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Lion Optimization Algorithm (LOA): A nature-inspired metaheuristic algorithm

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Abstract

During the past decade, solving complex optimization problems with metaheuristic algorithms has received considerable attention among practitioners and researchers. Hence, many metaheuristic algorithms have been developed over the last years. Many of these algorithms are inspired by various phenomena of nature. In this paper, a new population based algorithm, the Lion Optimization Algorithm (LOA), is introduced. Special lifestyle of lions and their cooperation characteristics has been the basic motivation for development of this optimization algorithm. Some benchmark problems are selected from the literature, and the solution of the proposed algorithm has been compared with those of some well-known and newest meta-heuristics for these problems. The obtained results confirm the high performance of the proposed algorithm in comparison to the other algorithms used in this paper.

Keywords: Lion Optimization Algorithm (LOA); Global optimization; Metaheuristic

1. Introduction

Many engineering optimization problems are usually quite difficult to solve, and many applications have to deal with these complex problems. In these problems, search space grows exponentially with the problem size. Therefore, the traditional optimization methods do not provide a suitable solution for them. Hence, over the past few decades, many meta-heuristic algorithms have been designed to solve such problems. Researchers have shown good performance of meta-heuristic algorithms in a wide range of complex problems such as scheduling problems [1–6], data clustering [7,8], image and video processing [9–12], tuning of neural networks [13–15] and pattern recognition [16–18], etc.

For many years, human have utilized the guidance of nature in finding the most appropriate solution for problems. Hence, during the last decades, there has been a growing attempt in developing algorithms inspired by nature [19–21]. For example, Genetic algorithm was proposed by Holland [22], and simulates Darwnian evolution concepts. Artificial Immune Systems [23], simulate biological immune systems for optimization. Ant Colony Optimization [24] was inspired by behavior of ants foraging for food. Particle Swarm Optimization [25] mimics the social behavior of a flock of migrating birds trying to reach an unknown destination. Marriage in Honey Bee Optimization Algorithm (MBO) was proposed by Abbass [26], and mimics processes of reproduction in the honey bee colony. Bacterial Foraging Algorithm [27] simulates search and optimal foraging of bacteria. The Shuffled Frog Leaping algorithm [28] was inspired by a frog population searching for food. The Cat Swarm algorithm [29] was developed based on the behavior of cats. Invasive weed optimization was proposed by Mehrabian and Lucas [30], and mimics the ecological behavior of colonizing weeds. Monkey Search [31] simulates a monkey in search for food resources. Water flow-like algorithm [32] was inspired by water flowing from higher to lower levels. Biogeography-based optimization algorithm was introduced by Simon [33], and inspired by biogeography which refers to the study of biological organisms in terms of geographical distribution (over time and space). The Fish

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School Search [34] was proposed based on the gregarious behavior of oceanic fish. Cuckoo Search [35] and Cuckoo optimization algorithm [36] are based on reproduction strategy of cuckoos. Bat-inspired Algorithm [37] was inspired by the echolocation behavior of bats. Firefly algorithm [38] simulates the social behavior of fireflies based on their flashing characteristics. Dolphin Partner Optimization [39] and Dolphin echolocation algorithm [40] were inspired by dolphins' behaviors. Flower pollination algorithm [41] mimics the pollination characteristics of flowering plants and the associated flower consistency of some pollinating insects. Krill herd [42] inspired by the herding behavior of krill individuals. Wolf search [43] and Grey Wolf Optimizer [44] are inspired by behaviors of wolves. Water cycle algorithm [45] was based on the observation of water cycle process and how rivers and streams flow to the sea in the real world. The Social spider optimization, inspired by the social behavior of a kind of spider, has been proposed recently [46]. Forest Optimization Algorithm [47] was inspired by few trees in the forests which can survive for many years, while other trees could live for a short time.

Aforementioned algorithms are widely applied by researchers in many different areas [48–51]. However, there is no particular algorithm to gain the most appropriate solution for all optimization problems. Some algorithms provide better solution for some particular problems compared with others. Therefore, pursuing for new optimization techniques is an open problem [52].

In this paper, an optimization algorithm based on lion's behavior and social organization, namely Lion Optimization Algorithm (LOA) is proposed. In the literature, Wang [53] and Rajakumar [54] proposed two algorithms inspired by few characters of lions. Rajakumar [54] described the main operator of Lion's Algorithm as “Mating that refers to deriving new solutions and Territorial Defense and Territorial Takeover intend to find and replace the worst solution by new the best solution”. Like Lion's Algorithm, Lion pride optimizer [53] is based on fighting between individual and mating. But lions in addition of mating and fighting exhibit other behaviors such as special style of prey capturing, territorial marking, migration, difference between life style of nomad and resident lions. So, proposed algorithm is inspired by simulation of the solitary and cooperative behaviors of lions which are completely different from the previous algorithm.

After this introduction, the remainder of this paper is structured as follows: In Section 2 the proposed Lion Optimization Algorithm (LOA) is outlined, and its implementation steps are explained in details. Comparative study and experimental results are presented in Section 3 to verify the efficiency of the proposed algorithm. Finally, conclusions are presented in the last section.

2. Lion Optimization Algorithm (LOA)

In this section, the inspiration of the proposed meta-heuristic is first discussed. Then, Lion Optimization Algorithm (LOA) is presented.

2.1. Inspiration

Lions are the most socially inclined of all wild cat species which display high levels of cooperation and antagonism [55]. Lions are of particular interest because of their strong sexual dimorphism in both social behavior and appearance. The lion is a wild felid with two types of social organization: residents and nomads. Residents lives in groups, called pride [56]. A pride of lions typically includes about five females, their cubs of both sexes, and one or more than one adult males. Young males are excluded from their birth pride when they become sexually mature [56]. As mention before, the second organizational behavior is called nomads, who move about sporadically, either in pairs or singularly. Pairs are more seen among related males who have been excluded from their maternal pride. Notice that a lion may switch lifestyles; residents may become nomads and vice versa [56].

Unlike all other cats, Lions typically hunt together with other members of their pride. Several lionesses work together and encircle the prey from different points and catch the victim with a fast attack. Coordinated group hunting brings a greater probability of success in lion hunts. The male lions and some lionesses usually stay and rest while waiting for the hunter lionesses to return from the hunt [57]. Lions do mate at any time of the year, and the females are polyestrous (when females not rearing their cubs are receptive) [58]. A lioness may mate with multiple partners when she is in heat [59]. In nature, male and female lions mark their territory and elsewhere, which seems a good place with urine.

In this work, some characters of lions are mathematically modeled in order to design an optimization algorithm. In the proposed algorithm, Lion Optimization Algorithm (LOA), an initial population is formed by a set of randomly generated solutions called Lions. Some of the lions in the initial population ($\%N$) are selected as nomad lions and rest population (resident lions) is randomly partitioned into P subsets called prides. S percent of the pride's members are considered as female and rest are considered as male,while this rate(sex rate ($\%S$)) in nomad lions is vice versa.

For each lion, the best obtained solution in passed iterations is called best visited position, and during the optimization process is updated progressively. In LOA, a pride territory is an area that consists of each member best visited position. In each pride, some females which are selected randomly go hunting. Hunters move towards the prey to encircle and catch it. The rest of the females move toward different positions of territory. Male lions in pride, roam in territory. Females in prides mate with one or some resident males. In each pride, young males are excluded from their maternal pride and become nomad when they reach maturity and, their power is less than resident males.

Also, a nomad lion (both male and female) moves randomly in the search space to find a better place (solution). If the strong nomad male invade the resident male, the resident male is driven out of the pride by the nomad lion. The nomad male becomes the resident lion. In the evolution, some resident females immigrate from one pride to another or switch their