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Earthquake Detection and Tsunami Disaster Management Using Vibration Sensors

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Abstract: An earthquake is a vibration or tremor that occurs on the Earth's surface due to the sudden release of energy from within, creating seismic waves. Earthquakes often occur without the public's knowledge, so an earthquake detection system is essential to minimize potential damage. The purpose of this research is to facilitate the detection of earthquakes, which frequently occur due to plate ruptures on the seabed or in mountainous areas. With the advancement of technology, an earthquake detection system is one solution to minimize the impact of earthquakes. This detection system is designed using an Arduino Uno. Using a device with a vibration sensor like this can detect the possibility of an earthquake, thereby anticipating potential adverse events, such as loss of life and so on.
Keywords: Natural Disaster; Vibration; Detection; Early Warning

INTRODUCTION

Indonesia is one of the countries located in the Pacific Ring of Fire, a region known for its intense seismic activity. This area is the meeting point of several major tectonic plates, including the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate(Sinaga et al., 2022). Due to its geological position, Indonesia is highly prone to natural disasters, especially earthquakes and volcanic eruptions(Dhira et al., 2021; Ira & Purwantara, 2021). Earthquakes in Indonesia can be either tectonic, caused by the shifting of earth's plates, or volcanic, triggered by volcanic activity(Ayuningtyas et al., 2021; Simanjuntak & Ririmasse, 2021).

Throughout its history, Indonesia has experienced numerous devastating earthquakes that have resulted in significant loss of life and extensive damage to infrastructure(Fuady et al., 2021). One of the most catastrophic events was the 2004 Aceh earthquake and tsunami, which killed more than 230,000 people across several countries, with Indonesia being the hardest-hit. Other notable events include the 2006 Yogyakarta earthquake, which claimed thousands of lives, and the 1979 Bali earthquake, which had a significant impact on the local population(Basid et al., 2021; Ramdhan et al., 2025). These events are clear evidence that regions across the Republic of Indonesia are indeed highly vulnerable to earthquake hazards.

Earthquakes are natural phenomena that cannot be accurately predicted in terms of time and location. To this day, no technology exists that can pinpoint exactly when and where an earthquake will strike. This has been emphasized in studies by Mar'atuzzulfa, Prathivi, and Susanto (2025), as well as Laia et al. (2023), who assert that earthquakes are sudden and unpredictable occurrences. This unpredictability places communities in a highly vulnerable position, especially in the absence of reliable early warning systems. The impact of an earthquake can be highly destructive. In addition to structural damage such as the collapse of buildings, bridges, and other infrastructures, earthquakes often result in significant loss of life and severe injuries. A primary cause of the high death toll during earthquakes is that many people are unable to escape or do not receive timely warning information. Many victims are found trapped under rubble because they had no time or opportunity to save themselves.

Field data show that current earthquake detection systems are still limited and heavily rely on manual monitoring by conventional personnel or operators(Al-Ali et al., 2024; Esposito et al., 2022). This presents a serious limitation, especially considering the speed and unpredictability of earthquake events. Therefore, there is an urgent need for disaster detection systems that can operate automatically and issue warnings in the shortest possible time(Clements, 2023; Fajri et al., 2021). The rapid advancement of technology in the past two decades has opened up great opportunities for the development of more sophisticated and efficient disaster detection

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systems(Zhukovsky et al., 2021). Various stakeholders from government agencies, research institutions, and universities to independent tech communities—are racing to develop technological solutions that can help mitigate the impact of natural disasters(Esposito et al., 2022; Gupta & Roy, 2024). One such innovation that has gained attention is the creation of early warning devices that emit signals or sounds when unusual vibrations are detected.

These early warning devices can function either mechanically or electronically. Mechanical systems typically use simple tools such as pendulums that move when vibrations occur(Chen et al., 2021; Patel & Allen, 2022; Romanssini et al., 2023). However, these systems have many limitations, particularly in terms of sensitivity and area coverage. As a result, modern approaches increasingly rely on electronic components based on microcontrollers such as Arduino, Raspberry Pi, and others(Komarizadehasl et al., 2021; Liu et al., 2025; Sekine & Hayakawa, 2022; Setiawan et al., 2022). Arduino Uno, one of the most widely used microcontroller boards for prototype development, is an ideal choice for building earthquake detection systems. Arduino Uno is favored for its ease of programming, availability of sensor libraries, and relatively low cost(Köhli et al., 2024). Vibration sensors like the SW-420 can be easily integrated with Arduino to detect sudden shaking. The system works by reading vibration values from the sensor and processing the data in the microcontroller. If the vibration exceeds a predetermined threshold, the device will trigger an alarm, either in the form of a siren, indicator lights, or even notifications sent to other devices via a network(Sekine & Hayakawa, 2022). With such a system, it is hoped that residents near the disaster area can take immediate action to evacuate(McBride et al., 2021).

One study that successfully developed such a system was conducted by Partaonan Harahap et al. (2023) titled "Implementation of an Arduino Uno-Based Earthquake Detection Device Using Vibration Sensors." In this research, the team designed and tested an earthquake detection system using Arduino and vibration sensors. The results showed that the system functioned effectively, providing warnings with very high accuracy—exceeding 90% and a very low error rate. These findings suggest that the system has strong potential for broader application, especially in earthquake-prone areas. Furthermore, another study by Siswanto and Saputra (2023), titled "Prototype of an IoT-Based Earthquake and Tsunami Early Warning System," expanded on this idea by designing a monitoring system that could detect both earthquakes and post-earthquake tsunami threats. Their system, based on the Internet of Things (IoT), used the SW-420 vibration sensor and JSNSR04T water level sensor. Detected data were processed in real-time using the Arduino Uno R3 and transmitted via network communication to the receiving unit.

The advantage of using an IoT-based approach is its ability to cover larger areas and transmit information quickly to multiple stakeholders(Nagasa & Johnson, 2025). Such systems are not only beneficial for the general public but also for government agencies, disaster response organizations, and educational institutions that seek to raise awareness and promote preparedness. With all the potential and progress made in developing technology-based earthquake detection systems, it is crucial to ensure that these innovations are implemented in real-world scenarios(Tian et al., 2023). Governments must fully support these efforts through funding and regulatory frameworks. Educational and research institutions can contribute by developing more efficient, affordable, and scalable technologies(Howard et al., 2021). Meanwhile, the public must be encouraged to understand the importance of disaster preparedness, including how to interpret and respond to early warnings.

The mass implementation of early warning systems in high-risk areas such as Aceh, Padang, Maluku, Nusa Tenggara, and Papua is an urgent necessity. These systems can be developed locally at relatively low costs, allowing villages and schools to establish their own detection networks. In the long term, investing in early warning technology will significantly reduce casualties, economic losses, and psychological trauma caused by earthquake disasters. In conclusion, earthquakes remain a real and constant threat to the people of Indonesia. While they cannot be prevented, their impacts can be minimized through the implementation of early warning and detection systems powered by technology. The use of microcontrollers such as Arduino Uno and their integration with IoT platforms have proven effective and efficient for deployment in various regions. Support from all sectors is needed to ensure these technologies move beyond research and into practical application, ultimately saving lives and building a more resilient society.

METHOD

Materials And Methods

Researchers develop an earthquake detection system and tsunami disaster management using existing vibration sensors, by adding the latest features that are automatically integrated via Smartphone. The system developed by adding a vibration sensor that functions to read vibrations that occur in the affected area is equipped with an automatic alarm notification (siren) that will be sent to the Smartphone via the Telegram application. to make it easier to detect earthquake warning signals faster.

The design that will be built is to automatically make it easier for the public to know before an earthquake occurs by implementing an automatic notification system (siren) that will be sent to the Smartphone via the

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Telegram application. The vibration sensor processes voltage data and Arduino Uno to calculate the vibration frequency. The vibration sensor is used for designing earthquake detectors and tsunami disaster management using automatic vibration sensors, controllers and as regulators of all the performance of the tools used.

In the design of this hardware system, it is described with a block diagram which is a basic description of the system design to be designed. Each block diagram has its own function, while the block diagram of the hardware system being designed is as shown in the following figure.

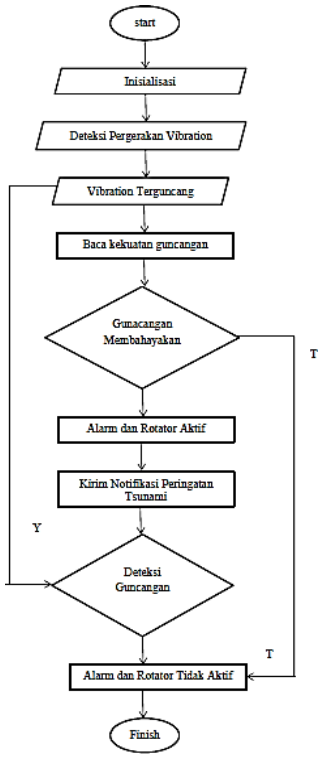

Figure 1. Block Diagram of Tool Simulation

The following is an explanation of the tool simulation diagram, namely:

1. Initialization is the initial stage in a live system to read all installed hardware.
2. Vibration Movement Detection is a tool installed to measure the strength of an earthquake.
3. Vibration Shaking is a tool that functions to send earthquake hazard notifications/signals via the telegram application.
4. Read Shock Strength is a tool that functions to measure the scale of earthquake strength.
5. Dangerous Shock is a tool that functions to measure the scale of strength in an earthquake and send a notification of a danger signal.
6. Alarm and Retector are tools that function as warning signs for earthquake hazards.
7. Send Tsunami Warning Notifications when there is a shock or vibration, the tool will automatically detect and send a dangerous earthquake warning signal via telegram.
8. Shock Detection when receiving vibrations will provide input 1 (HIGH) if there is no vibration input 0 (LOW).
9. Alarm and Retector are not active when there is a shock or vibration, then they are automatically inactive.

The Arduino Uno circuit functions as a central tool for processing input and output programs from a computer via a USB cable, the program will later be entered into the microcontroller(Agustanti et al. 2022). The following is a schematic of the Arduino Uno circuit.

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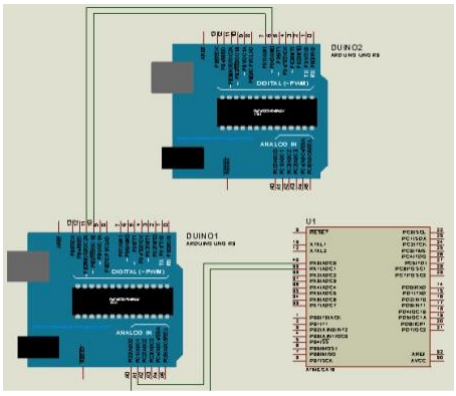

Figure 2. Arduino Uno Circuit Schematic

Arduino Uno is a microcontroller board based on Atmega 328 (Datasheet). It has 14 input pins from digital output where 6 input pins can be used as PWM output and 6 analog input pins, 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and reset button. To support the microcontroller to be used simply. just connect the Arduino Uno Board to the computer using a USB cable or AC power to a DC adapter or battery to run it. Each of the 14 digital pins on the Arduino Uno can be used as input and output, using the pin mode, digital write, and digital Read functions. These functions operate at 5 Volts, each pin can provide or receive a maximum current of 40 MA and has a pull up resistor (disconnected by default) 20-50 kOhm. The following is a display of the Arduino Uno software(Mamahit 2024).

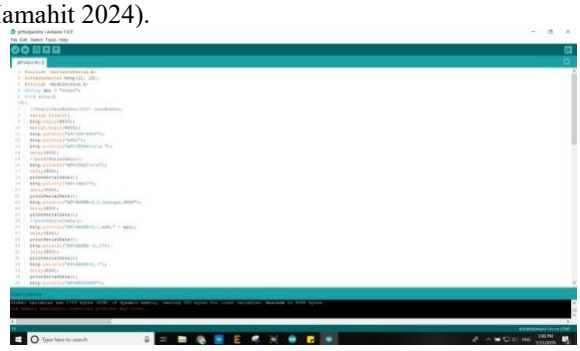

Figure 3. Arduino Uno Software Display

The relay functions to flow electric current from the main switch to other electrical components, such as the horn and headlights. In addition, the relay also functions to control the flow of electricity in the vehicle so that the voltage is appropriate and not excessive(Martin and Susandi 2022). The following is a schematic of the Relay circuit.

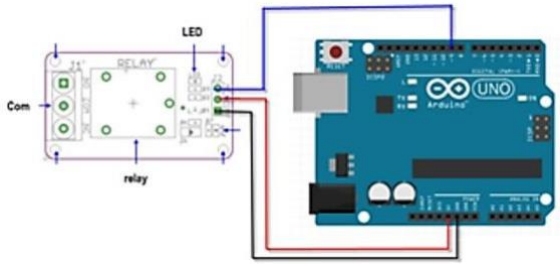

Figure 4. Relay Circuit Schematics

Alarms can generally be defined as warning sounds or notifications. In network terms, alarms can also be defined as messages containing notifications when there is a decrease or failure in the delivery of data communication signals or equipment that is damaged (performance degradation). In the network, alarms provide danger signs in the form of signals, sounds, or rays(Silalahi et al. 2022). A vibration sensor is a tool that functions to detect vibrations and will change vibrations into electrical signals. For its application, it can be applied, for example, if you often drive a vehicle then pass through a bad road that causes vibrations, then the vehicle is slowed down, then an example is if there is a vibration caused by an earthquake, sound the alarm and so on.

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Step down is very useful in electronics. Transformers or more commonly known as transformers are static devices that convert electrical power from one circuit to another without any moving parts. The function of a step down transformer is to change voltage and current without causing changes in frequency. An adapter is a circuit that is useful for converting high AC voltage to low DC. An adapter is an alternative to DC voltage (such as batteries, accumulators) because the use of AC voltage is longer and everyone can use it as long as there is electricity in that place. The following is a schematic of an AC/DC circuit.

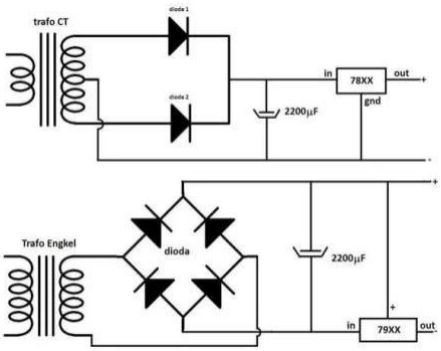

Figure 5. AC/DC Circuit Schematic

Rotary warning lights are lights that provide a warning sign of danger in a place with the aim that people who pass or pass by in that era will be more careful. With a rotating lamp model (Rotary) that has a reflector on the side of the lamp attracts people's attention to see, we often find this warning light installed at the entrance and exit of large vehicles on projects under construction.

RESULT

System implementation is a procedure carried out to complete the system design contained in the approved design document. In creating a system that detects earthquakes and handles tsunami disasters with vibration sensors using hardware and software, which can be seen in the following image.

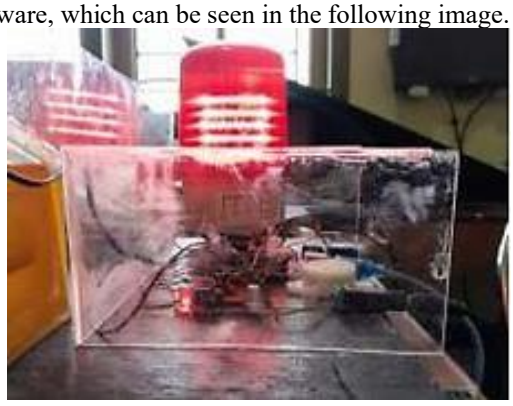

Figure 6. Front view of the system being built

The image above is the final result of the physical design that has been made, the display above is a simulation with a prototype aquarium made of acrylic with a thickness of 3 mm. Acrylic has a stronger ability than glass, in the earthquake detection system and tsunami disaster management. Acrylic functions to hold the water inside, acrylic is thermoplastic which means it can melt when heated to a certain temperature, the thickness of the acrylic is quite diverse, including having a thickness of 1.5 mm to a thickness of 25 mm. The following is an acrylic display.

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Figure 7. Acrylic View

Rotary lights have specifications of 3 inch - 6 inch size, the voltage of the electricity is 220 volts, 24 volts, 12 volts, Rotary lights are used when vibrations occur, then the Rotary lights flash or rotate automatically if an alarm sound occurs and the lights will automatically turn on as a danger signal. The following is a display of Rotary lights.

Figure 8. Rotary Light Display

Arduino Uno is a microcontroller board based on Atmega328 (datasheet)(Tansa et al. 2024). It has 14 input pins from digital output where 6 input pins can be used as PWM output and 6 analog input pins, 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and reset button, Arduino Uno circuit is a tool used to detect earthquake vibrations, this tool uses a vibration sensor that can detect vibrations with 2 outputs, namely LED and relay. The following is a display of the Arduino Uno circuit.

Figure 9. Arduino Uno Circuit Display

Relay is an electronic component in the form of an electronic switch that is driven by an electric current. In principle, a relay is a switch lever with a wire coil on an iron rod (Solenoid) nearby. When the solenoid is supplied with electric current, the lever will be attracted due to the magnetic force that occurs in the solenoid so that the switch contacts will close. When the current is stopped, the magnetic force will disappear, the lever will return to its original position and the switch contacts will open again. Relays are usually used to drive large currents/voltages, for example 4 ampere AC 220 V electrical equipment using small currents/voltages (for example 0.1 ampere 12 Volt DC). In its use, relays that are driven by DC current are usually equipped with a diode that is parallel to the coil and installed in reverse, namely the anode at the voltage (-) and the cathode (+). In this study,

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the relay is used to shorten the electric current that enters the voltage source to the ritory lamp and Arduino Uno. The following is a display of the relay.

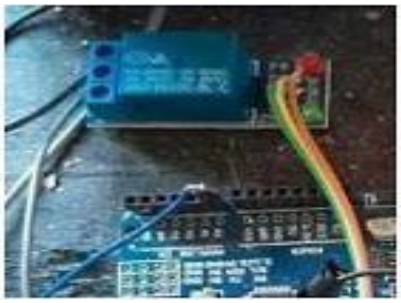

Figure 10. Relay Display

Alarms can generally be defined as warning sounds or notifications. when there is a decrease or failure in the delivery of data communication signals or there is equipment that is damaged (performance degradation). On the alarm network, it provides a warning sign in the form of a signal, sound, or light. The following is an alarm display.

Figure 11. Alarm Display

The vibration sensor test that is run will calculate the vibration on the sensor so that the vibration on the sensor will be calculated automatically. The vibration sensor is a tool that functions to detect the presence of a vibration, the vibration sensor functions when the sea water rises, the sensor will automatically detect the presence of a vibration that will detect the strength of the vibration that can cause an earthquake or tsunami. The following is a display of the vibration sensor.

Figure 12. Vibration Sensor Display

Notifications on this Smartphone use the telegram application which functions to anticipate when an earthquake or tsunami occurs in the affected area. This telegram application has been programmed so that it can connect to wifi or cellular data and provide notifications which can then be used for information facilities through the ITBI_GEMPA telegram group. The following is a display of notifications on a smartphone.

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Figure 13. Notification Display on Smartphone

Next, provide a simple program on the atmega328 microcontroller, the program entered is:

```
int PinAlarm = 3;
int PinGetar =A0;
int Rotary =8;
void setup(){
    Serial.begin(9600);
    pinMode(PinAlarm, OUTPUT);
    pinMode(PinGetar, INPUT);
    pinMode(Rotary, OUTPUT);
}
void loop(){
    long nilaigetar =nilai();
    Serial.print(nilaigetar);
    if(nilaigetar == 00){
        Serial.println(nilaigetar);
        Serial.println("tidak ada getaran");
        digitalWrite(PinAlarm, HIGH);
        digitalWrite(Rotary, HIGH);
    }else if(nilaigetar > 2500){
        Serial.println(nilaigetar);
        Serial.println("getaran tinggi");
        digitalWrite(PinAlarm, LOW);
        digitalWrite(Rotary, LOW); }
    delay(10);
    Serial.println("");
}
long nilai(){
    delay(100);
    long nilaigetar=pulseIn (PinGetar, HIGH);
    return nilaigetar;
}
```

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DISCUSSIONS

At this stage, a discussion is carried out on the working principles of the earthquake detection system and tsunami disaster management using vibration sensors, as follows: (1) Discussion of this application The use of this tool uses an internet/wifi network as a connection between the internet network and the sensor. (2) Earthquake Detector and Tsunami Disaster Management Using Vibration Sensors using Arduino Uno tools, Rotary lights, relays, LEDs, stepdowns, alarms and PCs and equipped with automatic alarm notifications (sirens). (3) Power supply is used to provide electrical power to a device. (4) Vibration Sensor is a tool that works to detect vibrations while with 3 outputs, LED, buzzer and relay. (5) LED is a tool to find out that the system is working and is used as an indicator of the system's operation.

From the results and discussions above, the advantages of the Earthquake Detection System and Tsunami Disaster Management Using Vibration Sensors are as follows: (1) Able to increase effectiveness in the presence of earthquake hazards. (2) Helping users to find out the number of fatalities. (3) Creating an earthquake detection system that can provide warnings to users in affected areas can provide easy access for young people to be aware of earthquakes. (4) An earthquake detection alarm system can be implemented so that it can be utilized properly.

In addition to the advantages, there are also disadvantages of the Earthquake Detection System and Tsunami Disaster Management Using Vibration Sensors, as follows: (1) The disadvantage of the earthquake detection system and tsunami disaster management using vibration sensors is that the tool cannot be used if it is not connected to the internet. (2) The system is still a prototype, which is still a simulation example and has not been developed in reality. (3) The system that the researcher designed still uses electric current.

CONCLUSION

Based on the analysis of the research results, the author concludes: The Earthquake and Tsunami Disaster Mitigation Detector was built using an Arduino Uno vibration sensor, rotary lights, relays, LEDs, stepdown switches, alarms, and a PC, and is equipped with automatic alarm notification (siren). This detection system can be used through the Telegram application and is equipped with an alarm notification directly connected to Telegram. When receiving vibrations, the device will provide an input of 1 (HIGH), and if there are no vibrations, it will provide an input of 0 (LOW). This device is expected to reduce casualties due to earthquakes because it can detect when they are likely to occur.

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