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

Tavishi Priyam, Elizabeth Bradley, Anne Sheehan

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

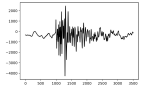
Background and Motivation

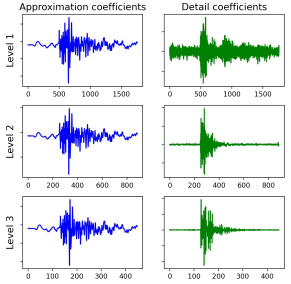
- Manual identification of the arrival times of P and S waves from seismometer data offers great precision but involves human bias and effort
- Deep-learning models can effectively automate this process, but they do not incorporate scientific knowledge, nor do they offer any understanding of the classification 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!



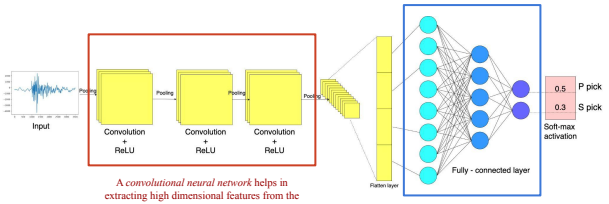


The effect of this preprocessing step is not only to remove noise, ut also more clearly expose the behavior of interest.

[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.

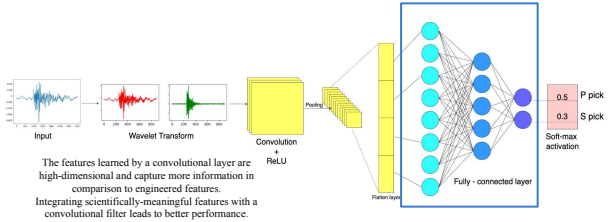
[2] Adhikari, B., Dahal, S., Karki, M. *et al.* Application of wavelet for seismic wave analysis in Kathmandu Valley after the 2015 Gorkha earthquake, Nepal. *Geoenviron Disasters* 7, 2 (2020). https://doi.org/10.1186/s40677-019-0134-8

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.

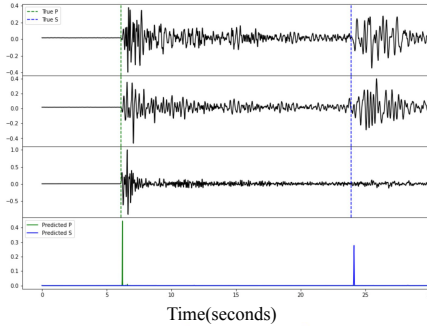
Future Work

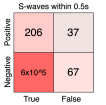
- Explore more feature engineering mechanisms for the seismic waves such as continuous wavelet transform, fingerprints.
- Explore a neural network model that can retain memory such as Long Short Term Memory (LSTM).
- Build a model with the ability to classify the various kinds of earthquake events such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

Results

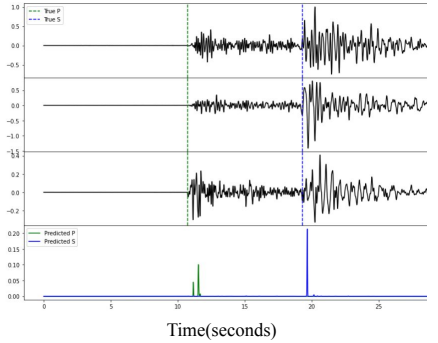
- Model with featurized input exhibits better performance in terms of precision and proximity to the analyst-picked arrival times.
- Model with raw input is able to detect similar number of events but with lesser precision.

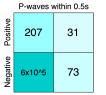
Wavelet transformed model prediction

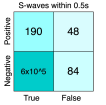




Raw input model prediction







Scan the QR for more details!