Earthquake warning system: Detecting earthquake precursor signals using deep neural networks

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In the earth sciences, earthquake prediction is one of the great unsolved problems. Despite decades of research attempting to identify earthquake precursors, there is no proven analytical method to predict earthquakes before they occur. The problem is challenging as there is no discernable signal in the seismic waveform prior to an earthquake. The data are multidimensional, so it is hard for humans to analyze. Moreover, there are a large number of signal processing algorithms that can be applied to the raw data, so choosing the optimum input data is difficult.The application of deep learning is rare in the literature, and therefore may offer a new avenue for research (e.g., Wang et al., 2017; Lipski et al., 2017). Our project will attempt to create an earthquake warning system utilizing deep neural networks and the available real time seismic monitoring systems.

Data are available and easily accessible through publicly funded seismic station networks that monitor and catalog seismic events. The seismic catalogs include information about the time, location, and magnitude of each seismic event going back decades depending on the monitoring station. To create our training and validation data, we can use the catalog to pinpoint time intervals preceding earthquake events (e.g. the 20 minutes prior to an earthquake) from multiple seismic stations. Accessing the data is relatively simple, and can be automated using available libraries such as Obspy (Krischer et al., 2015).

The main focus of our research will be applying conventional neural network and sequence models. The raw data consists of time series data across multiple channels. Therefore, we will start with deep learning implementations and algorithms related to audio signals as it is the closest to our application. For example, Piczak (2015) applied conventional neural networks to classify environmental sounds. This work is particularly pertinent as the audio data is extremely noisy (similar to our application). Also, the WaveNet model used for speech synthesis (van den Oord et al., 2016) might be useful.

In addition, we plan to utilize a number of previous work related to machine learning and earthquake prediction as a starting point for the project. For example, Gupta and Shahani (2011) used fourier transforms and neural networks to estimate radon gas emissions from the earth as a type of earthquake precursor. Asim et al. (2017) predicted earthquake magnitudes from time series seismic data using several machine learning algorithms including recurrent neural network, random forest, and boosted ensemble classifier. Wang et al., (2017) employed a long short term memory network to consider the spatio-temporal correlations among earthquakes events. Finally, a number of projects related to earthquake prediction and neural networks exists in the internet that might be useful (e.g., Chu, 2018)

We will attempt to obtain a probability of the a chance of an earthquake occuring in the next few minutes near the monitoring station using data from the previous few minutes. Because this is a classification problem (earthquake will occur, or not occur), a simple confusion matrix can be used to evaluate the results.

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