A Review on Lion Optimization: Nature Inspired Evolutionary Algorithm

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Abstract—Nowadays Nature inspired algorithms are gaining immense popularity in recent years to solve complex problems of real life. They are based on nature's behaviour and they are very robust and realistic. Many Machine learning Techniques use these algorithm to solve very complex problem. This paper presents a comprehensive review of these algorithms with main focus on lion algorithm. Lion Algorithm is based on lion unique social behaviour which makes them strongest animal in the world. Similar to Genetic Algorithm Loin Algorithm include generation, mutation, crossover etc.. Territorial defence and territorial take over behaviour of the lion makes this algorithm different from other algorithms.

Keywords— Evolutionary Algorithm, Genetic Algorithm, Lion Algorithm, Mutation, Crossover, Swarm Intelligence

I. Introduction

Nature-inspired algorithms have gained immense popularity in recent years to tackle hard real world problems and solve complex optimization functions whose actual solution doesn't exist. These algorithms are subject of computational intelligence. As the world is moving towards industrialization, engineering problems are becoming more and more complex and difficult to optimize. This is because of increasing dimensions, variables, time complexity, space complexity etc. To cope up with such situation, nature inspired algorithms are designed to optimize numerical benchmark functions , multi objective functions and solve hard problems for large number of variables, dimensions, etc. NIA are mainly categorized into evolutionary algorithms and swarm intelligence based algorithms. Evolutionary algorithms are based on the evolutionary behavior of natural systems. These algorithms are inspired by Charles Darwin theory : Survival of the fittest. A population of only those species reproduces who fits in the natural habitat – natural selection [3]. This paper makes an attempt to review nature inspired algorithms with main focus on lion algorithm-a novel optimization algorithm, which is based on lion's unique social behavior, hence termed as Lion Algorithm (LA).

The paper is organized as follows: Section 2 highlights the Literature Review. Section 3 discusses various nature inspired algorithms. The Lion social Behavior is discussed in Section 4.Atual Lion Algorithm is presented in section 5 with pseudo code. section 6 represents merit and demerits of Lion algorithm. In last Conclusion and acknowledgements are summarized.

II.LITERATURE REVIEW

B R Rajakumar [1] attempts to introduce a new optimization algorithm called as Lion algorithm to accomplish the system characteristics precisely. This algorithm is a simulation model of the lion's unique characteristics such as territorial defense, territorial takeover, laggardness exploitation and pride. Lion algorithm dominates when using standard bilinear model, whereas it is equivalent to differential evolution and better than genetic algorithm when using large scale bilinear model.

B R Rajakumar [2] in ICCCS-2012 proposes a novel solution search algorithm called Lion Algorithm. The natural inspiration behind the proposed algorithm is lion's social behaviour that aids to keep the mammal be strong in the world. The interpretation of such social behaviour to algorithmic perspective helps in searching out highly optimal solutions from a huge solution space. The algorithm solves both single variable and multi-variable cost function problems through the generation of binary structured and integer structured lion, respectively. The algorithm is implemented and tested using De-Jong's Type-I function and the results are compared against the evolutionary programming. The test results show the algorithm performance under varying sizes of solution spaces.

Parul Agrawal and Shikha Mehta [3] presents a comprehensive review of 12 nature inspired algorithms. This study provides the researchers with a single platform to analyze the conventional and contemporary nature inspired algorithms in terms of required input parameters, their key evolutionary strategies and application areas. A list of automated toolboxes available for directly evaluating these nature inspired Algorithms over numerical optimization problems indicates the need for unified toolbox for all nature inspired algorithms. It also elucidates the users with the minimum and maximum dimensions over which these algorithms have already been evaluated on benchmark test functions. Hence this study would aid the research community to know what all algorithms could be examined for large scale global optimization to overcome the problem of 'curse of dimensionality'.

Rashmi A. Mahale, S.D.Chavan [4] paper gives overview of most predominant and successful classes of bio inspired optimization methods involving evolutionary and swarm based algorithms inspired by natural evolution and collective behavior in animals respectively.

E.S.Ali *et al* [8] presents a paper aims to propose Ant Lion Optimization Algorithm (ALOA) for optimal allocation and sizing of renewable DG sources in various distribution networks. First the most candidate buses for installing DG are suggested using Loss Sensitivity Factors (LSFs). Then the proposed ALOA is employed to deduce the locations of DG and their sizing from the elected buses. The proposed algorithm is tested on 33 and 69 bus radial distribution systems. The obtained results via the proposed algorithm are compared with others to highlight its benefits in reducing total power losses and consequently maximizing the net saving. Moreover, the results are introduced to verify the superiority of the proposed algorithm to improve the voltage profiles for various loading conditions. Also, the Wilcoxon test is applied to confirm the effectiveness of the proposed algorithm.

Ramadan Babers *et al* [7] shows that Community detection problem can be represented as an optimization problem as the objective is how to divide the network to groups of nodes while the connectivity between nodes in the same group is better than connectivity with other nodes. In this research Ant Lion Optimization (ALO) has been used as effective optimization method to detect the number of communities in the networks automatically. The results show that ALO succeed to find an optimization community structure based on the quality function used.

Wang Bo *et al* [9] report a novel optimization algorithm, lion pride optimizer (LPO), which is inspired by lion pride behavior. The framework is mainly based on lion prides' evolution process and group living theory. In a lion pride, brutal competition of individuals happens among male lions both within and among prides; on the other hand, each member plays an important role in the persistence of a lion pride. Based on this framework, concepts from lion prides behavior, e.g., the strongest males occupy nearly all mating resources, and if a new cohort of males is able to take over a pride, they will seek to kill young cubs sired by their predecessors, are employed metaphorically to design optimum searching strategies for solving continuous optimization problems.

Satish Chander et al [5] presents a novel Fractional Lion Algorithm (FLA) as an optimization methodology for the clustering problems. The proposed algorithm utilizes the lion's unique characteristics such as pride, laggardness exploitation, territorial defence and territorial take over. The Lion algorithm is modified with the fractional theory to search the cluster centroids. The proposed fractional lion algorithm estimates the centroids with the systematic initialization itself. Proposed methodology is a robust one, since the parameters utilized are insensitive and not problem dependent.

Navneet et al [6] have developed a novel big data classification algorithm based on a nature inspired meta-heuristic algorithm (lion optimization algorithm). Lion optimization algorithm is an optimization algorithm based on the hunting and social behaviour of the lion. The developed algorithm uses the K-mean clustering to generate the pride and nomad. Then the hunting and migration behaviour of the lion is repeated to change pride and optimize the process.

III. NATURE INSPIRED ALGORITHMS

3.1 Genetic Algorithm (GA)

Genetic algorithm was given by John Holland during 1960s and 1970s [17] [18]. It is a biologically inspired computational technique motivated from Darwin's theory of evolution. It mimics the process of natural selection. Performance of GA is based on four factors: population size, mutation rate, crossover rate and number of generations. To determine the best individual among population, genes of corresponding individuals are evaluated against the objective function. The evolutionary mechanisms through which a new offspring (individual) is produced are crossover and mutation. In crossover mechanism, an offspring is produced by combining the genes of selected individuals among population while mutation causes some random changes in genes of an individual thereby producing new genetic individual. The evolutionary mechanism is carried out till convergence criteria are satisfied.

3.2 Ant Colony Optimization (ACO)

In 1992, Marco Dorigo [21] proposed a new algorithm in his PhD thesis, Ant colony optimization. Ants are small creatures that can intelligently find the shortest path between their nest and food source. Each ant represents a potential solution to an objective function. Ants establish their communication through trails of pheromone. When an ant comes out of their nest to search for food source, they move randomly in any direction, leaving pheromone in their path. On reaching the food source, ants return back with food, leaving pheromone again on same path. Hence, the path with the highest amount of pheromone represents the shortest route from ant's nest to the food source. Pheromone concentration in each path represents the quality of solution (goodness of fitness value).
The process is continued until stopping criteria is met.

3.3 Particle Swarm Optimization (PSO)

PSO was developed by J. Kennedy and R. Ederhart in 1995 [20]. PSO mimics the flocking behavior of birds. The birds fly in a solution space and their flocking behavior determines the optimum solution. They follow some path to reach their food destination. The shortest path followed by a bird is considered to be local or particle best solution. Particles tend to move towards its local best position (solution) (lbest) found by them so far. They also keep the track of global best (gbest) solution, the best (shortest) path found by any particle at particular instance. Each particle is associated with a velocity, through which it gets accelerated towards local and global best path, the position in 'n' dimension space and the current position of particle with respect to gbest and lbest. Birds communicate with each other to find the most optimum (best) path to reach its food sources. Hence, they learn from the experience of their local best solutions and global best solutions. The algorithm continues till global optimum solution is achieved.

3.4 Memetic Algorithm (MA)

Memetic algorithm is also inspired by Dawkin's theory of evolution [19]. Instead of genes, a set memes are considered to form chromosomes. In genetic algorithm, crossover and mutation operations begins immediately after the selection of individuals while in MA, an individual takes time to learn experience and then crossover and mutation operations are applied. When crossover between two individuals takes place, a new offspring is produced. This offspring undergoes local search to produce local optimum solution. Individual with best fitness value (solution) is selected and rests are abandoned. Thus in MA, evolutionary mechanism includes local search along with crossover and mutation.

3.5 Bacterial foraging optimization Algorithm (BFOA)

BFOA was developed by Kevin M. Passino in 2002 [12]. There are three main steps followed by bacteria to achieve global optimum solution: chemotactic step, reproduction step, elimination and dispersal step. In chemotactic step of BFOA, bacteria swims in direction of high nutrient surface while they tumble when noxious surface is encountered. Objective of BFOA is to minimize the cost of bacteria's movement in high
nutrient surface. At the end of this step, all bacteria are arranged in descending order of their fitness value. In reproduction step, first half of the bacteria with high cost die as they did not get sufficient nutrient to survive, while other half (bacteria getting sufficient amount to nutrient) are split into two parts thereby maintaining constant population size. In elimination and dispersal step, bacteria get

dispersed into complete surface thus controlling them to get trapped in local optima. The newly produced bacteria occupy position of eliminated bacteria. The bacteria with best fitness value, that is, minimum cost finally represent the solution to an objectivefunction. The process continues till desired number of generations gets exhausted.

3.6 Shuffled Frog Leaping Algorithm(SFLA)

SFLA was given by Muzaffar Eusuff and Kevin Lansey in 2003 [22]. This algorithm combines the best properties of two algorithms: MA and PSO. SFLA is inspired by leaping and shuffling behavior of frogs to exchange information among them in order to search for food. Each frog represents a potential solution for the specified problem. After computing the fitness value of each frog in SFLA, all frogs are arranged in descending order of their fitness value. Thereafter all frogs are divided into number of subsets called memeplexes in some special manner; each memeplex contains equal number of frogs. After this division local best solution is computed within each memeplex. In SFLA, local evolution is carried out within each memeplex and after defined number of memetic evolutions, all frogs are shuffled together for global evolution. The process continues unless desirable solution is achieved or stopping criteria is met.

3.7 Artificial Bee Colony Algorithm (ABC)

ABC algorithm was developed by Dervis Karaboga in 2005.The algorithm imitates the foraging behavior of honey bees [10] [11]. The term artificial bee is used because the behavior of actual bee is quite different from the behavior of bees assumed in ABC algorithm. Scout bee randomly searches food source position. These food positions are exploited by employed bees and they communicate nectar amount found in

particular food source to onlooker bees. Each food source is a potential solution of an objective function. Onlooker bees memorize the best food source position (one having highest nectar amount) and send employee bees to find better food position in neighborhood of best food source found so far. Hence optimized solution is the food source having highest nectar amount. The algorithm terminates when desired solution is achieved.

3.8 Firefly Algorithm (FFA)

Firefly algorithm was first introduced by Xin-She Yang in 2007[14]. The algorithm was motivated by mimicking the flashing behavior of fireflies for the purpose food acquisition [16]. Each firefly is attracted towards other firefly. This attraction is represented by their brightness, which increases or decreases depending on distances between the flies. For all fireflies, the light intensity (brightness) of each firefly is compared with other firefly. Low light intensity flies move towards high light intensity, thereby decreasing the distance and updating its own brightness. The firefly with high brightness and least distance is the best solution of an objective function.

3.9 Biogeography Based Optimization (BBO)

BBO is a new bio-inspired metaheuristic algorithm proposed by Dan Simon in 2008 [23]. It is based on migrating behavior of species in habitat. Each habitat represents a probable solution of a problem. Habitat suitability index (HSI) is an attribute of the habitat which gives the desirability of living in that habitat. Habitat immigration (species arriving in habitat) and emigration (species leaving habitat) rates are decided by HSI value. High HSI habitat (said to be good solution) has suitable environment for feeding and reproduction, hence contain large number of species than low HSI habitat. Emigration rate is higher than immigration rate in high HIS habitat and vice versa in low HSI habitat. Migrating species passes features of high HSI habitat to low HSI habitat. Each habitat suitability is characterized by SIV i.e. suitability index variables. Mutation (migration of some unexpected species into the habitat) causes disturbance in the equilibrium state (emigration rate μ and immigration rate are equal). This causes the change in SIV of any habitat. The process continues unless convergence criteria are satisfied.

3.10 Cuckoo Search Algorithm (CSA)

Cuckoo search algorithm is a metaheuristic algorithm developed by Xin-She Yang and Suash Deb in 2009 [16]. Cuckoo search algorithm (CSA) is inspired by breeding behavior of cuckoo bird. They select their home nest by randomly taking over the nest of some other birds for

reproduction. They lay their eggs in selected nest of host bird and drop the host bird’s egg. The host bird either drop cuckoo bird’s egg or abandon the whole nest. Some female cuckoo can imitate their eggs like host bird’s egg and lay their eggs just before the laying of host bird’s egg. This increases the probability of their chick survival. Each egg in nest represents one solution and cuckoo bird’s egg represents a new solution. Fitness for each solution is computed and nest with high quality of eggs (best fitness value) represents the best solution [38]. The process is continued unless global optimum solution is achieved.

3.11 Bat Algorithm

Bat algorithm was introduced by Yang in 2010 [15]. It simulates the echolocation behavior of microbats as microbats can generate high echolocation. The Bat produces a very high sound to detect its prey which echoes back with some frequency. Echolocation is a process of detecting an object by reflected sound. It is used to know how far the prey is from background object. By observing the bounced frequency of

sound, bats are able to distinguish between the prey and obstacle and can sense the distance between them in their nearby surroundings. They fly randomly with some velocity, frequency and sound (loudness) to search for food. Solution of objective function is to find prey at minimum distance. The frequency and zooming parameters maintain the balance between exploration and exploitation processes. The algorithm continued till convergence criteria are satisfied.

3.12 Flower Pollination Algorithm (FPA)

Flower pollination algorithm is a latest bio-inspired algorithm proposed by Xin-She Yang in 2012 [26]. It is inspired by fertilization (pollination) process of flowers. In FPA, abiotic and self pollination are considered for local pollination while biotic and cross pollination is considered for the global pollination between the flower plants. The algorithm maintains a balance between local and global pollination.Yang [28] assumed that each plant can have only one flower and each flower can have only one pollen grain for the purpose of optimizing the benchmark functions. The process of pollination is done by pollinators such as flies, insects or wind. Thus, each flower (or pollen) can be considered as a potential solution of an objective function. The objective function finds the best flower, which is capable of doing maximum pollination. The process continues unless stopping criteria is met.

3.13 Paddy Field Algorithm

It was proposed by Premaratne et al in 2009[33], which operate on a reproductive principle dependant on proximity to the global solution and population density similar to plant populations. In contrast to evolutionary algorithms, it does not involve combined behavior or crossover between individuals (optimum solution can migrate) instead it uses pollination and dispersal.

It consists of five basic steps: sowing, selection, seeding, pollination and dispersion.

3.14 Fish Swarm Algorithm

Fish Swarm Algorithm (FSA) is a new intelligent swarm modeling approach that consists primarily of searching, swarming, and following behaviors of fish. FSA technique proposed by Li et al in 2002[34], which is inspired by the natural schooling behavior of fish. FSA presents a strong ability to avoid local minimums in order to achieve global optimization. A fish is represented by its D-dimensional position Xi and food satisfaction for the fish is represented as FSi. The relationship between two fish is denoted by their Euclidean distance FSA responds to three typical behaviors of a fish, which are: searching, swarming and following

3.15 Intelligent Water Drop Algorithm

IWD is an innovative population based method proposed by Hamed Shah-hosseini in 2007[135]. The intelligent water drops (IWD) algorithm is a new swarm-based optimization algorithm inspired from observing natural water drops that flow in rivers. Based on the observation on the behavior of water drops, an artificial water drop is developed which possesses some of the remarkable properties of the natural water drop.

3.16 Artificial Immune System

Artificial Immune algorithm[36] is based on clonal selection principle and is a population based algorithm. The AIS is inspired by the human immune system which is a highly evolved, parallel and distributed adaptive system that exhibits the strengths like: immune recognition, reinforcement learning, feature extraction, immune memory, diversity and robustness. The mutation operator is the efficiency deciding factor of this technique. The steps in AIS are as follows: Initialization, cloning and Hyper mutation.

IV.LION SOCIAL BEHAVIOUR

Lions have an interesting social behavior to keep the animal stronger in every generation, unlike other cat spices. Lions are the most socially inclined of all wild felids, most of which remain quite solitary in nature, and have two types of social organization. Some lions are residents, living in groups of related lionesses, their mates, and offspring. Such a group is called a pride. Females form the stable social unit in a pride and do not tolerate outside females. Membership only changes with the births and deaths of lionesses, the average pride consists of around fifteen lions; including several adult females, up to four males (known as a coalition if more than one) and their cubs of both sexes. Male cubs are excluded from their maternal pride when they reach maturity at around 2–3 years of age [42] [46].

The second organizational behavior is labeled nomads, who range widely and move about sporadically, either singularly or in pairs. Pairs are more frequent among related males who have been excluded from their birth pride. Note that a lion may switch lifestyles; nomads may become residents and vice versa. Interactions between prides and nomads tend to be hostile, although pride females in estrous may allow nomad males to approach them [42][46].

The area a pride occupies is called a pride area, whereas that by a nomad is a range. The males associated with a pride tend to stay on the fringes, patrolling their territory. Members of the pride regularly tend to play the same role in hunts and hone their skills. Both males and females can defend the pride against intruders, but the male lion is better-suited for this purpose due to its stockier, more powerful build. Some individuals consistently lead the defense against intruders, while others lag behind. The male or males associated with the pride must defend their relationship to the pride from outside males who attempt to take over their relationship with the pride [42][46].

A. *Territorial defense*

A cub needs 2-4 years to attain sexual maturity and so the territorial lion needs to defend for the territory for the same number of years. In between these 2-4 years, nomadic lions may try to invade the pride, which we call it as territorial defense. In the territorial defense, a war is held between the territorial lions and nomadic lions. Coalition is built among the lions that belong to the pride to defeat the nomadic lion. If the nomadic lion defeats the territorial lion, the territorial lion may be either killed or driven out of the pride by the nomadic lion. The nomadic lion becomes the territorial lion by killing the cubs of lost lion. The new territorial lion can immediately force the female lion to estrus and copulate for its offspring [2].

B. *Territorial Takeover*

Territorial takeover is carried out between the old territorial male and new territorial male. Once the cubs of a pride reach sexual maturity and if they seem to be stronger than the territorial lion to take over the pride, the territorial lion may be either killed or driven out of the pride. The new stronger pride lion kills the cubs of the territorial laggard lion and prepare for copulation to give birth to their own cubs[2].

IV. LION ALGORITHM

The major functions involved in lion Algorithm is as below.

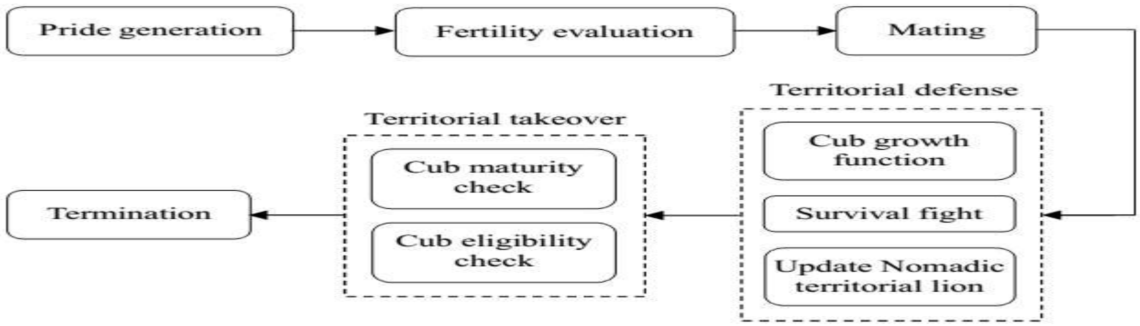

Fig.1: Block Diagram of Lion Algorithm[1].

1. Pride Generation

Initialize X^{male}, X^{female} and X_1^{nomad} of which X^{male} and its lioness X^{female} constitute pride. The elements of X^{male}, X^{female} and X_1^{nomad}, i.e., $X^{male}(l)$, $X^{female}(l)$ and, X_1^{nomad} (l) respectively are arbitrary integers generated within the minimum and maximum limits. Here, one of the two nomadic lions is initialized while the other nomadic lion will be initialized at the time of territorial defense only.

2. Fitness Evaluation

The fitness of all the three lions, termed as $f(X^{male})$, $f(X^{female})$ and $f(X_1^{nomad})$, are determined using De-Jong's Type-I objective function. For the further steps, we set $f^{ref} = f(X^{male})$ and $Ng = 0$, where Ng is the generation counter, which may be used for checking termination criterion. Also, we store X^{male} and $f(X^{male})$.

3. Fertility Evaluation

This stage evaluates and ensures the fertility of the territorial lion and lioness. In other words, the stage intends to avoid converging in local optima. The processing steps are discussed in the pseudo code as given below.

Process: Fertility Evaluation
Input: X^{male} , X^{female} , f^{ref} , Lr and Sr
Output: X^{male} , X^{female} , f^{ref} , Lr and Sr
// X^{male} Evaluation

If $f^{ref} \leq f(X^{male})$
$Lr \leftarrow Lr + 1$
else
Reset Lr
$f^{ref} \leftarrow f(X^{male})$
End if
// X^{female} evaluation
If Sr is not tolerable
Set uc and gc to zero
Do
Calculate X^{female}
$gc \leftarrow gc + 1$
If $f(X^{femal}) < f(X^{female})$
$uc \leftarrow 1$
$X^{female} \leftarrow X^{female}$
Reset Sr

End if
Until *gc* reaches gc^{max}
End if

Fig.2: Pseudo code for Fertility evaluation[1]

In above Fig., $X^{female+}$, f^{ref}, L_r , S_r , u_c and g_c are updated female lion, reference fitness, Laggardness rate, sterility rate, female update count and female generation count respectively. When the LA begins, L_r and S_r are initialized as zero, and at every call for fertility evaluation, L_r and S_r get lastly determined value. Checking the tolerance of S_r is nothing but checking whether they exceed their maximum limit S_r^{max} . S_r^{max} is set as four as the median duration of estrus is four days for lions. However after some trial and error evaluation, we finalized this as three. In order to avoid conflict and to maintain uniformity, we include both L^{max}_r (will be referred in Step 6) and S_r^{max} irrespective of gender. g_c^{max} is set as 10 based on trial and error method. $X^{female□}$ (□ $x^{female□}$) can be calculated as

$$x_l^{female+} = \begin{cases} x_k^{female+} & ; if\ l=k \\ x_l^{female} & ; otherwise \end{cases} \quad (1)$$

$$x_k^{female+} = \min[x_k^{max}, \max(x_k^{min}, \Delta_k)] \quad (2)$$

$$\Delta^k = [\ x_k^{female} + (0.1r_2 - 0.05)(x_k^{male} - r_1\, x_k^{female}) \quad (3)$$

Where, $x_l^{female+}$ and $x_l^{female+}$ are the lth and kth vector elements of $x^{female+}$, respectively, k is a random integer generated within the interval [1, L], ∇ is the female update function, r_1 and r_2 are random integers generated within the interval [0,1] .

4.Mating

In the mating, two primary steps called as crossover and mutation are included, which are found as significant operators for any evolutionary optimization [39-42]. We follow the maximum natural littering rate, i.e., four cubs (mostly) in a lioness pregnancy [43] and so we get four cubs ‘ X^{cubs} ’ from the crossover, which is of uniform in nature with random crossover probability C_r . The mathematical representation of the crossover operation can be given as

$$X^{cubs}(p) = B_p \circ X^{male} + \bar{B}_p \circ X^{female} \; : p \,□\, 1,2,3,4 \quad (4)$$

where, B is crossover mask of length L in which 1s and 0s are filled randomly based on Cr , $\bar{B}$ is the one’s complement of B , vector operator ‘ ○ ’ represents Hadamard product or schur product and

$X^{cubs}(p)$ is the p^{th} cub obtained from crossover. The X^{cubs} are subjected to uniform mutation with the mutation probability as Mr and hence equal number of new cubs X^{new} are obtained. The obtained X^{new} (from mutation) and
X^{cubs} (from crossover) are placed in the cub pool and subjected to further processes.
A secondary step, called gender clustering [37], is also included here to extract a single male cub and a female cub from the cub pool. Based on the lion's physical nature [44- 47], we select the cubs, which have the first and second best fitness, as the male cub $X\ m\_\ cub$ and female cub $X\ f\ \_\ cub$, respectively. Once the $X\ m\_\ cub$ and $X\ f\ \_\ cub$ are obtained, set their ages (commonly referred as cubs' age) $Acub$ as zero.

5.Cub Growth Function
Cub growth function is a local solution search function in which the X^{m_cub} and X^{f_cub} are subjected to uniform random mutation at a rate of G_r . If the mutated X^{m_cub} and X^{f_cub} are better than old X^{m_cub} and X^{f_cub} , then the mutated X^{m_cub} and X^{f_cub} replace old X^{m_cub} and X^{f_cub}, respectively. A_{cub} is incremented by one at every execution of cub growth function to illustrate the cubs' growth towards maturity. G_r should be less enough (possibly <0.2) to search the fine local solutions of X^{m_cub} and X^{f_cub} and need not be equal to M_r .

6.Territorial Defense
Territorial defense [37] is one of the primary lion operators to direct the algorithm to analyze the search space in a wider way. The territorial defense can be sequenced here as forming nomad coalition, survival fight and then pride and nomad coalition updates. Pseudo code for Territorial defense is given as follow.

Process: Territorial Defense
Get nomad coalition
Select x^{e_nomad}
if x^{e_nomad} wins
$xmale \leftarrow x^{e\_nomad}$
Remove x^{e_nomad} from nomad world
Kill x^{m_cub} & x^{f_cub}
Reset age(cubs)
Defense result←1
Else
Update nomad coalition
Defense result←0
End if

Fig.3: Pseudo code for Territorial defense[1]

Getting nomad coalition as given in above Fig. represents introducing two nomadic lions of which X_1^{nomad} has been initialized at Step 1, whereas X_2^{nomad} is initialized as based on L_r . Succinctly, X_2^{nomad} is initialized as like X_1^{nomad} , when X^{male} is not laggard (i.e., $L_r \le L^{\max}_r$). Otherwise, X_2^{nomad} is initialized as an updated version of X^{male} through uniform mutation with a mutation rate of $1 - M_r$.
Survival fight takes place between one of the two lions of nomad coalition and the pride, despite coalition between nomadic lions are also common [48]. Instead of engaging nomad coalition for territorial defense, we apply winner take all approach [49] so that only winning nomadic lion X^{e_nomad} among the coalition engage in territorial defense. The survival fight result comes in favour of the selected X^{e_nomad} if the following criteria are met

$$f(X^{e\_nomad}) < f(X^{male}) \quad (5)$$
$$f(X^{e\_nomad}) < f(X^{m\_cub}) \quad (6)$$
$$f(X^{e\_nomad}) < f(X^{f\_cub}) \quad (7)$$

Pride is updated by replacing X^{male} by X^{e_nomad} after removing it from nomad coalition, which happens only when X^{male} is defeated in the territorial defense. Likely, nomad coalition is updated only when X^{e_nomad} is defeated. The update process is done by selecting only one X^{nomad}, which has E^{nomad} greater than or equal to exponential of unity.

7. Territorial Takeover

Territorial takeover takes place only if $A_{cub} \geq A_{\max}$, otherwise the process is reiterated from Step 5. It is a process of giving territory to the X_{m_cub} and X_{f_cub} after they mature and become stronger than X_{male} and X_{female} . The pseudo code, which is given as below, depicts the processing steps of the territorial takeover operation. If X_{f_cub} is found to be better than X_{female} , X_{f_cub} retains X_{female} position. Such X_{f_cub} is probably fertile and hence S_r is set back to zero in the territorial takeover. Here *A*max is associated with attaining sexual maturity by cubs. Naturally, cubs mature in 1.5-2 years or 2-4 years [38].Hence the median has been fixed as maximum age for cub maturity, i.e., $A_{\max} = 3$. Now, one generation shall be considered as completed and hence is N_g incremented by one.

Process: Territorial Takeover
If $f(X^{male}) > f(X^{m\_cub})$
$X^{male} = X^{m\_cub}$
Endif
$X^{old} = X^{female}$
If $f(X^{female}) > f(X^{f\_cub})$
$X^{female} = X^{f\_cub}$
Endif
If $X^{female} \neq X^{old}$
Clear *Sr*
Endif

Fig.4: Pseudo code for Territorial takeover[1]

8. Termination Criteria

Here, the algorithm execution is terminated when any one of the following two termination criteria is met, otherwise the process is reiterated from Step 3, after storing X^{male} and $f(X^{male})$.

$$f(X^{male}) \leq e_T \qquad (8)$$
$$N_f > N_f^{max} \qquad (9)$$

where, Nf is the number of function evaluations, which is also initialized with zero and incremented by one, when a fitness evaluation is performed, N_f^{max} and e_T are the maximum number of function evaluations and target error, respectively.

V.MERITS AND DEMERITS

A. Merits

This method is typically inspired by behavioural phenomena from nature and have the advantage of being extremely robust, having an increased chance of finding a global or near global optimum. This method is more suitable for high dimension problems and scalable in its nature. This algorithm minimized the cost function i.e. found out the solution that minimizes the cost function in a consistent manner despite the size of the solution spaces. As this algorithm is inspired by merits of lion's social behavior in strengthening their generation, the convergence is very less time consuming and reliable [2].

B. Demerits

We can consider following demerits for Lion Algorithm.

1. Component Design: A major drawback in case of Bio inspired algorithms including lion algorithm is whether to compromise on competitive interactions or cooperative interactions[4].
2. Lack of data: lack of data on a system may affect the design of the algorithm derived from the analogous biological system[4].

CONCLUSIONS

Nature inspired Algorithms are based on behavioral phenomena from nature and they are very robust and realistic. Lion Algorithm is based on Lion's social behavior which is strongest animal on the earth. So this algorithm finds optimum or near optimum solution of the problem.

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