Anti-Predatory NIA for Unconstrained Mathematical Optimization Problems

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ABSTRACT

Nature-Inspired Algorithms (NIAs) are one of the most efficient methods to solve the optimization problems. A recently proposed NIA is the anti-predatory NIA, which is based on the anti-predatory behavior of frogs. This algorithm uses five different types of self-defense mechanisms in order to improve its anti-predatory strength. This paper demonstrates the computation steps of anti-predatory for solving the Rastrigin function and attempts to solve 20 unconstrained minimization problems using anti-predatory NIA. The performance of anti-predatory NIA is compared with the six competing meta-heuristic algorithms. A comparative study reveals that the anti-predatory NIA is a more promising than the other algorithms. To quantify the performance comparison between the algorithms, Friedman rank test and Holm-Sidak test are used as statistical analysis methods. Anti-predatory NIA ranks first in both cases of "Mean Result" and "Standard Deviation." Result measures the robustness and correctness of the anti-predatory NIA. This signifies the worth of anti-predatory NIA in the domain of mathematical optimization.

KEYWORDS

Anti-Predatory NIA, Evolutionary, Meta-Heuristic, Nature-Inspired Algorithms, Optimization, Swarm Intelligence

INTRODUCTION

Over the last decade, Nature-Inspired Algorithms (NIAs) have become surprisingly very popular for solving the mathematical optimization problems and even for various real-world optimization problems. This is because NIAs are highly flexible, efficient to solve optimization problems and do not trap in locally optimal solutions. These algorithms are so named, because the optimization methods adapt from natural phenomena (Fister Jr. et al., 2013). The natural phenomena always solve the problem in an optimal way. Based on that optimal way, NIAs try to solve optimization problems. A large number of NIAs are proposed till now, but no NIA gives a superior performance in all optimization problems (Wolpert and Macready, 1997). Hence, there is still a need of an efficient and robust NIA.

Based on the nature of objective function, optimization problems are classified as: maximization and minimization problems (Yang, 2013). These can also be constrained or unconstrained (Yang, 2013). Constrained problems impose restrictions on the parameters whereas unconstrained problems don't

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impose any restriction on the objective parameters. Often, constrained problems may be converted into an unconstrained problem by adding a penalized term in the objective function (Rao, 2016). The penalized term measures the violation of constraints. Its value will be nonzero when any constraint is violated otherwise its value is zero.

Anti-predatory NIA (Sachan and Kushwaha, 2019) is a recently proposed NIA, which is inspired by the anti-predatory behavior of frogs. Frogs protect themselves from the predators using self-defense mechanisms and improve their anti-predatory strength (fitness) and traits. Similar to other NIAs, anti-predatory NIA is a population based meta-heuristic algorithm. It searches the optimal solution from a randomly generated set of frog traits. A higher or lower anti-predatory strength is considered as an optimal solution for the maximization or minimization problem respectively.

This work makes an attempt to solve twenty unconstrained optimization problems using anti-predatory NIA. The obtained results are compared with six well-known meta-heuristic optimization algorithms in order to find its robustness. These algorithms are: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Artificial Bee Colony (ABC), Teacher Learning based Optimization (TLBO) and Jaya algorithm.

The rest of the paper is structured as follows: Section 2 reviews concept of other NIAs which are used for performance evaluation. The anti-predatory NIA is presented in Section 3. Computing steps to solve the Rastrigin function using anti-predatory NIA are demonstrated in Section 4. Section 5 includes experimental study and performance comparison of anti-predatory NIA with the other competitive NIAs. Section 6 presents statistical analysis of obtained results and Section 7 outlines the conclusion.

REVIEW OF NIAS

Most NIAs are driven by the social behavior of the species in the nature which depends on their biological necessities (Bragg, 1945). All species have three main biological necessities in life. These are food and feed; protection from enemies and the environment; and breeding (Bragg, 1945). These biological necessities form the basis of most NIAs proposed by researchers. Some of them are discussed here in terms of inspiration behind them.

GA (Holland, 1992) is a biological evolution-based algorithm. It is inspired by Darwin's theory which is defined as a sequence of genetic changes in a population over generations. In evolution process, every chromosome passes through three operations, namely crossover, mutation and selection; and the old chromosomes are replaced by the new fittest chromosomes (Sachan et al., 2016). Generally, the length of a chromosome is fixed, but Arora and Sinha (2013) have proposed a concept which has a variable length of a chromosome. This improves the efficiency of the GA and gives much better results for solving the dynamic applications (Arora and Sinha, 2014). PSO (Kennedy and Eberhart, 1995) is based on synchronous and collision-free movement of particles (birds/fishes) in the swarm for the search of food. In this process, particles change their position based on personal and global best positions; and maintain inter-individual distance in swarm. DE (Storn and Price, 1997) is one of the popular evolutionary strategy-based algorithm for optimization. DE calculates new solution by summation of a random solution with the weighted difference of two random solutions. Each iteration considers only those solutions that are better than the previous. ABC (Karaboga, 2005) is based on the intelligent and unique behavior of honey bees for foraging. In this behavior, employee bee searches food source and shares the food source information with onlooker bees. The onlooker bees select the best food source and the scout bees randomly search for other food sources. This is also known as foraging cycle. TLBO (Rao et al., 2011) is based on teaching-learning methodology of learners in the class. It is a two step process. In the first step, learners learn from the teacher and in a second step, learners learn