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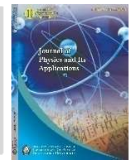

Innovation of Portable Tectonic Earthquake Detection System with Arduino Uno: An Affordable Early Warning System Solution

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ABSTRACT

Indonesia, located in a highly seismic region due to the convergence of the Indo-Australian, Eurasian, and Pacific plates, requires affordable earthquake early warning systems. This research aims to develop an easy-to-use, portable tectonic earthquake detection system based on the Arduino Uno platform. The methodology encompassed the design of hardware and software, the installation of accelerometer sensors, and the programming of the Arduino to detect ground vibration intensity. Test results demonstrate that the system is sensitive to changes in vibration and can provide an audible warning via a buzzer when a predefined vibration threshold is exceeded. Although its accuracy is lower than that of professional seismographs, the system presents an economical solution for deployment in remote areas. Future development could incorporate GPS sensors and artificial intelligence to enhance its accuracy and expand its applicability across various disaster scenarios.

1. Introduction

Indonesia is located at the convergent boundary of three major tectonic plates, the Indo-Australian, Eurasian, and Pacific plates, which makes it highly vulnerable to seismic activity [2]. Earthquake early detection systems are very important for reducing the impact of disasters, particularly by providing sufficient time for people to evacuate. One recent innovation is the creation of a detection system based on the Arduino Uno, a microprocessor known for its low cost, ease of programming, and simple hardware configuration. This Arduino-based device detects earthquake-related vibrations, offering a portable, cost-effective Early Warning System (EWS) that can be installed individually [3].

The need for such systems is highlighted by Indonesia's significant seismic activity. In 2023, the Meteorology, Climatology, and Geophysical Agency (BMKG) recorded a total of 10,789 earthquake events in Indonesia. This included 219 earthquakes with a magnitude above 5.0, 10,570 small earthquakes with a magnitude below 5.0, and 861 earthquakes that were felt by the public. This figure represents an increase from the usual annual average of around 7,000 earthquake events. Of the 10,792 earthquake occurrences of different magnitudes in 2022, 217 had magnitudes greater than 4.8 on the Moment Magnitude Scale (Mw). Approximately 7,000 earthquakes occur annually on average, with about 26 causing significant damage. In addition to tectonic earthquakes, Indonesia also experienced 1,085 ground motion events in 2023 that resulted in 208 fatalities and damage to 2,043 houses [21]. One significant earthquake was the 2019 Ambon event with a magnitude of Mw 6.5, which occurred 23 km northeast of Ambon City and reactivated a complex fault network in the Ambon and Seram regions [4].

The Arduino Uno, an affordable and versatile microcontroller, can detect ground movement when paired with an accelerometer sensor. The device identifies earthquakes by measuring ground vibrations and provides visual or auditory notifications. Remote alerts can also be sent using additional communication modules, such as GSM or Wi-Fi. The system offers the advantages of low cost, portability, and ease of maintenance, making it suitable for implementation by various communities, including those in hard-to-reach areas [5].

Vibration sensors are crucial components in vibration detection devices. They function to detect and measure vibrations in an object or system by converting mechanical vibrations into electrical signals that can be processed and analyzed [6]. The working principle is generally based on the piezoelectric effect, in which piezoelectric crystals produce an electric charge when subjected to pressure or vibration. These sensors can detect various vibration parameters such as amplitude, frequency, and acceleration. The data generated are sent to a processing unit or microcontroller to be analyzed and displayed in an interpretable form [7]. Using vibration sensors in detection devices offers various benefits, especially in condition monitoring and predictive maintenance [8]. By detecting changes in vibration patterns, they can help identify potential problems in machinery or structures before serious damage occurs, enabling timely preventive action, improving operational efficiency, and reducing the risk of equipment failure or accidents.

A buzzer is an electronic component that acts as a sound indicator in a vibration detector. Essentially, it is an electroacoustic transducer that converts electrical signals into sound vibrations. In the context of a vibration detector, the buzzer acts as an output that produces a warning sound when the sensor detects a vibration exceeding a certain threshold [9]. The buzzer operates by receiving an electrical signal from a microcontroller or other controlling circuit. When the vibration sensor detects significant vibrations, the microcontroller sends a signal to activate the buzzer, which then produces a sound at a specific frequency and volume as a warning [10].

The use of buzzers in vibration detection devices is essential because they provide an audible warning that humans can easily recognize. This allows users to immediately become aware of detected vibrations and take necessary actions, such as evacuation in the case of earthquake detectors [11]. Additionally, the buzzer can be programmed to produce different sound patterns according to the intensity level of the detected vibration, providing users with information regarding the severity of the event [12]. The intensity scale that triggers the buzzer is usually set based on the amplitude or frequency of the vibration detected by the sensor. This setting can be customized depending on the specific needs of the vibration detector. For example, for earthquake detection, the scale may refer to the Richter scale or a specific vibration intensity scale. The sensitivity can be adjusted through microcontroller programming or electronic circuit settings [13]. In some cases, the device can be set to detect vibrations ranging from very low to very high intensity. However, settings that are too sensitive may cause false alarms, while settings that are too high may result in the device failing to detect vibrations that should be recognized.

The creation of this tool includes hardware and software design, as well as setting up the Arduino IDE as a programming platform. Sensors such as the MPU6050 or piezoelectric vibration sensors detect changes in vibration on a particular axis and generate data that can be viewed through a graph or serial monitor on the Arduino [14]. In some cases, if the vibration data exceeds a predetermined level, the system will activate a warning device such as a buzzer or send a signal over a wireless network to notify nearby residents [15].

While these systems are efficient and easy to install, their accuracy and sensitivity are lower than those of professional seismographs. Further developments, such as the integration of GPS sensors, gyroscopes, and artificial intelligence algorithms, are needed to improve reliability and detection capability [22]. Nonetheless, this Arduino Uno-based device has the potential to be a local solution that can help communities prepare for earthquakes. This basic technology allows communities to create cheaper and more inclusive early warning systems. If widely adopted, this method could significantly improve disaster mitigation and protect more communities from seismic threats, especially in remote locations or those overlooked by traditional EWS [17].

This study aims to create a portable tectonic earthquake detection system based on an Arduino Uno that can be used as an inexpensive and user-friendly early warning system. This device uses accelerometer sensors to detect changes in ground vibration intensity in real time, providing early warning to individuals in earthquake-prone areas. Additionally, this study aims to assess the system's sensitivity and accuracy in comparison to traditional earthquake detection methods. It will also explore the potential for future development, including integration with GPS sensors and artificial intelligence, to enhance the system's effectiveness and precision.

2. Methods

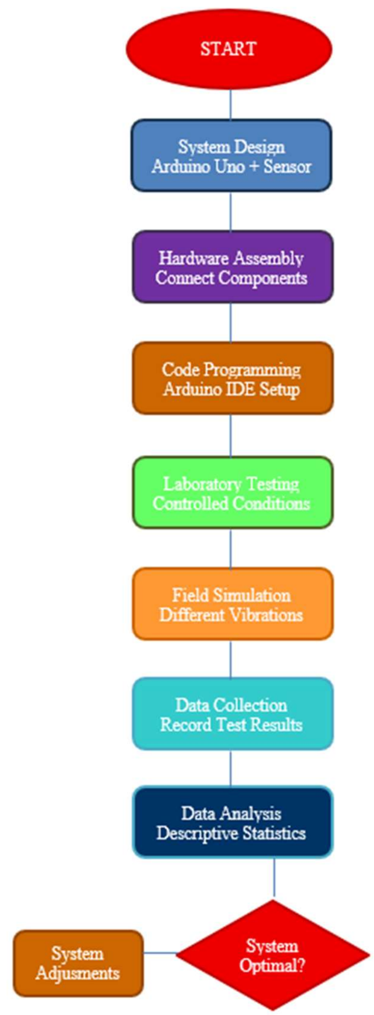

Fig. 1: Arduino Uno-Based Earthquake Detection System Development Flowchart

This flowchart in Fig. 1 illustrates the systematic workflow for developing a portable earthquake detection system based on Arduino Uno that functions as an early warning system. The process begins with the system design phase, which includes hardware and software design, followed by hardware assembly involving the integration of accelerometer sensors and buzzers into the Arduino Uno circuit. Upon completion of assembly, Arduino code programming is conducted using the Arduino IDE to configure sensor sensitivity, vibration detection thresholds, and buzzer activation for warning alerts. The subsequent phase involves staged testing, including laboratory tests and field simulations with various types of vibrations to evaluate system sensitivity, accuracy, and response speed. Testing data is then collected and analyzed using descriptive statistics to assess system performance. Based on the analysis results, adjustments are made to thresholds and program code to enhance system effectiveness, followed by final trials to ensure the system functions optimally under various conditions before comprehensive documentation and in-depth analysis of the research findings.

This research uses a quantitative method with an experimental approach to design and test a portable earthquake detection system based on Arduino Uno that can function as an early warning system. This system utilizes a vibration sensor connected to the Arduino Uno to detect earthquakes. Data from the sensor is processed by Arduino, and if the detected vibration exceeds the threshold, the system activates the buzzer as a warning [18]. The research steps include system design, hardware assembly, code programming for Arduino, and staged testing. After assembly, the system was tested in the laboratory and in field simulations with different types of vibrations to assess its sensitivity, accuracy, and response speed [19].

During testing, data was collected and analyzed using descriptive statistics to evaluate system performance, particularly sensor sensitivity and alert speed. Based on these results, adjustments were made to the thresholds and program code to improve the system's effectiveness [15]. After refinement, final trials were conducted to ensure the system functioned optimally under various conditions. The results of this research were then documented and analyzed in depth. This research is expected to produce an affordable and effective earthquake detection system, which can serve as an alternative early warning system, especially for earthquake-prone areas with limited access to advanced technology [20].

3. Result and discussion

The vibration sensor is tested by assembling it with a pre-programmed Arduino Uno microcontroller. For testing, the sensor is placed on a flat plane and then moved left, right, forward, and backward; the resulting data is output in the form of a graph. These movements are quantified on a scale of 0–6000, assumed to be equivalent to a magnitude (M) of 4–5, and are repeated to generate valid data. To ensure data validity, the test is conducted repeatedly under controlled conditions. The sensor is tested using movements of identical intensity and direction across multiple measurements to verify data consistency. Furthermore, the data validation approach involves comparing the sensor's output with known vibration measurement standards. If the results display a consistent pattern and align with theoretical expectations and seismic references, the data can be considered valid. From the data collected over multiple trials, it can be concluded that each movement produces a different magnitude value depending on the sensor's response and the speed of the movement [23].

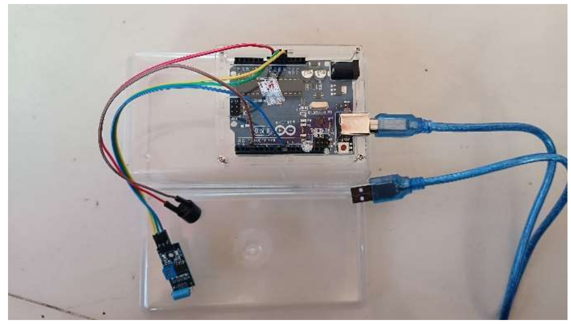

Fig. 2: Vibration sensor circuit connected to an Arduino Uno microcontroller.

The implementation of an Arduino Uno-based earthquake detection system, as shown in Fig. 2, utilizes vibration sensors as the main component to detect vibrations. The system is designed by integrating hardware and software, including the Arduino IDE setup as the programming platform. Sensors such as the MPU6050 or piezoelectric vibration sensors detect changes in vibration along a particular axis and generate data that can be visualized through graphs, or the serial monitor on the Arduino [14]. The process of converting mechanical vibrations into electrical signals utilizes the piezoelectric principle, whereby piezoelectric crystals produce an electrical charge when subjected to pressure or vibration [24]. These sensors can detect various vibration parameters such as amplitude, frequency, and acceleration, which are then sent to the processing unit.

Fig. 3: Arduino Uno R3

In the data processing stage, the Arduino microcontroller shown in Fig. 3 plays an important role in analyzing the signals received from the sensor. The data generated by the sensors are sent to the processing unit or microcontroller to be analyzed and displayed in an interpretable form for the user [25]. The system is designed to provide alerts when the vibration intensity reaches a certain threshold. The sensitivity settings for vibration detection can be adjusted through microcontroller programming or electronic circuit configurations [12]. As a system output, the buzzer functions as a sound indicator that converts electrical signals into sound vibrations. When the vibration sensor detects significant vibrations, the microcontroller sends a signal to activate the buzzer [26]. The buzzer can be programmed to produce different sound patterns according to the detected vibration intensity level, providing the user with additional information regarding the severity of the event [11].

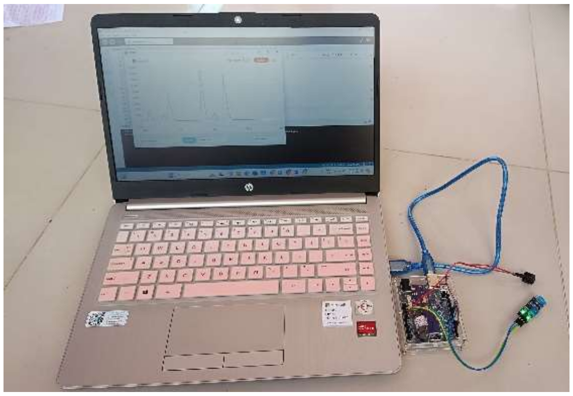

Fig. 4: A laptop connected to Arduino and sensors to display sensor data in real time.

Although the system shown in Fig. 4 has lower accuracy compared to professional seismographs, this Arduino Uno-based technology offers an affordable and effective solution for early earthquake warning systems, especially for remote areas or those with limited access to more advanced seismic detection technologies. Further developments, such as the integration of GPS or gyroscope sensors and artificial intelligence algorithms, are needed to improve its reliability and detection capabilities [27].

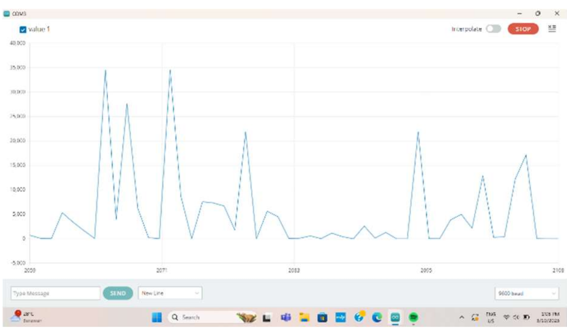

Fig. 5: Graph of experimental results on the Arduino Uno system.

The graph shows high value fluctuations with sharp peaks occurring at specific points, indicating signals or vibrations detected by the sensor. The data exhibits a consistent oscillatory trend, demonstrating the system's good sensitivity to changes in vibration intensity. In Fig. 5, several significant peaks exceed 6,000 to 10,000 units, indicating heightened vibration activity during these periods, accompanied by a loud, prolonged buzzer sound. These peaks represent the sensor's response to sufficiently strong vibration events, potentially indicative of seismic activity. Overall, the graph confirms that the sensor responds rapidly to vibration changes [26].

The graphs display significant value fluctuations with sharp peaks at certain points, demonstrating the system's sensitivity in detecting changes in vibration intensity [27]. The consistent oscillatory pattern indicates the system responds effectively to vibrational changes, aligning with the working principle of vibration sensors that convert mechanical vibrations into electrical signals via the piezoelectric effect for subsequent analysis [28].

The system demonstrated its capability by detecting several significant peaks reaching 6,000 to 10,000 units [29]. This sensitivity level is crucial for earthquake detection, particularly in Indonesia's earthquake-prone zone which experiences an average of 10,789 seismic events annually [30].

When the sensor detects peak vibrations exceeding 6,000 units, the buzzer responds with a prolonged, loud sound. This aligns with the buzzer's function as an electroacoustic transducer that converts electrical signals into sound vibrations. The system is programmed to produce different sound patterns corresponding to detected vibration intensity levels, providing users with additional information about event severity [31].

System implementation shows alignment with existing theory, with vibration sensors successfully detecting and measuring parameters such as amplitude and frequency. This Arduino Uno-based early warning system proves to be an affordable and effective community solution, particularly for remote areas [32]. Despite accuracy limitations, the system offers a practical approach to enhancing community preparedness for earthquake disasters [33]. Future development integrating GPS sensors and artificial intelligence algorithms could enhance the system's reliability and detection capabilities [34].

4. Conclusion

Based on the results and explanations detailed above, this research has successfully developed a portable, Arduino Uno-based tectonic earthquake detection system that functions as an affordable and user-friendly Early Warning System (EWS). This system utilizes an accelerometer sensor to detect ground vibrations and issues visual and auditory warnings when the vibration intensity reaches a predetermined threshold. Test results demonstrate that the device is sufficiently sensitive in detecting changes in vibration intensity, which is displayed via a fluctuation graph and buzzer activation. Although its accuracy is limited compared to professional seismographs, the system offers a viable and economical solution for communities in earthquake-prone areas with limited access to more advanced seismic detection technology.

This system contributes to knowledge in the field of earthquake early warning by proposing an alternative technology based on the Arduino Uno microcontroller that is accessible to a wider community. The deployment of this system in remote areas can enhance disaster preparedness and help reduce the impact of earthquakes on the population. For further development, integration with GPS sensors and artificial intelligence could be explored to improve the system's accuracy and efficiency. Additional experiments are also recommended, particularly to test the system's performance in real-world environments and under diverse disaster conditions.

Acknowledgment

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References

[1] Y. Manuel, K. A. Widodo, B. Romadhon, and P. D. Palevi, "Comparative Analysis Of Accelerometer

Sensor and Piezoelectric Sensor Capabilities In The Early Warning System Earthquake Disaster" J. Electr. Eng. Comput. (JEECOM), 7(1), (2025).
[2] Gunoro, Suprapto, J. Iriani, B. V. Sundawa, Abdullah, and Cholish, "Design of Earthquake Warning Alarm Using Accelerometer Sensor Based on Internet of Things" Int. J. Res. Vocat. Stud. (IJRVOCAS), 3(1), 32–35, (2023).
[3] M. N. Rahman and M. Yusfi, "Rancang bangun sistem alarm gempa bumi berbasis mikrokontroler avr atmega 16 menggunakan sensor piezoelektrik" J. Fis. Unand, 4(4), (2015).
[4] A. W. Baskara, D. P. Sahara, A. D. Nugraha, A. A. Rusdin, Z. Zulfakriza, S. Widiyantoro, W. Triyoso, A. Priyono, N. T. Puspito, H. A. Shiddiqi, D. Kusumawati, A. Rudyawan, and E. Elly, "Aftershock study of the 2019 Ambon earthquake using moment tensor inversion: identification of fault reactivation in northern Banda, Indonesia" Earth Planets Space, 75(1), (2023).
[5] F. A. Tritunggal, C. Pradana, and E. R. K. Pradani, "Sistem Deteksi Gempa Otomatis Berbasis Mikrokontroler Arduino dan Sensor Accelerometer MPU6050" J. Mech. Electr. Technol., 2(2), (2023).
[6] M. Romanssini, P. C. C. de Aguirre, L. Compassi-Severo, and A. G. Girardi, "A Review on Vibration Monitoring Techniques for Predictive Maintenance of Rotating Machinery" Eng, 3(4), (2023).
[7] D. Vanraj, A. Goyal, S. S. Saini, Dhami, and B. S. Pabla, "Intelligent predictive maintenance of dynamic systems using condition monitoring and signal processing techniques-A review" in Proc. Int. Conf. Adv. Comput. Commun. Autom. (ICACCA), (2016).
[8] F. Syahputra and Y. Ananda, "Perancangan Alarm Deteksi Gempa dan Peringatan Dini Berbasis Mikrokontroler ATmega 8" J. MeSTeRI, 17–25, (2022).
[9] D. Putriera Anggraeni, N. S. Aminah, and Y. Radiyono, "Equipment of earthquake detection and warning with vibration sensor" Prosiding ICTTE FKIP UNS, 1, 269–374, (2016).
[10] E. Putri Saptorini, "Pembuatan Simulasi Pendeteksi Getaran Sebagai Peringatan Dini Terjadinya Gempa Bumi" INDEPT, 8(3), 51–61, (2019).
[11] I. Nurpiansyah, "Rancang Bangun Alat Peringatan Dini Gempa Mikrokontroler" Universitas Satya Negara, Jakarta, (2024).
[12] S. Kholifah, A. Surtono, and G. A. Pauzi, "Realisasi Sistem Akuisisi Data Spektrum Getaran Pada Accelerometer MMA7361 Menggunakan Micro SD Dan Komputer" (2015).
[13] C. P. Fritzen, "Vibration-Based Structural Health Monitoring – Concepts and Applications" Key Eng. Mater., 293–294, 3–20, (2005).
[14] R. I. Alfian, A. Ma'Arif, and S. Sunardi, "Noise reduction in the accelerometer and gyroscope sensor with the Kalman filter algorithm" J. Robot. Control (JRC), 2(3), 180–189, (2021).
[15] F. H. Chen, H. L. Shieh, and J. F. Tu, "Development of Earthquake Detection and Warning System Based on Sensors" Sens. Mater., 35(4), 1211–1220, (2023).
[16] S. G. Krokidis, I. Vlachos, M. Avlonitis, A. Kostoglou, and V. Karakostas, "Data-driven performance evaluation of a low-cost seismograph" Meas. Control, 55(5–6), 340–358, (2022).
[17] A. B. Siregar, Ezwarsyah, H. M. Yusdartono, and F. A. Nasution, "Rancang Bangun Sistem Peringatan Gempa Menggunakan Sensor ADXL 345 Berbasis Lora Dengan ESP 32" J. Energi Elektrik, 11(2), (2022).
[18] M. Krishna, A. Vinitha, S. Ravinder, and D. Swetha, "Earthquake Detector using Arduino" J. Cardiovasc. Dis. Res., 9(4), 480, (2018).
[19] A. Hermansyah, S. K. Budhi, M. Agus, and P. Penggunaan, "Penggunaan Sensor Vibration Sebagai Antisipasi Gempa Bumi Dosen Teknik Informatika-ITM 2)" J. Electr. Tech., 5(2), (2020).
[20] D. F. Ramadhan and M. Royhan, "Simulasi Pendeteksi Gempa Menggunakan Sensor Getaran Berbasis Arduino Uno" eJ. Mahasiswa Inform. Telekomun., 1(1), (2019).
[21] R. R. Ribeiro and R. de M. Lameiras, "Evaluation of low-cost MEMS accelerometers for SHM: Frequency and damping identification of civil structures" Lat. Am. J. Solids Struct., 16(7), (2019).
[22] Y. Gong, H. Zhao, Y. Huang, and X. Jin, "Design and experimental study of acceleration sensor based on PVDF piezoelectric film" J. Comput. Methods Sci. Eng., 21(1), 31–40, (2021).
[23] A. Bin Mohd, K. A. Md Rezali, S. A. Rahim, A. M. Z. Abidin, and M. F. M. Yunus, "Vibration Monitoring using Arduino Data Acquisition to Detect Anomalies in the Operation of Water Pump" in J. Phys. Conf. Ser., 2721(1), (2024).
[24] W. S. Maulana, M. Y. Irvan, and L. N. S, "Use of vibration sensor as detection of railway in mechanical signaling systems" Int. J. Psychosoc. Rehabil., 24, (2020).
[25] M. A. Meier, Z. E. Ross, A. Ramachandran, A. Balakrishna, S. Nair, P. Kundzicz, Z. Li, J. Andrews, E. Hauksson, and Y. Yue, "Reliable Real-Time Seismic Signal/Noise Discrimination with Machine Learning" J. Geophys. Res. Solid Earth, 124(1), 788–800, (2019).
[26] P. Harahap, B. Oktrialdi, and R. F. Siregar, "Implementasi Alat Pendeteksi Gempa Berbasis Arduino Uno Dengan Memanfaatkan Sensor Getar (Vibration)" in Seminar Nasional Teknik Elektro (SNTE), 3(1), (2023).
[27] Y. Yang, L. Li, M. Akhmedovich, W. Ma, and D. Xu, "Design and Machining Applications of the Piezoelectric Vibration Sensing System" J. Manuf. Mater. Process., 7(5), (2023).
[28] P. Marius, P. Olga, U. George-Andrei, and I. Ursu, "Vibration and Mechanical Shock Monitoring Using Flexible Piezoelectric Sensors" in 2019 Int. Conf. Electromech. Energy Syst. (SIELMEN), (2019).
[29] V. Cascone, J. Boaga, and G. Cassiani, "Small Local Earthquake Detection Using Low-Cost MEMS Accelerometers: Examples in Northern and Central Italy" Seism. Rec., 1(1), 20–26, (2021).
[30] J. F. Lin, X. Y. Li, J. Wang, L. X. Wang, X. X. Hu, and J. X. Liu, "Study of building safety monitoring by using cost-effective mems accelerometers for rapid after-earthquake assessment with missing

data" Sensors, 21(21), (2021).
[31] B. C. Jung, Y. C. Huh, and J. W. Park, "A self-powered, threshold-based wireless sensor for the detection of floor vibrations" Sensors, 18(12), (2018).
[32] Y. Priyana, F. E. Laumal, and E. E. Husni, "Development of Earthquake Early Warning System Using ADXL335 Accelerometer" (2018).
[33] Sneha R, Gayatri, Nagaraj, N. R. N, and G. R, "Arduino UNO-Based Earthquake Detection System (AUEDS)" Int. J. Adv. Trends Eng. Manag. (IJATEM), (2024).
[34] G. S. Naik, R. Anupam, and D. Aiswarya, "Arduino Based Earthquake Detector using Accelerometer" Int. J. Adv. Res. Electr. Electron. Instrum. Eng., 9(7), 2003-2008, (2020).