study, chaotic KH-based (CKH) methods are introduced for the purpose of accelerating the convergence of KH. Various one-dimensional chaotic maps are employed in place of the parameters used in KH. The performance of the proposed approach is tested on fourteen benchmark problems. Experimental results indicate that CKH performance is superior to KH, ACO, BA, CS, DE, ES, GA, PBIL, and PSO. This is mainly because deterministic chaotic signals are used to replace linearly declined values.

The organization of this paper is as follows. Firstly, a brief overview of the basic KH algorithm and 12 chaotic maps are given in Section 2. The detailed presentation of the proposed CKH approach is provided in Section 3. Subsequently, the tuning of the inertia weights and selecting the optimal CKH are described in Section 4. In addition, the performance of the CKH approach is verified using fourteen benchmarks. Finally, a summary of the present work is represented in Section 5.

2. Overview of the KH and chaotic maps

2.1. KH method

KH [8] is a new type of meta-heuristic method for solving optimization problems. This method is inspired by the herding of krill swarms when searching for food in nature. For each krill, its position in search space is influenced by three components described below [45]:

i. movement induced by other krill;
ii. foraging action;
iii. random diffusion.

For simplicity, the above three motions in KH can be idealized to the following Lagrangian model [8] as shown in Eq. (1).

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

where N_i, F_i, and D_i are, respectively, corresponding to the above three motions for the ith krill [8]. The krill number is represented by i, and t is considered as generation.

2.1.1. Motion induced by other krill

The direction of the first motion, α_i, is approximately calculated according to the following three factors: target effect, local effect, and repulsive effect. For krill i, this movement can be modeled below:

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

where

$$\alpha_i = \alpha_i^{local} + \alpha_i^{target} \tag{3}$$

and $N^{\max}$ is the maximum speed, ω_n is the inertia weight in [0,1], N_i^{old} is the previous motion, α_i^{local} and α_i^{target} are the local effect and the target effect, respectively [45]. According to the literature [8], we set $N^{\max}$ to 0.01 ($\mathrm{m\,s^{-1}}$) in our study.

2.1.2. Foraging motion

The second motion is determined by the two main factors: the food location and the previous experience with respect to the food position. For the ith krill, the expression of this motion can be provided below [45]: