Machine Learning Techniques for Estimating Ground Motion Parameters

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Abstract : The main objective of this study is to evaluate the advantages and disadvantages of various machine learning techniques in forecasting ground-motion intensity measures given source characteristics, source-to-site distance, and local site condition. Intensity measures 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. Estimating these variables for future earthquake events is a key step in seismic hazard assessment and potentially subsequent risk assessment of different types of structures. 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 a statistical method in ground motion prediction such as Artificial Neural Network, Random Forest, and Support Vector Machine. The algorithms are adjusted to quantify event-to-event and site-to-site variability of the ground motions by implementing them as random effects in the proposed models to reduce the aleatory uncertainty. All the algorithms are trained using a selected database of 4,528 ground-motions, including 376 seismic events with magnitude 3 to 5.8, recorded over the hypocentral distance range of 4 to 500 km in Oklahoma, Kansas, and Texas since 2005. The main reason of the considered database stems from the recent increase in the seismicity rate of these states attributed to petroleum production and wastewater disposal activities, which necessities further investigation in the ground motion models developed for these states. Accuracy of the models in predicting intensity measures, generalization capability of the models for future data, as well as usability of the models are discussed in the evaluation process. 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.

Keywords : artificial neural network, ground-motion models, machine learning, random forest, support vector machine
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