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Chaos-enhanced Cuckoo search optimization algorithms for global optimization

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ABSTRACT

Cuckoo search optimization algorithm is a biologically inspired optimization algorithm, which is widely used to solve many optimization problems. However, it has been empirically demonstrated to easily get trapped into local optimal solutions and cause low precision. Therefore, in this work, we propose five modified Chaos-enhanced Cuckoo search (CCS) optimization algorithms, in which chaotic sequences are utilized to enhance initialized host nest location, change step size of Lévy flight and reset the location of host nest beyond the boundary. These five CCS algorithms are denoted by CCS1 (with Logistic map), CCS2 (with tent map), CCS3 (with Gauss map), CCS4 (with Sinusoidal iterator) and CCS5 (with Circle map) respectively. We test our algorithms in two function groups, denoted by Group A and Group B, respectively. In Group A, which consists of four Unimodal and five simple Multimodal functions, we compare the performance of five CCS algorithms and the standard CS. The numerical results show that the novel algorithm enhances the performance of the basic Cuckoo search optimization algorithm, and CCS3 achieves the best performance. In Group B, which is derived from CEC2013 test problems, we test three optimization algorithms (CCS3, CLPSO and TCPSO). The numerical results show that the CCS3 algorithm has better performance than others.

1. Introduction

Optimization is a theoretical tool to explore the puzzle of the optimal parameter value under the specified conditions. As far as mathematics is concerned, global optimization is to find the point (x^*) with minimization or maximization benchmark function value ($f(x^*)$), which can characterize some types of realistic problems. Optimization algorithms are methods used for acquiring optimal solutions of the optimization problems in many disciplines. Various optimization algorithms have been put forward in different industries. Generally speaking, the algorithms can be mainly classified into two categories: deterministic and stochastic. Stochastic algorithms include two types of algorithms, i.e., evolutionary and meta-heuristic [1]. Meta-heuristic algorithms, inspired by some successful characteristics of biological systems in nature, have better global optimal property and

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more extensive application in the real problems [2], such as genetic algorithms (GA) [3], differential evolution (DE) [4], particle swarm optimization (PSO) [5], simulated annealing [6], ant colony optimization [7], state transition algorithm (STA) [1,8], etc. However, these Meta-heuristic algorithms have the randomness to some extent so that it greatly reduces the global search ability and easily to fall into the local optima.

Chaos belongs to a characteristic of nonlinear systems. Chaotic motion can distribute homogeneously within a certain range since it has possessed some uncertainty, ergodicity and stochasticity. Hence, more and more researchers use the characteristics of chaotic ergodicity to solve the global optimal solution of complex nonlinear multi-peak problems [9–13], by weakening the randomness of metaheuristic optimization algorithm. Chao and Yu propose a new genetic algorithm (GA) which estimates system parameters from a time series by chaos synchronization [14]. Peng and Liu formulate a new differential evolution (DE) in which parameter estimation is generated by chaotic systems [15]. Ying and Xin put forward a new method in which time delay is considered as an additional estimates parameters in order to solve multidimensional optimization problems [16]. Referring to the development of the particle swarm optimization (PSO), Gandomi et al. [17] introduce chaos into the accelerated PSO [18] to further enhance its global search ability and to show some advantages in convergence. However, there are some defects in the approaches mentioned above since the chaotic sequences play an important role on parameter estimation methods, and do not change the nature of the traverse way. Those ideas may suffer from local-best solution dilemma and the processing techniques are too complex.

The standard Cuckoo search (CS) algorithm was proposed in 2009 by Yang and Deb [19,20], which is a biologically inspired computational search and optimization method based on the interesting breeding behavior of Cuckoo. Compared with other optimization algorithms, the standard CS algorithm has several advantages. Firstly, the standard algorithm uses *Lévy* flight [21–23] approach, which is a random walk with characteristics of a sequence of sudden jumps, that can change the nature of the traverse way of other meta-heuristic optimization algorithms. Thus, CS algorithm makes the global searches more effectively in the solution domain if the step size is set properly. Secondly, the number of adjusted parameters is less than that in other optimization algorithms and it is much more suitable to a broader class of optimization problems. Hence the standard Cuckoo algorithm holds a better performance for the local search. The standard CS, however, still belongs to meta-heuristic optimization algorithm. It is not ideal to solve the global optimal solution of complex multi-peak problems. For various problems in realistic or engineering applications, it is necessary to improve the standard Cuckoo search algorithm. In this paper, we analyze the defects of standard CS algorithm and propose a novel Chaos-enhanced Cuckoo search (CCS) algorithm.

The rest of this paper is organized as follows. Section 2 related works in the field of optimization are reviewed. Section 3 introduces the standard Cuckoo search algorithm and its disadvantages. After that, in Section 4, we propose CCS optimization algorithms. And then, in Section 5, we test our algorithm on two group functions. In Group A, the numerical results show that the novel algorithms enhance the performance of the basic Cuckoo search optimization algorithm. We use the average ranks to find that CCS3 (with Gauss map) performs much better than others. In Group B (CEC2013 test problems [48]), we test three optimization algorithms (CCS3 (with Gauss map), CLPSO and TCPSO). The numerical results show that the CCS3 (with Gauss map) algorithm has better performance than others. Finally, some conclusions are drawn in Section 6.

2. Research trends on Cuckoo search algorithm

Several modified Cuckoo search algorithms have been proposed to enhance the performance of the standard algorithm, which are helpful to increase the flexibility of the parameters so as to achieve the better effect of particle traversal. Walton and Hassan propose a modified Cuckoo search (MCS) method which can speed up convergence to an optimal value [24], and it changes the step size of the standard CS and adds information exchange between the eggs. Bulatovic and Boskovic present an improved Cuckoo search (ICS) which adopts dynamic change of probability parameter pi and step size [25]. In the problems of constrained engineering optimization, improved Cuckoo search has better solutions than the standard CS, and modifying the parameters of standard algorithms is also used to solving multi-objective optimization problems [26].

Other modifications include the hybrid algorithms which are created by combining two or three optimization algorithms. Those ideas are reassignment of interchangeable components in order to solve various problems in practice, in which some feasible methods are used to enhance the dependability of system. As an example, Layeb [27] presents a novel quantum inspired Cuckoo search algorithm (QICSA) which is a hybridization between quantum computing principles and Cuckoo search algorithm, and it can achieve better balance between exploration and exploitation. Chandrasekaran and Simon come up with a hybrid Cuckoo search algorithm (CSA) which integrates with fuzzy system in order to solve multi-objective unit commitment problem (MOUCP) [28]. Kanagaraj et al. [29] combines the standard Cuckoo search (CS) and genetic algorithm (GA) to solve the reliability and redundancy allocation problem. In addition, Cobos et al. introduces a new description-centric algorithm (WDC–CSK) for solving the clustering of web results [30], in which split and merge methods are integrated into the standard Cuckoo search algorithm to efficiently implement the searching for the global and local optima.

Although the methods mentioned above often focus on the problem of the Cuckoo search algorithm and are dedicated to search the global solution domain more effectively for various kinds of problems. There exist some obvious shortages when compared with other algorithms. The one is to increase the number of parameters, and it can be connected with the *Lévy* flight of the Cuckoo search (CS) performance. The other point is to increase the complexity of the standard algorithm.