17th Symposium on Earthquake Engineering
November 14-17, 2022
IIT Roorkee, India
Paper No. 401

ROSERS - A Deep Learning Framework for Earthquake Early Warning and its Interpretation

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Abstract

Earthquake early warning (EEW) systems are swiftly evolving from standalone physics-inferred methods (requiring computationally expensive inversions in real-time) to data-driven strategies for efficient earthquake hazard mitigation in real-time. Besides being speedy in prediction, data-driven approaches such as artificial neural networks usually require minimal assumptions in the training and execution processes. This study discusses and attempts to interpret the data driven EEW framework: ROSERS (Real-Time On-Site Estimation of Response Spectra) proposed by Fayaz and Galasso (2022). ROSERS aims to utilize the early non-damaging p-waves and the recording site characteristics to predict the acceleration response spectrum ($S_a(T)$) of the anticipated on-site ground motion waveform. The framework's efficacy is analyzed using an extensive database of ground motions, and it is observed that ROSERS leads to exceptional prediction power when implemented in a real-time backdrop. To provide a better interpretation of the framework, this study utilizes the concepts of explainable artificial intelligence (i.e., Shapley additive explanation, SHAP) to obtain insights into the decision-making process of the trained neural networks. Particularly, the cause-effect relationship of the computed latent variables and $S_a(T)$ is explored. The analyses showcase that the two latent variables of the framework complement each other in capturing stiff short-period and flexible long-period $S_a(T)$ thereby leading to excellent reconstruction power.

Keywords: Variational autoencoders, Neural networks, Earthquake early warning, Explainable artificial intelligence, Model-agnostic interpretability