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Developing fragility curves based on neural network IDA predictions

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ABSTRACT

A Soft Computing (SC) based framework for the fragility assessment of 3D buildings is proposed in this work. The computational effort required for a fragility analysis of structural systems can become excessive, far beyond the capability of modern computing systems, especially when dealing with real-world structures. For the purpose of making attainable fragility analyses, a Neural Network (NN) implementation is presented in this work, which can provide accurate predictions of the structural response at a fraction of computational time required by a conventional analysis. The main advantage of using NN predictions is that they can deal with problems, without having an algorithmic solution or with an algorithmic solution that is too complex to be found. The proposed methodology is applied to 3D reinforced concrete buildings where it was found that with the proposed implementation of NN, a reduction of one order of magnitude is achieved in the computational effort for performing a full fragility analysis.

1. Introduction

Structural analysis methods were based on rigorous scientific procedures that are formed on the principles of theoretical mechanics and mathematical methods and led to the implementation of numerical simulation methods based on discretized continua. However, three decades ago, a new family of computational methods, denoted as soft computing (SC) methods, have been proposed. These methods are based on heuristic approaches rather than on rigorous mathematics. Despite the fact that these methods were initially received with suspicion, they have turned out, in many cases, to be surprisingly powerful, while their use in various areas of engineering science is continuously growing. Neural Networks (NN), Metaheuristics and Fuzzy Logic are the most popular SC methods.

Over the past decades, risk management of structural systems has gained the attention of various economic and technical decision centres in modern society. The optimal allocation of the public resources for a sustainable economy requires proper tools for estimating the consequences of natural hazardous events on the built environment. The risk management addresses this claim indicating the way for implementing optimal choices. Risk assessment and decision analysis are the main steps of the risk management concept. A lot of research work has been published in an effort to establish a reliable procedure for assessing the seismic risk of structural systems. Seismic fragility analysis, which provides a measure of the safety margin for the structural system, is considered as the main ingredient of the risk assessment procedure.

A number of methodologies for performing fragility analysis of structural systems have been proposed in the past. Kennedy et al. [1] presented a methodology for determining the probability of earthquake induced radioactive releases. Kircher et al. [2] described building damage functions that were developed for the Federal Emergency Management Agency by the National Institute of Building Sciences (FEMA/NIBS) earthquake loss estimation methodology. Shinozuka et al. [3] presented a statistical analysis procedure of structural fragility curves. The significance of inherent randomness and modelling uncertainty in forecasting the building performance was examined by Ellingwood [4] through the fragility assessment of a steel frame. In the work by Shinozuka et al. [5], fragility curves were developed in order to determine the effect of earthquakes on the performance of transportation network systems. The importance of fragility analysis in various stages of consequence based engineering was indicated by Wen and Ellingwood [6]. A procedure to account for the uncertainty in the characteristics of future ground motions during seismic response assessment was presented in the work by Aslani and Miranda [7]. Fragility functions were developed by Pagni and Lowes [8] to identify the method to repair older reinforced concrete beam–column joints damaged due to earthquake loading. A methodology for the risk assessment of reinforced concrete and unreinforced masonry structures was presented by Kappos et al. [9], while Jeong and Elnashai [10] presented an approach where a set of fragility relationships with known reliability is derived based on the fundamental response quantities of stiffness,

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