Development of Seismic Fragility Curves for RC/MR Frames using Machine Learning Methods

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Research aim: Estimating seismic fragility curves provides significant assistance in quantitatively evaluating the earthquake vulnerability of structures. The objective of using machine learning techniques to estimate the parameters of fragility curves is to minimize computational costs while ensuring acceptable accuracy. Several studies have been conducted to implement machine learning methods for estimating the structural fragility curves. However, the selected datasets in these studies only include the considered ground motion characteristics. No attention has been given to the structural attributes and the location of construction in the datasets, and the analyses have been limited to a specific structure.

Research method: In this study, machine learning methods are employed to develop seismic fragility curves based on the structural period and the location of construction. Unlike previous studies that often relied on a fixed intensity measurement vector for model training, this research utilizes the Recursive Feature Elimination with Cross-Validation (RFECV) algorithm to identify the most relevant seismic features for each algorithm. In the initial phase of this study, a machine learning method is employed to develop seismic fragility curves for Reinforced Concrete Moment-Resisting (RC/MR) frames. The frames are categorized into three height groups (low-rise, mid-rise, and highrise) and three damage levels (slight, moderate, and extensive) based on the HAZUS classification. The mentioned method has been applied to a dataset consisting of selected ground motions using the Generalized Conditional Intensity Measure (GCIM) method. Seven machine learning algorithms are used to construct the predictive model, including decision tree, logistic regression, naive Bayes, support vector machine, random forest, gradient boosting, and XGBoost. The SMOTE-ENN sampling method has been utilized to balance the training data and mitigate potential result bias. In the second phase of this research, the approach of selecting ground motions has been reviewed to tackle the issue of high computational costs in data preparation. For this purpose, the magnitude of the earthquake, the distance from the seismic source, and the shear velocity are considered the most important attributes, which are collectively referred to as the code-based method.

Findings: To validate the estimated fragility curves from the machine learning approach, analytical fragility curves have been determined using the Multiple Stripe Analysis (MSA) method for a 5-story structure at three damage levels. These analytical curves have been compared to the machine learning-based fragility curves. The results indicate that the percentage of the area enclosed between the analytical and machine learning-based curves, relative to the area under the analytical curve, is less than 10% for the GCIM method and less than 5% for the code-based method. In addition, to provide a comprehensive evaluation, fragility curves have been generated for 8-story and 20-story regular structures, an 8-story vertical mass-irregular structure, and a 3-story structure with mass irregularity in plan using both the machine learning approach and the analytical method. The results have been compared using Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and enclosed area ratio.

Conclusion: The findings indicate that, except for torsional structures, the period of the structure alone serves as a sufficient feature of structures for generating the fragility curve using the machine learning method. In torsional structures, consideration of other features such as the percentage of mass eccentricity is also deemed necessary in addition to the period.

Keywords: Machine learning; Fragility curve; Multiple stripes analysis; GCIM method, Reinforced concrete structure.