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Research paper

Spotted hyena optimizer: A novel bio-inspired based metaheuristic technique for engineering applications

Gaurav Dhiman, Vijay Kumar*

Computer Science and Engineering Department, Thapar University, Patiala, India

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ABSTRACT

This paper presents a novel metaheuristic algorithm named as Spotted Hyena Optimizer (SHO) inspired by the behavior of spotted hyenas. The main concept behind this algorithm is the social relationship between spotted hyenas and their collaborative behavior. The three basic steps of SHO are searching for prey, encircling, and attacking prey and all three are mathematically modeled and implemented. The proposed algorithm is compared with eight recently developed metaheuristic algorithms on 29 well-known benchmark test functions. The convergence and computational complexity is also analyzed. The proposed algorithm is applied to five real-life constraint and one unconstrained engineering design problems to demonstrate their applicability. The experimental results reveal that the proposed algorithm performs better than the other competitive metaheuristic algorithms.

1. Introduction

In the last few decades, the increase in complexity of real life problems has given risen the need of better metaheuristic techniques. These have been used for obtaining the optimal possible solutions for real-life engineering design problems. These become more popular due to their efficiency and complexity as compared to other existing classical techniques [35].

Metaheuristics are broadly classified into three categories such as evolutionary-based, physical-based, and swarm-based methods. The first technique is generic population-based metaheuristic which is inspired from biological evolution such as reproduction, mutation, recombination, and selection. The evolutionary algorithms are inspired by theory of natural selection in which a population (i.e., a set of solutions) tries to survive based on the fitness evaluation in a given environment (defined as fitness evaluation). Evolutionary algorithms often perform well near optimal solutions to all types of problems because these methods ideally do not make any assumption about the basic fitness or adaptive landscape. Some of the popular evolutionary-based techniques are Genetic Algorithms (GA) [7], Genetic Programming (GP) [34], Evolution Strategy (ES) [6], and Biogeography-Based Optimizer (BBO) [56].

Some of well-known techniques such as Genetic Algorithms(GA) [7], Ant Colony Optimization (ACO) [12], Particle Swarm Optimization (PSO) [32] and Differential Evolution (DE) [57] are popular among different fields. Due to easy implementation, metaheuristic optimization algorithms are more popular in engineering applications [4,9,50](Fig. 1). The second category is physical-based algorithms. In these algorithms, search agents communicate and move throughout the search space according to physics rules such as gravitational force, electromagnetic force, inertia force, and so on. The name of few algorithms are Simulated Annealing (SA) [33], Gravitational Search Algorithm (GSA) [52], Big-Bang Big-Crunch (BBBC) [14], Charged System Search (CSS) [31], Black Hole (BH) [23] algorithm, Central Force Optimization (CFO) [16], Small-World Optimization Algorithm (SWOA) [13], Artificial Chemical Reaction Optimization Algorithm (ACROA) [1], Ray Optimization (RO) algorithm [29], Galaxy-based Search Algorithm (GbSA) [54], and Curved Space Optimization (CSO) [45].

The last one is swarm-based algorithms which are based on the collective behavior of social creatures. The collective intelligence is inspired by the interaction of swarm with each other and their environment. The well-known algorithm of SI technique is Particle Swarm Optimization (PSO). Another popular swarm-intelligence technique is Ant Colony Optimization [12], Monkey Search [47], Wolf pack search algorithm [61], Bee Collecting Pollen Algorithm (BCPA) [39], Cuckoo Search (CS) [64], Dolphin Partner Optimization (DPO) [55], Bat-inspired Algorithm (BA) [63], Firefly Algorithm (FA) [62], Hunting Search (HUS) [48]. Generally, swarm-based algorithms are easier to implement than evolutionary-based

* Corresponding author.
E-mail addresses: gdhiman0001@gmail.com (G. Dhiman), vijaykumarchahar@gmail.com (V. Kumar).

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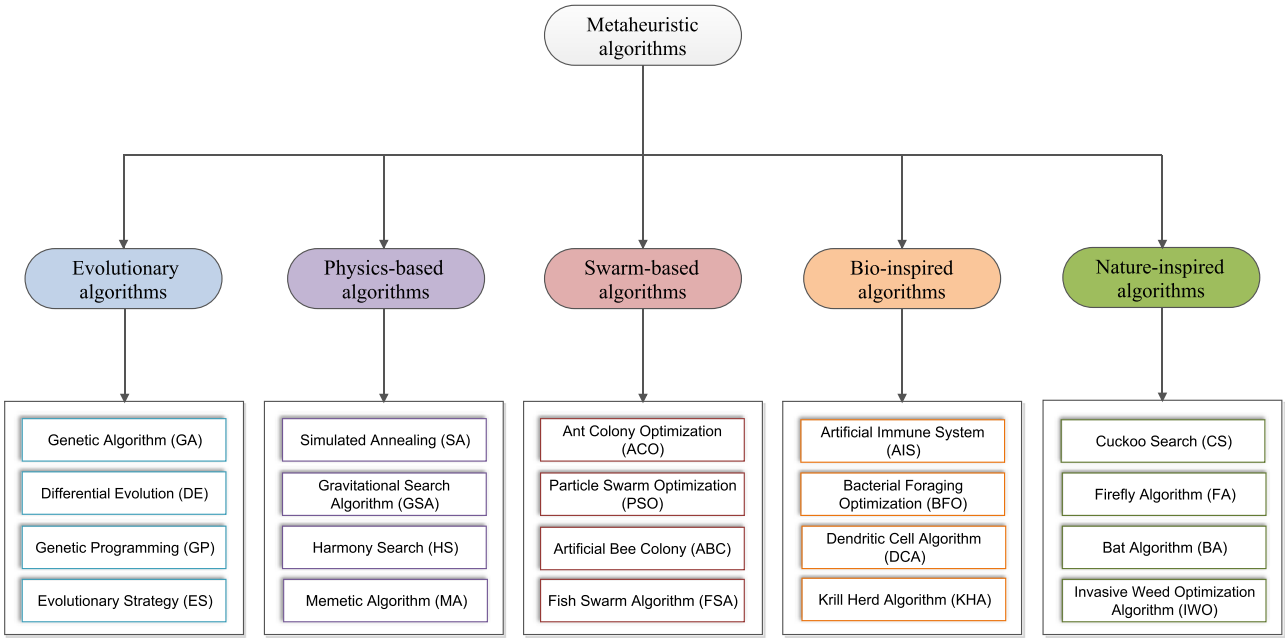

Fig. 1. Classification of metaheuristic algorithms.

algorithms due to include fewer operators (i.e., selection, crossover, mutation). Apart from these, there are other metaheuristic techniques inspired by human behaviors. Some of the popular algorithms are Harmony Search (HS) [19], Parameter Adaptive Harmony Search (PAHS) [35], Variance-Based Harmony Search [36], Harmony Search-Based Remodularization Algorithm (HSBRA) [3], Tabu (Taboo) Search (TS) [15,21,22], Group Search Optimizer (GSO) [24,25], Imperialist Competitive Algorithm (ICA) [5], League Championship Algorithm (LCA) [28], Firework Algorithm [59], Colliding Bodies Optimization (CBO) [30], Interior Search Algorithm (ISA)[17], Mine Blast Algorithm (MBA) [53], Soccer League Competition (SLC) algorithm [46], Seeker Optimization Algorithm (SOA) [10], Social-Based Algorithm (SBA) [51], and Exchange Market Algorithm (EMA) [20].

The main components of metaheuristic algorithms are exploration and exploitation [2,49]. Exploration ensures the algorithm to reach different promising regions of the search space, whereas exploitation ensures the searching of optimal solutions within the given region [38]. The fine tuning of these components is required to achieve the optimal solution for a given problem. It is difficult to balance between these components due to stochastic nature of optimization problem. This fact motivates us to develop a novel metaheuristic algorithm for solving real-life engineering design problem.

The performance of one optimizer to solve the set of problem does not guarantee to solve all optimization problems with different nature [60]. It is also the motivation of our work and describes a new metaheuristic based algorithm.

This paper introduces a novel metaheuristic algorithm for optimizing constraint and unconstrained design problems. The main objective of this paper is to develop a novel metaheuristic algorithm named as Spotted hyena Optimization (SHO), which is inspired by social hierarchy and hunting behavior of spotted hyenas. Cohesive clusters can help for efficient co-operation between spotted hyenas. The main steps of SHO are inspired by hunting behavior of spotted hyenas. The performance of the SHO algorithm is evaluated on twenty-nine benchmark test functions and six real structural optimization problems. The results demonstrate that the performance of SHO performs better than the other competitive algorithms.

The rest of this paper is structured as follows: Section 2 presents the concepts of the proposed SHO algorithm. The experimental results and discussion is presented in Section 3. In Section 4, the performance of SHO is tested on five constrained and one unconstrained engineering design problems and compared with other well-known algorithms. Finally, the conclusion and some future research directions are given in Section 5.

2. Spotted hyena optimizer (SHO)

In this section, the mathematical modeling of proposed algorithm is described in detail.

2.1. Inspiration

Social relationships are dynamic in nature. These are affected by the changes in the relationships among comprising the network and individuals leaving or joining the population. The social network analysis of animal behavior has been classified into three categories [26]:

- The first category includes environmental factors, such as resource availability and competition with other animal species.
- The second category focuses on social preferences based on individual behavior or quality.
- The third category has less attention from scientists which includes the social relations of species itself.

The social relation between the animals is the inspiration of our work and correlates this behavior to spotted hyena which is scientifically named as Crocuta.

Hyenas are large dog-like carnivores. They live in savannas, grasslands, sub-deserts and forests of both Africa and Asia. They live 10–12 years in the wild and up to 25 years in imprisonment. There are four known species of hyena these are, spotted hyena,

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