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Combined size and shape optimization of structures with a new meta-heuristic algorithm

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ABSTRACT

In this study, a new meta-heuristic algorithm called teaching-learning-based optimization (TLBO) is used for the size and shape optimization of structures. The TLBO algorithm is based on the effect of the influence of a teacher on the output of learners in a class. The cross-sectional areas of the bar element and the nodal coordinates of the structural system are the design variables for size and shape optimization, respectively. Displacement, allowable stress and the Euler buckling stress are taken as the constraint for the problem considered. Some truss structures are designed by using this new algorithm to show the efficiency of the TLBO algorithm. The results obtained from this study are compared with those reported in the literature. It is concluded that the TLBO algorithm presented in this study can be effectively used in combined size and shape optimization of the structures.

1. Introduction

Optimization of structure is to obtain a set of design variables that make the weight of structure minimum. In general, design variables are the cross-sectional areas, nodal coordinates and a determined topology. Using design variables, three types of optimization can be performed in the design of structures. These are size optimization, shape optimization and the topology optimization. Among these optimization types, size optimization is preferred to find the minimum weight of the structure under certain constraints. If the other optimization types are used with the size optimization the design variable space will be expanded. The solution of the problem becomes more difficult when the limit of design variables space increase. To overcome this difficulty different optimization algorithms have been presented in the literature. Wang et al. [1] presented a study for truss structure with combined size and shape optimization. A similar study has been made by Gil and Andreu [2] and Kaveh and Kalatjari [3]. Svanberg [4] and Zhou and Xia [5] optimized the truss structures for optimum geometry. Gholizadef et al. [6] made a shape optimization of structures using harmony search. Hasançebi and Erbatur [7], Rahami et al. [8], Tang et al. [9], and Rajan [10] optimized truss structures using genetic algorithm with sizing, geometry and topology design variables. A master thesis is made by Felix [11] for the shape optimization of trusses. Han [12] presented a shape optimization for general two dimensional structures. Kaveh and Laknejadi [13] made a study for layout optimization of truss structures.

There are different type of optimization problems presented by researches, such as size optimization, size and shape optimization or size, shape and topology optimization. Ahrari and Atai [14] presented a novel truss optimizer based on the principles of the state-of-the-art Evolution Strategies by taking into account the size and shape optimization. Miguel et al. [15] employs the Firefly Algorithm (FA) in the simultaneous optimization of size, shape, and topology in truss structures. They applied the FA to 2D and 3D truss structures. Miguel and Miguel [30] made a study on shape and size optimization of truss structures considering dynamic constraints through modern metaheuristic algorithms (Harmony Search (HS) and Firefly Algorithm (FA)). They used the multiple natural frequency of truss structure as a constraint of an optimization problem. Dede et al. [16] minimized the weight of the truss structures by using adopted Genetic Algorithm (GA). They presented value and binary encodings types in genetic algorithm for discrete and continuous optimization problems and developed a new strategy called as Restricted Range Approach (RRA). Sönmez [17] studied on truss structures taking into account the size optimization with Artificial Bee Colony algorithm (ABC). Sadollah et al. [18] presented a study on size optimization with discrete design variables of truss structures using the Mine Blast Algorithm (MBA). Kaveh and Talatahari [19] made a study on size optimization of space trusses using a Hybrid Big Bang-Big Crunch algorithm

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```
teacher = min ( f ( population_old ) )
difference = rand*( teacher –TF*mean(population_old) )
population_new= population_old + difference

for i = 1:size(population)
    if f(population(i)_new) > f(population(i)_old
     population(i)_new = population(i)_old
     end if
end for
```

Fig. 1. Pseudocode of teacher phase in TLBO.

```
for i = 1: Pn
    randomly select student_j, i≠j
    if f(student_i) < f(student_j)
        difference = student_i - student_j
    else
        difference = student_j – student_i
    end if
    student_new-i = student_i + r.difference
end for
```

Fig. 2. Pseudocode of student phase in TLBO.

(HBB-BC). In their study, HBB-BC is compared to Big Bang-Big Crunch (BB-BC), Genetic Algorithm (GA), Ant Colony Optimization (ABC), Particle Swarm Optimization (PSO), and Harmony Search (HS).

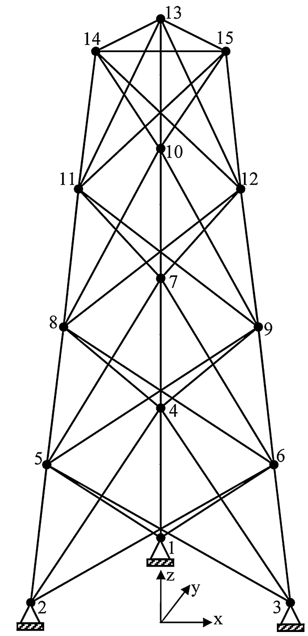

Fig. 4. 39-bar 3D truss structure.

The aim of this study is to find an optimal design for 2D and 3D truss structure with a new meta-heuristic optimization algorithm called Teaching-learning-based optimization (TLBO) under the some constraints. These constraints are the displacements, stresses and Euler buckling stress. In the optimization process, size and shape optimization is taken into account while the topology of the truss structure is fixed. Cross-sectional areas of the bar element and nodal coordinates of structural system are selected as design variables for size and shape optimization, respectively. Five truss structures are designed for numerical example. The results obtained from this study are compared to those of the literature to show the efficiency of the TLBO algorithm.

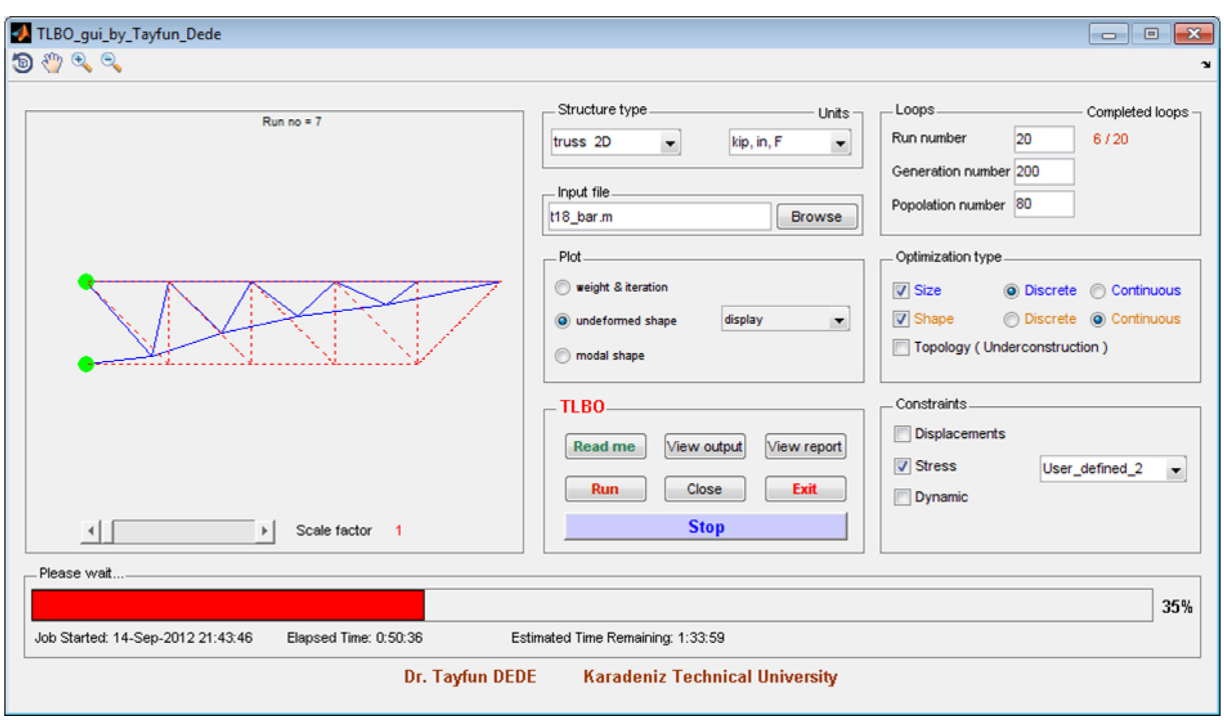

Fig. 3. Data interface of the developed program.