EGU2020-5107
https://doi.org/10.5194/egusphere-egu2020-5107
EGU General Assembly 2020

End-to-end PGA estimation for earthquake early warning using transformer networks

Jannes Münchmeyer[1,2], Dino Bindi[1], Ulf Leser[2], and Frederik Tilmann[1,3]
[1]Helmholtz Centre Potsdam German Research Centre for Geosciences - GFZ, Potsdam, Germany
[2]Institut für Informatik, Humboldt-Universität zu Berlin, Berlin, Germany
[3]Institut für geologische Wissenschaften, Freie Universität Berlin, Berlin, Germany

The key task of earthquake early warning is to provide timely and accurate estimates of the ground shaking at target sites. Current approaches use either source or propagation based methods. Source based methods calculate fast estimates of the earthquake source parameters and apply ground motion prediction equations to estimate shaking. They suffer from saturation effects for large events, simplified assumptions and the need for a well known hypocentral location, which usually requires arrivals at multiple stations. Propagation based methods estimate levels of shaking from the shaking at neighboring stations and therefore have short warning times and possibly large blind zones. Both methods only use specific features from the waveform. In contrast, we present a multi-station neural network method to estimate horizontal peak ground acceleration (PGA) anywhere in the target region directly from raw accelerometer waveforms in real time.

The three main components of our model are a convolutional neural network (CNN) for extracting features from the single-station three-component accelerograms, a transformer network for combining features from multiple stations and for transferring them to the target site features and a mixture density network to generate probabilistic PGA estimates. By using a transformer network, our model is able to handle a varying set and number of stations as well as target sites. We train our model end-to-end using recorded waveforms and PGAs. We use data augmentation to enable the model to provide estimations at targets without waveform recordings. Starting with the arrival of a P wave at any station of the network, our model issues real-time predictions at each new sample. The predictions are Gaussian mixtures, giving estimates of both expected value and uncertainties. The model can be used to predict PGA at specific target sites, as well as to generate ground motion maps.

We analyze the model on two strong motion data sets from Japan and Italy in terms of standard deviation and lead times. Through the probabilistic predictions we are able to give lead times for different levels of uncertainty and ground shaking. This allows to control the ratio of missed detections to false alerts. Preliminary analysis suggest that for levels between 1%g and 10%g our model achieves multi-second lead times even for the closest stations at a false-positive rate below 25%. For an example event at 50 km depth, lead times at the closest stations with epicentral

distances below 20 km are 6 s and 7.5 s. This suggests that our model is able to effectively use the difference between P and S travel time and accurately assess the future level of ground shaking from the first parts of the P wave. It additionally makes effective use of the information contained in the absence of signal at other stations.