

Design of Earthquake Detection Devices

Rintania E. Nuryaningsih

Department of Electrical
Engineering, Khairun
University, Ternate, Indonesia.
Jl. Jusuf Abdulrahman,
Gambesi, Kec. Ternate Selatan
Kota Ternate, Maluku Utara
rinta@gmail.com

Iswan La Baraja

Department of Electrical
Engineering, Khairun
University, Ternate, Indonesia
Jl. Jusuf Abdulrahman,
Gambesi, Kec. Ternate Selatan
Kota Ternate, Maluku Utara
iswanlabaraja91@gmail.com

Achmad P. Sardju

Department of Electrical
Engineering, Khairun
University, Ternate, Indonesia
Jl. Jusuf Abdulrahman,
Gambesi, Kec. Ternate Selatan
Kota Ternate, Maluku Utara
ahmadpsardju@unkhair.ac.id

Abstrak - Earthquakes are natural disasters that occur suddenly and can cause severe impacts, both in terms of structural damage and human casualties. To reduce the risks and consequences, an early warning system that provides rapid and accurate alerts is highly needed. This research aims to design and develop a simple yet effective earthquake detection device by utilizing the ESP32 microcontroller as the central processing unit. The system is equipped with an ADXL335 accelerometer sensor, which is capable of detecting vibrations or changes in acceleration along three main axes: X, Y, and Z. The sensor reads seismic activity and transmits the data to the ESP32 for real-time processing. When the detected vibration exceeds a predefined threshold, the system automatically activates a buzzer as an alarm and turns on three red LEDs as visual indicators. Each LED represents a level of earthquake intensity: mild, moderate, and strong. With these indicators, users can immediately recognize the severity of the earthquake and take prompt safety measures. The ESP32 not only processes data but also regulates the system's responses to operate efficiently. This device is designed for use in households or other small-scale environments, offering advantages such as low cost, easy installation, and the use of commonly available components. Therefore, this system is expected to serve as an alternative solution that contributes to enhancing community preparedness against earthquake hazards.

Keywords: Earthquake, ESP32, ADXL335, Buzzer, LED, Early detection

INTRODUCTION

As a country located in a region with high seismic activity, such as the Pacific Ring of Fire, Indonesia is often struck by earthquakes that result in significant loss of life and material damage. Although the National Disaster Management Agency (BNPB) has developed an Early Warning System (EWS) that has proven effective in some cases, such as earthquake management in Yogyakarta and Aceh, there are still weaknesses in this system. The lack of adequate education and early warnings leads to low public awareness of earthquake mitigation, which can ultimately exacerbate the impact of such disasters. Therefore, this research was initiated to explore potential innovations in earthquake early warning systems

that can be operated independently by the community, without relying on relevant agencies.

Considering the potential of Internet of Things (IoT) technology. In the design of an earthquake detection device [1] Based on data from the USGS and other sources, Indonesia has experienced over 160 earthquakes with a magnitude of 7.0+ on the Richter scale from 1900 to the present. Indonesia frequently experiences earthquakes and has a long history of destructive earthquakes. The earliest documented earthquake is the one from 1629, recorded in the Dutch East Indies records. Other major events continued to occur in each decade, the most significant being the earthquake in 1867 in Java, which destroyed many buildings and historical temples. [2] With technology continuing to advance rapidly, an example is the application of the Internet of Things (IoT) in earthquake detection. IoT itself is a concept that utilizes the internet to connect various devices. With the advent of IoT, this earthquake detection tool can operate automatically. With the availability of early warning technology that utilizes vibrations, it's possible for us to receive warnings a few seconds or minutes before a larger earthquake occurs. One solution to minimize this impact is to create an earthquake detection tool prototype using an ADXL335 accelerometer sensor based on the Internet of Things (IoT). This tool works by utilizing an accelerometer sensor that detects vibrations or shocks, which are then processed by ESP32 as a microcontroller and Telegram as an IoT-based monitoring dashboard thru notifications sent by a Telegram bot. A buzzer and LED indicator light are connected to the Telegram application to monitor earthquake alerts in real-time. [3] This research covers the design and implementation of an earthquake measuring device using ESP32 and Telegram based on IoT, with the aim of keeping up with the digital trends of the 4.0 era. Thru experimental studies conducted, this device was successfully programmed and tested, using components such as an earthquake sensor and ESP32. With the help of ESP32, SIGEMPA is able to detect earthquake activity and send real-time warning notifications via Telegram.

The advancement of hardware and software technologies makes it possible to use smartphones or

Internet of things for monitoring environments in realtime. In recent years, much effort has been made to develop a smartphone based earthquake early warning system, where low-cost acceleration sensors inside a smartphones are used for capturing earthquake signals. However, because a smartphone comes with a powerful CPU, spacious memory, and several sensors, it is waste of such resources to use it only for detecting earthquakes. Furthermore, because a smartphone is mostly in use during the daytime, the acquired data cannot be used for detecting earthquakes due to human activities. Therefore, in this article, we introduce a stand-alone device equipped with a low-cost acceleration sensor and least computing resources to detect earthquakes. To that end, we first select an appropriate acceleration sensor by assessing the performance and accuracy of four different sensors. Then, we design and develop an earthquake alert device. To detect earthquakes, we employ a simple machine learning technique which trains an earthquake detection model with daily motions, noise data recorded in buildings, and earthquakes recorded in the past. Furthermore, we evaluate the four acceleration sensors by recording two realistic earthquakes on a shake-table. In the experiments, the results show that the developed earthquake alert device can successfully detect earthquakes and send a warning message to nearby devices, thereby enabling proactive responses to earthquakes [4].

The device is also equipped with warning categories In an effort to increase awareness and minimize casualties from earthquakes. Therefore, a tool is needed to provide warnings and detect the occurrence of an earthquake. In this study, a prototype was created to detect earthquakes by utilizing WhatsApp message notifications. This prototype uses several modules such as Arduino Nano, ESP8266, SW 420 vibration sensor, ADXL335 accelerometer sensor, Buzzer, and LED. The ADXL335 accelerometer sensor detects vibrations and the direction of acceleration, while the SW 420 vibration sensor detects any vibrations. This data is then received and processed by Arduino UNO, and the results of the data calculation are forwarded to the ESP8266, which will then send it via WhatsApp. [5] The research objective is to produce an Internet of Things-based earthquake detection information system prototype using Telegram notifications.

State-of-the-art Earthquake Early Warning systems rely on a network of sensors connected to a fusion center in a client–server paradigm. The fusion center runs different algorithms on the whole data set to detect earthquakes. Instead, we propose moving computation to the edge, with detector nodes that probe the environment and process information from nearby probes to detect earthquakes locally. Our approach tolerates multiple node faults and partial network disruption and keeps

all data locally, enhancing privacy. This paper describes our proposal's rationale and explains its architecture. We then present an implementation that uses Raspberry, NodeMCU, and the Crowdquake machine learning model [7].

Traditional seismometers can precisely record earthquakes but are incapable of processing them on-site to initiate an alert and response mechanism. By contrast, internet of things (IoT) devices equipped with accelerometers and CPUs can record and detect earthquake signals in real time and send out alert messages to nearby users. However, the signals recorded on IoT devices are noisy because of two main factors: the urban buildings and structures these devices are installed in and their cost-quality trade-off. Therefore, in this work, we provide an effective mechanism to deal with the problem of false alarms in IoT devices. We test our previously proposed artificial neural network (ANN) with different feature window sizes ranging from 2 seconds to 6 seconds and with various earthquake intensities. We find that setting the size of the feature window to a certain interval (i.e., 4-5 seconds) can improve model performance. Moreover, an evacuation route guidance platform that considers user location is proposed. The proposed platform provides and visualizes information to user devices in real time through the communication between server and user devices. In the event of a disaster, safe shelters are selected on the basis of the information entered from the server, and pedestrian paths are provided. As a result, the direct and secondary damages caused by earthquakes can be avoided [8].

The detection of earthquakes in seismological time series is central to observational seismology. Generally, seismic sensors passively record data and transmit it to the cloud or edge for integration, storage, and processing. However, transmitting raw data through the network is not an option for sensors deployed in harsh environments like underwater, underground, or in rural areas with limited connectivity [9].

The Internet of Things (IoT) has been implemented to provide solutions for certain event detection because of ease of installation, computing and communication capability, and cost-effectiveness. Seismic event detection, however, is still a challenge due to a lack of high-fidelity sensing and classification efficiency. This study proposes BLESeis, an IoT sensor for smart earthquake detection. BLESeis comprises three main parts: (1) high-fidelity vibration sensing using a MEMS accelerometer and digital filtering; (2) an embedded earthquake detection algorithm; (3) BLE (Bluetooth low energy) beacon for earthquake notification. For high-fidelity vibration sensing, a triggering algorithm and embedded finite impulse response (FIR) low-pass filter are developed. The acquired vibration is then classified by the earthquake

detection algorithm developed to identify the earthquake signal from other vibration sources using time and frequency domain analysis. Upon detection of an earthquake, the BLE beacon broadcasts using the proposed data packet for efficient notification and visualization. The performance of the proposed system is evaluated through numerical simulations and a set of experiments using shaking table tests. The experiments show the feasibility of the low-cost earthquake detection and notification system [10].

Earthquake is a very big problem which causes damage to lives and property. Our project is a small step to save these losses by giving information about earthquake before it strikes, this device will depend on the motion in 3-D. As the motion in any of the three dimensions occurs LED display will start showing the figures here arduino uno is the central system which can be software tunable and we can implement signal processing through algorithm where we can define the limits of Motion in 3-D by Checking the data of earthquake from Indian meteorological department, how much magnitude of earthquake is disastrous setting those figures as upper limit in algorithm if figures of motion in any of the three dimensions is greater than the fixed upper limit figure LED light will start to glow and buzzer will start ringing. This three dimension motion will be detected by the MPU6050 sensor [11]. Earthquake is a vibration that occurs on the surface of the earth, earthquakes are usually caused by the movement of the earth's crust (earth's plates). Earthquakes are also used to indicate the area from which the earthquake occurred. Even though our earth is solid, it always moves and earthquakes occur when the pressure caused by that movement is too large to be able to withstand. One of the effects of the earthquake vibration itself that reaches the earth's surface and if the vibration is large enough can damage buildings and other infrastructure such as roads and bridges, railroad tracks, dams and others, causing casualties and property losses. So that we can avoid the danger caused by an earthquake, it is necessary to design an earthquake detection device with a pendulum swing method based on the ATmega328 Microcontroller. The ATmega328 microcontroller is the core of all the systems that exist in this design. In the design of earthquake measuring device using infrared sensors and photodiodes. Where the infrared beam construction is determined by the pendulum which detects the swing [12].

Earthquake detection is the critical first step in earthquake early warning (EEW) systems. For robust EEW systems, detection accuracy, detection latency, and sensor density are critical to providing real-time earthquake alerts. Traditional EEW systems use fixed sensor networks or, more recently, networks of mobile phones equipped with microelectromechanical systems (MEMS) accelerometers. Internet of things edge devices, with

built-in tiny machine learning (tinyML) capable microcontrollers, and always-on, internet-connected, stationary MEMS accelerometers provide the opportunity to deploy ML-based earthquake detection and warning using a single-station approach at a global scale. Here, I test and evaluate tinyML deep learning algorithms for earthquake detection on a microcontroller. I show that the tinyML earthquake detection models can generalize to earthquakes outside the training set [13]. For organizations and governments around the world disaster management is a crucial area of concern. There is a growing demand for effective and efficient disaster management systems due to the frequency and severity of natural and man-made disasters. A viable way to improve disaster management skills is possible because of the development of the Internet of Things (IoT). IoT-based disaster management system enhances preparedness, response, and recovery efforts by utilizing networked devices, sensors, and data analytics. In this work, a complete and real-time catastrophe management framework is created using the advantages of sensor-based monitoring and IoT. This work offers capabilities for real-time monitoring combined with early warning of earthquakes which provides room for effective resource allocation for disaster management. By implementing such a system, communities can become much more resilient overall and save money and lives during critical situations [14]. Earthquakes are experienced everywhere, and alertness is an important method to remain safe. This study aids in keeping people safe by developing an efficient device that produces sound when motion has been detected. The researchers developed an Automated Earthquake Detector Alarm with a Digital Clock, LED, and LCD Recorded Time Display that is powered by Arduino Uno and performs automated functions with the use of the repeated looping of acceleration checks by the Arduino microcontroller due to the loop () function of the inputted code of the Arduino IDE. Each component has its specific functions; the Buzzer can produce sound that serves as an alarm. As a result, it was proven that the device is effective for alarming people when an earthquake has been detected. The 4-digit seven segment is used to show the time in Philippine Standard Time with the help of the RTC module, where it is proven that there is no significant difference in the developed device. The LCD shows the recorded time of when the movement occurs. This applied experimental research introduced the device's uses, advantages, and features. This study introduced a safer experience with earthquakes by preparing ahead of time to prevent uncertainty and evacuating the room early to avoid potential earthquake causes. This study recommends adding a memory to the device to record the earthquake's magnitude and intensity,

inform the people that an earthquake occurs, and a battery in case of a power outage [15].

In this study, the approach used is the prototype method. This method involves creating a simple model or prototype that illustrates the main features and functions of the system being developed. The methodology for creating a prototype is an approach in system development that aims to create a system that can be used to test and refine the resulting system.

METHODS

This research uses a system design and testing approach. The research stages were carried out by collecting information from various sources such as journals, books, and scientific articles related to IoT technology, the Adxl335 sensor, and earthquake detection systems. The aim was to obtain a theoretical foundation to support the design of the tool.

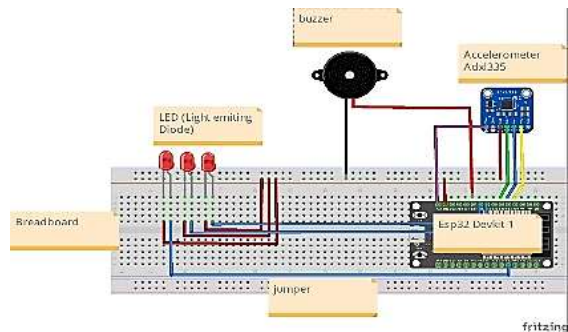


Figure 1. System Design

The tool was designed by connecting each component until they were all linked together, forming the framework of an IoT-based earthquake detection tool consisting of an ESP32, an ADXL335 sensor, a red LED, and a buzzer. At this stage, all components are assembled according to the design, and then the program that has been created is uploaded to the microcontroller. The system was tested to ensure the sensor could read ground acceleration and send data via IoT. Testing was conducted by providing simulated vibrations using various intensity levels (light, medium, and strong). The test data was analyzed to determine the accuracy of the sensor readings, the speed of notification delivery, and the overall reliability of the system.

RESULTS AND DISCUSSION

The image below shows the comparison results between the normal state and the presence of vibration from the earthquake detection tool that was designed.



Figure 2. Serial Monitoring Display and Physical Form of the Device When There is No Vibration

When the acceleration does not exceed the threshold, the device will not give a warning signal or a message like in Figure 2.



Figure 3. Serial Monitor Display and Telegram Notification When Slight Vibration Occurs

When the acceleration exceeds the light threshold, one LED will light up, the buzzer will sound, and a message from the ESP32 will be sent to the user via Telegram, as shown in Figure 3.



Figure 4. Serial Monitor Display and Telegram Notification When Moderate Vibration Occurs

Figure 4 shows that the earthquake detection device has already detected acceleration exceeding the moderate threshold, causing two LEDs to light up, the buzzer to sound, and a message from the ESP32 to be sent to the user via Telegram.



Figure 5. Serial Monitor Display and Telegram Notification When Strong Vibration Occurs

Figure 4 shows that the sensor has detected acceleration exceeding the threshold, causing three LEDs to light up as visual indicators, a buzzer to

sound as an audio indicator, and a message to be sent via Telegram.

Table 1. Comparison of normal, mild, moderate, and severe conditions

Condition	Acceleration value	The effect that occurred	IoT Response
Without vibration	$<1.20 \text{ m/s}^2$	I don't feel anything.	No alarm, no message sent.
Light earthquake	$>1.20 \text{ m/s}^2$	I felt a little something, things moved a little.	The alarm sounded, LED 1 lit up, and a message was sent to Telegram.
Moderate earthquake	1.40 m/s^2	Things were shaking, and there were a few cracks.	The alarm sounds, LEDs 1 and 2 light up, and a message is sent to Telegram.
Strong earthquake	$>1.60 \text{ m/s}^2$	If the goods fall, some of the structure might be damaged.	The alarm sounds, LEDs 1, 2, and 3 are on, and a message is sent to Telegram.



Figure 6. Graph Under Normal Conditions

Figure 6 shows a graph from the Arduino serial plotter displaying vibration deviation values. The vibration values are still below the light limit, indicating normal conditions without significant vibration.

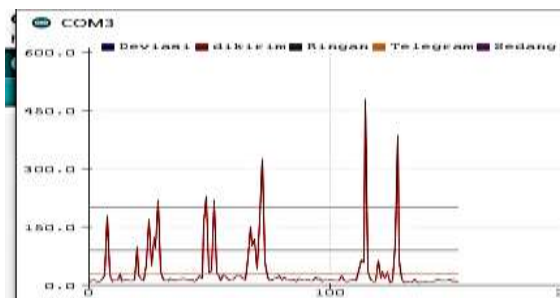


Figure 7. Graph showing the presence of vibration

Figure 7 shows a graph of the ADXL335 sensor deviation experiencing high vibrations exceeding the threshold. The deviation rises to over 300-450, indicating strong vibrations.

CONCLUSION

This IoT-based earthquake detection system is a simple and quite effective system that uses the

ESP32 microcontroller and the ADXL335 accelerometer sensor to monitor vibrations and determine if they exceed the threshold. If vibrations occur, the system will immediately activate the LED as a visual indicator and the buzzer as a sound indicator, and the ESP32 will also send a notification to the Telegram bot user. Based on the discussion above, it can be concluded that the earthquake detection tool will send a warning signal when the sensor detects that the vibrations occurring exceed the threshold (1.20, 1.40, and 1.60). Although this earthquake detection tool is not as accurate as professional earthquake detection tools, it can help increase awareness of potential disasters. The earthquake detection system designed is capable of classifying the level of vibration into several categories, such as light, moderate, and strong earthquakes, based on the measured deviation value or total acceleration.

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