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A NEURAL NETWORK-BASED METHOD FOR PREDICTING SEISMIC RESPONSE OF STRUCTURES

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Simulating and predicting the realistic behavior of structures subjected to seismic excitations has been one of the most cited topics in structural issues over recent years. Accordingly, an accurate estimation of the seismic displacement demands requires solving the governing differential equation of motion either analytically or numerically (i.e. time-history analysis) for the given ground motion. However, the aleatoric variability and epistemic uncertainty in earthquake records can result in a significant variability in seismic structural response. Therefore, the precise assessment of the maximum lateral displacement of structures requires solving numerous differential equations for a large number of earthquakes. However, the analytical procedure is time consuming and computationally intensive.

On the other hand, data-driven modeling techniques have been widely utilized in reducing the computational burden of numerous Civil Engineering problems (Hola and Schabowicz, 2005; Schmid and Schmid, 2007; Joghataie and Farrokh, 2008; Mortezaei and Mortezaei, 2012; Sahoo and Chakraverty, 2018). As simplified mathematical models of human brain, supervised Artificial Neural Networks (ANNs) can be considered as parallel computing systems capable of input-output mapping aiming at simulating the desired output by only using the information generated from past experiences (Lazarevska, 2014).

Therefore, the current paper proposes the novel idea of the application of Wavelet Neural Networks (WNNs) for rapid and precise seismic response assessment of structures using ground motion indices. To achieve this objective, a wavelet activation function is considered as the nonlinear estimator of a classic multi-layer feed forward neural network to predict the maximum lateral displacement of simplified lumped mass models subjected to real unidirectional seismic excitations.

For this purpose, 23 different acceleration-, velocity- and displacement-related ground motion intensity measures are selected and calculated for a large dataset of real earthquake records. Nonlinear time-history analyses are then carried out to determine the maximum nonlinear horizontal response of different inelastic spring-mass SDOF systems. The studied seismic parameters are listed in Table 1.

The WNN models' parameters are then calibrated by employing different input and output pairs of training dataset, aiming at estimating the associated target pattern of data which were not applied in the training process. Accordingly, sensitivity analyses are also conducted to determine the relative importance of the seismic parameters in characterizing damage potential of the studied structural systems.

The feasibility, efficiency and accuracy of the proposed technique are investigated in determining the corresponding seismic behavior of structures caused by earthquake accelerograms. Based on the obtained results from sensitivity analysis, the seismic parameters of DI, D_s, SED, CAV and I_H have higher levels of interdependency with the maximum structural response of the inelastic mass-spring system with the frequency of 0.5 Hz. Therefore, displacement- and energy-related parameters have stronger correlation with displacement demands of long-period structures, compared to acceleration- and velocity-related variables.

Table 1. The examined ground motion intensity indices (Mashmouli et al., 2019).

Description of Intensity			
Acceleration-related parameters	Velocity-related parameters	Displacement-related parameters	Other parameters
Peak Ground Acceleration (PGA)	Peak Ground Velocity (PGV)	Peak Ground Displacement (PGD)	Arias Intensity (I_A)
Acceleration Intensity (AI)	Velocity Intensity (VI)	Displacement Intensity (DI)	Housner Intensity (I_H)
Earthquake Power Index Acceleration (PI_A)	Earthquake Power Index Velocity (PI_V)	Earthquake Power Index Displacement (PI_D)	Peak Velocity and Acceleration ratio (PGV/PGA)
Square Acceleration (A_S)	Square velocity (V_S)	Square Displacement (D_S)	Specific Energy Density (SED)
Root Mean Square Acceleration (A_{RMS})	Root Mean Square Velocity (V_{RMS})	Root Mean Square Displacement (D_{RMS})	Characteristic Intensity (I_C)
Root Square Acceleration (A_{RS})	Root Square Velocity (V_{RS})		Cumulative Absolute Velocity (CAV)

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