

# MACHINE LEARNING FOR FAST AND RELIABLE SOURCE- LOCATION ESTIMATION IN EARTHQUAKE EARLY WARNING

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**ABSTRACT-** We develop a random forest (RF) model for rapid earthquake location with an aim to assist earthquake early warning (EEW) systems in fast decision making. This system exploits P-wave arrival times at the first five stations recording an earthquake and computes their respective arrival time differences relative to a reference station (i.e., the first recording station). These differential P-wave arrival times and station locations are classified in the RF model to estimate the epicentral location. We train and test the proposed algorithm with an earthquake catalog from Japan. The RF model predicts the earthquake locations with a high accuracy, achieving a Mean Absolute Error (MAE) of 2.88 km. As importantly, the proposed RF model can learn from a limited amount of data (i.e., 10% of the dataset) and much fewer (i.e., three) recording stations and still achieve satisfactory results (MAE<5 km). The algorithm is accurate, generalizable, and rapidly responding, thereby offering a powerful new tool for fast and reliable source-location prediction in EEW.

## 1. INTRODUCTION

Earthquake hypocenter localization is essential in the field of seismology and plays a critical role in a variety of seismological applications such as tomography, source characterization, and hazard assessment. This underscores the importance of developing robust earthquake monitoring systems for accurately determining the event origin times and hypo center locations. In addition, the rapid and reliable characterization of on-going earthquakes is a crucial, yet challenging, task for developing seismic hazard mitigation tools like earthquake early warning (EEW) systems. While classical methods have been widely adapted to design EEW systems, challenges remain to pinpoint hypo center locations in real-time largely due to limited information in the early stage of earthquakes.

## 2. IDENTIFY, RESEARCH AND COLLECT IDEA

Among various key aspects of EEW, timeliness is a crucial consideration and additional efforts are required to further improve the hypocenter location estimates with minimum data from the first few seconds after the P-wave arrival and the first few seismograph stations that are triggered by the ground shaking. The localization problem can be resolved using a sequence of detected waves (arrival times) and locations of seismograph stations that are triggered by ground shaking. Among various network architectures, the recurrent neural network (RNN) is capable of precisely extracting information from a sequence of input data, which is ideal for handling a group of seismic stations that are triggered sequentially following the propagation paths of seismic waves. This method has been investigated to improve the performance of real time earthquake detection and classification of source characteristics. Other machine learning based strategies have also been proposed for earthquake monitoring. Comparisons between traditional machine learning methods, including the nearest neighbor, decision tree, and the support vector machine, have also been made for the earthquake detection problem. However, a common issue in the aforementioned machine learning based frameworks is that the selection of input features often requires expert knowledge, which may affect the accuracy of these methods. Convolution neural networks based clustering methods have been used to regionalize earthquake epicenters or predict their precise hypo center locations. In the latter case, three-component waveforms from multiple stations are exploited to train the model for swarm event localization. In this study, we propose a RF-based method to locate earthquakes using the differential P-wave arrival times and station locations. The proposed algorithm only relies on P-wave arrival times detected at the first few stations. Its prompt response to earthquake first arrivals is critical for rapidly disseminating EEW alerts. Our strategy implicitly considers the influence of

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the velocity structures by incorporating the source-station locations into the RF model. We evaluate the proposed algorithm using an extensive seismic catalog from Japan. Our test results show that the RF model is capable of determining the locations of earthquakes accurately with minimal information, which sheds new light on developing efficient machine learning.

### 3. PROPOSED APPROACH

The system proposes a RF-based method to locate earthquakes using the differential P-wave arrival times and station locations. The proposed algorithm only relies on P-wave arrival times detected at the first few stations. Its prompt response to earthquake first arrivals is critical for rapidly disseminating EEW alerts. Our strategy implicitly considers the influence of the velocity structures by incorporating the source-station locations into the RF model. The proposed system evaluates the proposed algorithm using an extensive seismic catalog from Japan. Our test results show that the RF model is capable of determining the locations of DATA CHARACTERISTICS

Test case is an object for execution for other modules in the architecture does not represent any interaction by itself. A test case is a set of sequential steps to execute a test operating on a set of predefined inputs to produce certain expected outputs. A manual test case is executed manually while an automated test cases is executed using automation. In system testing, test data should cover the possible values of each parameter based on the requirements. Since testing every value is impractical, a few values should be chosen from each equivalence class. An equivalence class is a set of values that should all be treated the same. Ideally, test cases that check error conditions are return separately from the functional test cases and should have steps to verify the error messages and logs. Realistically, if functional test cases are not yet written, it is ok for testers to check for error conditions when performing normal functional test cases. It should be clear which test data, if any is expected to trigger errors.

### 4. FUTURE WORK

To predict the early warning earthquakes are useful to save the human beings and alert the peoples for earthquakes. It decreases the harmful.

### 5. CONCLUSION

We use the P-wave arrival time differences and the location of the seismic stations to locate the earthquake in a real-time way. Random forest (RF) has been proposed to perform this regression problem, where the difference latitude and longitude between the earthquake and the seismic stations are considered as the RF output. The Japanese seismic area is used as a case of study, which demonstrates very successful performance and indicates its immediate applicability. We extract all the events having at least five P-wave arrival times from nearby seismic stations. Then, we split the extracted events into training and testing datasets to construct a machine learning model. In addition, the proposed method has the ability to use only three seismic stations and 10% of the available dataset for training, still with encouraging performance, indicating the flexibility of the proposed algorithm in real-time earthquake monitoring in more challenging areas. Despite the sparse distribution of many networks around the world, which makes the random forest method difficult to train an effective model, one can use numerous synthetic datasets to compensate for the shortage of ray paths in a target area due to insufficient catalog and station distribution.

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