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Improved Teaching-Learning-Based Optimization Algorithm and its Application in PID Parameter Optimization

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ABSTRACT

The teaching-learning-based optimization (TLBO) algorithm has been applied to many optimization problems, but its theoretical basis is relatively weak, its control parameters are difficult to choose, and it converges slowly in the late period and makes it too early to mature. To overcome these shortcomings, this article proposes a dual-population co-evolution teaching and learning optimization algorithm (DPCETLBO) in which adaptive learning factors and a multi-parent non-convex hybrid elite strategy are introduced for a population with high fitness values to improve the convergence speed of the algorithm, while an opposition-based learning algorithm with polarization is introduced for a population with lower fitness values to improve the global search ability of the algorithm. In a proportion integration differentiation (PID) parameter optimization experiment, the simulation results indicate that the convergence of the DPCETLBO algorithm is fast and precise, and its global search ability is superior to those of the TLBO, ETLBO and PSO algorithms.

KEYWORDS

Dual-Population, Co-Evolution Teaching, Learning Optimization Algorithm, Proportion Integration Differentiation, Teaching-Learning-Based Optimization Algorithm

INTRODUCTION

The Teaching-Learning-Based Optimization (TLBO) algorithm was first proposed by Rao et al. in 2011 and is a new intelligent optimization algorithm[1]. The TLBO algorithm is inspired by educational activities in people's lives. To try to simulate the "teaching" and "learning" processes in educational activities, the TLBO algorithm performs individual evolution in two "teaching" and "learning" stages. The TLBO algorithm has a simple design with few parameters and is easy to implement. It achieves high speed, high precision and strong convergence capability. In the few short years since the TLBO algorithm was put forward, scholars, such as Rao[2], have conducted a large amount of

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performance improvement research. Undoubtedly, this research promoted the rapid development of the TLBO algorithm.

The TLBO algorithm has been widely used in heat exchangers, thermoelectric refrigerators, mechanical design, reactive power distribution networks, and continuous large-scale nonlinear optimization. It shows strong local search ability and convergence performance in these specific applications because of its superior performance. The TLBO algorithm has become an area of interest in the field of intelligent optimization algorithms[2].

However, due to the short development history of the TLBO algorithm, there are many aspects that require further research. For example, the theoretical foundation is relatively weak, the control parameters are difficult to choose, and the convergence in the late period is slow and premature[3,4]. This paper presents some research on the improvement of the TLBO algorithm and introduces the dual-population co-evolution model for the improvement of the TLBO algorithm. The convergence speed of the algorithm is improved by introducing adaptive learning factors and a multi-parent non-convex hybrid elite strategy. A reverse learning algorithm with polarization is introduced to improve the global search capability of the algorithm. In this paper, the improved dual-population co-evolution TLBO (DPCETLBO) algorithm is applied to proportion integration differentiation (PID) control parameter optimization. The experiment shows that the DPCETLBO algorithm can effectively solve the problem of PID parameter optimization with superior performance compared to other algorithms.

TEACHING-LEARNING-BASED OPTIMIZATION ALGORITHM

Basic Principles of Teaching-Learning-Based Optimization Algorithm

The TLBO algorithm consists of two main stages: “teaching” and “learning”. In the first phase, teachers teach the students and a good teacher can contribute to students’ overall achievement. In the second phase, each student randomly selects another student in the class from whom to learn, with the goal of improving his or her academic performance.

The optimization problem is defined in Formula (1):

$$Z = \max_{XeS} f(x) \tag{1}$$

where $X = (x_1, x_2, ..., x_d)$ is the independent variable, which represents an individual in the population, namely, one student; x_i is the decision variable, namely, the course; d is the dimension; $S = \{X \mid x_i^L \le x_i \le x_i^U, i = 1,2,...,d\}$ is the population, namely, the class; $f(x)$ is the target function; and $X_i = \arg\max f(X)$ is the best student in the class, namely, the teacher.

Assuming the size of the population is NP, a class can be represented by the following Formula (2):

$$\left[\begin{array}{c|c} X^1 & f(x^1) \\ X^2 & f(x^2) \\ \vdots & \vdots \\ X^{NP} & f(x^{NP}) \end{array}\right] = \left[\begin{array}{cccc|c} X_1^1 & X_2^1 & \cdots & X_d^1 & f(X^1) \\ X_1^2 & X_2^2 & \cdots & X_d^2 & f(X^2) \\ \vdots & \vdots & & \vdots & \vdots \\ X_1^{NP} & X_2^{NP} & \cdots & X_d^{NP} & f(X^{NP}) \end{array}\right] \tag{2}$$