Engineering Structures 106 (2016) 355–369

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Multi-class teaching–learning-based optimization for truss design with frequency constraints

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ARTICLE INFO

Article history:
Received 27 June 2015
Revised 9 September 2015
Accepted 22 October 2015
Available online 11 November 2015

Keywords:
Optimization
Teaching–learning-based optimization (TLBO)
Truss structures
Shape and size optimization
Frequency constraints

ABSTRACT

The primary objective of this study is to introduce a multi-class teaching–learning-based optimization (MC-TLBO) technique for structural optimization with frequency constraints. Teaching–learning-based optimization (TLBO) is based on a simple and efficient algorithm with no intrinsic parameters controlling its performance. The multi-class approach proposed here increases the initial exploration capability of the optimization process resulting in a more efficient search. MC-TLBO extends the concept of the education process from a single classroom to a school with multiple parallel classes. The MC-TLBO algorithm employs a two-stage procedure: in the first stage, parallel classes explore the search space; in the second stage, the best solutions of the first stage form a super class to be the initial population for a modified TLBO. In order to examine the efficiency of the proposed methodology, the MC-TLBO algorithm is applied on various benchmark truss optimization problems with frequency constraints and the designs results are compared to the results of both a modified TLBO algorithm and other optimization methods.

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1. Introduction

Applications of population-based evolutionary optimization have become very common in science and engineering. Many of these methods seek to model both learned and innate natural behaviors that have been shown to be very efficient at transferring information among individuals within a group or population. Some of the most popular methods are: genetic algorithms (GAs), that first introduced by Holland [1] and Goldberg [2], which models the process of natural evolution; ant colony optimization (ACO), developed by Dorigo [3], which models some of the foraging behaviors of an ant colony; and particle swarm optimization algorithm (PSO), proposed by Kennedy and Eberhart [4], which simulates the social behavior and interactions that occur in a flock of birds or a school of fish. Typically, these metaheuristic methods systematically reduce the search space through iterative processes and focus the population, based on some measure of performance, toward feasible, high-quality solutions. Therefore, there is a growing interest in development of new algorithms and their applications in structural optimization [5–7].

Rao et al. [8] introduced an innovative approach called teaching–learning-based optimization (TLBO) which uses simple models of teaching and learning within a classroom as the basis for an evolutionary optimization algorithm. TLBO considers the teacher's effect on a population or class of students as well as the transfer of information between students in an iterative process to increase the performance level of the students and overall performance of the class. A TLBO algorithm has two main parts: a Teacher Phase, where the average performance or knowledge of the class is moved toward that of a teacher; and a Learner Phase, where students share information and cooperatively interact with each other. TLBO method is a relatively simple algorithm with no intrinsic parameters controlling its performance. Several modifications to TLBO have been introduced to improve its performance for solving optimization problems [9–11].

In this study, a multi-class approach is proposed that can improve the overall performance of TLBO. The idea is to extend the concept of the education process from a single classroom to a school with multiple simultaneous classes. A multi-class technique allows for better exploration and exploitation of the search space and can be applied to other optimization algorithms. In order to examine the effectiveness of this approach, structural optimization problems with frequency constraints are considered.

Weight optimization of structures with frequency constraints is considered to be a challenging problem. The dynamic response of a

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http://dx.doi.org/10.1016/j.engstruct.2015.10.039
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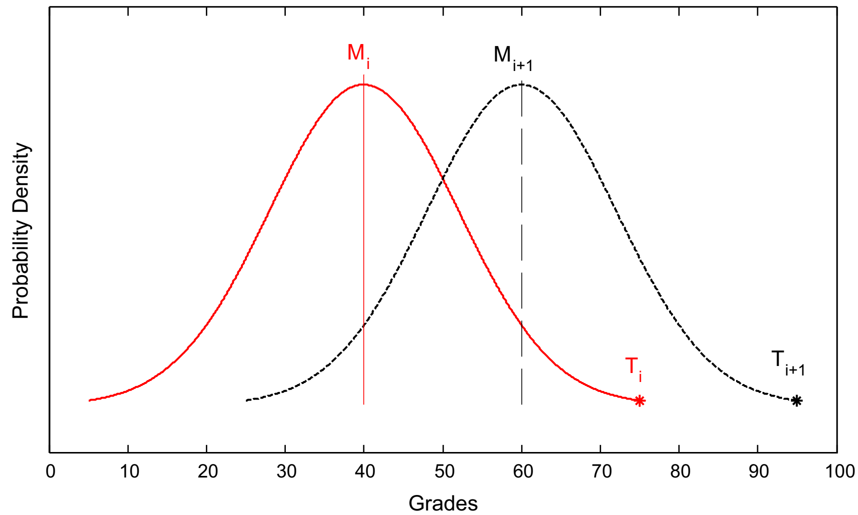

Fig. 1. Distribution of grades obtained by students of a class, for two consecutive iterations.

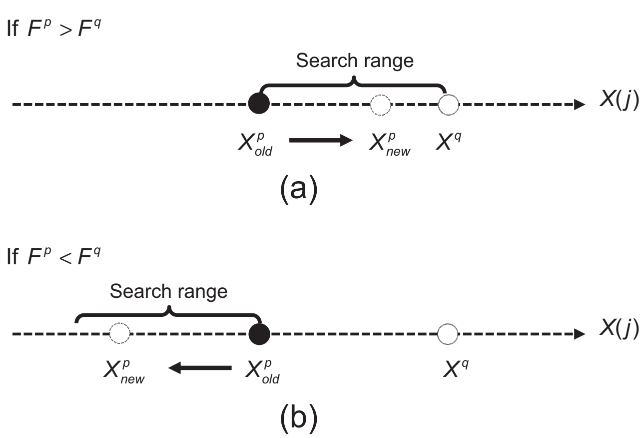

Fig. 2. Illustration of Learner Phase for *j*th design variable, when (a) student *q* is better than student *p* and (b) student *p* is better than student *q*.

structure is primarily a function of its fundamental frequencies and mode shapes. Therefore, the ability to manipulate fundamental frequencies of a structure can significantly improve its performance [12]. It has been shown that the response of a structure is much more sensitive with respect to its geometry, and more effective designs can be generated by optimizing both shape and size parameters. Accounting for both size and shape optimization can result in more effective designs [13]. Many optimization techniques have been applied to solve this problem: Sedaghati et al. [14] applied mathematical programming based on the sequential quadratic programming (SQP) technique and finite element analysis based on the integrated force method; Lingyun et al. [15] introduced a Niche Hybrid Parallel Genetic Algorithm (NHPGA); Zuo et al. [16] proposed an adaptive eigenvalue reanalysis approach for fast optimization with frequency constraints using a GA; Gomes [17] used a particle swarm algorithm (PSO) for truss optimization; Kaveh and Zolghadr [18] introduced democratic particle swarm optimization (DPSO) to improve the exploration capabilities of PSO and to address the problem of premature convergence; Miguel and Fadel Miguel [19] used harmony search (HS) and a firefly algorithm (FA) for solving shape and sizing optimization of benchmark truss structures; Kaveh and Javadi [20] applied a mixed particle swarm-ray optimization combined with harmony search (HRPSO) to the optimization problem; Khatibinia and Naseralavi [21] proposed orthogonal multi-gravitational search algorithm (OMGSA) to eliminate the drawback of improved gravitational search algorithm (IGSA) and enhances its local search ability; and most recently, Kaveh and Ilchi Ghazaan [22] employed two hybridized PSO algorithms and an enhanced version of colliding body optimization (CBO) to solve the problem.

In this study, a multi-class teaching–learning-based optimization (MC-TLBO) algorithm is applied to solve shape and size truss optimization problems with multiple natural frequency constraints. To demonstrate the efficiency of the proposed algorithm, five common benchmark truss optimization problems with multiple frequency constraints are studied and the optimization results

First stage:

Generate N_c independent classes of size N (N_c x N total students)
Perform TLBO for each class independently
Check termination criterion for each class
Identify the overall best N students from all N_c classes

Second stage:

Perform TLBO for the new class of size N (N total students)
Check termination criterion for the second stage

Fig. 3. MC-TLBO algorithm pseudo-code.

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