Machine Learning Techniques in Seismic Risk Assessment of Structures

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Abstract : The main objective of this work is to evaluate the advantages and disadvantages of various machine learning techniques in two key steps of seismic hazard and risk assessment of different types of structures. The first step is the development of ground-motion models, which are used for forecasting ground-motion intensity measures (IM) given source characteristics, source-to-site distance, and local site condition for future events. IMs such as peak ground acceleration and velocity (PGA and PGV, respectively) as well as 5% damped elastic pseudospectral accelerations at different periods (PSA), are indicators of the strength of shaking at the ground surface. Typically, linear regression-based models, with pre-defined equations and coefficients, are used in ground motion prediction. However, due to the restrictions of the linear regression methods, such models may not capture more complex nonlinear behaviors that exist in the data. Thus, this study comparatively investigates potential benefits from employing other machine learning techniques as statistical method in ground motion prediction such as Artificial Neural Network, Random Forest, and Support Vector Machine. The results indicate the algorithms satisfy some physically sound characteristics such as magnitude scaling distance dependency without requiring pre-defined equations or coefficients. Moreover, it is shown that, when sufficient data is available, all the alternative algorithms tend to provide more accurate estimates compared to the conventional linear regression-based method, and particularly, Random Forest outperforms the other algorithms. However, the conventional method is a better tool when limited data is available. Second, it is investigated how machine learning techniques could be beneficial for developing probabilistic seismic demand models (PSDMs), which provide the relationship between the structural demand responses (e.g., component deformations, accelerations, internal forces, etc.) and the ground motion IMs. In the risk framework, such models are used to develop fragility curves estimating exceeding probability of damage for pre-defined limit states, and therefore, control the reliability of the predictions in the risk assessment. In this study, machine learning algorithms like artificial neural network, random forest, and support vector machine are adopted and trained on the demand parameters to derive PSDMs for them. It is observed that such models can provide more accurate estimates of prediction in relatively shorter about of time compared to conventional methods. Moreover, they can be used for sensitivity analysis of fragility curves with respect to many modeling parameters without necessarily requiring more intense numerical response-history analysis.

Keywords : artificial neural network, machine learning, random forest, seismic risk analysis, seismic hazard analysis, support vector machine
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