*Peer-Reviewed Structured Abstract*

# The Potential of Spiking Neural Networks in Predicting Earthquakes in New Zealand

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## Summary

This study investigates the use of Spiking Neural Networks (SNNs) in earthquake prediction, focusing on New Zealand, a seismically active region. Traditional earthquake prediction methods struggle with accuracy and real-time warning capabilities. SNNs, inspired by the brain's biological processes, excel at handling dynamic time-series data, making them a promising tool for tasks involving spatio-temporal patterns such as seismic waveforms. Utilizing the NeuCube platform, we processed seismic data from 56 stations across New Zealand in 2022. Our model achieved an accuracy increase from 38% to 70% as the seismic event approached, highlighting its potential for real-time earthquake monitoring. Although further optimization is required, this research demonstrates SNNs' potential in improving early earthquake warning systems. Future work will focus on refining the model's architecture and incorporating multimodal data to enhance prediction accuracy and applicability.

## Background

Earthquake prediction is a critical challenge in seismology, especially in high-risk regions like New Zealand, located along the Pacific Ring of Fire. Earthquakes in these areas can cause widespread damage, making early warning systems essential for minimizing loss of life and economic impacts. However, traditional prediction methods based on geological data often fail to provide accurate or timely warnings, particularly because of the complexity of seismic waveforms and the difficulties in extracting predictive patterns from noisy, time-dependent data [1][3][4][5]. Spiking Neural Networks (SNNs) offer a promising solution to this problem. Unlike conventional neural networks, SNNs process information as discrete events or spikes, similar to how biological neurons communicate. This allows them to better capture the spatio-temporal patterns inherent in seismic data [1][2]. Using the NeuCube platform, specifically designed for spatio-temporal processing, this research explores the potential of SNNs in improving earthquake prediction accuracy in New Zealand, aiming to address the limitations of traditional models [6][7].

## Methodology

The dataset for this study consists of seismic waveform data collected from 56 stations across New Zealand during 2022. It includes 13 major seismic events (above magnitude 5) and 13 minor ones (below magnitude 2), along with 24 hours of pre-event waveforms. The inclusion of both major and minor events ensures that the model can distinguish between different magnitudes of earthquakes.

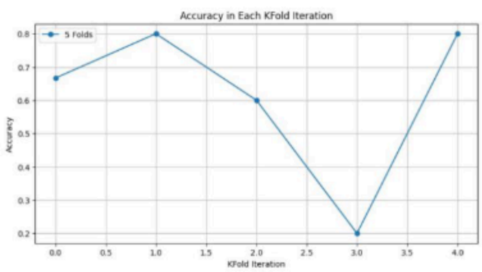
Data preprocessing involved using the ObsPy library to extract, filter, and normalize the raw seismic data. Low-frequency noise from environmental sources was removed using high-pass filters, and missing data points were filled through linear interpolation. This ensured the dataset was clean and consistent, providing a solid foundation for training the SNN model [11].

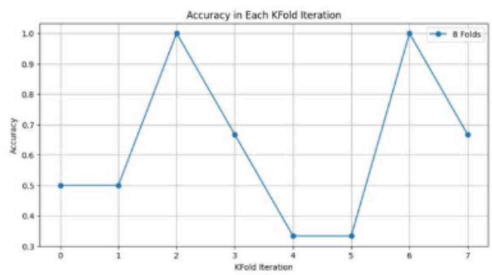
We implemented the model using NeuCube, a platform specifically designed for spatio-temporal data. Each seismic station was represented as a neuron within a three-dimensional space, allowing the network to account for both the spatial distribution of the stations and the temporal patterns in the data. The learning process relied on Spike-Timing-Dependent Plasticity (STDP) [1][8][9][10] a mechanism that adjusts connection strengths between neurons based on the timing of their spikes. The model was trained with 70% of the dataset, while 30% was reserved for testing and validation.

## Results and Observations

The model initially achieved a prediction accuracy of 38%, which improved to 70% as the seismic event approached. This suggests that SNNs are particularly effective at identifying early-warning signals in seismic waveforms, especially in the critical moments leading up to an earthquake. The NeuCube-enhanced SNN model captured complex temporal patterns that are often missed by traditional machine learning approaches, highlighting its potential for real-time monitoring and prediction.

Additionally, the neuron activation maps generated during testing indicated that the model was able to differentiate between major and minor seismic events. Major earthquakes triggered more concentrated and sustained neural activity, whereas minor events resulted in more scattered and intermittent activations. These results confirm that SNNs can distinguish between different earthquake magnitudes, an important feature for any effective early warning system.



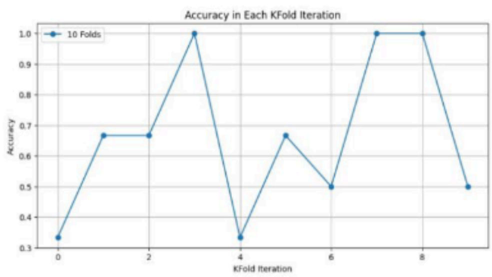



Fig. 1. Results of 5-fold, 8-fold, and 10-fold cross validation accuracy

Cross-validation using 5-fold, 8-fold, and 10-fold methods revealed some variability in accuracy, ranging from 30% to 100%, presented in Table. 1. This reflects the challenges of working with heterogeneous seismic data, which can vary significantly in terms of depth, location, and magnitude. Despite this variability, the model consistently showed improved accuracy as seismic events neared, reinforcing its applicability in early warning systems.

Table 1. Cross-Validation Result

| Cross-Validation | Confusion Matrix | Predicted Positive | Predicted Negative | Precision | Recall | Accuracy | F1 Score |
|---|---|---|---|---|---|---|---|
| 5-Fold | Actual Positive | 10 | 3 | 0.667 | 0.769 | 0.692 | 0.714 |
| | Actual Negative | 5 | 8 | | | | |
| 8-Fold | Actual Positive | 9 | 4 | 0.75 | 0.692 | 0.731 | 0.720 |
| | Actual Negative | 3 | 10 | | | | |
| 10-Fold | Actual Positive | 11 | 2 | 0.688 | 0.846 | 0.731 | 0.758 |
| | Actual Negative | 5 | 8 | | | | |

## Conclusion

This study demonstrates the potential of Spiking Neural Networks in improving earthquake prediction, particularly in seismically active regions like New Zealand. By leveraging the NeuCube platform's ability to process spatio-temporal data, the model showed significant improvement in accuracy as seismic events approached, reaching up to 70%. This suggests that SNNs are well-suited for capturing the complex, time-dependent patterns in seismic data that are critical for real-time earthquake monitoring and prediction.

However, further optimization of the model is needed to ensure more consistent results across varying datasets. Future work should focus on enhancing the model's architecture, incorporating additional data sources such as geological and environmental factors, and expanding the dataset to include more diverse seismic events. With continued development, SNNs could play a key role in the future of earthquake early warning systems, helping to mitigate the risks associated with natural disasters and save lives.

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