A survey on Cuckoo Search Algorithm for Optimization Problems

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Abstract

Cuckoo search algorithm is one the efficient algorithms in solving global optimization problems. This paper provides an overview of cuckoo search algorithm as well as its latest applications and developments in the last decade. Regarding cuckoo search algorithm many papers have been published in the last few years and the relevant literature has also been expanded significantly. This Paper summarizes briefly the majority of the literature of last decade from 2009 to 2019 about cuckoo search, published in peer-reviewed journals and conferences. The references can be used as a basis for further research in cuckoo search as it is systematically classified into appropriate categories.

1 Introduction

Computational intelligence and optimization are the active area which are growing quite rapidly and expanding their literature. For most applications, resources, money and time are always limited and therefore, it is one of the most important requirement to design optimal solutions to maximize their utilization. However, it is really hard
to find optimal solutions of many optimization problems in the real world. There are some problems which are NP-Hard problem such as travelling salesman problem.

In general, these NP-hard problems have no efficient algorithms. In most of the cases, the only alternative for Np-Hard problems is to apply heuristic or metaheuristics methods. The solutions of heuristic methods are based on trial and error, while metaheuristic methods are based on higher level heuristic methods that utilize selection and information of the solutions to help in the search process. Though the optimality is not always found or reachable, still optimization are the techniques and tools to solve such problems having the aim to find the optimal solutions in the real-world systems.

In the last few decades, nature-inspired metaheuristic algorithms have achieved huge popularity in optimization, data mining, computational intelligence, machine learning artificial intelligence and other engineering applications. The formulation of optimization problems can be framed in many ways such as, the least-squares is a specific case of maximum-likelihood formulations in the commonly used methods. A nonlinear optimization problem is formulated as

\[
\text{minimize} \quad f_m(x), (m = 1, 2, \ldots, M)
\]

subject to the constraints

\[
h_j(x) = 0, \quad j = 1, 2, \ldots, J
\]
\[
g_k(x) \leq 0, \quad k = 1, 2, \ldots, K
\]

where \( f_m, h_i \) and \( q_k \) are the functions, which is nonlinear and the design variable or design vector \( x = (x_1, x_2, \ldots, x_d) \) ca be discrete, continues or mixed in d-dimensional space. The functions \( f_m \) are called cost functions or objective functions and if \( M \neq 1 \), then optimization problem is called multicriteria or multiobjective problem.

There are so many optimization problems are available and corresponding so many optimization algorithms also available in the literature but there is not a single algorithm is suitable for all optimization problems. Even so, researchers still forms the major efforts in the search for efficient algorithm. Metaheuristic algorithms have attracted the attention of researcher now a days, in the area optimization. Metaheuristic algorithms are often nature-inspired and have many benefits over conventional algorithms.

Cuckoo Search is an evolutionary and Metaheuristic optimization algorithm which is developed by Xin-She Yang and Suash Deb in 2009 [1]. The theory of this optimization search algorithm is inspired by the bird species, called cuckoo. Cuckoo are the birds which make the beautiful sound and has a aggressive reproduction system,
by reproduction strategy mature cuckoos lay their eggs in the nests of other species or host, which is known as obligate blood parasitism [6]. In addition, cuckoo search algorithm is enhanced by the so-called Levy flights.

Biological inspiration

- Eggs in nests: Set of solutions of optimization problem
- Cuckoo egg: New solution of optimization problem.
- Less fit solutions will be replaced by better and new solutions.
- After leaving nest, Cuckoos change position with Levy flights.

2 Cuckoo Search Methodology

Cuckoo Search algorithm has attracted the attention of researchers due to its promising efficiency in real-world applications and solving many optimization problems. For describing the standard Cuckoo Search, the following three idealized rules [5] are used:

- At a time, one egg is laid by each cuckoo, and it is dumped in a randomly chosen nest;
- The best nests with high-quality eggs will be carried over to the next generations;
- The number of available host nests are fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $p_a \leq (0, 1)$. In this case, the host bird can either get rid of the egg, or simply abandon the nest and build a completely new nest.

Based on the above three standards, the basic steps of the Cuckoo Search can be summarized as the pseudo code shown in fig 2 [11] and following fig 1 shows a flowchart of the Cuckoo search Algorithm.
Figure 1: Flowchart of Cuckoo Search Algorithm

begin
  Objective function \( f(\mathbf{x}) \), \( \mathbf{x} = (x_1, ..., x_d)^T \)
  Generate initial population of \( n \) host nests \( \mathbf{x}_i \) (\( i = 1, 2, ..., n \))
  while (\( t < \text{MaxGeneration} \)) or (stop criterion)
    Get a cuckoo randomly by Lévy flights
    Evaluate its quality/fitness \( F_i \)
    Choose a nest among \( n \) (say, \( j \)) randomly
    if \( F_i > F_j \),
      replace \( j \) by the new solution;
  end
  A fraction (\( p_a \)) of worse nests are abandoned and new ones are built;
  Keep the best solutions
  (or nests with quality solutions);
  Rank the solutions and find the current best
end while
Postprocess results and visualization
end

Figure 2: Pseudo code of the Cuckoo Search
3 Literature Survey

Since the first appearance of cuckoo search algorithm in 2009, there are so many variants of the cuckoo search algorithm have been proposed and developed by many researchers in different domains. The major variants are shown in fig. 3 and different applications and proposed work in different domains of last decade from 2009 to 2019 are explained as following and summarized in table 1, table 2, table 3 and table 4.

![Diagram of Cuckoo Search Variants](image)

**Figure 3: Variant of cuckoo search**

In production and real life, There are the problems which require optimization for multiple conflicting points simultaneously, are called Multi-objective optimization problem. Xingjuan Cai et al. [7] proposed a optimization method for kind of problems based on Multi-objective cuckoo search algorithm.

Echo state network is neural network which solves the complexities in Recurrent neural networks. Abubakar Bala et al. [8] proposed an echo state network, in which cuckoo optimize search algorithm was used for right parameter and topology. It was observed that cuckoo search algorithm performed better than classical echo state network, particle swarm optimization and binary particle. The propose method was tested for degradation prediction on turbofan engine using.

For faster and better services in cloud computing effective and optimize methods are require for task scheduling. Prem Jacob et al. [9] proposed an optimized algorithm to solve the issues of scheduling task in cloud computing based on a hybrid
approach by the combining Particle swarm optimization and Cuckoo search algorithm. The proposed method reduced the cost factors as user cost and performance cost.

Liang Chen et al. [10] proposed an Dimension by dimension enhanced cuckoo search algorithm. To provide the optimal solution, the proposed algorithm takes the advantage of all the dimensions by observing the dimensions which are bringing and updating the information.

Tejeswara Rao et al. [11] used cuckoo optimization search algorithm and fuzzy logic to reduce the power losses by placing Static VAR Compensator at optimal and efficient location.

In Grid Computing Transaction Scheduling is known as the NP hard Problem. Dharmendra Prasad Mahato [13] proposed a optimal hybrid approach to solve this problem using the combination of cuckoo optimization search and ant colony optimization algorithms. In the proposed approach the clusters of resources were generated based on their loads to generate an optimal transactions schedule and cuckoo search Algorithm was used to generate the clusters.

Chunguang Zhang [14] proposed a cuckoo optimization search algorithm based on adaptive Cauchy mutation. In order to provide optimal quality of service in Internet of Things, the improved cuckoo search algorithm was used for hierarchical resource scheduling.

Tran-Ngoca [15] proposed an approach which was based on flexible combination of Cuckoo Search and Artificial Neural Network for detection of damage in bridges and beam like Structure. In proposed method, Cuckoo search was used for improving Artificial Neural Network training parameters such as bias and weight.

Cuckoo Search algorithm can be used along with Machine Learning Algorithm for better prediction. Sweta Kumari [17] proposed a model for improving the prediction accuracy of the required effort in Software development which was based on Artificial Neural Network and Cuckoo Search Algorithm.

The Social media such as Twitter, Facebook and Google plus etc. have changed the way of online communication. These Social media has become important platform of sharing and representing the sentiment of people, due to this there is need of effective and optimal sentiment analyses using data mining. Avinash Chandra Pandey [19] proposed a method of sentimental analysis on the data set of the social media called Twitter using a meta heuristic hybrid approach using cuckoo search and K-means Algorithms.

Effective an accurate Electric load forecasting is one of the most important part of power system. Xiaobo Zhanga [20] developed a satisfied and reliable method for load forecasting of electric by integrating singular spectrum analysis, support vector
machine and Cuckoo search algorithms.

Sarangthem Sanajaoba [21] proposed an approach using Cuckoo Search Algorithm for optimal sizing of schemes such as Wind Battery, Photovoltaic Battery and Photovoltaic Wind Battery system of renewable energy system which are applicable in remote areas also.

Voltage stability enhancement and Reduction power loss is one of the essential requirement in Distribution networks. Thuan Thanh Nguyen [22] proposed a method to optimize this problem based on Cuckoo Search algorithm for optimally reconfiguration of network and allocation of distributed generation in distributed networks.

In the field of medical, machine learning algorithms are widely used for detection and prediction of diagnosis. However to make machine model more accurate and more accurate P. Mohapatra et al. [23] proposed a approach based on extreme learning machine and improved cuckoo search algorithms.

Due to environment problems and energy crisis. So now a days, it is very essential to find alternative of traditional energy resources. Solar energy is one the alternative, which has widely attracted the attention of researcher now a days. Jianzhou Wang et al. [24] proposed a hybrid model fro solar radiation forecasting based on Cuckoo Search algorithm and Extreme Learning Machine.

Image segmentation is quite popular now a days, it is used to select the meaningful objects. A segmentation extract the proper value of threshold to optimize the criterion using entropy. Ashish K Bhandari et. al. [25] proposed an approach for multilevel thresholding of satellite image segmentation based on wind driven optimization and cuckoo search algorithm.

Aziz Ouaraarab et. al. [26] in 2014 proposed a discrete and extended version of basic cuckoo optimization search algorithm to solve Travelling salesman problem.

Yildiz et. al. [27] presented cuckoo search and implemented it successfully in milling operation for selection of machining parameter optimally.

Optimization of system reliability plays an very essential role in different real world application. Ehsan Valian et. al. [28] in 2013 proposed an improved and extended approach of cuckoo search for the optimization of reliability problems to solve engineering problems.

To provide the efficient and optimal fuel efficiency and to reduce cost of vehicle design, Ismail Durgun et. al. [29] in 2012 proposed a optimization model based on Cuckoo Search Algorithm, which is able to find better structural design of Vehicle Components.

Amira Gherboudj et. al. [30] in 2012 propose a discrete version of cuckoo search for dealing with binary optimisation problems.

Under complex nonlinear constraints in engineering many design problems are
typically multiobjective. In order to solve multi objective problem of design optimization, Xin-She Yang et. al. [3] proposed a multiobjective cuckoo search in 2011.

S. Walton et. al. [4] presented a modified cuckoo search algorithm in 2011 and it observed that modified cuckoo search algorithm outperformed basic cuckoo search algorithm.

In 2010, Kutzelnigg et. al. [2] presented the detailed analysis of Cuckoo Hashing and indicated some drawbacks and benefits also.

For solving optimization problems a metaheuristic algorithm, called Cuckoo Search was Proposed and formulated by Xin-She Yang and Suash Deb [1] in 2009. This algorithm is based on the obligate brood parasitic behaviour of some cuckoo species in combination with the Levy flight behaviour of some birds and fruit flies.
| S.No. | Authors                  | Year | Domain                  | Application                   | Proposed Work                                                                                                                                       |
|-------|--------------------------|------|-------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Xingjuan Cai et. al.    | 2019 | Machine Learning        | Software defect prediction   | An optimized method for Software defect prediction is proposed, in which a hybrid multi-objective cuckoo search is used for optimized parameter selection of Support Vector Machine model. |
| 2     | Abubakar Bala et. al.   | 2019 | Artificial intelligence | Predict failures in turbofan engines | The cuckoo optimization search algorithm is used to choose right parameters and topology for the echo state network.                                      |
| 3     | Prem Jacob et. al.      | 2019 | Cloud Computing         | Optimal Task Scheduling      | A hybrid approach was proposed by combining the Particle swarm optimization and Cuckoo search algorithm to improve and optimize the scheduling performance and to reduced the cost factors as user cost and performance cost in cloud computing scheduling tasks. |
| 4     | Liang Chen et. al.      | 2019 | Meta-heuristic Search   | Dimension by dimension enhancement | Proposed a cuckoo search algorithm to solve multi dimension optimization problem and enhance its performance.                                                  |
| 5     | Tejeswara Rao et. al.   | 2019 | Fuzzy Logic             | Power loss minimization      | Proposed an method for transmission losses reduction using multi-objective cuckoo optimization search algorithm.                                       |
| 6     | Zhihua Cui et. al.      | 2019 | Meta-heuristic search   | Many objective optimization search | Proposed a hybrid many objective search based on cuckoo search algorithm.                                                                          |

Table 1: Cuckoo search in the last decade
| S.No. | Authors | Year | Domain | Application | Proposed Work |
|-------|---------|------|--------|-------------|---------------|
| 7     | Dharmendra Prasad Mahato et. al. [13] | 2019 | Grid Computing | Transactions Scheduling | Proposed an optimize hybrid approach with the combination of ant colony optimization and cuckoo search. |
| 8     | Chunguang Zhang et. al. [14] | 2019 | Internet of Things | Resource Scheduling | Cuckoo optimization search algorithm was proposed based on adaptive Cauchy mutation and this improved cuckoo search is used in Internet of Thing for hierarchical resource scheduling. |
| 9     | H. Tran-Ngoca et. al. [15] | 2019 | Artificial Intelligence | damage detection | A flexible combination of Cuckoo Search and Artificial Neural Network was proposed to improve Artificial Neural Network Parameters such as bias and weight. |
| 10    | Maoqing Zhang et. al. [16] | 2018 | Local search | Multi objective optimization | Hybrid multi-objective Search is proposed using cuckoo search algorithm to enhance the local search ability. |
| 11    | Sweta Kumari et. al. [17] | 2018 | Machine Learning | Software development effort prediction | Proposed an approach for better estimation of Software development effort and its prediction based on Cuckoo search algorithm and Artificial Neural Network. |
| 12    | Xiaohua Zhu et. al. [18] | 2018 | fluid catalytic | Improve the population diversity | Proposed an approach to design new RNA crossover operator to improve the population diversity based on cuckoo search algorithm. |

Table 2: Cuckoo search in the last decade (continue..)
| S.No. | Authors | Year | Domain       | Application          | Proposed Work                                                                                                                                 |
|-------|---------|------|--------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| 13    | Avinash Chandra Pandey et. al. [19] | 2017 | Social Media | Sentiment analysis   | Proposed an approach for the analysis of Twitter sentiment using flexible combination of cuckoo search and K-means algorithm.             |
| 14    | Xiaobo Zhang et. al. [20]          | 2017 | Machine Learning | Electric load forecasting | Proposed a novel model for electric load forecasting using a hybrid approach with singular spectrum analysis, support vector machine and Cuckoo search algorithms. |
| 15    | Sarangthem Sanajaoba et. al. [21]  | 2016 | Renewable energy | Optimal sizing       | Applied Cuckoo Search Algorithm for optimal sizing.                                                                                           |
| 16    | Thuan Thanh Nguyen et. al. [22]    | 2016 | Distribution network | Optimal network reconfiguration | Proposed a methodology to optimize topology of network and distributed generation placement in distribution network using cuckoo search algorithm. |
| 17    | P. Mohapatra et. al. [23]          | 2015 | Machine Learning | Medical data classification | Proposed an algorithm for classification of medical data based on improved cuckoo search and machine learning algorithm.                 |
| 18    | Jianzhou Wang et. al. [24]         | 2015 | Energy        | Solar radiation forecasting | Proposed hybrid model based on Cuckoo search algorithm for solar radiation forecasting.                                                      |
| 19    | Ashish K Bhandari et. al. [25]     | 2014 | Image segmentation | Multilevel thresholding | Proposed an approach for multilevel thresholding of satellite image segmentation based on wind driven optimization and cuckoo search algorithm. |

Table 3: Cuckoo search in the last decade (continue..)
| S.No. | Authors                  | Year | Domain                  | Application                         | Proposed Work                                                                 |
|-------|--------------------------|------|-------------------------|-------------------------------------|--------------------------------------------------------------------------------|
| 20    | Aziz Ouaarab et. al. [26]| 2014 | Combinatorial optimisation | Traveling salesman problem          | Proposed a discrete and improved version of cuckoo optimization search algorithm to solve Travelling salesman problem. |
| 21    | Ali R. Yildiz et. al. [27]| 2013 | Milling operations      | Optimal machining parameters        | Proposed a model for selection of machining parameter optimally using cuckoo search algorithm. |
| 22    | Ehsan Valian et. al. [28]| 2013 | Meta-heuristic          | Reliability problem                 | Proposed an extended cuckoo search for the optimization of reliability problems. |
| 23    | Ismail Durgun et. al. [29]| 2012 | Vehicle Components      | Structural Design                   | Proposed a method to solve the optimization problems of structural design based on cuckoo optimization search algorithm. |
| 24    | Amira Gherboudj et. al. [30]| 2012 | Meta-heuristics         | Knapsack problems                  | Proposed a discrete binary cuckoo search to solve 0-1 knapsack problems. |
| 25    | Xin-She Yang et. al. [3]  | 2011 | Multi-objective problems| Design optimisation                 | In order to solve multi objective problem of design optimization, Proposed a multi-objective cuckoo search. |
| 26    | S. Walton et. al. [4]    | 2011 | Meta-heuristic          | Optimisation algorithm              | Proposed a modified cuckoo search algorithm and it had been shown that modified cuckoo search algorithm performed better than basic cuckoo search algorithm. |
| 26    | Kutzelnigg et. al. [2]   | 2010 | Meta-heuristic          | Cuckoo Hashing                     | Presented the analysis of Cuckoo Hashing with Random Graphs and a Stash. |
| 26    | S. Xin-She Yang and Suash Deb [1] | 2009 | Meta-heuristic          | Cuckoo Search                      | Proposed and formulated metaheuristic algorithm, called Cuckoo Search for solving optimization problems |

Table 4: Cuckoo search in the last decade (continue..)
4 Conclusion

In this brief survey, a relatively comprehensive bibliography regarding cuckoo search algorithm has been summarised. References have been sorted systematically into proper categories. The speedily expanding literature implies that cuckoo search algorithm is a very recent, active and hot research field in the area of optimization such as Data fusion in wireless sensor networks, Engineering optimization problems, Neural network training, Manufacturing scheduling and NP-hard combinatorial optimization problems etc. Therefore, There is no doubt that more publication and studies on cuckoo search will appear in the near future.

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