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Comparison of parameter-less meta-heuristic algorithms for structural optimization with frequency constraints

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Abstract

Dealing with structural mass minimization, special consideration should be given to frequency limits for dynamic problems. It is generally more complicated than structural optimization under stress and displacement constraints. Therefore, powerful methods are desired to accomplish such a challenging task. In this regard, a class of meta-heuristic algorithms is concerned here which does not need substantial tuning effort. Having just the population-size and iteration-number as mere control parameters, they act as general tools for common engineering practice. The present work compares optimization performance in designing a number of benchmark structures with frequency constraints. As a result, relative priority of these methods over each other is obtained. It is found that the most rewarding ones take advantageous of some differential evolution operators.

Keywords: Sizing Optimization, Modal Frequency, Structural Dynamics, Meta-heuristic Algorithms.

1. INTRODUCTION

Optimal structural design constitutes a challenging field of optimization problems that is characterized with narrow feasible search space and several behavior constraints. These constraints are usually evaluated by numerical methods rather than symbolic formula. Furthermore, many real-world problems deal with functions of discrete variables that are not differentiable. Consequently, zero-order class of optimization methods; including meta-heuristics, are best suited for this type of problems [1].

Every meta-heuristic algorithm utilizes its own operators and control-parameters to balance the intensification and diversification in searching the problem optima. According to the *No-Free-Lunch Theorem*, no single algorithm or set of its control parameters will be the best for all the problems [2]. As the number of such parameters increases, more computational effort is required to tune them for a specific problem. Hence, it is practically desired to apply algorithms with less parameters to tune.

As majority of current meta-heuristic methods are population-based, the population size is an essential parameter in them. The number of iterations or function calls is commonly used to determine when the algorithm is terminated and its best solution is announced. Here, an algorithm is called parameter-less when its control parameters are just limited to these two.

The present work concerns a number of well-known and recent parameter-less meta-heuristics to solve the problem of structural mass minimization with frequency constraints. Such a challenging problem have already been treated and tested on truss structures by several investigators [3–5]. Some of well-known parameter-less algorithms are treated here including TLBO[6], SOS[7], Jaya[8], OTLBO[9], in addition to basic forms of PSO[10] and DE [11]. Performance of the algorithms are studied in solving structural problems with dynamic constraints and their relative priority is discussed via comparison of statistical results.

2. TREATED PARAMETER-LESS META-HEURISTICS

A wide category of current meta-heuristic algorithms utilize vector-sum operators to search the design space. *Particle Swarm Optimization*, PSO is perhaps the most popular and pioneering algorithm in this class of *directional search* methods[10, 12, 13]. According to PSO, an i^{th} particle in the population of search agents is denoted by a vector: X_i . Its position is updated via Eq.(1) and Eq.(2) in every iteration of the search: