14 June 2022

Rapid Seismic Detection by Reformatting Phasenet

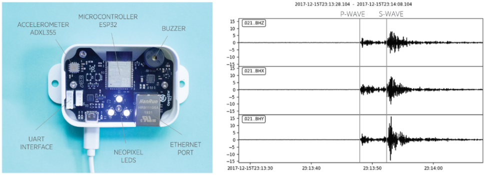
Xixiang Hu, Zhiyu Li, Qixuan Wu, Wen Xiang, Jiangchen Zhao

Introduction

An earthquake early warning system limits the impact of future earthquakes on communities living nearby. The system detects an earthquake at its very beginning and rapidly issues alerts to users in its path. The alert outpaces strong earthquake shaking and may provide critical time to take basic protective actions such as seeking cover or exiting a building.

Design

A seismic station is a device that records ground motion. The device records the ground acceleration in three components - two horizontal ones and one vertical (x, y, z).



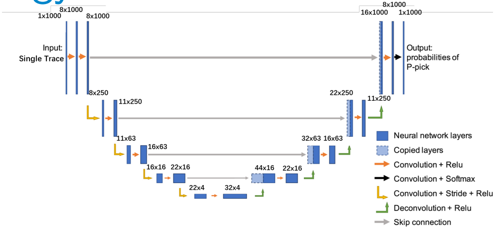
Once an earthquake occurs, it generates two kinds of waves (P-wave, S-wave) that penetrate the Earth as body waves. Each wave has a characteristic speed and style of motion.

Dataset

A network of about 20 Grillo instruments has been monitoring the southwest coast of Mexico since 2017. Grillo recorded segments with and without earthquake P-waves (a.k.a. signal and noise). And the task will be to train a model that can distinguish between them.

- Signal: Roughly 1,223 earthquake records from Grillo stations. Each record comes from a single seismic station, has 3 independent channels (x, y, z) and is 2000 data samples long. The records are centered at earthquake P-wave, which starts always at data sample 1,000.
- Noise: Randomly selected noise segments from the data and non-earthquake disturbances. There are 17,850 noise segments. Noise segments are also 2,000 data samples long.

Methodology



The architecture of PhaseNet is modified from U-Net (Ronneberger et al. 2015) to deal with 1-D time-series data. The mapping to our problem is to localize the properties of our time-series into three classes: P pick, S pick and noise. In our experiments, the input and output sequences contain 1000 data points for each component. The P and S arrival times are extracted from the first time the result value passing through the threshold.

Methodology

Focal loss is an improved version of cross-entropy which can handle the imbalance of classes. The formula of focal loss is:

$$FL(p_t) = -\alpha_t (1 - p_t)^\gamma log(p_t)$$

γ can be used to adjust the penalty to the misclassification of hard class. The higher γ is, the heavier the penality will be. After several experiments, we find that $\gamma = 3$ gives the best performance in this case.

Result

Evaluation Metrics:
$F1score = 2 * (Precision * Recall)/(Precision + Recall)$ where
$Precision = (TruePositives)/(TruePositives + FalsePositives)$
$Recall = (TruePositives)/(TruePositives + FalseNegatives)$

Successful earthquake detection is defined as with 3 seconds of the earthquake arrival.

	Noise	Earthquake
Noise	1778	2
Earthquake	4	106

$F1Score = 0.9383886255924171$

Conclusion

We have built a training data set using manually picked P and S arrival times from the data provided by Grillo. We have built our network based on PhaseNet, a deep neural network algorithm that uses three component waveform data to predict the probability distributions of P pick, S pick and noise.

Thank you for listening.