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Lion Optimization Algorithms (LOAs): A Review on Theory, Variants, and Applications

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Abstract— The problem of optimization has always existed in all scientific and industrial fields. This issue has been raised in mathematics and computer science as finding the best answer among different answers. This problem has become an essential area for research in the last decades. Not only analytical methods but also meta-heuristic methods have been developed to solve this problem. The Lion Optimizing Algorithm (LOA) is a meta-heuristic algorithm for optimization problems. The LOA was inspired by various aspects of lions' lives, such as hunting, mating, roaming, defense, and migration. So far, this algorithm has been used in several fields such as classification, clustering, image processing, cloud computing, and task scheduling. The LOA has proved promising results in these areas. Multiple algorithms have flourished to tackle various constraints and challenges of the LOA. In this paper, the LOA, its variants, and applications are reviewed from the beginning until now.

Keyword: Analytical methods, meta-heuristics methods, optimization problems, Lion Optimization Algorithm (LOA).

1. Introduction

In recent decades, various issues have arisen in industrial production fields and daily life, and many techniques have been developed to improve these issues. It has also attracted much attention from researchers. Some of the optimization problems we face in real life have discontinuity, non-linearity, multi-extremum, and non-differentiability features [1].

Proposed algorithms for optimization problems are divided into different categories. A group of these algorithms is nature-inspired algorithms which are inspired by natural processes and collective behaviors in animals. These algorithms focus on the various rules, aspects of animal group life, and Swarm Intelligence. Some of the most popular of these algorithms are Genetic algorithm (GA) [2], Ant Colony Optimization (ACO) [3], and Particle Swarm Optimization (PSO) [4], which are human genetic behaviors, and social organizations and behavior and socially flocked birds are modeled, respectively.

So far, various nature-inspired algorithms with acceptable performance have been proposed. Such as the Cat Swarm algorithm, inspired by the behavior of cats [5], and the Bat-inspired Algorithm, inspired by the life of bats [6]. There are also other algorithms, the Bees algorithm [7], Firefly algorithm [8], and Gray Wolf Optimizer (GWO) [9], and many different nature-inspired algorithms.

Rajakumar [10] introduced Lion's Algorithm (LA), inspired by the social behaviors of lions. Another algorithm called the Lion Optimization Algorithm (LOA) was introduced by Yazdani and Jolai [11] differently, with the same focus like the LA algorithm, on lion life. In this article, the variations and applications of LOA are reviewed.

The LOA is inspired by the wild lions' social behavior such as territory selection, hunting, mating, etcetera. The lions are savage cats with two social organizations called Nomad and Resident. Residents typically live in groups called pride. And each pride consists of 5 or 6 female lions with their offspring and one or two male lions. Only one of these dominant male lions has the right to mate with females. In each pride, each member has a unique role. Female lions are responsible for hunting. Male lions are responsible for maintaining territory. Offspring lions have to leave the pride and become nomad lions when they reach adulthood.

The second group is nomad lions. In nomad lions, there is usually one male and one female lion. But it also may include

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only one lion, male or female. Lions may change from resident to nomad or vice versa.

The LOA algorithm has been used in various fields. Prince and Lin [12] evaluate the performance of hunting algorithms through Belief, Desire, and Intent (BDI) Agent simulation, which proved LOA is more resistant than GWO.

Developments and applications of the LOA algorithm have been used in various fields such as secret key generation, image processing, and cloud computing. Faheem et al. [13] developed the LOA algorithm for multi-objective problems for wireless networks. Also, Shunmugathammal et al. [14] introduced a new B*tree-based fitness function to solve the VLSI Floorplanning problem.

The rest of this article is organized as follows. In section 2, the LOA algorithm is introduced. The third section is a brief review of LOA variants, and in the fourth section, the different applications of the algorithm are discussed. The last section includes the discussion about the performance of LOA and concludes the paper.

2. Lion Optimization Algorithm (LOA)

In the LOA algorithm, based on the lions' behavior, initially a random population of lions will be generated. This population is divided into two groups, the nomads and the residents. First, randomly, a percentage of the initial population is considered as nomad lions. The remaining lions are divided into P pride which specifies the territory of each pride.

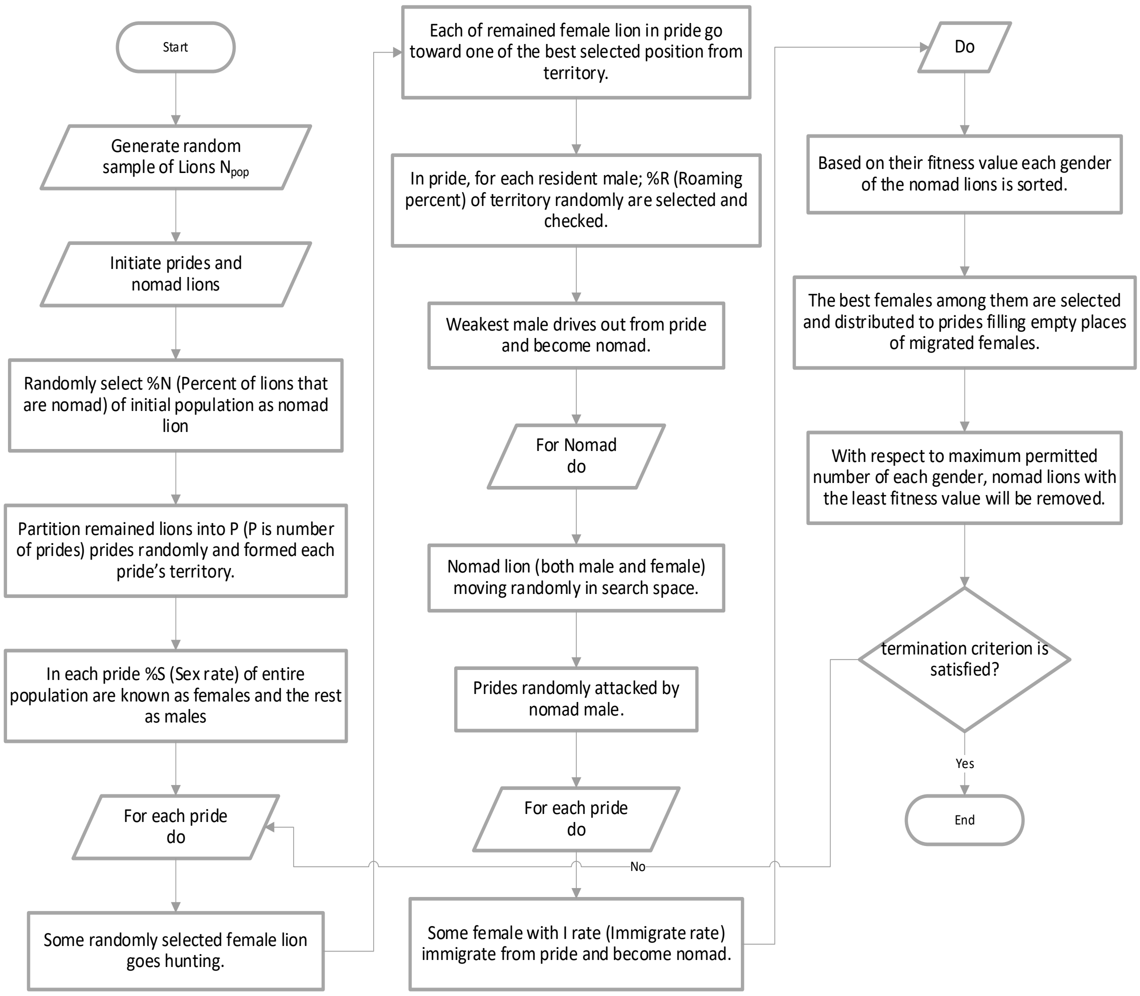

Fig 1. The flowchart of lion optimization algorithm.

In each pride, S% of the entire population is considered as female lions, and the rest as male lions. In nomad lions, this rate is vice versa, and S% of the population is considered as male lions, and the rest as female lions.

For each pride, some female lions are randomly selected and go hunting. The remaining females will move to find the best answer in the territory. Weaker male lions are expelled from the pride and become nomad lions. Also, for each pride, some females migrate and become nomads.

For the Nomad, the lions (both males and females) move randomly in the search space. Some of Nomad's females' mate with one or more resident males in pride. After each mate, two offspring will be generated. Yazdani and Jolai [11] introduced the LOA as follows where the flowchart of this algorithm is also shown in figure 1.

2.1. Initialize

The LOA algorithm starts with generating a random population of lions in the n-dimension search space as:

$$lion_i = [x_{i1}, x_{i2}, x_{i3}, \dots, x_{iN_{var}}] \tag{1}$$

Where N_{var} is the search space dimension.

Initially, *N%* of the primary population is taken as residents, and the rest taken as nomads. The residents are divided into *p* group named pride, and *S%* of each pride, usually from 75 to 90 percent, is selected as the female lion, and the remaining is selected as male.

S'% of the nomad lions' population is selected as the female lions and the rest as male lions. *S'* is determined from 0 to 25. The territory of each *P* is determined based on the position of its lion.

Also, the cost function can be evaluated using equation (2):

$$\text{fitness value of } \mathrm{lion_i} = \mathrm{f(lion_i)} = \mathrm{f(x_{i1}, x_{i2}, x_{i3}, \dots, x_{iN_{var}})} \tag{2}$$

Where N_{var} is the dimension of search space.

In this tournament strategy, each lion has a success rate if the lion's best position has been improved, and could be calculated using equation (7). The success of lion i in pride P at iteration t is :

$$\mathrm{S(i,t,P)} = \begin{cases} 1 & \mathrm{BEST_{i,P}^{t} < BEST_{i,P}^{t-1}} \\ 0 & \mathrm{BEST_{i,P}^{t} = BEST_{i,P}^{t-1}} \end{cases} \tag{7}$$

where the $BEST_{i,P}^{t}$ is the best founded position by lion i until iteration t. To calculate the number of lions in pride j which improved their fitness in the last iteration, $K_j(s)$, equation (8) is used:

$$\mathrm{K_j(s)} = \textstyle\sum_{i=1}^{n} \mathrm{S(i,t,P)} \quad \mathrm{j = 1,2,\dots,P} \tag{8}$$

where $S(i,t,P)$ is the success rate of lion i in pride P at iteration t, and n is the number of lions in pride j. The tournament size is defined as follows:

$$\mathrm{T_j^{size}} = \max\left(2, \mathrm{ceil}\left(\frac{\mathrm{K_j(s)}}{2}\right)\right) \quad \mathrm{j = 1,2,\dots,P} \tag{9}$$

2.4. Roaming

Every male lion roams in the territory of pride. The male lion selects *R%* of the territory and moves in it. If it reaches the optimal point, the best solution will be updated. An angle is added to its direction to improve the male lion's exploration. The rotation operation simulates a local search. Also, nomad lions roam the rest of the search space. The rotation of these valves avoids getting stuck in the local optimum. Each lion moves towards the selected area of the territory by *X* units:

$$\mathrm{X \sim U(0, 2 \times d)} \tag{10}$$

where X is a random number with a uniform distribution, and d in the distance between male lion's position and the selected area of the territory.

Each of nomad lions' position through the roaming can be calculated as follow:

$$\mathrm{lion_{ij}}' = \begin{cases} \mathrm{lion_{ij}} & \text{if } \mathrm{rand_j < pr_i} \\ \mathrm{RAND_j} & \text{otherwise} \end{cases} \tag{11}$$

where $lion_{ij}$ is the current position of the nomad lion, $rand_j$ is a random uniform number within [0,1], j is the dimension, $RAND$ is a random vector in search space and pr_i is a probability that calculated for each lion as follow:

$$\mathrm{pr_i} = 0.1 + \min\left(0.5, \left(\frac{(\mathrm{Nomad_i - Best_{nomad}})}{\mathrm{Best_{nomad}}}\right)\right)$$

$$i = 1,2,\dots, \text{number of nomad lions} \tag{12}$$

2.5. Mating

In each pride, the *ma%* of female lions will mate with one or more resident male lions in the same pride. For nomad lions, the mating process is that each female will mate with only one other male. Mating is done with a linear combination of parents to create children. Two offspring will be created in each mating, one of which will be randomly selected as male and the other as female. Although lion cubs inherit their traits from their parents, there is still a mutation in each of their genes.

$$\mathrm{Offspring_j\ 1} = \beta \times \mathrm{Female\ Lion_j} + \sum \frac{\frac{(1-\beta)}{\mathrm{NR}}}{\sum_{i=1} \mathrm{si}} \times \mathrm{Male\ Lion_j^i} \times \mathrm{S_i} \tag{13}$$

$$\mathrm{Offspring_j\ 2} = (1-\beta) \times \mathrm{Female\ Lion_j} + \sum \frac{\frac{\beta}{\mathrm{NR}}}{\sum_{i=1} \mathrm{si}} \times \mathrm{Male\ Lion_j^i} \times \mathrm{S_i} \tag{14}$$

In the above equation, j is the dimension, S_i is 1 if male i is chosen for mating; Otherwise, S_i is set to 0. The β is the number of resident male lions in the pride. Also, NR is randomly generated. It is a normal distribution with a mean value of 0.5 and a standard deviation of 0.1.

2.6. Defense

After the male lion's maturity in each pride, these lions fight the other male lions, and the defeated lion is forced to leave the pride and become a nomad lion. Defense is divided into two types:

1. Defense against the new resident male lions.

2. Defense against male nomad lions.

Defense is done in this algorithm to keep the strong male lions. The algorithm converges faster with the defense process.

2.7. Migration

Each pride performs migration to exchange information and diversify of the population. In this way, some female lions in the pride are selected for migration. The number of selected female lions is equal to the number of lions over the scale of each pride. These lions change from resident to nomad. The best nomad female lions are selected and distributed in the pride and changed from nomad to resident to fill in the blanks of the female lions migrating from the pride.

2.8. Lion population balance

Each iteration of the algorithm removes some nomad lions with the least compliance.

2.9. Convergence

The algorithm stops with the condition of time or number of specific iterations or unrepeatable iterations, etcetera.

2. The variants of LOA

As various optimization algorithms have always had problems and have changed following some aspects, LOA has also had problems for using in some areas. For example, to use an optimization algorithm to solve a multi-objective problem it is necessary to develop the algorithm for this purpose. In this section, we briefly review the variants of LOA. Four variants of LOA are developed. A summary of these methods and all variants of LOA are prepared in table 1.

3.1. The Least Lion Optimization Algorithm (LLOA)

Menaga & Revathi [15] used a modified lion optimization algorithm called the Least lion optimization algorithm (LLOA) to improve security and privacy-preserving association rule hiding.

The main idea in LLOA is that the database provided to third-party users, needs to hide sensitive information and does not reveal confidential information, also does not much different from the original database. This idea needs a randomly encrypt key creation technique to create a secure database. This strategy consists of two phases:

1- Hiding rules to protect privacy: extracting the dependencies rules with the Whale Optimization Algorithm by a modified function.

2- Creating a secure key by integrating the least mean square method (LMS method) into the update equation of LOA and convert the database into a sanitized database. Finally, it retains sensitive information using two privacy factors and a helpful factor in its target performance.

The LLOA adopts the LMS weight update into the LOA update equation. The secret key selects optimally using a multi-objective fitness function. This fitness function formulation in LLOA considers two issues: First, to make the database hide all confidential owner information. Second, to maintain utility.

Finally, the LMS weight update equation is adopted for the female lions roaming. The female lions that are not selected for hunting will elect for roaming, and the position of these female lions requires the calculation of the adopting LMS weight update equation. This method improves the search process.

Table 1. Summary of LOA variants.

Method name	Author(s)	Main context
LLOA	[15]	Improves the security and privacy in databases
OLOA	[16]	Improves the performance of VMs scheduling
MLOA	[13]	Reduce local search and find the best routing solution between cluster-based source and destination dynamically in the BASNs network
PSO+LOA	[17]	Produce a better balance between exploration and exploitation during the optimization process for scheduling scientific workflows in the cloud

3.2. Oppositional Lion Optimization Algorithm (OLOA)

Pradeep and Jacob [16] used a hybrid approach named OLOA for task scheduling in cloud computing. The OLOA Scheduler has combined LOA and the Opposition Based Learning (OBL) algorithm.

The algorithm initially considers two solution sets, an encoding solution set, and an opposition-based learning solution set. Then find the best solution through both solution sets using LOA.

This approach improves the performance of VMs scheduling and selects within a range of 100 to 500 tasks, and 100 VMs and 200 VMs as the training set. The OLOA minimizes Cost and Makespan for task scheduling.

3.3. Multi-objective Lion Mating Optimization Algorithm (MLOA)

Faheem et al. [13] present a multi-objective method based on lion mating optimization, inspired routing protocol, for body area sensor networks (BASNs) in Internet of things (IoT) healthcare applications.

In the proposed method, the modified Multi-Objective Lion Mating Optimization Algorithm (MLOA) helps reducing local search and finding the best routing solution between the cluster-based source and destination in the BASNs network.

LOA just can't be used for the Multi-Objective Problems (MOPs) in BASNs. It requires some fundamental changes on different protocol stack levels to make it suitable for BASNs networks. Therefore, some alterations such as Pareto search, PREY hunting location information, a dynamic mating model, hunting speed and direction, search boundary limitation, and the survival of the best have been added to avoid the local search.

The proposed MLOA provides the best solution among a set of objectives in BASNs. The provided fitness function and the previous history in this algorithm help to avoid getting stuck in the local search space.

In MLOA, maintaining population diversity is an important task. Because if diversity is lost, it becomes difficult to track a new optimal position in the environment. Crossover and mutation from GA are used to achieve a new optimal position and lead to a good convergence in the network. The survival selection also determines the quality of the selected solution in the optimization process. This selection is the most popular Pareto-based selection method which might create all the objectives for different BASNs problems by creating an accurate Pareto front.

A decomposition method is used to provide a precise Pareto front. This method first divides the problems into a set of sub-problems. Then, the exact Pareto fronts are generated from the sub-problems and will be used to get the frontier of the original problem.

In this method, each solution is a lion. Each lion is a biosensor node in the BASNs network. Each lion's territory is specified by these nodes. Each male lion is a cluster leader, and each node related to the female lions in that group is linked to this leader. These nodes in the group are isolated and at least linked to one biosensor node of the network. The PREY is a network biosensor node with the required information for neighboring nodes. These PREYs are used for transmitting packets over the network. Also, when female lions are hunting, it means the middle nodes in a region are more likely to cooperate in the packet forwarding process. An attack by a lion means that one node tries to communicate with the biosensor of the other nodes. During the packet forwarding process, a cluster leader with high residual energy and a short distance to the next hop towards the sink, will be selected as the relay node in the network.

3.4. PSO+LOA for scheduling scientific workflows in the cloud

Li et al. [17] have combined the PSO and LOA. The main idea is to produce a better balance between exploration and exploitation during the optimization process. The developed algorithm uses the Euclidean distance between two particles to escape the local optimum in a way that separates them from each other. Also, some adaptive parameters are introduced to reach an efficient convergence. This method proves a better average relative deviation index than GA algorithm. It is also satisfactory when there is a budget constraint.

The method contains three steps as follow:

1- To estimate the proximity between particles and the displacement of each two similar particles, a Euclidean distance (ED) aware particle reposition method is adapted for exploring more potential solutions.

2- To help individuals evolve their step size to improve search functionality and convergence performance, adaptive parameters are embedded into all velocity updating processes.

3- To increase search space, the PSO and LOA are integrated through the population diversity of the LOA multi-swarm collaboration. Also, to improve search mechanisms, the adaptive evolution of PSO is used.

An innovative fitness function is introduced and adopted by considering two goals. This fitness function is a solution from objective optimality and constraint satisfiability aspects. This function uses the makespan, the solution cost, and the minimal and maximal makespan of a workflow to estimate the fitness of each solution.

A new concept is introduced to estimate the closeness between particles. This concept is Euclidean distance (ED) between particles, which is used for preventing PSO from falling into the local optimum. This concept prevents redundant searching in some space that has already been searched or will be searched by another particle. Also, to increase global search capability and the early convergence barricade, some Adaptive parameters are introduced for the PSO velocity update.

In PSO+LOA, the positions and velocities for nomad lions are updated using PSO. The mate of lions will happen as defined in LOA. Residents are divided into two hunters and resident males' subgroups and will be updated as defined in the LOA. The remaining females use the PSO updating formulation. This combination of PSO and LOA inherited the PSO's fast convergence ability and has better capabilities to balance exploration and exploitation.

4. The LOA applications

So far, the LOA algorithm has been used in various fields and applications. This algorithm, like all inspired algorithms, has shown a good performance. The following is a brief review of some of these applications. Table 2 contains a summary of the LOA applications, and Table 3 reviews its applications in combination with the other methods.

4.1. Cloud computing

Service companies such as apple, amazon, google, Microsoft uses cloud computing to provide services to their users. Cloud computing supports variable workloads and dynamic access to computing resources. Performance efficiency of task scheduling is an important issue and scientific research in the cloud computing field. Finding an optimal solution is considered an NP-complete problem. Scheduling algorithms are based on strategies. The most critical challenges are time, cost, energy, and fault tolerance. There are metaheuristic algorithms like min-min, min-max, Heterogeneous Earliest Finish Time (HEFT), GA, PSO,and ACO on which scheduling algorithms are based on. Among the algorithms, ACO, PSO, and GA generally generate the optimal schedules.

Almezeini et al. [18] used the LOA algorithm for task scheduling in cloud computing. In this study, the scheduling algorithm for LOA considers a list of cloudlets and VMs as input.

The output of this algorithm is the best solution for task allocation on VMs. The metaheuristic algorithms LOA, GA, and PSO are compared based on makespan, cost, average resource utilization, and degree of imbalance. The results showed the cost of LOA is between PSO and GA, although the difference is not so much.

Kumar et al. [19] also studied efficient load balancing in cloud computing using the LOA algorithm. This study aims to optimize virtual machine migration and balance the load between all VMs by determining the percentage of the virtual resource load.

This approach proved the response time is vastly improved over the previous algorithm. Therefore, the algorithm can ensure effective load balancing and improve the performance.

Table 2. Summary of LOA Applications.

Author(s)	Main area	Specific area of application
[18]	Cloud computing	Task scheduling
[19]	Cloud computing	Efficient load balancing
[20]	Cloud computing	Task scheduling
[21]	Cloud computing	Security
[22]	Cloud computing	Dynamic resource provisioning and optimizing Quality of Service
[23]	Cloud computing	Intrusion detection
[24]	Image processing	Efficient fuse computer tomography and magnetic resonance image
[25]	Image processing	Image degradation and denoising
[26]	Image processing	Detection of hand-drawn arrow diagrams and digital logic circuit diagrams in a stroke-based mode
[27]	Image processing	Segmentation for diagnosis of Alzheimer's disease
[28]	Classification	Data imputation
[29]	Classification	Reducing misclassification in mammogram images
[30]	Classification	big data classification
[31]	Classification	signal classification of Electroencephalogram
[32]	Classification	Feature Selection
[33]	Classification	select and adjust SVM parameters optimally for image classification
[34]	Clustering	community detection
[35]	Clustering	community detection
[36]	Clustering	Enhancing K-Prototype clustering
[37]	Clustering	Finding data similarity
[38]	Privacy and security	DDoS attack detection
[39]	Networks	Node placement and lifetime optimization in an LWSN

[40]	Networks	Classification for detecting the available spectrum in the CR environment
[41]	Networks	Improving route efficiency in ad-hoc networks
[42]	Networks	Optimizing the architecture of multilayer perceptron
[43]	Networks	Efficient emergency message broadcasting
[44]	Networks	Optimal energy-efficient routing in wireless networks
[45]	Networks	Optimizing the QoS in Patient Monitoring Wireless Body Area Network systems
[46]	Optimizing and Industry	Obtaining the desired surface roughness in plastic
[47]	Optimizing and Industry	Optimal design of double-layer space barrel vaults
[48]	Optimizing and Industry	Determining the active power rescheduling value for efficient transmission congestion in power systems
[14]	Optimizing and Industry	VLSI floorplanning problem
[49]	Optimizing and Industry	Test suite minimization for regression testing
[50]	Optimizing and Industry	Monitoring pipelines and base station placement in LWSN
[51]	Optimizing and Industry	Generating the protein through DNA synthesis optimally

Table 3. Summary of LOA hybridized with other methods

Methods hybridized	Author(s)	Main context
LMS + LOA	[15]	Improves the security and privacy in databases
OBL + LOA	[16]	Improves the performance of VMs scheduling
PSO + LOA	[17]	Produce a better balance between exploration and exploitation during the optimization process for scheduling scientific workflows in the cloud
DROPS + LOA	[21]	Provides security for distributed computing for efficient cloud computing with high security
KFCM + T2FNN + LOA	[23]	Select the parameters of T2FNN optimally for intrusion detection in cloud
DTCWT + LOA	[24]	Provide an efficient fuse of computer tomography and magnetic resonance image
SVM + LOA	[26]	Enhancing online detection of hand-drawn arrow diagrams and digital logic circuit diagrams in a stroke-based mode
HKFC + LOA	[28]	Improves data imputation for classification
SVM + LOA	[29]	Reducing misclassification in mammogram image classification
K-means + LOA	[30]	Efficient big data classification
SVM + LOA	[31]	signal classification of Electroencephalogram for epileptic seizure detection
DE + GSO + LOA	[32]	Correlation-Based Ensemble Feature Selection
SVM + LOA	[33]	select and adjust SVM parameters optimally for image classification
k- Prototype + LOA	[36]	Enhancing K-Prototype clustering
k-means + GA + LOA	[37]	Finding data similarity
CNN + LOA	[38]	DDoS attack detection
LM + LOA	[40]	Classification for detecting the available spectrum in the CR environment

Almezeini and Hafez [20] proposed an enhanced task scheduling algorithm for a cloud computing environment called Lion Cloud Optimizer (LCO) based on the LOA algorithm. The enhancement is applied by benchmarking the performance of the task scheduling algorithm using actual workload traces to evaluate a high level of realism performance and effectiveness.

Workload traces are documents that describe all scheduling information of batch jobs, including requested resources, utilized resources, submission time, start time, etcetera. Every single row in a workload trace describes a job (cloudlet). This approach considers real workload traces as tasks (cloudlets) to show a high level of realism when used directly in evaluation experiments. The method considers list of cloudlet (Tasks) and list of Virtual Machines (VMs) as Lions for input. And output must be the best solution for task allocation on VMs. A comparative study has been applied among LCO, GA-based, and PSO-based task scheduling algorithms. The results proved LCO is better especially in large-scale problems. In general, as mentioned, this method is suitable for environments with a larger number of tasks. According to the statistics provided, this approach is performed better than PSO and GA for more than 600 task workloads. Otherwise, there is not much difference between LOA and GA.

Periyanatchi and Chitra [21] used LOA for efficient cloud computing with high security. In this approach, LOA is used for division and replication of data in the cloud for optimal performance and security (DROPS). This algorithm fragments data and replicates the fragmented data over the cloud node using LOA. This means if an attack occurs on a node, the attacker will not receive any valuable data.

This algorithm aims to determine the distributed computational plan; also to reduce and limit the span of the arrangement via LOA.

Finally, the proposed algorithm provides security for distributed computing using LOA. In this way, it stores a package in nearby hubs. So, the delay time of each node is reduced.

Chaitra et al. [22] have proposed an approach for dynamic resource provisioning and optimizing Quality of Service (QoS) in a multi-cloud environment. This approach uses LOA for optimizing a multi-objective problem which simultaneously minimizes the cost and maximizes the revenue. As the number of tasks increased, the algorithm showed better results than the PSO technique in cost, completion time, average response time, average resource utilization, and makespan.

One of the most challenging problems in cloud computing is intrusion detection. Srilatha and Shyam [23] proposed an Intrusion Detection System (IDS) to address the problem. It used kernel fuzzy c-means clustering (KFCM) and an optimal type-2 fuzzy neural network (T2FNN). Also, LOA is used to select the parameters of T2FNN optimally. The proposed method outperformed for precision, recall, and F-measure and allows only regular data to be stored in the cloud.

4.2. Image processing

Image processing is one of the most absorbing fields in computers. Ravichandran and Selvakumar [24] discussed the problem of fuse computer tomography (CT) and magnetic resonance image (MRI). They offer a framework that uses the Dual-Tree Complex Wavelet Transform (DTCWT) to transform the low and high-frequency signals to solve the mentioned problems.

This approach modifies the lion optimization technique in the DTCWT domain for the medical image fusion process. The fusion weight of an image will be selected by LOA optimally.

This framework includes five steps: decomposition process, segmentation process, fusion of low-frequency sub-images, fusion of high-frequency sub-images, and inverse DTCWT in image processing. In the third step LOA is employed to get optimal weights and frequencies.

This framework has increased the resolution of images in MRI and CT scans, and is able to diagnose the brain tumor of a 25-year-old patient. However, with other approaches such as Non-subsampled contourlet transform (NSCT), NSCT-PCNN, DTCWT-PSO, Curvelet, DTCWT, Schrieffer Wolff transformation (SWT), and discrete wavelet transform (DWT), the brain tumor of a 25-year-old patient could not be detected. However, the proposed method cannot fuse for multi-modal images.

Jayapal and Ravi Subban [25] have studied image degradation and noise problems. This study uses LOA to optimize the performance of adaptive filters. The main idea is to eliminate human interventions and automate the system denoising which uses the adaptive filters.

With the advancement of technology and the increasing use of digital images, one of the issues that have been considered by researchers today is the problem of image degradation and denoising. This method tries to blend some spatial filters and use them in digital images to reduce mixed noise. The LOA algorithm helps to optimize the performance of the mentioned filters. It is noteworthy that the proposed method can be used for different image types and is not provided only for specific applications such as medical or aerial images.

LOA is used here to decide on the best filter. The fitness function is considered with the value of Peak Signal to Noise Ratio (PSNR), and the fitness value is calculated and compared in each repetition.

The approach has been compared with Curvelet-based, NSCT+Bandelet, and Superpixel clustering and has obtained better result.

In another work, Altun and Nooruldeen [26] present an approach for the online detection of hand-drawn arrow diagrams and digital logic circuit diagrams in a stroke-based mode. For this purpose, the method performs text separation, symbol segmentation, feature extraction, classification, and structural analysis for the sketches.

In the proposed method, based on extracted features, most related designs are classified into similar groups using two methods, the p-distance method and Euclidean distance. Also, it uses a modified support vector machine (MSVM) classifier for symbol recognition.

In the original SVM model, the training time takes very long, and the kernel function may be selected inefficiently. The MSVM model is purposed to solve this problem. In the model, the SVM parameters will be optimized by the LOA algorithm. Besides, another goal of the MSVM model is to optimize the max-sum problem in structural analysis.

Chitradevi et al. [27] proposed a diagnosis method for Alzheimer's disease. This method has adopted LOA in the Segmentation of the hippocampus (HC) task. The hippocampus is a complex brain structure embedded in the medial temporal lobes. It is responsible for erasing old memories and preserving new ones. The proposed method has recommended the BAT algorithm, GA, PSO, and artificial bee colony for HC task. Because of escaping from local optima, LOA has better performance than other suggested algorithms.

4.3. Classification

Data mining techniques are often used to discover new patterns and relationships in data. Missing data in databases can cause many problems in data mining. Data imputation is the process of estimating data from data analysis. The main concern in learning on incomplete data is that it can lead to bias, a negative impact on the classification performance.

Rajani [28] proposed an approach for solving the problem. This approach uses a combined Hybrid Kernel Fuzzy Clustering (HKFC) and Feed Lion Neural Network (FLNN) model.

The LOA is included to improve the performance of data calculation and classification. In this model, once the missing values are determined, then the appropriate weights are select by LOA. Also, LOA is used in FLNN to choose the suitable data weights.

This approach is compared with three other existing techniques, the combination of Fuzzy Clustering (FC) and FLNN, the FC and K- Nearest Neighbor (KNN) combination, and the form of K-means and KNN. The result shows that the proposed approach has a better mean-square error (MSE) and accuracy.

KanimozhiSuguna and Ranganathan [29] used LOA for the early detection of breast cancer. LOA is used to reduce misclassification in mammogram images. The proposed approach includes some typical image preprocessing and a classification process. A combination of LOA and SVM is used for the classifier.

Gill [30] introduced a novel algorithm for big data classification based on LOA called Classification Assisted Lion Optimization Algorithm (CALOA). This approach uses the K-means clustering algorithm for the pride and nomad generation with Schwarz criteria. In this method, a group of instances (lions) that make a cluster through the clustering process, considered as a pride. Each instance that doesn't belong to any cluster is considered a nomad lion.

Ali et al. [31] proposed an approach on the signal classification of Electroencephalogram (EEG) using LOA algorithm. This study presented a hybrid Model named SVM-LOA for epileptic seizure detection with SVM and LOA to determine the optimum parameters of SVMs for the classification of EEG signals. This method uses the DWT for preprocessing and feature extraction phases.

In the method, the SVM classifier accuracy is optimized by automatically solving the SVM model selection by approximating the best values of the kernel parameters. These best values are obtained by an optimization framework based on LOA. The RBF kernel function has been utilized for the SVM classifier. Once the RBF kernel is nominated, the parameters needed to be optimized using LOA. LOA-SVM approach is utilized as a powerful tool for EEG signal classification. The overall experimental results showed LOA-SVM classifiers have higher accuracy than SVM.

Christo et al. [32] Presented a framework for clinical diagnosis in a study of the Correlation-Based Ensemble Feature Selection. This framework uses three bioinspired algorithms, including Differential Evolution (DE), Lion Optimization, and Glowworm Swarm Optimization (GSO). It also uses an ensemble method, the Correlation-based ensemble method, which selects three subsets of optimal features. The output of each optimization algorithm is a classifier.

Houssein et al. [33] present the LOA-SVM method for finding the liver in any medical images. This method uses classification algorithms, including combination of LOA algorithm and SVM. The method uses the LOA algorithm to select and adjust the optimal parameters for SVM. The results show proposed method has increased the performance of SVM classification.

4.4. Clustering

Clustering is one of the popular fields used in data mining statistics, object recognition, image segmentation, pattern recognition, bioinformatics, and many other problems. Clustering is the segmenting or data objects partitioning into called subgroups (clusters) [52].

Babers et al. [34] used the LOA algorithm for the community detection problem. Community detection is a clustering problem that refers to finding connections between different people on social networks. This study aims to identify the community as a topic of optimization and divide the network into node communities. The LOA is used as an effective optimization method to recognize the number of communities.

The algorithm was applied with two different quality functions to get the intuition of communities, community fitness, and modularity. The community visualization in social networks represents the nodes and their relationships. It also helps researchers to understand the data of these social networks. In communities, community boundaries are determined by measuring the edges between communities.

The results show that the algorithm successfully detects an optimum community structure based on a quality function. As the result, the LOA algorithm and modularity combination has improved performance.

Chand et al. [35] conducted a study on community detection. The community identification methods are proposed in two categories:

- Community detection for the unsigned social networks.

- Community detection for the signed social networks.

In the meantime, the Gray Wolf algorithm is mentioned as an efficient method for this problem. The number of connections found in this study are the same for the Gray Wolf and LOA.

Nithya and Arun Prabha [36] used LOA differently for the clustering field. In their study, k- Prototype clustering is combined with the LOA algorithm to increase productivity and overcome the problems encountered in K-Prototype Clustering. In the proposed approach, the centroids of clusters will be selected by the LOA algorithm optimally. k-means and k-prototype methods were compared with five different data sets. The results showed better performance for the proposed lion optimizing-based K-Prototype Clustering algorithm.

Also, Wahid et al. [37] combined the k-means clustering algorithm with the LOA algorithm and GA, named the LOA-KM-GA algorithm. In this method, the k-means algorithm is used to find the data similarity degree and initial clustering. The LOA algorithm is used to improve this work where plays a significant role in optimizing the algorithm. Finally, the GA algorithm uses to mutate and improve the repetition of the algorithm.

4.5. Privacy and security

Software-Defined Network (SDN) is the most exhaustive world-used network management software. But experience has shown that the software is too weak against Distributed Denial of Service (DDoS) attacks. Arivudainambi et al. [38] present the LOA-IDS method to identify DDoS attacks. This method uses Convolutional Neural Networks (CNN) with the LOA algorithm to detect and deal with these attacks early. This technique is strong enough in any number of attacks.

4.6. Networks

The Linear Wireless Sensor Network (LWSN) is being used extensively for monitoring long natural gas, water, and oil pipelines. LWSNs can also be used for the efficient and safe management of air conditioners, Piped Natural Gas, and water pipelines in large buildings. Varshney et al. [39] proposed a scheme for optimal placement of sensors and base stations (BS) in a linear fashion to monitor the various pipelines used in large buildings. This approach is used the LOA for node placement and lifetime optimization in a LWSN.

The main challenge in Cognitive Radio (CR) design is the lack of bandwidth available for communication. Therefore, assigning a channel for communication is a challenging task for any user entering the CR environment. CR system design for the wireless environment tries to solve the spectrum shortage problem through optimization and better spectrum usage. CR connects different wireless devices, and communication between these devices is done by reconfiguring electromagnetic parameters.

To solve the mentioned problem, Yelalwar et al. [40] presents an approach for detecting the available spectrum in the CR environment called cooperative spectrum sensing (CSS). Then, the channel availability is identified by providing test statistics as input for both a fuzzy classifier and a modified Levenberg Marquedet lion-based neural network (LML-NN).

The main task of this system is to provide an optimal fusion score to find the available channel using the LML-NN classifier. The LML-NN classifier is the combination of LOA and Levenberg–Marquardt (LM) which helps finding the minimum of a nonlinear function as a fuzzy classifier.

In this field, two challenges of Ad-hoc networks are 1) energy consumption and 2) mobility of network nodes. The more the distance between the nodes of the network increases, the more the transmission power increases. Moreover, the most energy is consumed when transporting data packets.

Alani et al. [41] proposed a new technique for improving route efficiency in ad-hoc networks using the LOA algorithm that considers all possible network routes. In this study, the mating, PREY hunting, territorial marking, mutation, and defense strategies of the LOA algorithm are used to solve the mentioned problems. This technique not only provides lion survival but also provides a better initial solution.

In another study, Bansal et al. [42] proved the LOA algorithm can be used to optimize the architecture of multilayer perceptron (MLP). The design of neural networks (ANNs) has always been complex due to the functionality and architecture of the network. The main focus of this study is on optimizing the architecture of ANNs. The LOA is used to create a suitable MLP architecture for a classification problem. The proposed algorithm focuses on optimizing the number of hidden layers, the number of neurons in each hidden layer, concealed layer transfer function, learning speed, and impulse.

In another field, with mobile communication, data can be exchanged anywhere and anytime. Portable Networks divide into VANET (VEHICLE AD HOC NETWORK) and Manet (MOBILE AD HOC NETWORK). Among them, VANET has made significant progress. One of VANET's security programs is the local danger warning (LDW), which sends identified risks to the driver in the form of warning messages to reveal the driver's status. When there are sufficient proofs, the vehicle will receive an alert from the driver help framework. The problem with LDW arises when two vehicles next to each other are trying to broadcast a message. This problem may cause frequent contention and broadcast storms.

Selvi et al. [43] proposed an adaptive scheduled partitioning and broadcasting technique (ASPBT) for a reliable and efficient emergency message. It uses network density to determine the size of partitions; and the transfer scheduling for each partition is estimated using the LOA.

The proposed ASBPT uses LOA to work well with different network densities and simulation scenarios, reducing unnecessary redistribution and completion delay. This method was compared with other playback techniques such as Distributed Optimized Time (DOT), preferred group broadcasting mechanism (PGB), Timer-based Backbone Network (TBN), and others. The comparison results show better performance for the proposed algorithm in packet delivery ratio, information coverage, average transmission delay, and reliability.

Wireless Networks (WN) are widely working in all real-life areas. Optimal energy-efficient solution is one of the most important challenges in WN. One solution is to adopt SDN to allow the control logic separated from the sensor nodes/actuators in these networks. Ragavan and Ramasamy [44] proposed a hierarchical cluster-based routing technique using LOA. This scheme clusters the sensor nodes using the LOA algorithm and establishes routes to convey data. The results prove this technique has better control and scalability over the network, and LOA helps achieve better cluster-based routing. Although the energy consumption is minimal, it can be said that the throughput is reasonable.

Kathuria and Gambhir [45] also use Lion Cooperative Hunt Optimization (LCHO) technique which is inspired by the Lion-inspired optimizing algorithm to optimize the QoS in a Patient Monitoring Wireless Body Area Network (PA-WBAN) systems.

4.7. Optimizing and Industry

Today, hard rollers or balls are used to shape plastic in many workshops and industries. Tamilarasan et al. [46] used the LOA algorithm to optimize the combustion parameters to obtain the desired surface roughness in plastic. Combustion parameters include burning speed, burning depth, and burnishing feed.

In this study, to obtain the quality surface roughness in plastic, the objective functions have been determined, including burning force, the number of passes, and feed rate. Then, a mathematical model is developed to minimize surface roughness and is given to the LOA algorithm as a fitness function. Experimental results prove the LOA algorithm converges in the 200th iteration, and the best answer is obtained in the 40th iteration.

Kaveh and Mahjoubi [47] proposed an approach for the optimal design of double-layer space barrel vaults using the Lion Pride Optimization Algorithm (LPOA) [53] and LOA mating method. The LPOA was inspired by LA (Rajakumar [10]).

Gope et al. [48] focused on transmission congestion as a problem in deregulated power systems. They present a transmission congestion management approach using the LOA. Voltage limitation leads to congestion in the power system. The generator rescheduling techniques will use to manage this congestion by scheduling it Optimally. In this approach, the LOA is used for determining the active power rescheduling value, the congestion value, and minimizing cost. LOA is used for rescheduling generators, and the result shows that generator setting and congestion cost achieved by applying the LOA algorithm is better than PSO and LOA algorithms.

Shunmugathammal et al. [14] proposed a method for solving the VLSI floorplan to minimize the measures such as area, wirelength, and dead space (unused space) between modules using LOA. The floorplanning problem has been proved to be an NP-hard problem. Simulation results achieve significant savings in wire length. It also produces better results for the highest benchmark circuits in dead space minimization compared to previous floorplanners.

Asthana et al. [49] proposed a method to optimize the regression testing by selecting the test cases list and performing regression testing for a given application successfully. The proposed method reduces cost by test suite minimization using the LOA. These test cases have been executed earlier and detected all the faults in minimum time. This technique considers current attributes and does not have any critical dependency on other parameters like code coverage analysis, feature risks, and requirements.

Varshney et al. [50] have modified LOA for the problem of monitoring pipelines called Lightning Attachment Procedure

Optimization (LAPO). It defines the position of sensor nodes using the lightning procedure of the cloud for routing jump and redirect routing scheme. Also, it depicts lightning and is inspired by the nature of clouds. The LAPO solves the node/base station (BS) placement and network lifetime optimization of a LWSN. In LAPO, the lions represent the sensor nodes, also called falconers, and the quarry represents the BS. The fitness function has been modified based on placing the node at the maximum distance, minimum delay, and drop ratio. Finally, LAPO is compared with the ACO, GA, and LOA and shows better results.

Al-Janabi and Alkaim [51] proposed a solution to generate protein optimally through DNA synthesis. In this solution, the initial population of lions has been considered as DNA sequences and sorted by distance. In this algorithm, four features are added to the LOA. The kernel of the LOA algorithm has been replaced by spirally searching and Bubble net searching. The development of these features in the mentioned model has resulted in reduced execution time, increased accuracy, and robustness to work with any length of DNA sequence.

5. Conclusion

In this paper, the Lion Optimization algorithm and its variants and applications were reviewed. Several applications of the LOA in fields such as classification, clustering, image processing, cloud computing, task scheduling, and Industry are reviewed. This algorithm showed better performance than PSO in like cloud computing applications. One of the LOA applications on Alzheimer's disease diagnosis returns an accuracy of 94%. Also, in a framework for clinical diagnosis in a study of the Correlation-Based Ensemble Feature Selection achieved an accuracy of 98.734%. Different variants of this algorithm have been developed for image processing, security & privacy, task scheduling in cloud computing.

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