Information Sciences 267 (2014) 191–200

Contents lists available at ScienceDirect

Information Sciences

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

How novel is the "novel" black hole optimization approach?

Adam P. Piotrowski *, Jaroslaw J. Napiorkowski, Pawel M. Rowinski

Institute of Geophysics, Polish Academy of Sciences, Ks. Janusza 64, 01-452 Warsaw, Poland

ARTICLE INFO

Article history:
Received 23 April 2013
Received in revised form 8 January 2014
Accepted 15 January 2014
Available online 24 January 2014

Keywords:
Black hole algorithm
Particle Swarm Optimization
Evolutionary algorithm
Global optimization
No Free Lunch theorems
Nature-inspired heuristic

ABSTRACT

Due to abundance of novel optimization algorithms in recent years, the problem of large similarities among methods that are named differently is becoming troublesome and general. The question arises if the novel source of inspiration is sufficient to breed an optimization algorithm with a novel name, even if its search properties are almost the same as, or are even a simplified variant of, the search properties of an older and well-known method. In this paper it is rigidly shown that the recently proposed heuristic approach called the black hole optimization is in fact a simplified version of Particle Swarm Optimization with inertia weight. Additionally, because a large number of metaheuristics developed during the last decade is claimed to be nature-inspired, a short discussion on inspirations of optimization algorithms is presented.

1. Introduction

In recent years a lot of novel metaheuristics have been proposed and most of them were, according to their inventors' claim, inspired by some processes, behaviors or philosophies that are widely known to human beings for years. Examples include the algorithms inspired by the process of evolution [29,2,22,46,1], the behavior of animals [14,12,8,24], the cooperation [32,9], the harmony of music [21], the chemical reactions [31], the physical laws [27,38] or the philosophical concepts [26,7]. However, not all inspirations lead to truly successful algorithms [10].

As plenty of metaheuristics exist [6], some of them, although use different names and are claimed to be inspired by different entities, in fact share large similarities with, or are simply an extension of, the others. The inspiring discussion on large and important similarities between a few types of Genetic Algorithms [25,44] and the basic variants of Biogeography-Based optimization [41], Differential Evolution [46], (μ,λ)-Evolution Strategy [33] and Particle Swarm Optimization (PSO) [14] has been given by Simon et al. [42]. However, the above-mentioned newer metaheuristics are the extensions of Genetic Algorithms, and hence open new possibilities that could be (and usually are) further "successfully" extended and examined in the future. But it seems difficult to accept that an algorithm which is a simplification of the well known older method should bear a novel name and be called a "new" approach. If such a path would be followed, soon plenty of "novel" names (but not necessarily truly "novel" methods) could emerge in the literature. A good example is the recently proposed black hole optimization approach [23] – this "new" metaheuristic is de facto a significant simplification of PSO with inertia weight, what will be shown in the next sections.

* Corresponding author. Tel.: +48 22 6915 858; fax: +48 22 6915 915.
E-mail address: adampp@igf.edu.pl (A.P. Piotrowski).

http://dx.doi.org/10.1016/j.ins.2014.01.026

2. Black hole optimization approach

The optimization method called black hole approach [23] is a population-based algorithm. As the method is said to be inspired by the black hole phenomenon, the solutions that are moving in the search space are called stars. The meaning of the “stars” is exactly the same as that of “individuals” in Evolutionary Algorithms, “particles” in PSO, “points” in Nelder-Mead algorithm [34], etc. In this elitist method, the best solution found so-far is called the black hole. The algorithm works as follows. First, the $N + 1$ stars, $\mathbf{x}_i \in R^D$, $i = 1,\ldots,N + 1$ (where N is population size), are randomly initialized in the search space. Their fitness is evaluated and the best one is termed the black hole $\boldsymbol{x}_{BH}$. As the black hole is static – it does not move until a better solution is found by the other stars – the number of individuals that search for the optimum is equal to N. Then in each generation every star is moving towards the black hole according to the following equation:

$$\mathbf{x}_i(t+1) = \mathbf{x}_i(t) + rand_i(0,1) \times (\mathbf{x}_{BH} - \mathbf{x}_i(t)); \quad i = 1,\ldots,N \tag{1}$$

where $rand_i(0,1)$ is a random number generated within an interval $[0,1]$. Note that according to [23] in each generation only a single $rand_i(0,1)$ is generated for each individual i. Then the fitness of each ith star in the new location $\boldsymbol{x}_i(t + 1)$ is evaluated. If the fitness of $\boldsymbol{x}_i(t + 1)$ is better than the fitness of $\boldsymbol{x}_{BH}$, then $\boldsymbol{x}_i(t + 1)$ becomes a black hole and the former black hole becomes a star $\boldsymbol{x}_i(t + 1)$.

In the black hole algorithm, the star that comes too close to the black hole (closer than the so-called event horizon) disappears. The radius of the event horizon (R) is defined by

$$R = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \tag{2}$$

If a star disappears, a new star is randomly generated in the search space, hence the number of stars (population size) is constant.

According to [23] the proposed approach is not the first optimization algorithm inspired by the black holes, as one of PSO variants was already based on their behavior [53]. However, the black hole optimization approach proposed in [23] and summarized above is claimed to be “completely different from the black hole PSO”. Unfortunately, when comparing the algorithm defined in [23] with the basic PSO method with inertia weight [40] one may see that the black hole approach [23] is just a simplification of the latter. As the black hole approach was proposed to data clustering in [23] it must be stressed here that, among plenty of other algorithms (some of the most recent include [16,3,19]), also a large number of PSO variants have been successfully applied to this task – the detailed review may be found in [37].

3. Particle swarm optimization

Particle Swarm Optimization [14] is a very popular stochastic population-based algorithm, inspired by the behavior of the swarm of animals. In PSO the solutions in the D-dimensional search space are called particles. Initial positions $\mathbf{x}_i(0)$ of N particles ($i = 1,\ldots,N$) are usually generated randomly within the bounds of the search space. The initial velocities $\mathbf{v}_i(0)$ of each particle are usually generated from pre-specified interval, which frequently depends on the differences between upper and lower bounds of the search space. The fitness value is evaluated for each particle. Then in each generation (t) the particles are moving through the search space according to the following equation:

$$\begin{aligned} v_i^j(t+1) &= w \cdot v_i^j(t) + c_1 \cdot rand1_i^j(0,1) \cdot (pbest_i^j(t) - x_i^j(t)) + c_2 \cdot rand2_i^j(0,1) \cdot (gbest^j(t) - x_i^j(t)) \\ x_i^j(t+1) &= x_i^j(t) + v_i^j(t+1) \end{aligned} \tag{3}$$

where $j = 1,\ldots,D$, $\boldsymbol{pbest_i}(t)$ and $\mathbf{gbest}(t)$ are the best position visited during the search by ith particle and the best position visited by any particle in the swarm, respectively; $rand1_i^j(0,1)$ and $rand2_i^j(0,1)$ are two random numbers generated at each generation from $[0,1]$ interval for each i and j index separately, and c_1 and c_2 are acceleration coefficients (algorithm parameters to be set by the user). As may be seen, for each ith particle three vectors are remembered – its current position $\mathbf{x}_i(\mathrm{t})$, the best position $\mathbf{pbest}_i(\mathrm{t})$ visited by the ith particle since the initialization of the search and ith particle’s current velocity $\mathbf{v}_i(\mathrm{t})$. The parameter w is the so-called inertia weight. Its value may be a function of time or not, its precise definition significantly depends on the variant used. Although w was not used in the first PSO algorithm proposed by Eberhart and Kennedy [14], it was quickly added in [40] to balance the global and local search ability. Today, PSO approaches are considered among the most popular and successful metaheuristics [15].

4. Discussion

The black hole algorithm is composed of two parts: the movement of stars described by Eq. (1) and the re-initialization of stars that cross the D-dimensional hypersphere, called event horizon, around the black hole, with the radius defined by Eq. (2).

The first part is a core of the black hole approach – it fully determines the movement of solutions in the search space. However, let us consider the movement of particles in PSO with inertia weight (Eq. (3)). If one sets $w = 0$, $c_1 = 0$, $c_2 = 1$