Seismic Phase Picking Automation Using an Implicit Model

Susana Haing[1], Alicia Y. Tsai[2], Lindsay Y. Chung[3]
[1]El Camino College, [2]University of California, Berkeley,
[3]Georgia Institute of Technology

Berkeley UNIVERSITY OF CALIFORNIA

El Camino College

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Abstract

Seismic phase picking is the crucial first step in earthquake monitoring. Traditional methods require trained analysts to manually identify signals from digital seismic data, which is labor intensive. Deep learning based automated phase pickers have revolutionized this process, showing high precision in detecting and classifying seismic phases, enhancing earthquake monitoring efficiency. However, deploying this on small, low-cost devices is challenging due to their computational requirements. Using an implicit model, we are able to train a more compact model, making it possible to use RaspberryShake devices, which are cheaper and smaller than traditional seismometers. Successful implementation of a compact deep neural network with an implicit model on RaspberryShake devices will enable various applications, such as urban environmental monitoring, early earthquake warning (EEW) systems, and scientific educational outreach.

Significance

- Seismic Phase Picking (SPP) is the first step to earthquake (EQ) monitoring but requires trained analysts
- Deep learning automates SPP, improving precision and efficiency
- Automated SPP has high computational requirements, making it unable to be deployed on small, low-scale devices
- Successful integration enables various applications: urban environmental monitoring, early earthquake warning systems (EEW), and scientific educational outreach

Project Goal

The goal of this project is to use an implicit model and determine whether it can be used to reduce the computational load of automated SPP.

Should the implicit model be applicable, it will then be applied to small scale devices such as RaspberryShake for EEW, EQ monitoring and more.

Previous research indicates that using deep learning to automate the picking of P-waves and S-waves has a similar precision to manual picking by human analysts[3]

Dataset & Analysis

The ETHZ[2] dataset comes from Switzerland's Swiss Seismological Service. Containing 36,743 waveform examples of seismic data points from several seismic networks and stations of which include: CH[2], C4[3], 8D[4], S[5], and XT[6] (Fig. 1).

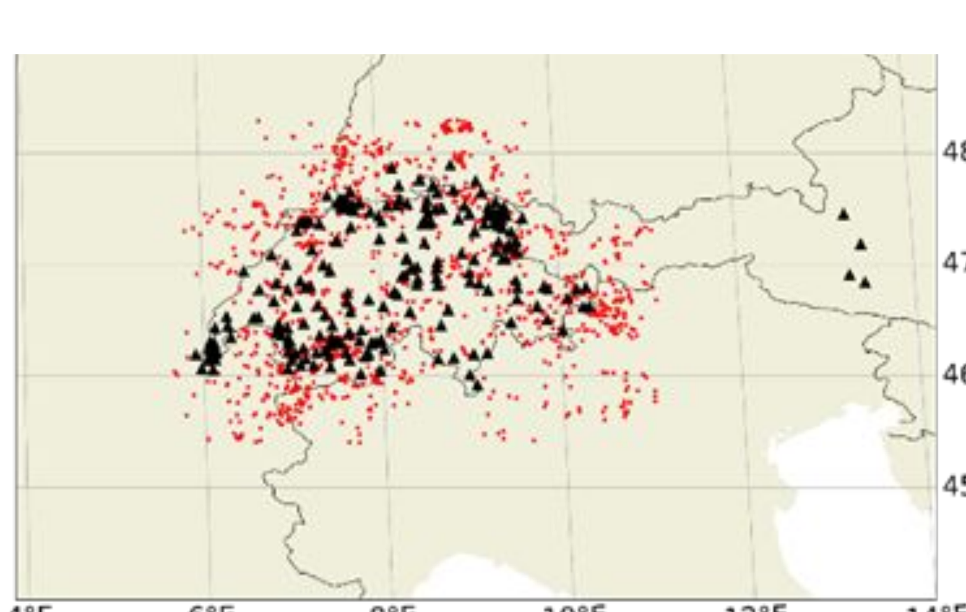

Figure 1. Dataset Mapping[1]

Methods

- Train and test the implicit model on the ETHZ benchmark public dataset on P-wave and S-wave traces
- Determine whether the model generates a reliable precision value based on its loss and error
- Compare the results to previous research and actual hand picked phase analysis
- Apply to RaspberryShake should it be applicable

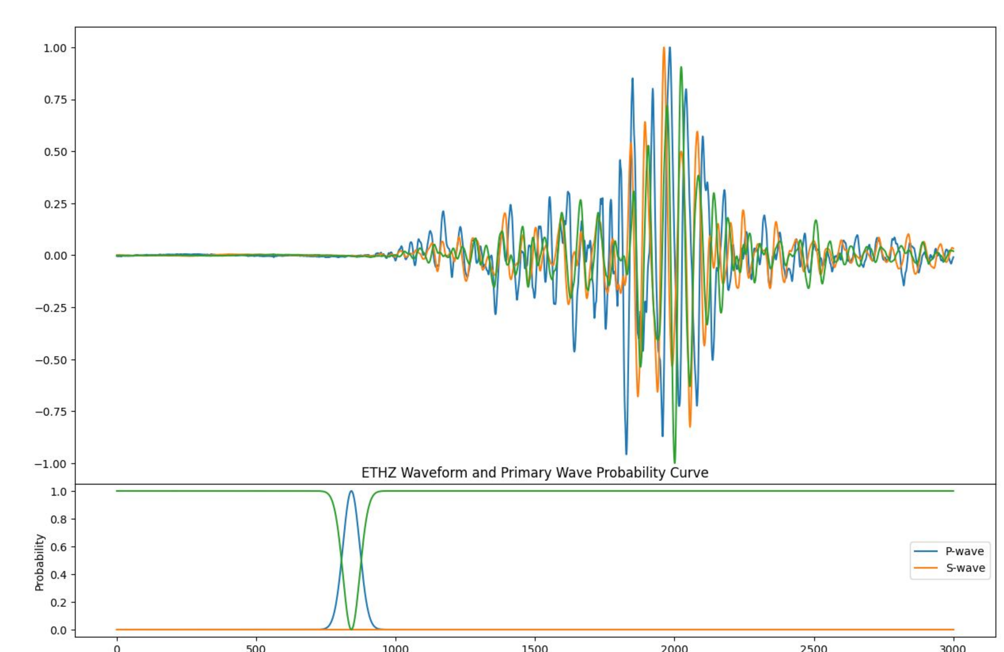

Figure 2. ETHZ Waveform and P-wave Probability Curve

Background

- The arrival time differences of Primary waves (P-waves) and Secondary waves (S-waves) can be used to determine an EQ's location (Fig. 3, 4)

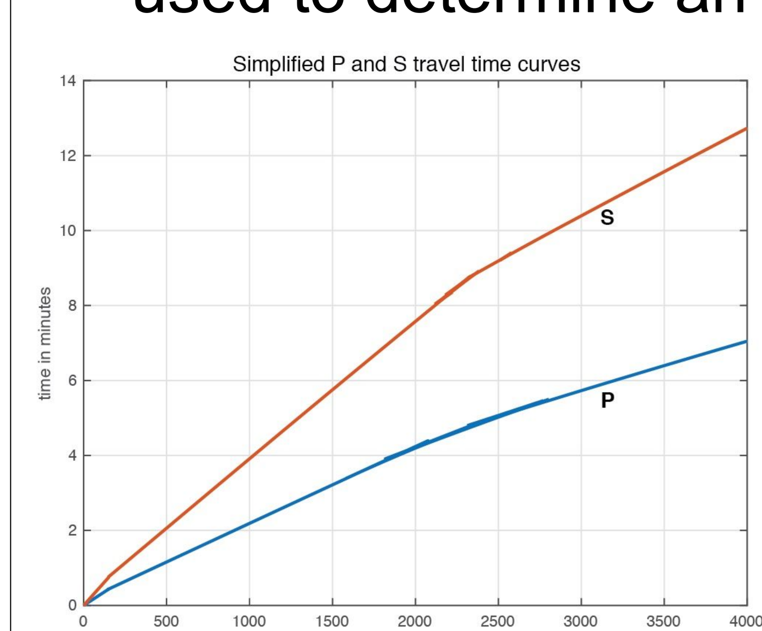

Figure 3. Simplified P and S wave travel curves[2]

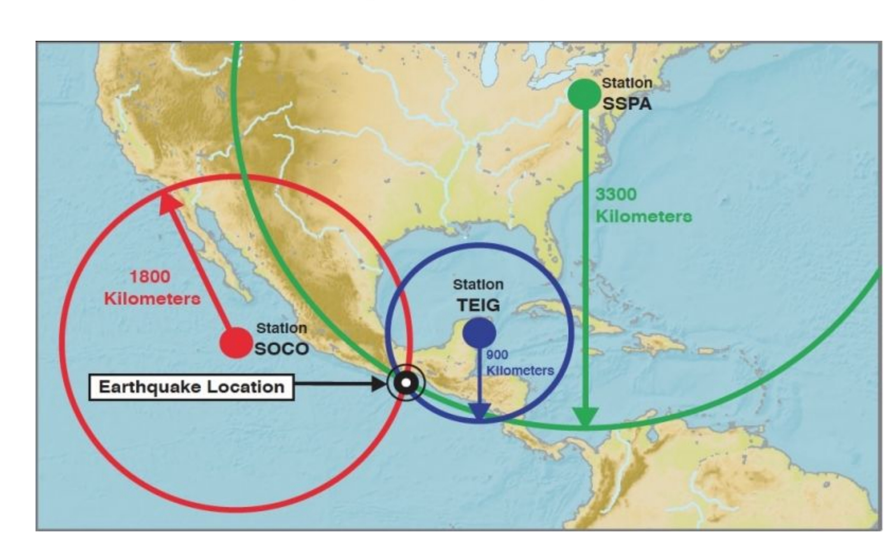

Figure 4. Triangulation of an earthquake using P-wave and S-waves[2]

References

[1]"SED | Waveform Data." http://www.seismo.ethz.ch/en/research-and-teaching/products-software/waveform-data/ (accessed Aug. 03, 2023).

[2]Seismology basics," *Google Docs*. https://docs.google.com/presentation/d/1cZe9c5_msXV_gGb4Ewvpf1T1sOHPY-AEFw-T2zh3fH8/edit?usp=embed_facebook (accessed Aug. 03, 2023).

[3]S. M. Mousavi, W. L. Ellsworth, W. Zhu, L. Y. Chuang, and G. C. Beroza, "Earthquake transformer—an attentive deep-learning model for simultaneous earthquake detection and phase picking," *Nat. Commun.*, vol. 11, no. 1, p. 3952, Aug. 2020, doi: 10.1038/s41467-020-17591-w.

Contact Information
haingqsusana@gmail.com

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