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Recent Advances in Nature-Inspired Swarm Metaheuristic Algorithms

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ABSTRACT: Nature has always supplied solutions to a variety of issues that we face.Computational Intelligence includes a number of nature-inspired strategies for solving various complex computing challenges. Ant Colony Algorithm, Particle Swarm Optimization, Artificial Bee Colony Algorithm, and other inspired algorithms have been proved to be effective in finding good(not optimal) solutions to many NP-Complete Problems. The effectiveness of these challenges inspired researchers to create solutions to several difficult problems by drawing inspiration from how nature tackles various problems in the environment. We review five swarm-based nature-inspired algorithms proposed in the literature in this paper.

I. INTRODUCTION

Most real-world problems are highly complex, with non-linear constraints, interdependencies amongst variables and a large solution space. This requires the use of techniques that is capable of solving complex optimisation problems in real time. Optimisation is concerned with finding the best value of a set of variables in order to achieve the goal of minimising (or maximising) an objective function subject to given set of constraints.

Optimisation techniques can be broadly classified into exact and approximate methods. Exact approaches produce optimal answers and ensure that they are optimal. Methods such as the branch and bound algorithm, dynamic programming, and others fall within this area. The goal of approximate approaches is to provide a high-quality solution in a reasonable period of time. Approximation algorithms and heuristic approaches are two types of approximate procedures. The former approach guarantees solution quality and time bounds, whereas the latter focuses on finding a fair good solution in a reasonable amount of time.

Heuristic algorithms are highly problem specific. Metaheuristics are a type of algorithm that serves as a guide for the underlying heuristics. They are not problem- or domain-specific, and they can be used to solve any optimization problem. Metaheuristic algorithms strike a balance between the search's intensification and diversification. The majority of heuristic and metaheuristic algorithms are inspired by biological or physical systems in nature.

Metaheuristics are generally classified into three categories -Physical-based approaches, evolutionary-based methods, and swarm-based methods. Physical-based approaches use electromagnetic force, displacement, inertia force, gravity, and other physical laws to move search agents over the search space. In evolutionary-based methods, biological processes such as reproduction, recombination, selection, and mutation are inspired to generate algorithms for problem solving. Swarm-based methods are based on the collective behavior of social creatures. The collective activity is complemented by collective intelligence derived from their surroundings. A combination of deterministic rules and randomization has been used to create several swarm algorithms that replicate the behaviour of insect or animal groups in nature. Such methods include the social behavior of bird flocking such as the Particle Swarm Optimization (PSO) algorithm [11], the cooperative behavior of bee colonies such as the Artificial Bee Colony (ABC) technique [12], the social foraging behavior of bacteria such as the Bacterial Foraging Optimization Algorithm (BFOA) [13], the mating behavior of firefly insects such as the Firefly (FF) method [14] and the emulation of the lifestyle of cuckoo birds such as the Cuckoo Search Algorithm (CS) [15].

The implication of Wolpert and Macready's No Free Lunch (NFL) theorem necessitates the deployment of a large number of metaheuristic algorithms . According to the NFL theorem, all algorithms have the same averaged

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performance for all potential tasks. As a result, there is no general distinction between the performances of any two algorithms, except in cases where one algorithm is more suited to a particular application than the other.

The claim of an optimization algorithm for all optimization problems is completely eliminated by the No Free Lunch theorem. As a result, the demand for new meta-heuristic algorithms remains a popular research area. We look at five swarm-based meta heuristic algorithms that can be used to solve challenging real-world situations in this article.

1. Emperor Penguins Colony Algorithm(EPC)

As suggested by Harifi et. al[1] in 2019, EPC is a swarm-based nature-inspired algorithm inspired by the behavior of the Emperor penguins in Antarctica.

Biologial Inspiration : This algorithm is based on how the emperor penguins in a colony try to retain the required heat and thus regulate their body temperature, which is coordinated and controlled by the penguins' movement. They compose huddles consisting of hundreds of penguins to stay warm and confront extreme climatic conditions. And they perform spiral-like forms of movement to achieve the heat balancing within the huddle, thereby directing the members in the huddle environment to the center of the huddle.

Method : Assume that all of the penguins are dispersed throughout the habitat. Each penguin's location and cost are determined, and the costs are compared to one another. Penguins will constantly move towards a penguin with a low absorption cost (high heat intensity). The cost is determined by the severity of the heat and the distance travelled. The heat intensity is adjusted, a new solution is examined, and the attraction is done. All of the solutions are sorted, and the best one is chosen. Heat radiation, movement, and heat absorption are all subjected to a damping ratio. Heat radiation is emitted by all penguins in the initial population and they attract each other due to absorption coefficient. The attraction of penguin is done according to the amount of heat in the distance between two penguins.

Algorithm

1. Generate initial population array of EPs (n), position and cost of each EP;
2. Determine initial heat absorption coefficient;
3. For It=1 to MaxIteration do
1. Generate repeat copies of population array;
2. For i=1 to n do
1. For j=1 to n do
1. If cost [j]< cost [i] then
1. Calculate heat radiation
2. Calculate attractiveness
3. Calculate coordinated spiral movement
4. Determine new position
5. Evaluate new solutions;
2. End
2. End
3. End
4. Sort and find best solution;
5. Update heat radiation (decrease);
6. Update mutation coefficient (decrease);
7. Update heat absorption coefficient (increase);
8. End

Characteristics: This algorithm assumes that the emperor penguin colony uses spiral-like movement to optimise temperature without having to establish the huddle's boundaries; it has quick convergence; and it solves high-dimensional problems with acceptable performance. EPC has been modified to include Archimedes spiral-like movement and Hyperbolic spiral-like movement instead of spiral-like movement [2], and the results were better than the original EPC algorithm.

2. Military Dog Optimizer(MDO)

Proposed by Tripathi et al[3], this algorithm mimics the searching capability of the trained military dogs.

Method : Military dogs have keen senses of smell, allowing them to look for suspicious objects and communicate with one another through barking. All of these military canines can communicate with one another by barking at each other. The intensity of the barking reflects how close it is to the target object. When a troop of military dogs is sent out into the open to search for a target object buried ,they begin searching the area at random. Military dogs use their sense of smell to examine a specific site and define its suitability in terms of loudness. The best location among them is indicated by the loudest volume. The military dog goes to explore the search space depending on the volume of barking and takes small steps based on the scent smell in a particular spot to exploit the local search area. The military canines' smelling sensation analysis allows them to approach closer to the target object and exploit the existing location. Military dogs separate to search for the target object and then converge to indicate that the object is approaching.

Algorithm :
1. Initialization of MDO parameters like number of military dogs, sniff movement probability Pm, smoke or vegetation constant α, wind factor K and the position of each military dog in the search space.
2. Sniffing around current area (exploitation step): In this step, each Military dog(MD) modifies its Feasible Solution Vector(FSV) based on the information got from the loudest barking dog. While searching, the dogs take a random walk and steer around the new location. MD searches around the target object and may either move directly towards the military dog at best position with movement probability Pm or they may take random movements according to its own position and the position of the MD nearest to the target object.
3. Movement due to barking of other dogs(exploration step): It is the general nature of the military dogs that they bark loudly where they smell the suspected object. This creates a global movement of the military dogs. After a certain threshold of barking military dogs try to explore the search region with respect to the most loudly barking military dog. Each military dog takes a random move by considering the loudest barking military dog as global best and any randomly chosen barking military dog.
4. Go to step two for the next iteration. This loop continues till the predefined number of iterations, or the desired solution has been found .

Characteristics and Applications: This algorithm was tested on a variety of benchmarking functions and compared against MVO, ES, Pbil, GA, and PSO. This algorithm outperformed other algorithms in seven out of eight multi-model functions, demonstrating the MDO algorithm's superior exploration capacity. From the standpoint of application, this technique was used to detect fake reviews and resulted in the development of ideal cluster centroids for untangling the problem of false review detection.

3. BlackWidow Optimization Algorithm(BWO)

The Black Widow Optimization Algorithm (BWO), proposed by V. Hayyolalam and A. Pourhaji Kazem [4] in 2020, is based on the peculiar mating behaviour of black widow spiders. This approach includes a one-of-a-kind stage known as cannibalism. Species with insufficient fitness are eliminated from the circle at this stage, resulting in early convergence.

Method : In Black widow Optimization Algorithm (BWO), the potential solution to each problem has been considered as a Black widow spider. To start the optimization algorithm, a candidate widow matrix of size N pop × N var is generated with an initial population of spiders. Then, at random, pairs of parents are chosen to execute the procreating phase of mating, during or after which the male black widow is consumed by the female (Pro creation and sexual cannibalism). The children and their mother are added to an array and sorted by their fitness value; now, some of the best people are added to the newly formed population based on their cannibalism rating. These steps apply to all pairs. Some solutions are randomly selected from the population and mutated based on a parameter called mutation rate. Three stop/convergence conditions can be considered, like with other evolutionary algorithms:(a) a predefined number of iterations. (B) Observation of no change in the best widow's fitness value after multiple iterations. (C) Achieving the required level of precision.

Algorithm :

1. Initialize the population of black widow spiders, procreating rate, cannibalism rate and mutation rate.
2. Based on procreating rate, calculate the number of reproductions ‘nr’
3. Select the best ‘nr’ solutions in the population and save them in pop1
4. For i = 1 to nr do
1. Randomly select two solutions from pop1 as parents
2. Generate D children
3. Destroy father
4. Based on the canninalism rate, destroy some of the children
5. Save the remaining solutions in pop2
5. Based on the mutation rate, calculate the number of mutation children,’nm’
6. For i = 1 to nm do
1. Select a solution from pop1
2. Mutate the solution to obtain a new solution.
3. Save the new one into pop3
7. Update pop = pop2 + pop3
8. Return the best solution from pop
9. Repeat from Step 4 until terminating condition is reached.

Characteristics and application : In order to demonstrate the algorithm's performance, 51 benchmark functions and three genuine engineering design challenges were used to test it. When BWO is compared to other well-known or recent algorithms, it shows that BWO performs astonishingly well in terms of identifying true global optima with great accuracy and speed. This algorithm's application can be observed in feature selection and clustering challenges.

4. **Lion Optimization Algorithm(LOA)**

This algorithm, proposed by Yazdani et al[5], is based on the unique lifestyle and cooperation characteristics of lions. The lion is a wild felid that is divided into two social groups: residents and nomads. Residents are organised into pride groups. A lion pride usually consists of roughly five females, their male and female cubs, and one or more adult males. Nomads are people that roam about sporadically, either in pairs or alone. Several lionesses work together to encircle the prey from various angles and attack the victim quickly.

Method: Every solution in this method is referred to as a "Lion". N pop solutions are created at random in search space in the first stage. N percent of created solutions are chosen at random to be nomad lions. The rest of the population will be split into P prides at random. Every solution in this algorithm has a distinct gender, which was maintained throughout the optimization process. To reflect this, in each pride, a percentage S (75–90%) of the total population produced in the previous phase is referred to as females, while the balance is referred to as males. This percentage is reversed for nomad lions (1 – S). During the search, each lion makes a note of its best location . Every pride's territory is defined by these specified positions. As a result, the region of each pride is defined by the marked positions (best visited positions) by its members.

Algorithm:

1. Generate random samples of lion population Npop
2. Initialize pride and nomad lions
1. Randomly select %N(Percent of lions that are nomads) of initial population as nomad lion. Partition remaining lions into P(P is the number of prides) prides randomly and form each lion's territory.
2. In each pride %S(sex rate)of entire population are known as females and the rest as males. This rate in nomad lions is reversed.
3. For each pride do
1. Select some random female lion to go for hunting
2. Each of the remaining female lion in pride go toward one of the best selected position from territory.
3. In pride for each resident male, %R(roaming percent) of territory randomly are selected and checked. %Ma(Mating probability) of females in pride mate with one or several resident males.->New cubs become mature
4. Weakest male drive out from the pride and becomes a nomad.
4. For nomad do
1. Nomad lion(both male and female) move randomly in search space. %Ma(Mating probability) of nomad female mate with one of the best nomad male -> New cubs become mature.
2. Prides randomly attacked by nomad male.
5. For each pride do
1. Some female with I rate(Immigration rate) immigrate from pride and become nomad.
6. Do
1. Based on the fitness values, each gender of the nomad lions are sorted. After that the best females among them are selected and distributed to prides filling empty places of migrated females
2. With respect to the maximum permitted number of each gender, nomad lions with the least fitness value are removed.
7. If termination criterion is not satisfied go to step 3.

Characteristics and Application: The Lion optimization algorithm used to solve engineering optimization problems like data clustering, neural networks tuning, scheduling problems, pattern recognition, image processing and video processing.[6],[7],[8]

5. Grasshopper Optimization Algorithm(GOA)

Saremi et al. introduced the GOA algorithm[10], which is a new and intriguing swarm intelligence algorithm that simulates grasshopper foraging and swarming behaviours.

Although grasshoppers are normally seen alone in nature, they form part of one of the world's largest swarms. The swarm's size might be continental, creating a nightmare for agriculture. The grasshopper swarm is unique in that it exhibits swarming behaviour in both nymph and adult stages. Hundreds of millions of nymph grasshoppers jump and move in a cylinder-like pattern. They consume practically all vegetation in their path. When they reach adulthood, they continue their behaviour and create a swarm in the air.

Method : The GOA begins the optimization process by generating a set of random solutions. The search agents reposition themselves. In each iteration, the position of the best target obtained thus far is updated. In addition, in each cycle, the factor c is determined, and the distances between grasshoppers are normalised. Iterative position update is carried out till the end criterion is met. Finally, the best target's position and fitness are returned as the best approximation for the global optimum.

Algorithm :
1. Initialize the swam Xi(i =1,2,...,n)
2. Initialize cmax, cmin and number of iterations
3. Calculate the fitness for each agent
4. T = the best search agent
5. While (l<MaxNoofIterations)
1. Update c
2. For each search agent
1. Normalize the distances between grasshoppers
2. Update the position of the current search agent
3. Bring the current search agent back if it goes outside the boundaries
3. Update T if there is a better solution
4. l = l+1
6. Return T

Characteristics and Applications: GOA has been used to handle a variety of optimization issues, including feature selection, scheduling, load frequency management, economic dispatch, and engineering. Adaptive GOA, binary GOA, chaotic GOA, Opposition based Learning GOA, and other forms of GOA have been proposed in the literature[9].

II. CONCLUSION

In this paper, we have surveyed five Swarm based nature inspired metaheuristic algorithms which were recently proposed and yet to be explored fully. These algorithms have already been proven to provide promising results for various real world problems they have applied upon. We believe that these algorithms will continue to show their prominent advantages when they are systematically applied to more sophisticated real world problems.

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