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A global optimization algorithm inspired in the behavior of selfish herds

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ABSTRACT

In this paper, a novel swarm optimization algorithm called the Selfish Herd Optimizer (SHO) is proposed for solving global optimization problems. SHO is based on the simulation of the widely observed selfish herd behavior manifested by individuals within a herd of animals subjected to some form of predation risk. In SHO, individuals emulate the predatory interactions between groups of prey and predators by two types of search agents: the members of a selfish herd (the prey) and a pack of hungry predators. Depending on their classification as either a prey or a predator, each individual is conducted by a set of unique evolutionary operators inspired by such prey-predator relationship. These unique traits allow SHO to improve the balance between exploration and exploitation without altering the population size. To illustrate the proficiency and robustness of the proposed method, it is compared to other well-known evolutionary optimization approaches such as Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Firefly Algorithm (FA), Differential Evolution (DE), Genetic Algorithms (GA), Crow Search Algorithm (CSA), Dragonfly Algorithm (DA), Moth-flame Optimization Algorithm (MOA) and Sine Cosine Algorithm (SCA). The comparison examines several standard benchmark functions, commonly considered within the literature of evolutionary algorithms. The experimental results show the remarkable performance of our proposed approach against those of the other compared methods, and as such SHO is proven to be an excellent alternative to solve global optimization problems.

1. Introduction

The intelligent collective behavior of many species of animals and insects, have attracted the attention of researches for many years. Many animal species such as birds, ants, and fishes, which live in social animal groups such as flocks, colonies and schools respectively, exhibit particular aggregative conducts widely known as swarm behavior. Such collective phenomenon has been studied by entomologist in order to model the behavior of the many biological swarms. Computer science researchers have studied and adapted these models as frameworks for solving complex real-world problems, giving birth to a branch of artificial intelligence commonly addressed as swarm intelligence [REF]. As a result of this, many unique swarm optimization algorithms, which mimic the collective behavior of groups of animals or insects, have been developed to solve a wide variety of optimization problems. Some of these methods include well know state-of-the-art techniques such as Particle Swarm Optimization (PSO,) which emulates the social behavior of bird flocking and fish schooling (Kennedy and Eberhart, 1995), Artificial Bee Colony (ABC), which is based on the cooperative behavior of bee colonies (Karaboga and Basturk, 2008), Firefly Algorithm (FA) which mimics the mating behavior of firefly insects (Yang, 2010), and Cuckoo Search (CS), which draws inspiration from the cuckoo bird lifestyle (Rajabioun, 2011). Although most of these methods are widely used to solving complex optimization problems, they are known to suffer from some serious flaws, such as premature convergence and the difficulty to overcome local optima (Wang et al., 2011; Xiang and An, 2013), which prevent them from finding optimal solutions. The cause of such issues is usually related to the operators used to modify each individual's position. In the case of PSO, for example, the position of each search agent for the next iteration is updated yielding an attraction towards the best particle position seen so-far, while in the case of ABC, positions are updated with respect of some other randomly chosen individuals. As the algorithm evolves, those behaviors allow the entire population to, either rapidly concentrates around the current best particle or to diverge without control, which in return favors the premature convergence or a misbalance between exploration and exploitation respectively (Wang et al., 2013; Banharnsakun et al., 2011). In addition, most state of the art swarm algorithms only model

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individual entities that perform virtually the same behavior. Under such circumstances, the possibility of adding new and selective operators based on individual unique characteristics (such as task-responsibility, strength, size, sex, etc.) that could improve several important algorithm characteristics such as population diversity and searching capabilities.

While it is true that a wide range of organisms living in aggregations show distinctive cooperative behaviors, this is not true for every single animal species living in social units. In contrast to the popular hypothesis that social behavior is based on mutual benefits for the entire population, the widely accepted selfish herd theory proposed by William D. Hamilton in 1971 illustrates that actions among individuals within aggregations (referred as herds) exhibit an unusual degree of selfishness, particularly when members of such aggregations are endangered by the presence of predators (Hamilton, 1971). In fact, the selfish herd theory establishes that decisions made by any member of such herds do not only benefit the individual itself but also, in exchange, there are usually some negative repercussions for other members on said aggregation.

In this paper, a novel swarm optimization algorithm called Selfish Herd Optimizer (SHO) is proposed for solving optimization problems. Such algorithm is inspired in the behaviors described on Hamilton's selfish herd theory. The algorithm considers two different kinds of search agents: predators and prey. Each of these agents movements are conducted by a set of unique rules and operators based the observed natural behavior of individuals on a selfish herd while they are endangered by a pack of hungry predators. The rest of this paper is organized as follows: in Section 2, we address the selfish herd theory, as proposed by Hamilton (1971); in Section 3, we illustrate our proposed swarm optimization approach (SHO); in Section 4, we summarize all steps the proposed SHO algorithm; in Section 5, we open a discussion about SHO and its most distinctive traits in comparison to other similar methods; in Section 6, we illustrate our experimental setup and results; finally, in Section 7, conclusions are drawn.

2. The selfish herd theory

The selfish herd theory, as proposed by Hamilton (1971), is an antithesis to the common view of gregarious behavior as a way of seeking mutual benefits among members of a population or group of organism. In his paper, Hamilton proposed that gregarious behavior may be considered a form of cover-seeking, in which each individual attempts to reduce their chance of being caught by a predator. It is also stated that, during a predator attack, individuals within a population will attempt to reduce their predation risk by putting other conspecifics between themselves and the predator(s). The basic principle governing the selfish herd theory is that, in aggregations, predation risk increases among individuals in the periphery and decreases toward the center of such aggregation. It is also proposed that more dominant (stronger) animals within the population are easily able to obtain low-risk central positions among the aggregation, whereas subordinate (weaker) animals are usually forced into higher risk positions.

Hamilton illustrated his theory by modeling a circular lily pond in which a population of frogs (a group of prey) and a water snake (a predator) are sheltered. Upon appearance of the water snake, it is supposed that the frogs will scatter to the rim of the pond and that the water snake will most certainly attack the one nearest to it. In this model Hamilton suggests that the predation risk of each frog is related not only to how close they are from the attacking predator, but also with the relative position of all other frogs on the pond. Under these considerations, Hamilton proposes that each frog has a better chance of not being closest to, and thus, vulnerable to attack by the water snake, if other frogs are between them. As a result, modeled frogs attempt to reduce their predation risk by jumping to smaller gaps between other neighboring frogs in an attempt to use them as a "shield". Hamilton also went on to model two-dimensional predation by considering lions as examples. He proposed that movements which would lower an individual's domain of danger are largely based on the theory of marginal predation, which states that predators attack the closest prey (which are typically those at the periphery of an aggregation). From this, Hamilton suggested that, in the face of predation, there should be a strong movement of individuals toward the center of an aggregation. Research has also revealed that there exist several factors which may influence chosen movement rules, such as initial spatial position, population density, the predator's attack strategy, and vigilance. In particular, it has been observed that individuals holding initially central positions are more likely to be successful at remaining in the center of the aggregation, increasing their chances of surviving a predator attack (Morrell et al., 2010).

The selfish herd theory may also be applied to the situation of group escape, in which, the safest position, relative to predation risk, is not the central position but rather that in the front of the herd. In this sense, members at the back of the aggregation have the greatest domain of danger, and thus, suffer the highest predation risk. As the most likely targets for predation, these slower members must choose whether to stay with the herd, or to desert it, which may in turn entice the pursuit of the predator to such vulnerable individuals. This strategy, formally known as herd desertion, is mainly used by slower individuals among the aggregation in an attempt to escape from the sight of predators, although this in turn may signal their vulnerability and thus promote the predators to pursuit such individual (Eshel et al., 2011).

By considering this, it could be assumed that the escape route chosen by members in front of the herd may be greatly affected by the actions of the slowest members. For example, if the herd's leader chooses an escape route that promotes the dispersal of the slowest members of the group it may endanger itself due to the dissipations of its protective buffer. Also, it is known that the leader's chosen escape strategy is often affected by terrain particularities (Eshel et al., 2011).

Many examples of selfish herd behavior have been witnessed in nature. One of the most extensively studied examples is that of aggregations of fiddler crab, in which, dispersed groups are more likely to form an aggregate when subjected to a danger while at the same time individual members attempt to move toward the center of the forming group (Viscido and Wethey, 2002). Other selfish herd behavior examples include that of mammals living in open plains, such as wildebeest and zebras (which aggregations are likely associated with predation risk reduction), many species of fishes (such as minnows, which school to reduce their individual predation risk) (Orpwood et al., 2008), the Adelie Penguins (which frequently wait to jump into the water until they have formed an aggregate to form protective buffers against seal predation) (Alcock, 2001), and the Forest Tent Caterpillar (famous for foraging in groups as a strategy to reduce predation risk) (Mcclure and Despland, 2010).

3. The selfish herd optimizer algorithm

The selfish herd theory establishes that, in the face of predation, each individual within a herd of possible prey pursues to increases their chance of survival by aggregating with other conspecifics in ways which could potentially increase their chances of surviving a predator attack without regard of how such behavior affects other individuals' chances of survival (Hamilton, 1971).

In this paper, the selfish herd behavior particularities observed by several groups of organism has been used as guidelines for developing a new swarm optimization algorithm known as the Selfish