VARIANTS OF THE CUCKOO SEARCH AND ITS APPLICATIONS

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Abstract – The bio-inspired meta-heuristic algorithm Cuckoo Search (CS) was created in 2009 by XinShe Yang and Suash Deb. The algorithm makes use of the key characteristics of Cuckoo brood parasites such as their co-evolution with host birds. One of the most efficient approaches for resolving issues with global optimization is the Cuckoo Search algorithm. In many applications, this algorithm has been used. A lot of articles have been published about Cuckoo Search in recent years. The Cuckoo Search Algorithm, which may replace a number of previous processes, is described in this work. Cuckoo Search uses the Levi flying method based on Egg Laying Radius to find a solution that is relevant to the problem. Therefore, efficiency, accuracy and convergence speed have been improved through the CS optimization algorithm. First, this paper describes the key features of Cuckoo Search and a number of variations in that algorithm as well as its development status with regard to many applications.

Keywords – Bio-inspired, Cuckoo search, Levi flights, Optimization, Swarm-based algorithm

1.   INTRODUCTION

Metaheuristic algorithms are now commonly employed to solve optimization problems in engineering, data mining, big data analysis, cloud computing, machine learning, and image processing [1]. In spite of their success, there is a number of areas that remain under-explored and under-applied, and so additional research opportunities exist in many domains. It is impossible to address all of the metaheuristic algorithms. Rather, we concentrate on the uses and possibilities of cuckoo search (CS) and its derivatives. As a result, the paper is structured as follows. The conventional cuckoo search and its variants are outlined in Section II. Section III shows some of the most recent applications.

2.   CUCKOO SEARCH ALGORITHM BASICS

2.1   Cuckoo Breeding Behavior

According to an entomologist's long-term studies, the cuckoo has chosen a unique breeding approach known as parasitic brood [2]. It lays eggs in other birds' nests, allowing other birds to

hatch. To lessen the risk of being discovered by host birds, the cuckoo will select host birds who have similar eating patterns and are easier to duplicate in size and color. When it flies to a nest, it only lays one egg and removes the host's egg before spawning, forcing the host to lay eggs again. When the cuckoo's hatchlings hatch, they have a propensity of taking the host bird's babies from the nest, allowing the cuckoo to benefit from the host bird's care. When the host birds, on the other hand, discover foreign eggs are seen in their nests they also throw parasitic eggs or abandon their nests and construct new ones elsewhere.

2.2 Levy Flights

Many studies have found that the flying behavior of many animals and insects reflects the basic characteristics of Levy flights [3,4,5]. Fruit flies or Drosophila melanogaster investigate their environment utilizing a sequence of straight flight pathways punctuated by a rapid 90-degree turn, resulting in a Levy-flight-style intermittent scale-free search pattern, according to research by Reynolds and Frye. The fundamental feature of Levy flights may also be noticed in human behavior studies, such as the Ju/'hoansi hunter-gatherer feeding habits. Levy flights can even be linked to light [6]. Levy flight is the optimal search strategy for M independent search seekers where the goal location is random and sparsely dispersed. The walking step satisfies a stable distribution of heavy-tailed in Levy flight, which is one sort of random walk. Short-distance exploration and the rare long-distance trek alternate in this style of walking. In an intelligent optimization system, Levy flight can broaden the search window, boost population variety, and make it easier to leave the local optimum. Following that, analogous behavior has been applied to optimization and optimum search, with promising preliminary results [7].

3. Cuckoo Search Algorithm Developed in 2009 by XinShe Yang and Suash Deb, Cuckoo Search (CS) is a bio-inspired meta-heuristic algorithm. It takes advantage of the important characteristics of some cuckoo brood parasites and their co-evolution with the host bird species [8]. In a true cuckoo-host species system, eggs laid by cuckoos are sufficiently similar to host species eggs in terms of texture, size, and color. The cuckoo host species form an arms race system that allows the cuckoo eggs to be found and released with a probability pa ∈ [0, 1][2]. In the usual cuckoo search, one main implication is that a cuckoo lays only one egg which represents an answer vector and every nest can have one egg. In this case, there's no difference between an egg, a nest, or a cuckoo. To simplify the explanation of the standard Cuckoo search, we use three ideal rules:

         Each cuckoo lays an egg and throws it into a randomly selected nest.
         The best nests with high quality eggs will be passed down to the next generation.
         The number of available host nests is fixed, and eggs laid by cuckoos are found by host birds with a probability of Pa [0, 1]. In this case, the host bird can either remove the eggs or leave the nest to create a whole new nest.

For straightforwardness, we apply x = (x1, x2,...,xD) to address a D- dimensional vector for an improvement issue with an Objective Function f(x) dependent upon different limitations. The basic condition of CS for simulating the similarity between spawning behavior and solution (egg) can be written as:

$$x_i^{t+1} = x_i^t + \beta s \otimes H(p_a - \varepsilon) \otimes (x_j^t - x_k^t) \quad (1)$$

Where in Equation 1 xtj and xtk are two different solutions chosen arbitrarily by arbitrary permutation. Here, the probability pa of cuckoo egg detection by the host bird is realized by the heavy side function (H (u) = 1 if u> 0, H (u) = 0 if u <0). Also, ε is a random number that is uniformly distributed at [0,1], and s is an increment. Where α is the magnification. On the other hand, the global random walk is carried out using Levy flights.

$$x_i^{t+1} = x_i^t + \alpha \otimes L(s, \lambda), \quad\quad\quad (2)$$

Where,

$$L(s, \lambda) \sim \frac{\lambda \Gamma(\lambda) \sin \pi\lambda/2}{\pi} \left(\frac{1}{s^{1+\lambda}}\right), (s \gg 0) \quad (3)$$

where '~' indicates that the random numbers L (s, λ) should be selected from the Levy distribution, which is approximated by a fat-tailed distribution like a power-law distribution with an exponent λ. The step size scaling factor is established by the scales or bound ranges of the parameter α > 0. a conflict of interest from the standpoint of implementation, $\otimes$ is an entry-wise operator.

3.   CUCKOO SEARCH VARIANTS

The CSA proposed in 2009 is a recent swarm-based algorithm in comparison with the firefly, bee colony, PSO, and ant colony algorithms proposed in 2008, 2005, 1995, and 1992, respectively. However, the CSA has been updated for several variants developed by researchers to cope with the nature of the search space of the optimization problem.
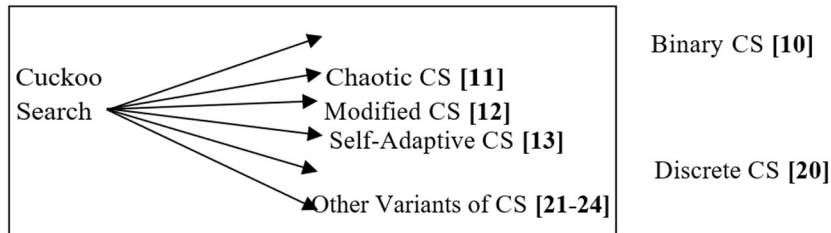

Figure1. Cuckoo search variants

4.   APPLICATIONS OF CUCKOO SEARCH

The Cuckoo Search Algorithm has a wide range of applications, and research on it is ongoing. It would be impossible to review even a fraction of the thousands of research articles published in the last few years. As a result, we've concentrated on a few common examples, particularly recent studies, to show the breadth of these applications. Obviously, there are several application fields; nonetheless, we must select a few:

4.1   Design Optimization

Hanh-Phong Dao, Shyh-Chour Huang, and Pham Toan Thang [15] optimized a compliant focus placement platform using a hybrid Taguchi-cuckoo search algorithm. To begin, an experimental matrix was created using Taguchi's L16 orthogonal Array, and then the S/N ratios of each response were determined. Second, the ANOVA was used to examine the influence of each design parameter on each quality response. The results demonstrated that the HTCS algorithm produces

superior outcomes than DE, GA, PSO, AEDE, and PSOGSA. The suggested HTCS strategy is a valuable tool for similar design Optimization challenges.

A.H. Gandomi, X.S. Yang, and A.H. Alavi [16] The Cuckoo search method is a metaheuristic approach to structure optimization. This hybrid cuckoo search optimization (hCSO) algorithm provides a suitable and efficient configuration of metaheuristics to conduct optimization of difficult multi constraint or multi variable engineering problems. The hybrid CSO method discovers the optimal solution space for the complicated wellbore trajectory TMD optimization scenario investigated faster than six other algorithms utilizing a similar population size and the same number of iterations, VBA coding, and execution on the same machine.

David A. Wood [17] Dynamic, chaos-enhanced, fat-tailed distribution sampling and metaheuristic profiling were used to help in the application of Hybrid cuckoo search optimization algorithms to complicated wellbore trajectories. Significant changes introduced in hCSO are by replacing the space sampling using the Levy flight solution with a stochastic arbitrary number. As the algorithm iterates the simpler fat tail distribution sampling using a dynamic sampling window that moves through the distribution. Randomly sampled samples will be further adjusted with scaled- chaotic sequences give you more flexibility in controlling the sampling granularity in solution space. More metaheuristics features have been added to improve the default CSO Algorithm to balance between local search and global search. Metaheuristics include three chaotic adjustments to a dynamic stochastic sampling of search metrics distributions (fat-tailed and other, stepped ranges, highly non-linear). The Hybrid CSO algorithm is able to find the optimal solution space for a complex Wellbore trajectory TMD optimization case examined more quickly than six (Hybrid Genome Algorithm, Hybrid Particle Swarm, Hybrid Ant Colony, Hybrid Bee Colony, Hybrid Harmony Search, Hybrid Bat Flight) on the same computer. Evolutionary algorithms can be used with comparable population sizes, iterations, VBA code, and execution.

4.2   Economic Load dispatch and Power System

Abd Elazim, S.M., Ali, E.S. [18] find the Optimal power system stabilizers design using cuckoo search algorithm. CS algorithm is planned for optimum designing of PSSs parameters. The PSSs parameters standardization problem is developed as an optimization problem and CS algorithm is employed to hunt for optimum parameters. An eigenvalue based objective function reflecting the mix of damping issue and damping ratio is optimized for numerous operational conditions. Simulation results ensure the hardiness and power of the planned controller in providing smart damping characteristics to system oscillations over a large vary of loading conditions. Moreover, the planned CSPSS demonstrates its effectiveness over others via completely different performance indices.

Chaine, S., Tripathy, M., Jain, D., [19] an ultra-modern multi-objective optimization strategy is created to optimize the number of regulator parameters. The issue deals with optimization of regulators of double fed induction creator designed for frequency regulation in an inter- associated two area indispensable energy equals thermal installation. The volley of the integral regulator of the automatic generation operation circle and therefore the corresponding and by- product regulators of the twice fed induction creator inertial operation circle are optimized in a really

coordinated way by employing a multi-objective nondominated sorting unnaturally grounded ditz hunt algorithmic rule. The algorithmic rule is made by synthesizing the resemblant looking capacities of ditz hunt algorithm (CSA) with thenon-dominated sorting fashion espoused in nondominated sorting heritable computation (NSGA- II). The work justifies the truth that the more intelligent advancement strategy of CSA, once combined with correct determination of non-dominated financial expert optimal set of solutions, the performance of indistinguishable improves compared to NSGA-II.

Nadjemi, O., Nacer, T., Hamidat, A., Salhi, H., [20]. A novel technique for the optimum size of grid connected hybrid PV/wind energy system based on associate improved discrete cuckoo search algorithm is proposed. A system including PV panels, turbine and battery storage bank is optimized employing a multi-objective minimizing function. two case studies area unit conducted to analyse the approach performance: the primary one could be a residential household and also the second could be a cattle farm. The simulation results confirm that the Cuckoo Search algorithm converges to the optimal solution quicker than PSO and it is additional accurate in identifying the optimal system size. the whole system value is greatly affected by the PV panels initial value and the renewable electricity sellback price making the promotion of grid connected renewable energy systems possible by subsidizing the PV panel's value and applying additional attractive feed-in-tariff.

4.3   Data Mining

Mohammed, Rasha & Duaimi, Mehdi. [25] Association rule mining (ARM) is a basic and widely used method. Data mining techniques for obtaining useful information about data. traditional ARM algorithms are less computationally efficient due to too much mining Association rules that are not suitable for a particular user. Recent research (ARM) examines the use of metaheuristic algorithms to search for only a subset of high-quality rules, the algorithm for mining correlation rules based on the CS algorithm is called. DCSARM is used to extract high quality association rules. The results show that DCS-ARM is Best than BSO-ARM in terms of the number of valid rules and their quality. Moreover, DCS-ARM is much less time consummation than BSO-ARM. Indeed, while the number of transactions and the number of items becomes so large, the CPU time will increase seriously.

Shailaja, G.K. and Rao, C.V. Guru. [26] A unique PPDM method, which contains levels like statistics sanitization and data restoration, which had been commenced after the association regulations generation. Accordingly, in each the sanitization and restoration processes, the important thing is extraction has a major function that is turned into selected optimally by OI-CSA. Here, four studies objectives, namely, HF rate, IP, FR, and DM had been to reduce the usage of the adopted sanitization and restoration processes. The results show that the proposed method for the chess dataset on considering the in-general cost function was 0.76%, 0.49%, 0.28%, and 0.23% better than the PSO, GA, DE, and CSA algorithms and for the retail dataset, the proposed OI-CSA model was 1.89%, 3.02%, 2.64%, and 2.64% better than PSO, GA, DE, and CSA algorithms.

Mlakar, Uroš & Fister jr, Iztok & Marković, Monika & Fister, Iztok. [27]. association rules are mined by applying an objective function composed of support and confidence weighted by two

parameters to control each measure's importance. The rules are mined in a Nationwide Inpatient Sample dataset, which is a collection of discharge records of several hospitals in the USA. Only those records, where a patient was diagnosed with Type II diabetes mellitus were extracted for association rule mining. The results illustrate that the establish rules are simple, easy to understand and also interesting, as they were varied with real clinical studies.

Almayyan, Waheeda. [28]. In this work a two-stage heuristic feature selection strategy to classify sports articles utilizing Tabu search and Cuckoo search by means of Lévy flight. Lévy flight is utilized to avoid the solution from being trapped at nearby optima. The results confirmed that employing Tabu and Cuckoo search strategies significantly reduced feature numbers. The suggested model improved overall accuracy performance and produced encouraging outcomes. Furthermore, using the SMOTE approach to change the original data helped to expand the minority class region, which in turn assisted with coping with unbalanced data.

4.4   Deep learning

Cristin, R., Kumar, B.S., Priya, C. et al. [29]. The Algorithm is designed by integrating the features of CSA with ROA and used for training the DBN. After training the DBN using Rider-CSA classification to detect disease in plants. The Plant Village database is used to achieve this strategy, which is based on factors like specificity, accuracy, and sensitivity. The proposed Algorithm shows good results as compared to existing approaches with a maximum sensitivity of 0.862, along with maximum accuracy of 0.877 and a specificity of 0.877.

 Nilesh Rathod, Sunil Wankhade [30]. The proposed approach is based on Cuckoo Search with invasive weed optimization and extreme learning machine for training feed forward network, The proposed model CSIWO-ELM will optimize input weights and hidden neurons. The analysis is done using 3 datasets which are Cleveland, Hungarian, and Switzerland. This proposed algorithm is compared with, ELM-Sparse CM, KELM-AE, PSO-ELM, GA-ELM. The result shows that CSIWO is better than other algorithms by recording different parameters and reducing the training time also.

J. Li, D. Xiao, H. Lei, T. Zhang, and T. Tian [31] In this Paper CS with Q-Learning and genetic operators-based algorithm is proposed, and then DMQL-CS algorithm is used to solve the address of logistics distribution center and then adopts Q-Learning scheme to learn the individual optimal step size strategy according to the effect of individual multi-steps From the results it can be concluded that the proposed DMQL-CS algorithm clearly outperforms the standard CS algorithm and Comparing with some other improved CS variants and DE variants, it seems that the DMQL-CS algorithm outperforms the other algorithms on a majority of benchmarks. The effectiveness of the proposed technique was further verified by comparing it with CS, ICS, CCS, and IGA for both 6 and 10 distribution centers.

4.5   Image Processing

Image processing involves transforming an image into a digital format and executing various operations on it in order to extract relevant information from the image and improve its view. Due to its significant applications in numerous areas of business, research in the field of image

processing continually expanded. Both engineering and computer science consider image processing to be a fundamental area of research.

S. Tiwari [32] introduced CSA on an array of feature vectors that were obtained from a picture using a 2-D discrete cosine transform. He used Euclidean distance to identify the images from the database that most closely matched each other. When used in the image recognition area, CSA outperformed the PSO and ACO optimization techniques.

In order to get the best multilayer thresholding, Bhandari et al. [33] used CSA with wind-driven optimization (WDO). Through the use of initial random threshold values, this combination algorithm selects the best fitness value of the best solution. A solution's quality is determined using the correlation function. According to test results, CSA paired with WDO employing Kapur's entropy criterion can be effectively used in multilevel thresholding, which enhances the extraction of significant portions of a satellite image.

Salim Chikhi et al [34] used a CS method to improve the contrast of fingerprint photos in grayscale. The best fingerprint picture quality is achieved with this method, which is based on gray level mapping, by meta-heuristically obtaining the ideal new set of gray levels using the CS process with a modified objective function. A set of low-quality grayscale fingerprint photographs from the FVC2000 database were used to evaluate the suggested method. In comparison to state-of-the-art enhancers, the results quantitatively and qualitatively show the effectiveness of the suggested strategy.

4.6   Cloud Computing

Cloud computing, often known as Internet-based computing, is a technique in which the resource is made available to the user as a service through the Internet. There are a number of software and hardware options for the issue of energy efficiency in cloud operation by reducing the environmental effect of cloud computing. Virtualization concepts are used in cloud computing to make better use of hardware and software [35].

Silambarasan Kumar [36] focused primarily on the Cuckoo Search (CS) method, which speeds up virtual machines and reduces execution time. To increase system effectiveness, use the Cuckoo Search (CS) algorithm. The proposed method uses the MATLAB framework to calculate a fitness value; this methodology results in higher system performance.

Agarwal, M., Srivastava, G.M.S. [37] To reduce the task's execution duration in a distributed context, utilize Cuckoo Search-Based work Scheduling in a cloud computing environment to map the task to the virtual machines (VMs). The comparative findings show that in terms of make span, the suggested Cuckoo Search method performs noticeably better than the other algorithms.

Salami et al. developed a c CS [38] motivated technique for resolving the VMPP. New cost and perturbation functions are designed to increase the algorithm's performance. The recommended method was examined using two recognized benchmark datasets. This novel CS technique was particularly better than first-fit decreasing (FFD), best-fit decreasing (BFD), reordered grouping genetic algorithm (RGGA), and multi-CSA, another CS technique.

Table 1. Different applications of Cuckoo Search algorithms

Application	Method Name	Description of Modifications	Reference
Design Optimization	HTCS	incorporates the Taguchi method for experimental design and optimization.	[15]
	hCSO	tailored for solving complex engineering problems with multiple constraints and variables	[16]
	hCSO	designed for optimizing complex wellbore trajectory Total Measured Depth (TMD) problems	[17]
Economic Load dispatch and Power System	CSPSS	optimize the parameters of Power System Stabilizers (PSSs) by formulating the problem as an optimization task	[18]
	hCSO	a hybrid algorithm that combines elements of the Cuckoo Search Algorithm (CSA) with non-dominated sorting	[19]
	IDCS	a novel technique for optimizing the size of grid-connected hybrid PV/wind energy systems using an improved discrete Cuckoo Search Algorithm	[20]
Data Mining	DCSARM	focuses on improving the efficiency and effectiveness of Association Rule Mining (ARM) by introducing the DCS-ARM algorithm, which uses the CS algorithm to extract high-quality rules while minimizing computational time	[25]
	OI-CSA	Privacy-Preserving Data Mining (PPDM) approach that utilizes optimization techniques	[26]
		Employs association rule mining techniques using an objective function that combines support and	[27]

		confidence measures with parameter control	
		a two-stage heuristic feature collecting strategy for identifying sports goods that links the Tabu search and Cuckoo search algorithms, as well as Lévy flight	28
Deep learning	ICS	combines Cuckoo Search Algorithm (CSA) and Random Optimization Algorithm (ROA) characteristics for training a Deep Belief Network (DBN) utilized in plant disease diagnosis.	[29]
	CSIWO-ELM	enhancing the Cuckoo Search algorithm by incorporating two additional optimization techniques: Invasive Weed Optimization (IWO) and the Extreme Learning Machine (ELM)	[30]
	DMQL-CS	enhancing the Cuckoo Search (CS) algorithm by combining it with Q-Learning and genetic operators	[31]
Image Processing	Modification in CSA	This modification involves using CSA for image recognition purposes based on feature vectors obtained from images using a 2-D Discrete Cosine Transform (DCT)	[32]
	CSA-WDO	combining CSA and WDO to optimize multilevel image thresholding, particularly for satellite image analysis	[33]
	Modification in CSA	application of the Cuckoo Search algorithm to optimize gray level mapping for enhancing the contrast of grayscale fingerprint images	[34]
Cloud Computing	Modification in CSA	modification introduced in this study focuses on using	[35]

		the Cuckoo Search algorithm to optimize virtual machine performance.	
	Modification in CSA	modification of the Cuckoo Search algorithm is introduced and applied in the context of task scheduling in cloud computing	[36]
	Modification in CSA	modification in this study involves designing a CS-inspired technique with new cost and perturbation functions for solving the Virtual Machine Placement Problem	[38]

5. CONCLUSION

Many research publications were researched and analysed in order to come up with a solid inference for scholars concerned in working on Cuckoo Search Algorithm in this survey paper. The survey thoroughly summarised the references issued between 2009 and the first half of 2022. According to the studies acquired for this research, CSA applications in a range of disciplines, including Design Optimization, Economic Load dispatch and Power System, Data Mining, and Deep learning, gained the largest share. Cloud computing, computational intelligence, big data, transportation systems, telecommunications, energy-efficient buildings, and other areas of research are all potential possibilities.

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