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A Novel Hybrid Binary Bat Algorithm for Global Optimization

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ABSTRACT

In this article, a novel hybrid binary bat algorithm named HBBA is proposed for global optimization problems. First, to avoid simultaneous updating of bat velocity's dimensional components, i.e., elements of velocity vector, a random black hole model is modified to adapt to binary algorithm for updating in unknown spaces for each dimensional component individually. Through this way, the search ability of bats around the current group best is increased greatly. Second, a time-varying v-shaped transfer function, rather than a time-invariant one as in closely related works, is proposed to map velocity in continuous search space to a binary one. This accelerates the speed to switch individuals' positions, i.e., solutions in binary space. Third, a chaotic map is utilized to replace monotonous parameters in original binary bat algorithm, which is beneficial for avoiding premature convergence. Simulation results demonstrate the effectiveness of the proposed algorithm by three types of benchmark functions and unit commitment problem.

KEYWORDS

Binary Bat Algorithm, Random Black Hole Model, Transfer Function, Composition Benchmark Function, Unit Commitment

INTRODUCTION

Metaheuristic optimization algorithms are typically used to solve some complex optimization problems including nonconvex and nonlinear ones, which generally cannot be well solved by conventional mathematical methods. Although the solution generated by heuristic algorithms may not be equal to the exact optimal one, it is generally acceptable for real world engineering optimization problems.

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Therefore, heuristic optimization algorithms have gained considerable interests during the past few decades (Abualigah et al., 2021; Hashim & Hussien, 2022). Several excellent representatives include genetic algorithm (GA) (Holland, 1992), particle swarm optimization (PSO) (Kennedy & Eberhart, 1995), differential evolution (DE) (G. Wang et al., 2022), grey wolf optimizer (GWO) (Nadimi-Shahraki et al., 2022), harmony search (HS) (Abarajithan & Vijayarani, 2022), ant colony optimization (ACO) (Dorigo & Gambardella, 1997), and bat algorithm (BA) (X. Yang, 2010; Akila & Christe, 2022).

Nearly all heuristic optimization algorithms proposed at the beginning are devoted to solving continuous variable optimization problems. However, many optimization problems in reality have discrete binary search space such as feature selection (El-Kenawy et al., 2022), 0–1 knapsack problem (Du et al., 2023), and unit commitment problem (Reddy et al., 2018). Therefore, some binary optimization algorithms are proposed according to their corresponding continuous versions to deal with binary optimization problems. For example, a sine cosine hybrid optimization algorithm with modified whale optimization algorithm (SCMWOA) was proposed by El-Kenawy et al. (2022). Its aim was to take advantage of WOA and SCA to solve problems with continuous and binary decision variables. An artificial algae algorithm's binary version (Turkoglu et al., 2022) was put forward to solve optimal attribute set for classification algorithms. A new binary multi-objective grey wolf optimizer was applied to dimensionality reduction problem in classification by Al-Tashi et al. (2020). By comparing and analyzing eight transfer functions including V-shaped and S-shaped, a binary quilibrium optimization algorithm was proposed by Abdel-Basset et al. (2021). A novel binary DE algorithm based on Taper-shaped transfer function (He et al., 2022) was proposed for solving knapsack problem and uncapacitated facility location problem. Besides, several other binary algorithms were proposed (Hichem et al., 2022; Pashaei & Pashaei, 2022; Usman et al., 2022) to solve feature selection problems. Although binary algorithms are proposed on the basis of continuous ones, there exist essential differences between them. Particularly, a transfer function is always required to map continuous space to a binary one in binary algorithm.

In the existing related works, the commonly used transfer functions are sigmoid function and its variants, both called S-shaped function (El-Kenawy et al., 2022; Pashaei & Pashaei, 2022). However, the application of S-shaped transfer function may slow down the convergence speed of algorithms because this type of function forces individuals to take values in 0 or 1. This means that the position will keep unchanged when speed increases. To overcome this drawback, V-shaped transfer function was proposed. The advantage of binary algorithms based on it is that they do not need to force individuals to take values in 0 or 1. More specifically, positions will keep unchanged if the corresponding velocity values are low, and will be replaced by their complements if the corresponding velocity values are high (Mirjalili & Lewis, 2013). This characteristic accelerates an individual's position change when search speed is changed (Usman et al., 2022; Mirjalili et al., 2014). Although algorithms with V-shaped transfer functions always show better performance than those with S-shaped transfer functions, the former are easy to suffer from local optima or premature convergence since the intrinsic drawbacks of original continuous algorithms are inherited by the binary ones. To further improve the diversity of populations, a time-varying mirrored S-shaped transfer function was proposed by Beheshti (2020) to help particles escape local optima. The performance of this method was demonstrated to be superior to S-shaped and V-shaped transfer functions based on methods by several benchmark functions.

Binary bat algorithm (BBA) was first proposed based on continuous BA (Mirjalili et al., 2014). There are lots of artificial bats in BA or BBA whose objective is to find an optimal solution for an optimization problem. Each artificial bat has some properties, such as velocity and position just as in PSO and GWO. Moreover, some unique properties, such as frequency, also exist in artificial bats. In BBA, some rules about velocity and position updating of artificial bats are carried out to adapt to binary problems. Typically, V-shaped transfer function is introduced to map continuous value space to a binary one, and the position (which is a binary value of artificial bat) is updated according to the corresponding velocity vector (which is a continuous value). The newly generated position is then