Seismic Event Detection from Volcanic Regions using Feature Extraction and Deep Learning

Tavishi Priyam[1], Elizabeth Bradley[1,2], Anne Sheehan[3], Rey Koki[1]

1. Department of Computer Science, University of Colorado Boulder, 2. Department of Computer Science, Santa Fe Institute, 3. CIRES and Department of Geological Sciences, University of Colorado Boulder

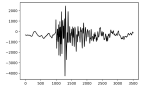
Background and Motivation

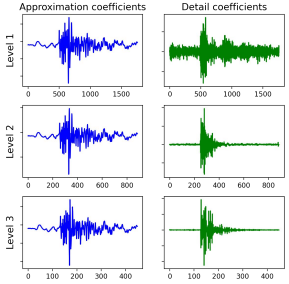
- Manual identification of the arrival times of P and S waves from seismometer data offers great precision but involves human bias and effort
- Deep-learning models can effectively automate this process, but they do not incorporate scientific knowledge, nor do they offer any understanding of the classification process
- By pre-processing the data into scientifically meaningful features and using them as input to deep-learning models, we hypothesize improved performance and understanding

Why Wavelet?

- Seismic events like earthquakes possess characteristic temporal signatures
- Templates [1] have been used to capture these signatures.
- Wavelets [2] are a good way to operationalize this for the purposes of feature engineering for ML methods.

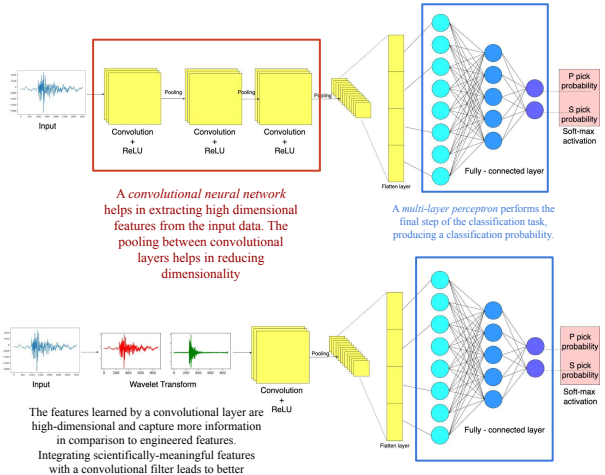
What a wavelet transform does!





The effect of this preprocessing step is not only to remove noise, but also more clearly expose the behavior of interest.

A Comparative Analysis



A *convolutional neural network* helps in extracting high dimensional features from the input data. The pooling between convolutional layers helps in reducing dimensionality

A *multi-layer perceptron* performs the final step of the classification task, producing a classification probability.

The features learned by a convolutional layer are high-dimensional and capture more information in comparison to engineered features. Integrating scientifically-meaningful features with a convolutional filter leads to better performance.

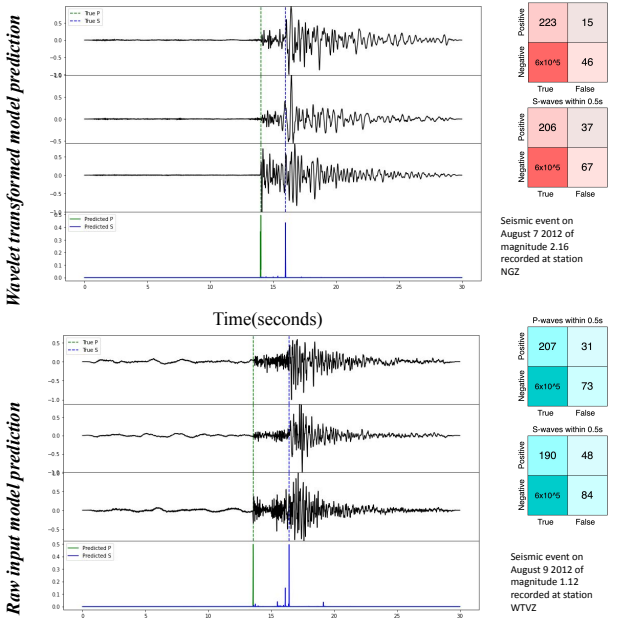
Details: One year of seismic data from the southern Taupo Volcanic Zone, New Zealand collected using a short-period seismometer with three component sensor aligned to North. Split into training and testing sets in a 70:30 ratio.

Future Work

- Explore more feature engineering mechanisms for the seismic waves such as continuous wavelet transform, fingerprints.
- Explore a neural network model that can retain memory such as Long Short Term Memory (LSTM).
- Build a model with the ability to classify the various kinds of earthquake events such as tremor and low-frequency earthquakes.

Results

- Model with featurized input exhibits better performance in terms of precision and proximity to the analyst-picked arrival times.
- Model with raw input is able to detect similar number of events but with lesser precision.



Scan the QR for more details!

[1] Dawei Mu, En-Jui Lee, Po Chen, Rapid earthquake detection through GPU-Based template matching, Computers & Geosciences, Volume 109, 2017, Pages 305-314, ISSN 0098-3004, https://doi.org/10.1016/j.cageo.2017.09.009.

[2] Adhikari, B., Dahal, S., Karki, M. *et al.* Application of wavelet for seismic wave analysis in Kathmandu Valley after the 2015 Gorkha earthquake, Nepal. *Geoenviron Disasters* 7, 2 (2020). https://doi.org/10.1186/s40677-019-0134-8