Chapter V

Optimum Design of Structures for Earthquake Induced Loading by Wavelet Neural Network

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Abstract

Optimum design of structures for earthquake induced loading is achieved by a modified genetic algorithm (MGA). Some features of the simulated annealing (SA) are used to control various parameters of the genetic algorithm (GA). To reduce the computational work, a fast wavelet transform is used. The record is decomposed into two parts. One part contains the low frequency of the record, and the other contains the high frequency of the record. The low-frequency content is used for dynamic analysis. Then using a wavelet neural network, the dynamic responses of the structures are approximated. By such approximation, the dynamic analysis of the structure becomes unnecessary in the process of optimisation. The wavelet neural networks have been employed as a general approximation tool for the time history dynamic analysis. A number of structures are designed for optimal weight and the results are compared to those corresponding to the exact dynamic analysis.
Introduction

Optimum design of structures is usually performed to select the design variables such that the weight or cost of the structure is minimized, while all the design constraints are satisfied. The external loads on the structures can be static (Salajegheh, 1996a, 1996b; Salajegheh & Salajegheh, 2002) or dynamic (Papadrakakis & Lagaros, 2000). In the present study, the design variables are considered as the member cross-sectional areas, which are chosen as discrete variables. The design constraints are bounds on member stresses and joint displacements. Optimum design problem is formulated as a mathematical nonlinear programming problem and the solution is obtained by the MGA (Salajegheh et al., 2005).

For problems with large number of degrees of freedom, the structural analysis is time consuming. This makes the optimal design process inefficient, especially when a time history analysis is considered. In order to overcome this difficulty, a discrete wavelet transforms (DWT) and a fast wavelet transforms (FWT) are used. Using these transformations, the main earthquake record is modelled as a record with a very small number of points. Thus, the time history dynamic analysis is carried out with fewer points. In Refs. (Salajegheh, & Heidari 2002, 2005) the DWT and FWT are used for the dynamic analysis of structures. These transformations are powerful means for the dynamic analysis and the time required is far less than the classical methods. Therefore, the FWT are used for optimisation of structures with earthquake loading (Salajegheh, Heidari, & Saryazdi, 2005). Despite substantial reduction in the dynamic analysis, optimisation process requires a great number of time history dynamic analyses; thus, the overall time of the optimisation process for earthquake record is very long.

In this work, in order to overcome this difficulty, using a wavelet neural network (WNN) (Thuillard 2001; Zhang & Beveniste, 1992) the dynamic responses of the structures are approximated. By such approximation, the dynamic analysis of the structure is not necessary during the optimisation process. Both feedforward neural networks and wavelet decompositions inspire this network. An algorithm of backpropagation type is proposed for training the network. In this network, the input is the damping ratio and the angular natural frequency of the structure and the output is the dynamic responses of a single degree of freedom structure against these reduced points. After training the network, using inverse wavelet transform (IWT) the results of the dynamic analysis is obtained for the original earthquake record from the output of the network. The numerical results of optimisation show that this approximation is a powerful technique and the required computational effort can be substantially reduced.

In the following, first a brief discussion of the MGA is presented. Then a brief discussion of the FWT and WNN are outlined. The details of the optimisation approach with approximation concepts are discussed and some numerical examples for optimum design of structures are presented. The computational time is compared to those of the exact optimisation method.
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