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Bird mating optimizer: An optimization algorithm inspired by bird mating strategies

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ABSTRACT

Thanks to their simplicity and flexibility, evolutionary algorithms (EAs) have attracted significant attention to tackle complex optimization problems. The underlying idea behind all EAs is the same and they differ only in technical details. In this paper, we propose a novel version of EAs, bird mating optimizer (BMO), for continuous optimization problems which is inspired by mating strategies of bird species during mating season. BMO imitates the behavior of bird species metaphorically to breed broods with superior genes for designing optimum searching techniques. On a large set of unimodal and multimodal benchmark functions, BMO represents a competitive performance to other EAs.

1. Introduction

As a fertile source of concepts, principles, and mechanisms, nature can be an inspiration to design artificial computation systems for solving complex computational problems. Evolutionary algorithms (EAs), inspired by biological evolution, and swarm intelligence (SI) algorithms, inspired by collective animal behavior, are two main classes of nature-inspired computations which have attracted more and more attentions during recent years.

Owing to their simplicity and flexibility, EAs have been widely applied to solve scientific and engineering problems and have been the most successful artificial computation systems to tackle complex computational problems [1]. An evolutionary algorithm is a generic population-based metaheuristic optimization approach, trying to simulate some mechanisms of biological evolution. There are different variants of evolutionary algorithms, but the common underlying idea behind all these problem-solving techniques is the same [2]. Candidate solutions to the optimization problem play the role of individuals in a population, and fitness function specifies the environment within which the solutions live. Evolution of the population then happens to improve the quality of the individuals by applying recombination (crossover) and mutation operators. Recombination is applied to the selected solutions (parents) to generate new ones (offspring). They are also mutated by making a small change to the solution. Such operators are employed to discover regions of space for which good solutions have already been acquired.

Success of an optimization algorithm depends mostly on its ability to establish good balance between exploration and exploitation [2]. Exploration refers to generation of new solutions in as yet untested regions of search space and exploitation means the concentration of the algorithm's search at the vicinity of current good solutions. The inability of the algorithm to make a good balance between exploration and exploitation results in premature convergence, getting trapped in a local optima, and stagnation. In EAs, selection tries to provide exploitation while crossover and mutation operators provide exploration.

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The various dialects of EAs follow some general outlines, and differ only in technical details. EAs process a whole collection of candidate solutions simultaneously, use recombination to mix information of more candidate solutions into a new one, employ mutation to maintain the diversity of the population, and are stochastic. Four major EA paradigms are genetic algorithm (GA) [3], genetic programming (GP) [4], evolutionary programming (EP) [5,6] and evolution strategy (ES) [7]. EP and ES borrow ideas from each other and also from GA. Though they work in a different way to GA, the broad principles are in many respects, similar. The most popular method among EAs which is mostly used in optimization problems is GA. GA is a search technique used in computer science and engineering to obtain the approximate solutions of optimization problems [8]. One reason behind the GA's success is the fact that its advocates are very good at describing the algorithm in an easy to understand and non-mathematical way.

In GA, a population of solutions is initialized subject to certain constraints. Each solution is coded as a vector, termed a *chromosome*, with elements being described as genes. GA can quickly discover good solutions, even for difficult search spaces, but it has some drawbacks: (1) GA has a trend to converge towards local optima rather than the global optimum, unless the fitness function is well defined; (2) there is a difficulty to operate on dynamic data sets; and (3) simpler optimization algorithms may find better solutions than GA at a same amount of computation time [9]. There is another important concern in GAs known as premature convergence. This happens when the population of chromosomes reaches a formation such that crossover no longer generates offspring that can outperform their parents, as must be the case in a similar population. Under such conditions, all standard forms of crossover simply regenerate the current parents [10]. On the other words, premature convergence is the result of losing population diversity too quickly and getting stuck in a local optimum.

Initially, improvements in GA have been sought in the optimal proportion and adaptation of the main parameters (probability of crossover and mutation, population size and crossover operator) [11], but, recently, attention has been shifted to breeding (process of forming new candidate chromosomes). Consequently, in recent years, some researchers have developed various versions of GAs where the improvements are to seek the optimal breeding conditions [12–14].

EAs utilize the general rules of natural evolution (selection, crossover, and mutation) and try to develop ways to produce new solutions using these rules. However, though various living organisms of nature make use of these general rules to perform evolution process, the ways used by them is different in details. It is obvious that the performance of optimization algorithm will be extremely affected by the mechanism of forming new solutions. Hence, different ways lead to varying quality generations. From this aspect, we can add more algorithms to the category of so-called EAs.

Evolution process with the way used by some special organisms can be an inspiration to devise new evolutionary-based optimization techniques, with which we may obtain more accurate results than the other ones. In this paper, inspired by bird mating strategies, we propose a novel evolutionary optimization algorithm, named bird mating optimizer (BMO) [15,16] for global optimization.

Birds are the most speciose class of tetrapod vertebrates having around 10,000 living species [17]. Mating process in bird's society has very similarities with an optimization process in which each bird breeds or attempts to breed a brood with high quality genes (a perfect state), because a bird with better genes has more chance to live. In the same way, an optimization process searches to discover a global solution (a perfect state) in which the quality of each solution is determined by a criterion named objective (fitness) function. In engineering optimization, decision variables are given values in the search space and a solution vector is made. If a good solution is acquired, that experience is memorized and the possibility of making a better solution increases at the next time.

During mating season birds employ a variety of intelligent behaviors such as singing, tail drumming or dancing to attract potential mates [17]. Some courtship rituals are quite elaborate and serve to form a bond between the potential mates. The quality of each bird is specified by its features such as beak, tail, wing, and so on. The related gene of each feature determines the quality of that feature, together making the overall quality of the bird. A gene is a hereditary unit that can be passed on through breeding to next generations. Imagine a bird which has good genes among a species. This bird can fly adeptly and get more food. Hence, it is healthier than the other birds, lives longer and breeds more. The bird passes these genes for better ones onto its broods by selecting a superior mate. They also live longer and have more broods and the gene continues to be inherited generation after generation.

The ultimate success of a bird to raise a brood with superior features depends on the strategy it uses. Different ways result in broods with diverse features. Study among bird's society reveals that they employ different strategies to conduct mating process. In general, there are five strategies: monogamy, polygyny, polyandry, parthenogenesis and promiscuity [17–19]. According to its species, each bird makes use of one of these ways to breed. Most birds are monogamous [18], meaning that a male bird only mates with a female one. In the monogamous behavior, parental duties are shared between the pair so that the male bird defends of the territory while the main task of the female is to produce eggs and supply them [19]. In polygynous species, a male tends to mate with several females while in polyandrous a female tends to mate with several males. Polygyny is much more common than polyandry in the bird's society [19]. Parthenogenesis denotes a mating system in which a female is able to raise brood without the help of males. Promiscuity is another mating strategy employed by a few bird species, meaning mating systems with no stable relationships in which mating between two birds is a one-time event. This type of mating indicates a rather chaotic social structure in which the male will almost certainly never see his brood or the nest, and most likely will not see the female for another brief visit [19].

The BMO proposed in this paper, is a population-based optimization algorithm which employs mating process of birds as a framework. Under this framework, concepts and strategies are metaphorically adopted for designing optimum searching techniques. In BMO, each bird is a feasible solution for the problem and is specified by a vector with predefined number of