Progress Report 2: Designing a Low-Cost, Machine Learning-Based Early Earthquake Detection System for Developing Countries

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December 11, 2025

Objective: Set up fundamental framework for Machine Learning, optimize dual sensor setup.

finalize CAD of schematic before building,

Materials Finalization

During the past weeks, we have finalized our materials list, obtaining the exact brand and cost of each item. These items involve the PZT discs, Raspberry Pi 4, an amplifier, an analog to digital converter, frames, ESP dev board, MEMS accelerometer sensor module, and other various materials need to assemble the prototype. After confirming all the components align with each other and fit within the budget, we submitted our FUSE Funds application. Last Thursday, we received that our application was approved, so now we are in the process of ordering the materials and receiving them before winter break. Once we have all the materials, we will begin building the framework and setting up the prototype into it.

In the past weeks, we met with professors from Stanford University and Johns Hopkins University for deep discussions about the next steps in our project. We gained tons of insight, including articles from people who have worked on projects similar to ours at the University level. Our FUSE funds also got approved and processed. After this, in the coming weeks, we look forward to beginning the structural design process of our project, building the base of the design. In addition, we expect to be able to finish up assembling the electrical parts too, having a project finish date of about the beginning of the second semester. The CAD model will be finalized within the week to ensure a smooth construction of the electrical components. We will also begin to set the bounds to a fundamental machine learning framework to eventually implement into our design.

Sensor Architecture Progression

We have slightly shifted our approach into using a dual sensor model including a MEMS accelerometer module for picking up low frequencies ranging from 0-20hz typical of p-waves. This sensor setup allows us to broaden our scope of data that our initial immunosensor piezoelectric setup missed. Additionally, an article by Noda et al. (2016), stated that measuring high-frequency amplitude with respect to time provides rapid magnitude estimation for large scale earthquakes. Something the PZT piezoelectric sensor can do with its high frequency detection giving us a promising metric to go off. Overall, a dual sensor design addresses limitations to each sensor, and combing both into a singular system drastically improves robustness in noisy, real-world environments.

Machine Learning Model

After reviewing several approaches to building the ML model for this system, we have decided to utilize a 1D convolutional neural network to analyze the vibration data collected from the sensors. We chose the 1D CNN over other options as it was more suited for detecting crucial patterns such as sudden amplitude changes, repeating oscillations, and other signs of p-waves. We have the ML model structure planned out now as well. This involves preprocessing the raw waveform data which is essentially just preparing the sensor signal before it enters the model. Additionally, the model will create feature maps with the use of filters to display important patterns and overtime the classifier will be trained enough to distinguish between potential seismic events and other noises. To create an effective feature map, the model must have proper trained weights. Each filter contains a set of weights that the model uses during training. At first, these weights will be random values, then after constant exposure to the waveforms, it will gradually adjust to become a pattern detector. Lastly, we have chosen a few hyperparameters that involve filter size, number of layers, and evaluation metrics. Once the model is completed, it will be transferred from my computer to the Raspberry Pi 4.

In the next few weeks, we will obtain our materials, assemble the framework of the prototype, finish building the ML model and begin training it to become a proper patten detector. Additionally, we must test the various components within the system such as communication between the Raspberry Pi 4, ESP Dev Board, and the sensors.

References

Amini, A., & Soleimany, A. (Instructors). (2020). *6.S191: Introduction to deep learning* [Online course]. MIT OpenCourseWare. Massachusetts Institute of Technology. https://ocw.mit.edu/courses/6-s191-introduction-to-deep-learning-january-iap-2020/

Datta, Avoy. "DeepShake: Shaking Intensity Prediction Using Deep Spatiotemporal RNNs for Earthquake Early Warning." *ADS*, 1 May 2022, https://ui.adsabs.harvard.edu/abs/2022SeiRL..93.1636D/abstract.

LeCun, Y., & Bengio, Y. (1995). *Convolutional networks for images, speech, and time-series.* In M. A. Arbib (Ed.), *The handbook of brain theory and neural networks* (pp. 255–258). The MIT Press.

Noda, Shunta. "Rapid Estimation of Earthquake Magnitude from the Arrival Time of the Peak High-Frequency Amplitude." *USGS Home*, 1 Jan. 2016, https://pubs.usgs.gov/publication/70176044.