ABSTRACT

The present paper focus on the improvement of the efficiency of structural optimization, in typical structural optimization problems there may be many locally minimum configurations. For that reason, the application of a global method, which may escape from the locally minimum points, remain essential. In this paper, a new hybrid simulated annealing algorithm for large scale global optimization problems with constraints is proposed. The authors have developed a stochastic algorithm called SAPPSA that uses Simulated Annealing algorithm (SA). In addition, the Simultaneous Perturbation Stochastic Approximation method (SPSA) is used to refine the solution. Commonly, structural analysis problems are constrained. For the reason that SPSA method involves penalizing constraints a penalty method is used to design a new method, called Penalty SPSA (PSPSA) method. The combination of both methods (Simulated Annealing algorithm and Penalty Simultaneous Perturbation Stochastic Approximation algorithm) provides a powerful hybrid stochastic optimization method (SAPPSA), the proposed method is applicable for any problem where the topology of the structure is not fixed. It is simple and capable of handling problems subject to any number of constraints which may not be necessarily linear. Numerical results demonstrate the applicability, accuracy and efficiency of the suggested method for structural optimization. It is found that the best results are obtained by SAPPSA compared to the results provided by the commercial software ANSYS.

Keywords: FEM, Global Optimization, Hybrid Method, Simulated Annealing, Simultaneous Perturbation Stochastic Approximation, Structural Optimization

INTRODUCTION

The domain of design engineering is in constant progress and the race toward an optimal solution continues to good train. The increasing need for optimum structural designs with the most efficient use of material without violating constraints has given rise to several developments in the past three decades. A good deal of effort has been centred toward the search of optimal structural designs (Queau & Trompette, 1980; Hyun et al., 2004; Meske et al., 2005; Tran & Nguyen, 1999; Shyy et al., 1988; Yang, 1990; Bennett & Botkin, 1984; Herskovits et al., 2000;
Tai & Fenner, 1999; Phan & Phan, 1999; Bruyneel et al., 2002). In many of the previous studies the authors have used local search algorithms, such algorithms can only be successful if it is used to improve the current design (Queau & Trompette, 1980; Hyun et al., 2004; Meske et al., 2005) or only a small segment of the boundary is allowed to move (Queau & Trompette, 1980; Tran & Nguyen, 1999; Shyy et al., 1988; Yang, 1990; Hyun et al., 2004), or only a small number of dimensional parameters are used to define its shape (Meske et al., 2005; Bennett & Botkin, 1984; Tai & Fenner, 1999; Phan & Phan, 1999) or if the objective function is convex. In fact, in real world’s problems structures have became more and more complex, a design engineer working in the field of research and development has to often design completely new structures. The loading and support conditions of a particular design problem are usually known in advance, but the designer is unsure of what the final or optimal structure should look like. The essential goal of a designer in using an optimization algorithm is just to state the boundary conditions and let the algorithm do some iterations without human intervention until automatically produce the best design. In this respect, the previous studies had only a relative success. Many of them relied too much on designer’s intuition including the choice of initial design, or imposed tight restrictions on the movements of boundary. For these reasons, global optimization should take part in structural problems. In some of the previous studies global search algorithms were used, but the accuracy remained questionable. Structural engineering and mathematical programming theory should, both of them, collaborate in some way to develop a powerful and sophisticated programming system for structural optimization; this includes the utilization of High Performance Finite Element solver as well as a robust global optimization method. In this paper, on the other hand, a new hybrid simulated annealing algorithm for global optimization with constraints is proposed. SAPSPSA was designed in order to find the absolute minimum of an objective function without being sensitive to the starting point, capable of handing problems subject to any number of design variables or equality/inequality constraints, the solution is reached so that a reasonable compromise is made between the optimum and a shorter computational time. The present method can help researchers and practitioners devise optimal solutions to countless real-world problems. Numerical results demonstrate the applicability, accuracy and efficiency of the suggested method for structural optimization.

This paper is organized as follows. In Section 2 formal optimization problem is presented, in Section 3 the proposed method is described in details, Section 4 reports numerical experiments of the hybrid method through five benchmark functions well-known in the literature, the hybrid method is tested by five difficult nonlinear continuous functions and is compared with other global methods for performance analysis and in Section 5 some conclusions are derived.

**PROBLEM STATEMENT**

Formal optimization is associated with the specification of a mathematical objective function and a collection of factors (or parameters) that can be adjusted to optimize the objective function. In particular, one can formulate an optimization problem as follows:

\[
\begin{align*}
\min f(x) \\
\text{Subject to } x \in C
\end{align*}
\]  

where \( f : \mathbb{R}^p \rightarrow \mathbb{R} \) represents some loss function to be minimized, \( x \) represents the \( p \)-dimensional vector and \( C \subset \mathbb{R}^p \) represents a constraint set defining the allowable values for the parameters \( x \). In the present paper we are interested in problems for which \( x \) represents a vector of continuous parameters.

To solve problem (1) we have applied SAPSPSA, the method was designed to avoid being trapped by local optimum and to identify the global design optimum with high accuracy.
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