An Enhanced Earthquake Early Warming System based on Deep Learning and Multi-station Data

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Earthquakes are natural disasters that can result in significant destruction and losses. As such, establishing and applying earthquake early warning models are crucial, providing a valuable time window for people to take timely measures before the earthquake occurs. However, since early warning systems are typically at the national level and require careful handling during dissemination, accuracy becomes the major consideration.

Current seismic intensity estimation models can mainly be classified into onsite early warning modeling and regional early warning modeling. For the former, each station operates independently, deciding whether to issue an alert only after receiving the p-wave signal. While the school of methods offers satisfactory accuracy, they usually suffer from shorter leading times. The alternative is regional early warning modeling, which involves various implementations. One of the advantages of regional simulation is that even if only one station receives earthquake signals, earthquake predictions can be made at different locations, and warnings can be promptly issued for these locations if needed. As a result, it extends the lead time for early warnings. Nevertheless, these approaches usually encounter challenges in maintaining high accuracy.

Machine learning is a rapidly developing scientific field, and the domain of deep learning, in particular, has sped up advancements across various research subjects. In the context of seismic research, most of the research concentrates on the onsite approaches, and only limited literature has been studied on regional earthquake early warning (EEW) models using deep learning. However, the relationships among multiple stations may bear value.

In order to harness the power of current technology and leverage the relationships among stations, this study focuses on proposing a regional early warning framework. Our contributions are at least twofold. First, a novel deep learning-based regional early warning model is proposed by leveraging multi-station data. Second, beyond fundamental acceleration waveforms, background knowledge and statistics from history are also considered in the model. Third, a waveform filtering module is introduced to address the possible presence of low-quality waveforms within real systems so as to make the model more robust. By implementing the aforementioned model in practical operations, our system gathers real-time waveform data from stations across the entire region. It then proceeds to forecast the seismic intensity of forthcoming earthquakes in diverse areas. In the end, we evaluate our model using Taiwan as an example. Experiments show that the proposed framework can obtain superior results. Compared to conventional onsite methods, our framework improves leading time by more than 2 seconds on average.

References:

A. Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones, A. N. Gomez, Ł. Kaiser, and I. Polosukhin, “Attention is all you need,” Advances in neural information processing systems, vol. 30, 2017. https://doi.org/10.48550/arXiv.1706.03762

J. Münchmeyer, D. Bindi, U. Leser, and F. Tilmann, “The transformer earthquake alerting model: A new versatile approach to earthquake early warning,” Geophysical Journal International, vol. 225, no. 1, pp.

646–656, 2021.
C.-T. Lee and B.-R. Tsai, “Mapping vs30 in taiwan,” TAO: Terrestrial, Atmospheric and Oceanic Sciences, vol. 19, no. 6, p. 6, 2008. https://doi.org/10.1093/gji/ggaa609
Y.-M. Wu, H. Mittal, D.-Y. Chen, T.-Y. Hsu, P.-Y. Lin, “Earthquake Early Warning Systems in Taiwan: Current Status” Journal Geological Society of India, vol.97, pp. 1525-1532, 2021. https://doi.org/10.1007/s12594-021-1909-6
D. M. Boore, G. M. Atkinson, “Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s,” Earthquake Spectra, vol. 14, no. 1, p. 99, 2008. https://doi.org/10.1193/1.2830434

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