Impact of Focal Depth on Short-Term Earthquake Prediction using Deep Learning

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Introduction 1

- **Short term earthquake prediction** attempts to classify an earthquake right before it happens.
- Early-warning systems can help mitigate earthquake damage.
- Due to complexity of data, prediction is a difficult task
- Recurrent neural networks, LSTMs and convolutional neural networks have been used for earthquake prediction.
- Earthquakes can be classified by their depth. Shallow earthquakes are above the depth of 70km, while intermediate and deep earthquakes are below 70km [1]. There are differences in cause and resulting measurement [2].

Problem 2

"Are deep learning models better at predicting deep or shallow earthquakes?"

Use case: Deep and shallow earthquakes are corelated, training separate models can improve overall prediction [3], guide further research into properties of earthquakes that influence model performance.

Hypothesis: The shallow earthquake trained model will outperform the deep earthquake trained model.

Method 3

- Get equal number of pre-earthquake and normal background waveforms from the Geonet New Zealand dataset [4] .
- Preprocess earthquake seismic waveforms.
- Split dataset based on depth of 70km into 2 sets.
- Train the same model separately for these sets.
- Compare accuracy, precision and recall by training multiple times.

Terms

LSTM – Long Short Term Memory, a type of Recurring Neural Network

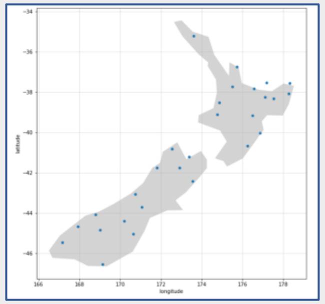

Figure 1. 28 measuring stations used

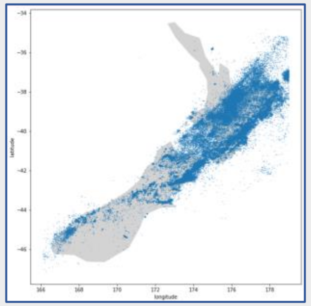

Figure 2. Earthquake data plotted

Data preparation 4

- Retrieved 30 seconds of waveform data 3 seconds before an earthquake, for every station
- Normal data taken 1000 seconds before the earthquake.
- Only earthquakes with magnitudes in the range [1,3] were used.
- Bad-performing and corrupted data prone measuring stations were filtered based on prediction accuracy. Final list of 28 (Figure 1).
- Downsampling waveforms from 100hz to 50hz, normalizing with L2 (Figure 3).
- Final number of 8037 deep/shallow earthquakes used for training.
- 70%, 20%, 10% training, test and validation split.

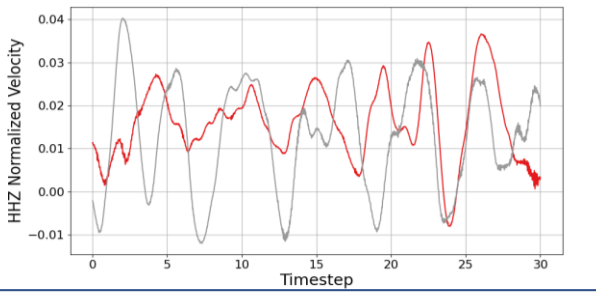

Figure 3. Processed waveform and model input

Model 5

- **T** seconds of waveform data is provided (Figure 4).
- Measurements from **N** stations provided.
- Input matrix of size (N x T).
- Binary output: did an earthquake happen after **H** seconds?
- **LSTM** network used due to prevalence in previous research and ability to deal with time series data.
- Dropout layer used to prevent overfitting.

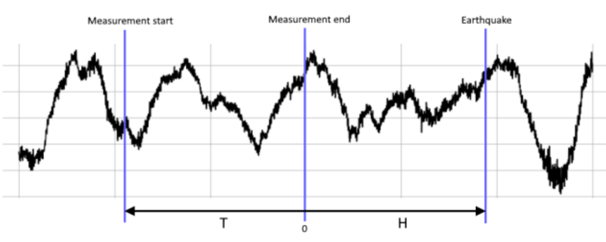

Figure 4. Measurement timeline

Results 6

- Averages taken from 20 training runs (Figure 5).
- Deep and shallow earthquake trained models showed similar accuracies and precision, with lower recall for deep model (Table 1).
- Precision was higher than the recall for both, showing difficulty in distinguishing low-magnitude earthquakes from background noise.

	Shallow			Deep		
Metric	Accuracy	Precision	Recall	Accuracy	Precision	Recall
Standard Deviation	0.006	0.014	0.012	0.006	0.026	0.017
Mean	0.869	0.924	0.804	0.850	0.923	0.766

Table 1. Comparison of shallow and deep model metrics

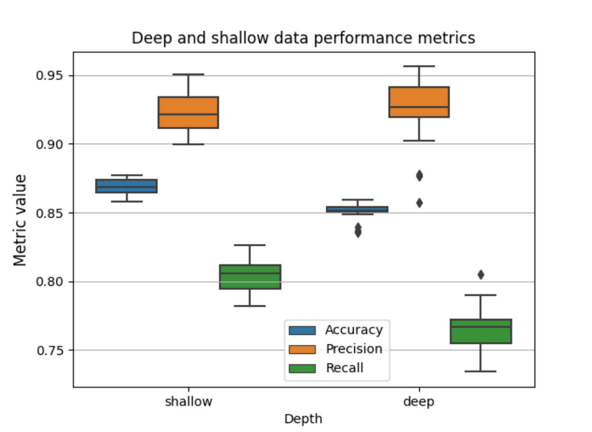

Figure 5. Box plot of test accuracy, precision, and recall. Collected from the same model trained separately 20 times

Conclusion and discussion 7

- Achieved results different from hypothesis, possibly caused by differences in magnitude between deep and shallow sets. Also used equal number of samples for both sets, which is not perceived in nature.
- Higher accuracy achieved than previous research on the same dataset, main difference in H value used and normalization.
- Results can not be conclusively generalized to all scenarios.
- Further research should involve using a different model, different earthquake region and changing the magnitudes considered.

References

[1] USGS, Determining the Depth of an Earthquake, n.d. [Online]. Available: https://www.usgs.gov/programs/earthquake-hazards/determining-depth-earthquake
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[3] K, Mogi, Relationship between shallow and deep seismicity in the western Pacific region, Tectonophysics,Volume 17, Issues 1–2, 1973, Pages 1-22
[4] FDSN web service for New Zealand. [Online]. Available: https://www.geonet.org.nz/data/tools/FDSN}. Accessed: April 20, 2022.