Chapter XI

Soft Computing Techniques in Probabilistic Seismic Analysis of Structures

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Abstract

Earthquake-resistant design of structures using probabilistic analysis is an emerging field in structural engineering. The objective of this chapter is to investigate the efficiency of soft computing methods when incorporated into the solution of computationally intensive earthquake engineering problems. Two methodologies are proposed in this work where limit-state probabilities of exceedance for real world structures are determined. Neural networks based metamodels are used in order to replace a large number of time-consuming structural analyses required for the calculation of a limit-state probability. The Rprop algorithm is employed for the training of the neural networks; using data obtained from appropriately selected structural analyses.
**Introduction**

The advances in computational hardware and software resources since the early 1990s resulted in the development of new, nonconventional data processing and simulation methods. Among these methods, soft computing has to be mentioned as one of the most eminent approaches to the so-called intelligent methods of information processing. Neural networks (NNs), fuzzy logic, and evolutionary algorithms are the most popular soft-computing techniques. NNs have been widely used in many fields of science and technology and are now becoming popular solution methods for an increasing number of structural engineering problems. NNs constitute a powerful tool that can be used to replace time consuming simulations required in many engineering applications. In the previous years, NNs have been applied mostly for predicting the behavior of a structural system in the context of structural optimal design (Lagaros, Charmpis, & Papadrakakis, 2005; Patnaik, Guptill, & Hopkins, 2005; Salajegheh, Heidari, & Saryazdi, 2005; Zhang & Foschi, 2004), for structural damage assessment (Huang, Hung, Wen, & Tu, 2003; Reda Taha & Lucero, 2005; Sanchez-Silva & Garcia, 2001), on structural reliability analysis (Hurtado & Alvarez, 2002; Nie & Ellingwood, 2004; Papadrakakis & Papadopoulos, 1996), on structural identification (Chakraverty, 2005; Masri, Smyth, Chassiakos, Caughey, & Hunter, 2000; Mróz & Stavroulakis, 2005), for the evaluation of buckling loads of cylindrical shells with geometrical imperfections (Waszczyszyn & Bartczak, 2002) or for the simulation of non-Gaussian stochastic fields (Lagaros, Stefanou, & Papadrakakis, 2005).

Many sources of uncertainty (e.g., material, geometry, loads) are inherent in structural design. Probabilistic analysis of structures leads to safety measures that a design engineer has to take into account due to the aforementioned uncertainties. Probabilistic analysis problems, especially when seismic loading is considered, are highly computationally intensive tasks since, in order to obtain the structural behaviour, a large number of dynamic analyses (e.g., modal response spectrum analysis or nonlinear timehistory analysis) are required (Papadrakakis, Tsompanakis, Lagaros, & Fragiadakis, 2004). In this work, two metamodel based applications are considered in order to reduce the aforementioned computational cost. The efficiency of a trained NN is demonstrated, where a network is used to predict maximum interstory drift values due to different sets of random variables. As soon as the maximum interstory drift is known, the limit-state probabilities are calculated by means of Monte Carlo simulation (MCS). In the first application the probability of exceedance of a limit-state is obtained using proposed by Eurocode 8 (1994). Multimodal Response Spectrum Analysis is. In the second application fragility analysis of a 10-story moment resisting steel frame is evaluated, where limit-state fragilities are determined by means of nonlinear timehistory analysis.

In both applications considered in this chapter, the use of NNs is motivated by the large number of time-consuming simulations required by MCS. The Rprop algorithm is implemented for training the NN, utilizing available information extracted from each record. The trained NN is used to predict maximum interstory drift values, leading to a close prediction of the limit-state probabilities.
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