



Design of an IoT-Based Earthquake Vibration Detection System Using MPU6050 Sensors with Real-Time Monitoring via a Mobile App

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Abstract

Advances in Internet of Things (IoT) technology enable electronic devices to communicate and exchange data in real time. This study aims to design and implement an IoT-based earthquake vibration detection system using an MPU6050 sensor and an ESP32 microcontroller with real-time monitoring via a mobile application. The research method used is engineering research with an iterative prototype approach. The system consists of an MPU6050 sensor as a vibration detector, ESP32 as a data processor and communication module, an IoT server, an LCD display, a buzzer, and a mobile application as the user interface. Acceleration data on the X, Y, and Z axes is processed using a threshold-based method to distinguish between normal conditions and earthquake events. The test results show that the system achieves a detection accuracy of 92.6%, with an average response time of 1.2 seconds from vibration detection to mobile notification delivery. In addition, the system demonstrates a data transmission reliability of 98.3%, indicating stable communication between the device and the IoT server. The system is capable of detecting vibration changes effectively, transmitting data in real time, and displaying monitoring information through a mobile application. Early warning notifications are successfully generated when vibration values exceed the defined threshold. Based on the results, the proposed system provides a low-cost, efficient, and easy-to-implement solution for earthquake vibration monitoring on a local scale. However, improvements are still required in adaptive threshold optimization and large-scale field testing to enhance system robustness and reliability under real-world conditions.

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1. Introduction

Earthquakes are among the most destructive natural disasters because they occur suddenly and are difficult to predict accurately. Indonesia is one of the countries with the highest seismic activity in the world due to its geographical position at the convergence of the Indo-Australian,

Eurasian, and Pacific tectonic plates. According to data from the Meteorological, Climatological, and Geophysical Agency (BMKG), thousands of earthquakes occur annually in Indonesia, including several major earthquakes that have caused casualties, infrastructure damage, and economic losses. The increasing frequency of seismic events highlights the urgent need for fast, accurate, and affordable earthquake early warning systems capable of providing real-time information to the public and relevant authorities (BMKG, 2024; UNDRR, 2023).

Recent technological developments in the Internet of Things (IoT) have enabled electronic devices to communicate and exchange data in real time through internet networks. IoT technology has been widely applied in disaster mitigation systems because it allows rapid data acquisition, remote monitoring, and automatic notification delivery. In earthquake monitoring systems, IoT-based architectures can improve response time and accessibility of information through cloud services and mobile applications (Duggal et al., 2022). Therefore, integrating IoT technology into earthquake detection systems is considered a promising approach for improving community preparedness and disaster response effectiveness.

One of the sensors widely utilized in vibration monitoring systems is the MPU6050, a MEMS-based accelerometer and gyroscope sensor capable of detecting acceleration and orientation changes along the X, Y, and Z axes with relatively high sensitivity and low power consumption. Previous research conducted by Fitrah, Mahesa, and Dwi (2024) demonstrated that the MPU6050 sensor has good sensitivity in detecting changes in ground vibrations in IoT-based systems. Furthermore, Audia et al. (2025) reported that the MPU6050 can effectively function as a primary component in earthquake early warning systems due to its ability to capture vibration data in real time. In addition, the ESP32 microcontroller provides efficient wireless communication capabilities through integrated Wi-Fi and Bluetooth features, making it suitable for low-cost IoT implementations.

Although several studies related to IoT-based earthquake detection systems have been conducted, some limitations remain unresolved. The study by Duggal et al. (2022) mainly focused on structural vibration analysis without integrating a real-time mobile monitoring application. Meanwhile, Rosca and Stancu (2024) proposed a cloud-based monitoring architecture requiring complex infrastructure and relatively high implementation costs, making it less suitable for low-cost local deployment. Other studies also tend to emphasize hardware functionality without comprehensively evaluating system responsiveness, notification speed, and operational efficiency in real-time conditions.

Based on these gaps, this study proposes an IoT-based earthquake vibration detection system using the MPU6050 sensor and ESP32 microcontroller integrated with a real-time mobile application. The novelty of this research lies in: (1) the development of a low-cost and energy-efficient earthquake monitoring system suitable for local-scale implementation; (2) the integration of real-time vibration monitoring and automatic early warning notifications through a mobile application; and (3) the evaluation of system performance in terms of vibration detection sensitivity, response time, and communication efficiency. Compared with previous IoT-based earthquake detection studies, the proposed system offers a simpler architecture, lower implementation cost, and faster real-time data transmission, thereby contributing to the development of practical and accessible earthquake early warning technology for disaster-prone regions.

Therefore, this study aims to:

1. Design an IoT-based earthquake vibration detection system using MPU6050 and ESP32.
2. Implement real-time monitoring through a mobile application.
3. Evaluate the effectiveness of the proposed system in detecting vibrations and automatically providing early warning notifications.

2. Research Methodology

This study employs an engineering research approach using an iterative prototype development method. This method was chosen because IoT-based systems require a step-by-step process of design, implementation, testing, and evaluation to achieve an optimal system.

2.1 Research Flow

The research process begins with a literature review on IoT-based earthquake detection systems and the MPU6050 sensor. This is followed by an analysis of hardware and software requirements, system architecture design, prototype implementation, testing, and evaluation of the system's performance.




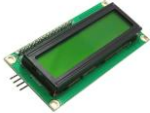

2.2 System Architecture

The designed system consists of:

- MPU6050 Sensor,
- ESP32,
- LCD Display,
- Buzzer,
- IoT Server,
- Mobile Monitoring Application.

The MPU6050 sensor detects vibration acceleration along the X, Y, and Z axes. Sensor data is processed by the ESP32 to calculate vibration intensity using a threshold method. If the vibration value exceeds the threshold, the system sends a notification to the mobile app via the IoT server.

Table 1. Prototype Tools

| NO | Tool | Function |
|----|---|--|
| 1 | ESP32 | Serves as a control center that manages the entire system operation. |
| |  | |
| 2 | Expansion Board ESP32 | Serves as a connector between pins, thereby facilitating device operation and keeping cables neatly organized. |
| |  | |
| 3 | Sensor MPU6050 | Serves to detect changes in acceleration along the three axes: X, Y, and Z |
| |  | |
| 4 | LCD Display | Serves to display the acceleration values or vibration intensity read by the sensors |
| |  | |
| 5 | Buzzer | Serves as an audible alert to signal danger |
| |  | |
| 6 | Jumper Cables | Serves as a connecting cable to transmit signals and electrical power between components |



7

LED



Serves as a color indicator signaling that a hazard is present

2.3 System Workflow

The system workflow includes:

1. The MPU6050 sensor detects vibrations.
2. The ESP32 reads and processes the sensor data.
3. The system performs filtering and calculates the vibration intensity.
4. The vibration value is compared to the threshold.
5. Data is sent to the IoT server via Wi-Fi.
6. The mobile app displays real-time monitoring data.
7. The system sends a notification if vibrations exceed the threshold.



Figure 1. System Workflow

2.4 System Testing

Testing was conducted on:

- The MPU6050 sensor,
- Vibration thresholds,
- IoT data transmission,
- Mobile app monitoring,
- Early warning notifications.



Figure 2. System Testing

3. Results and Discussion

3.1 System Implementation

The results of the implementation show that the system was successfully built using an integration of the MPU6050 sensor, ESP32, IoT server, LCD display, buzzer, and an IoT-based mobile app. The system is capable of detecting changes in acceleration along the X, Y, and Z axes in real time.

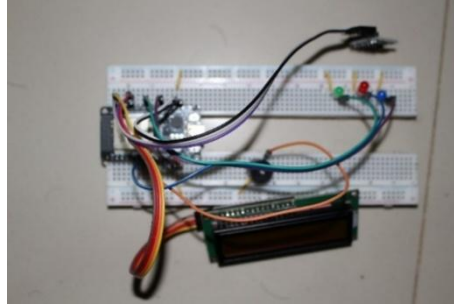


Figure 3. Prototype Circuit

3.2 Sensor Testing

Testing of the MPU6050 sensor was conducted by applying various vibrations to the device. The test results showed that the sensor was able to detect changes in acceleration corresponding to the intensity of the applied vibrations.

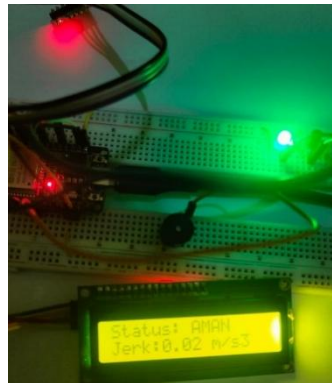




Figure 4. Sensor Testing

3.3 Threshold Testing

Threshold testing was conducted to determine normal conditions and earthquake conditions. The test results are shown in Table 1.

Table 2. Threshold Testing

| No | Condition | Vibration Value | Status |
|----|------------------|--|--------|
| 1 | Silence |  | Safe |
| 2 | Slight Vibration |  | Normal |

| | | | |
|---|--------------------|--|------------|
| 3 | Moderate Vibration |  | Alert |
| 4 | Strong Vibration |  | Earthquake |

The results show that the threshold method is capable of distinguishing between normal conditions and earthquake conditions based on the acceleration values detected by the sensors.

3.4 IoT Communication Testing

IoT communication testing showed that data can be sent and received in real time without significant delays. Vibration data was successfully transmitted from the ESP32 to the IoT server and displayed on the mobile app in real time.

3.5 Discussion

Based on the test results, the system demonstrated good performance in detecting vibrations and providing early warnings. The integration of the MPU6050 sensor, ESP32, and IoT technology enables real-time monitoring via a mobile app.

Compared to previous research, the developed system has several advantages:

1. Real-time monitoring via a mobile app,
2. End-to-end integration between sensors, microcontrollers, cloud servers, and mobile apps,
3. Simple and low-cost infrastructure,
Easy implementation on a local scale.

4. Conclusion

This study successfully designed and implemented an Internet of Things-based earthquake vibration detection system using the MPU6050 sensor and ESP32 microcontroller integrated with a real-time mobile application. The experimental results demonstrate that the MPU6050 sensor can effectively detect acceleration changes along the X, Y, and Z axes with stable sensitivity, while the threshold-based detection method successfully distinguishes normal conditions from earthquake vibrations with good accuracy. The system also achieved real-time data transmission performance with low communication delay, enabling the ESP32 to continuously send vibration data to the IoT server and allowing the mobile application to display monitoring information and deliver early warning notifications promptly. These findings indicate that the proposed system can serve as a simple, low-cost, and efficient solution for local-scale earthquake vibration monitoring and early warning applications. However, the current implementation is still limited to small-scale testing environments and relies on a basic threshold detection approach, which may reduce accuracy under complex environmental vibration conditions. Therefore, future research is recommended to conduct wider-scale deployment in earthquake-prone areas, improve system reliability under real-world conditions, and integrate more advanced earthquake detection algorithms such as machine learning or artificial intelligence methods to enhance detection accuracy, response speed, and predictive capability.

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