Chapter 12

Optimum Design of Structures for Earthquake Loading by a Cellular Evolutionary Algorithm and Neural Networks

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ABSTRACT

The present chapter deals with optimum design of structures for earthquake induced loads by taking into account nonlinear time history structural response. As the structural seismic optimization is a time consuming and computationally intensive task, in this chapter, a methodology is proposed to reduce the computational burden. The proposed methodology consists of an efficient optimization algorithm and a hybrid neural network system to effectively predict the nonlinear time history responses of structures. The employed optimization algorithm is a modified cellular genetic algorithm which reduces the required generation numbers compared with the standard genetic algorithm. Also, the hybrid neural network system is a combination of probabilistic and generalized regression neural networks. Numerical results demonstrate the computational merits of the proposed methodology for seismic design optimization of structures.

INTRODUCTION

Optimum design of structures is a process of selecting the design variables such that an objective function is minimized while all of the design constraints are satisfied. During the last decades, structural optimization problems have been solved using gradient-based algorithms. As the mathematical programming based methods need gradient calculations, the considerable part of the optimization process is devoted to the sensitivity analysis and the computational work of these methods is usually high. Optimal design of real-world structures subject to seismic loading is
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One of the major concerns in the field of structural engineering. When structures are subjected to severe earthquakes, a huge amount of inertia loads is imposed on the structures. In this case, considering linear elastic behavior and ignoring the nonlinear structural responses during the optimization process may lead to vulnerable structural systems. Therefore, seismic design codes suggest that, under severe earthquake events, the structures should be designed to deform inelastically. To achieve structural seismic design optimization, it is necessary that the nonlinear structural time history analysis be performed many times. In this case, the computational burden of the optimal seismic design process is so large that could prevent designer from comprehensively exploring the design space, and could ultimately result in unsuitable structures. Consequently, it is necessary to employ efficient computational strategies to achieve optimal seismic design of structures spending low computational costs.

In the last decades, soft computing procedures have been widely used to solve massive and complex engineering problems. Soft computing includes many components and the most attractive ones are meta-heuristic optimization algorithms and neural networks. As meta-heuristic or evolutionary optimization algorithms need not gradient calculations they are more robust than the mathematical programming based techniques and usually present better global behavior. Besides the mentioned computational advantages, the disadvantage of these methods is a slow rate of convergence towards the global optimum. A neural network is an interconnected network of simple processing elements. The processing elements interact along paths of variable connection strengths which when suitably adapted can collectively produce complex overall desired behavior. Neural networks operate as black box, model-free, and adaptive tools to capture and learn significant structures in data. Their computing abilities have been proven in the fields of prediction, pattern recognition, and optimization. They are suitable particularly for problems too complex to be modeled and solved by classical mathematics and traditional procedures.

The main objective of this chapter is to propose a computationally efficient methodology to optimal design of structures subject to earthquake loading considering inelastic structural behavior. To achieve this task, an efficient genetic algorithm (GA) based evolutionary optimization algorithm is employed to reduce the required analyses. Also, a hybrid neural network system is employed to effectively predict the nonlinear time history responses of structures during the optimization process.

BACKGROUND

During the last years, a number of researchers have employed evolutionary algorithms to optimal design of structures subject to dynamic loadings. Kocer and Arora (1999, 2002) employed GA for the optimal design of H-frame transition poles and latticed towers conducting nonlinear time-history analysis. They proposed the use of GA and Simulated Annealing (SA) for the solution of discrete variable problems, although the computational time required was excessive. Salajeghehand Heidari (2005) incorporated wavelet transforms and neural networks into the GA-based optimization processes to predict linear structural responses for a specific earthquake time history loading. Lagaros et al. (2006) examined the influence of various design procedures on the dynamic performance of real-scale steel buildings. Gholizadeh and Salajegheh (2009) employed meta-heuristic particle swarm optimization (PSO) algorithm, fuzzy inference systems (FIS) and radial basis function (RBF) neural network for optimizing linear structures subject to earthquake loading. Gholizadeh and Salajegheh (2010a) incorporated wavelet RBF neural network into a hybrid PSO-GA optimization algorithm for seismic optimization of a real-scale steel building considering
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