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Modified cuckoo search algorithm with self adaptive parameter method

Xiangtao Li, Minghao Yin *

School of Computer Science and Information Technology, Northeast Normal University, Changchun 130117, China

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ABSTRACT

The cuckoo search algorithm (CS) is a simple and effective global optimization algorithm. It has been applied to solve a wide range of real-world optimization problem. In this paper, the proposed method uses two new mutation rules based on the rand and best individuals among the entire population. In order to balance the exploitation and exploration of the algorithm, the new rules are combined through a linear decreasing probability rule. Then, self adaptive parameter setting is introduced as a uniform random value to enhance the diversity of the population based on the relative success number of the proposed two new parameters in the previous period. To verify the performance of SACS, 16 benchmark functions chosen from literature are employed. Experimental results indicate that the proposed method performs better than, or at least comparable to state-of-the-art methods from literature when considering the quality of the solutions obtained. In the last part, experiments have been conducted on Lorenz system and Chen system to estimate the parameters of these two chaotic systems. Simulation results further demonstrate the proposed method is very effective.

1. Introduction

Many real-world problems may be formulated as optimization problems with variables in continuous domains. In the past decade, we have viewed different kinds of evolutionary algorithms advanced to solve optimization problems, such as genetic algorithm (GA), particle swarm optimization algorithm (PSO), estimation of distribution algorithms (EDA), ant colony optimization (ACO), krill herd algorithm (KHA), biogeography based optimization (BBO), differential evolution (DE), artificial bee colony (ABC), and cuckoo search algorithm (CS) [4,13,16,19,34–39].

Among them, cuckoo search algorithm [4] is a population-based heuristic evolutionary algorithm inspired by the interesting breeding behavior such as brood parasitism of certain species of cuckoos. In CS, each cuckoo lies an egg at a time and dumps its egg in a randomly chosen nest. The best nests with high quality of eggs will carry over to the next generation. The number of available host nests is fixed, and the egg lays by a cuckoo is discovered by the host bird with a probability. In this case, the host bird can either abandon the egg away or throw the nest, and build a completely new nest. In order to accelerate the convergence speed and avoid the local optima, several variations of CS have been proposed to enhance the performance of the standard CS recently. Moreover, CS has been proved to be really efficient when solving real world problems. Yang et al.

* Corresponding author. Tel./fax: +86 0431 84536338.
E-mail addresses: lixt314@nenu.edu.cn (X. Li), Minghao.Yin1@gmail.com (M. Yin).

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[40] proposed a new evolutionary algorithm to solve engineering design optimization problems, including the design of springs and welded beam structures. Walton [30] proposed modified cuckoo search algorithm which can be regarded as a modification of the cuckoo search algorithm. The modification involves the addition of information between the top eggs. Gandomi et al. [7] proposed the CS for solving structural optimization problems which is subsequently applied to 13 design problems. The performance of the CS algorithm is further compared with various algorithms representative of the state of the art in the area. Layeb [18] proposed a new inspired algorithm called quantum inspired cuckoo search algorithm, which a new framework is relying on quantum computing principles and cuckoo search algorithm. Tuba et al. [29] implemented a modified version of this algorithm where the step size is determined from the sorted rather than only permuted fitness matrix. Noghrehabadi et al. [14] proposed a hybrid Power series and Cuckoo Search via Lévy Flights optimization algorithm (PS–CS) method is applied to solve a system of nonlinear differential equations arising from the distributed parameter model of a micro fixed–fixed switch subject to electrostatic force and fringing filed effect. The obtained results are compared with numerical results and found in good agreement. Moreover, the present method can be easily extended to solve a wide range of boundary value problems. Yildiz [41] proposed CS for the optimization of machining parameters. The results demonstrate that the CS is a very effective and robust approach for the optimization of machining optimization problems. Durgun and Yildiz [5] proposed to use the cuckoo search algorithm (CS) algorithm to solve structural design optimization of a vehicle component. Agrawal et al. [1] used the cuckoo search algorithm to find the optimal thresholds for multi-level threshold in an image. Ouaarab et al. [26] presented an improved and discrete version of the CS to solve the famous traveling salesman problem. Burnwal et al. [3] proposed a new algorithm to solve scheduling optimization of a flexible manufacturing system by minimizing the penalty cost due to delay in manufacturing and maximizing the machine utilization time. Wang [33] proposed for solving optimization tasks within limited time requirements. The improvement includes the addition of krill updating (KU) and krill abandoning (KA) operator originated from cuckoo search (CS) during the process when the krill updating so as to greatly enhance its effectiveness and reliability dealing with numerical optimization problems. The KU operator inspired the intensive exploitation and marked the krill individuals search the space carefully in the later run phase of the search, while KA operator was used to further enhance the exploration of the CSKH in place of a fraction of the worse krill at the end of each generation. The elitism scheme was also applied to save the best krill during the process when updating the krill. Gandomi et al. [12] developed to solve truss optimization problems. The new algorithm was examined by solving five truss design optimization problems with increasing numbers of design variables and complexity in constraints. Li et al. [20] used a new search strategy based on orthogonal learning strategy to enhance the exploitation ability of the basic cuckoo search algorithm. Experiment results show the proposed method is very effective. However, it should be noted that these methods seem to be difficult to simultaneously achieve the balance between exploration and exploitation of the CS. Therefore, a large number of future researches are necessary in order to develop new effective cuckoo search algorithms for optimization problems.

This paper first proposes two new mutation rules based on the rand and best individuals among the entire population. In order to balance the exploitation and exploration ability of the algorithm, a linear decreasing probability rule is used to balance these two new mutation rules. Then, the self adaptive parameter setting is introduced to enhance the diversity of the population based on the relative success number of the proposed two new parameter methods in the previous period. Our algorithm has a very simple structure and thus is easy to implement. To verify the performance of SACS, 16 benchmark functions chosen from literature are employed. Compared with other evolution algorithms from literature, experimental results indicate that the proposed method performs better than, or at least comparable to state-of-the-art approaches from literature when considering the quality of the solution obtained. In the last part of the paper, experiments have been conducted on Lorenz system and Chen system to estimate the parameters of these two systems. Simulation results and comparisons demonstrate the proposed method is very effective.

The rest of this paper is organized as follows: In Section 2 we review the basic CS. The self adaptive cuckoo search algorithm is presented in Section 3 respectively. Benchmark problems and corresponding experimental results are given in Section 4. The parameter estimation of chaotic system is given in Section 5. In the last section we conclude this paper and point out some future research directions.

2. Cuckoo search algorithm

Cuckoo search algorithm [4] is an evolutionary algorithm inspired by the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds. During the search process, there are mainly three principle rules. The first rule is that for each time, each cuckoo can only lay one egg, which will be dumped in a randomly chosen nest. The second rule is that the best nests with better eggs will be retained to the next generation. The third rule is that during the whole search process the number of available host nests is a constant number, and the host bird will find the egg laid by a cuckoo with a probability. When it happens, the laid egg will be thrown away or the host bird will abandon the nest to build a new nest. Based on these rules, the standard cuckoo search algorithm is described as follows: