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Cuckoo Search - An Evolutionary Optimisation Algorithm

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Abstract: ***Metaheuristics are procedures that help to find or generate optimal solutions for different types of problems. Metaheuristics can be nature inspired of which Cuckoo Search is one example. It is a relatively new algorithm developed in 2009. It is inspired by brood parasitism of some cuckoo species. They lay eggs in the nests of their birds of different species. Each cuckoo lays one egg at a time and dumps it in a randomly chosen nest. The best nest with high quality of eggs (solutions) will carry over to the next generations. This paper studies the applications of this algorithm in various fields like image compression, scheduling, flowshop scheduling, medical images, energy conservation and more. This is an attempt to provide a comprehensive view on the use of this algorithm in different areas of research.***

Keywords: Cuckoo Search, Levy Flight, Flowshop, Energy Consumption, Image Compression

1. Introduction

Cuckoo search (CS) was developed by Yang and Deb in 2009, and CS is quite efficient in solving problems related to global optimisation. In this paper, we have reviewed the fundamental ideas of cuckoo search and the latest developments along with its applications. We analyze the algorithm carefully and understand the search mechanism it follows and find out different reasons and factors governing its efficiency. Various researchers have shown a keen interest in scheduling strategies due to exponential increase in number of resources in different organizations. Scheduling allows optimal resource allocation among various tasks in a finite time resulting in quality service [1]. Scheduling and resource allocation are considered as NP hard problems. Population based metaheuristics are found to be effective for finding optimal or near optimal solutions. Optimization covers a wide range of disciplines and their applications. Since time and resources are always restricted, optimization is becoming important than ever before. For example, there is an increasing need for energy saving designs and green solutions to many industrial problems. In this article, we will focus on the introduction of cuckoo search, a nature inspired metaheuristic algorithm for optimization and computational intelligence.

1.1 Metaheuristics

A metaheuristic is a procedure that helps to find or generate an algorithm that may help to generate optimal solutions. Metaheuristics are of various types based on search strategy, single solution based, nature inspired etc.

Cuckoo Search Algorithm: It is inspired by brood parasitism of some cuckooo species. They lay eggs in the nests of ther birds of different species. Below are the three basic rules for this algorithm:

- One egg is laid at a given time and dumped in a randomly selected nest.
- Only the nest having the higher quality eggs are moved to the next generation.
- The number of host nests is fixed and probability of discovering the egg laid by the cuckoo by the host bird is p_a [2]. The host can possibly discard the egg or it can abandon the nest and build a fresh one.

1.2 Advantages of Cuckoo Search

1. Global Convergence
2. Global Optimality
3. Deals with multi-criteria optimisation problems.
4. Easy to implement
5. It can still be hybridised with other swarm based algorithms.
6. Simplicity

1.3 Multi-criteria

Multi-criteria or multi-objective optimization is a type decision making criteria. In this, two or more than two objective functions are optimized simultaneously. It comes in use when optimal decisions are required to be taken in presence of trade-offs between two or more contradictory functions. In mathematical terms, it can be written as:

$\min(g_1(x), g_2(x),\ldots\ldots g_a(x))$
s.t. $x \epsilon X$

where the integer $\mathbf{a \geq 2}$ and **a** is the number of objectives and **X** is the set of feasible decision vectors. This value of **a** indicates that minimum 2 objectives are required.

```
1.  begin
2.  Define objective function f(o)
3.  Formulate the initial population of h host nest
4.     Eggs should be ranked after assessing the  fitness
5.     while (z>MaxGeneration) or stopping criteria is met
6.  z= z+1
7.     Get a cuckoo arbitrarily or produce new solution by
       Levy flights
8.  Assess fitness, Fi
9.  Choose a nest j, randomly
10. if( Fi > Fj )
11. Replace j with the new solution
12. end if
13.       Abandon the worst net with probabilty Pa and a new
          nest is then built
14.       Assess fitness, rank the solutions and find the
          current best
15. end while
16: end
```

Figure 1: Pseudo Code for Cuckoo Search

1.4 Performance Metrics

Before going further, below are some performance metrics that are desired by different types of users and providers:

A. **Makespan:** Makespan refers to the total length of the schedule i.e. the finishing time of the last task. İt is the most popular optimisation criterion and indicates the productivity of a system. Lesser the value of makespan, more efficient is the scheduler [3].

$$\text{Makespan} = \text{Max}_{k \epsilon tasks}\,(T_k),$$

where T_k is the finishing time of task k.

B. **Flowtime:** The sum of finalisation times of all tasks is called flowtime.

$$\text{Flowtime} = \sum_{k \epsilon tasks}\,(T_k),$$

where T_k is the finishing time of task k.

C. **Convergence Speed:** The speed at which an iterative sequence converges to a point where it reaches an optimal or near optimal solution is called the speed of convergence.

D. **Throughput:** The number of jobs that complete their execution per unit time is termed as throughput. İn other words, it is the amount of work done by a system in given time.

E. **Energy Consumption:** It is the amount of power or energy used by a system. It is preferable that a system uses less energy because it is more economical.

F. **Budget Constraint:** It represents the total cost restriction for executing all jobs.

2. Related Work

A new evolutionary algorithm named CSA based on Cuckoo Search is proposed in [4]. It is based on Levy flight behavior and obilgate blood behavior of some cuckoo species. The results of experimental evaluation show that when P_a value is less, speed and coverage of the algorithm become very high. Babukartik and Dhavachelvan [5] proposed a hybrid by combining the merits of ACO and Cuckoo search. The simulation results show that task creation time and results retrieval also increase with the increase in number of tasks. FA undergoes a problem when brighter fireflies are unsubstantial and PSO suffers from instability in convergence when particle velocity is very high. So, Chiranjeevi [6] proposed Cuckoo search (CS) metaheuristic optimization algorithm that optimizes the LBG codebook by levy flight distribution function which instead of Gaussian distribution, follows the Mantegna's algorithm. Cuckoo search consumes 25% of convergence time for local and 75% of convergence time for global codebook, so it guarantees the global codebook with appropriate mutation probability and this behavior is the major merit of CS.

Ahmed and Salam [7] proposed a Maximum Power Point Tracking (MPPT) for PV system using Cuckoo Search (CS) method. The results showed that Cuckoo Search was capable of tracking MPP within 100–250 ms even under various types of environmental change. Furthermore, it can handle the partial shading condition very efficiently. Musrat and Chang [8] introduced Cuckoo Search for finding the optimal scaling factors (SFs) in digital image watermarking in order to improve robustness. This was the first application of the CS technique to the image watermarking problem. Coelho [9] describes that the mismanagement of chillers can lead to increase in electrical energy consumption in a multi-chiller system, hence significant energy savings can be achieved if optimizing of the chiller operations of heating, ventilation and cooling systems is done. He proposed a new CSA approach using differential operator (DCSA) to solve the optimal chiller loading design problem. Daniel and Anitha [10] modified the conventional nest building of Cuckoo Search Optimisation using using Adaptive Rebuilding of Worst Nests (ARWN). Experimental results were analyzed using various performance matrices, and OWBM shows improved results as compared with other reported literature. Dasgupta [11] presented a discrete version of inter-species cuckoo search algorithm. The performance of proposed DISCS algorithm was validated by two different sets of discrete problems. The first one was a multistage Hybrid Flow-shop Scheduling (HFS) problem with the objective of minimizing the sum of mean flow time and makespan. A real world case study was taken to test the algorithm performance and on comparison with Genetic Algorithm (GA), Ant Colony Optimization (ACO) and Discrete Firefly Algorithm (DFA). Puja and Lalit [12] present an automatic generation control (AGC) of three unequal area thermal systems with single reheat turbine and appropriate generation rate constraints (GRC) in each area. A two degree of freedom (2DOF) controller called 2DOF-integral plus double derivative (2DOF-IDD) was proposed for the first time in AGC as secondary controller. Sensitivity analysis revealed that the CS optimized 2DOF-IDD controller parameters obtained in presence of IPFC in all three areas at nominal condition of loading and size of step load perturbation (SLP) are robust and need not be reset with wide changes in system loading and SLP.

3. Comparative Analysis

Ref. No	Technique Used	Year	Objectives	Type of Jobs	Remarks
[4]	Cuckoo Search	2015	Fitness Function, Flowtime, Speed & Coverage of algorithm.	Workflow	Simple Cuckoo Search
[5]	Ant Colony Optimisation and Cuckoo Search	2012	Makespan	Workflow	Hybrid proposed by combining the merits of ACO and Cuckoo Search.
[6]	Cuckoo Search Optimisation, Firefly Algorithm, PSO	2016	Image Compression	Vector Quantisation	Cuckoo search consumes 25% of convergence time for local and 75% of convergence time
[7]	Cuckoo Search, PSO	2013	Step Size, Convergence Speed, Fluctuations	MPPT	Reduction in energy loss
[8]	Cuckoo Search	2014	Optimal Scaling Factors, Robustness	Wavelet Domain	Cuckoo Search is incorporated for selecting the suitable scaling factor to satisfy the robustness and invisibility.
[9]	Cuckoo Search and Differential Cuckoo Search	2014	Energy Consumption	Differential Operator	DCSA achieves promising solutions on all tested cases.
[10]	Cuckoo Search and Genetic Algorithm	2016	Contrast Enhancement	BrainWeb and MIAS database images.	In medical diagnosis, the contrast of images has more importance and is obtained through our technique.
[11]	Cuckoo Search, Genetic Algorithm, Ant Colony Optimisation	2015	Makespan, Mean Flow Time	Flowshop Scheduling	Superiority of Discrete Inter-Species Cuckoo Search with respect to many other existing metaheuristic search algorithms.
[12]	Cuckoo Search	2014	Optimised Gains, Sensitivity Analysis, Convergence	2DOF-IDD controllers	The comparison of convergence curve of various algorithms reveals that CS algorithm converges much faster than others.
[13]	Cuckoo Search	2012	Energy Efficiency	Wireless Sensor Networks	The hybrid approach offers consistency in the cluster formation, minimal number of clusters, average energy consumption and energy consumption per rounds.
[14]	Cuckoo Search	2014	Makespan, Robustness, Effectiveness	Hydrothermal Scheduling	The proposed CSA can be an efficient method for solving short-term fixed head hydrothermal scheduling problems.

Dhivya [13] formulated optimisation of network by Cuckoo Based Particle Approach (CBPA). Nodes were assigned in a random manner and organized as static clusters by Cuckoo Search (CS). The information was collected, aggregated and forwarded to the base station after the cluster heads were selected, using a generalized particle approach algorithm. The proposed approach can significantly lengthen the network lifetime when compared to traditional methods. Nguyen [14] proposed a cuckoo search algorithm (CSA) for solving short-term fixed-head hydrothermal scheduling (HTS) problem considering power losses in transmission systems and valve point loading effects in fuel cost function of thermal units. The effectiveness of the proposed CSA was tested on different hydrothermal systems and the result comparison has shown that the CSA can obtain higher quality solutions than many other methods.

4. Conclusion

This paper gives a wide review of different types of the applications of Cuckoo Search Algorithm and its different variants in various fields like image compression, job scheduling, energy conservation, wireless sensor networks (WSN) etc. The various issues and problems found in the individual metaheuristic can be overcome by using the hybridization of two or more metaheuristic techniques. Cuckoo Search gave optimal results in comparison to many different metaheuristic techniques like Particle Swarm Optimisation, Genetic Algorithm etc. due to its better convergence and less probability to get stuck in local optima.

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