Design of earthquake early warning system based OMRON D7S vibration sensor

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Abstract. Indonesia is a country that is very prone to earthquake. This disaster can have a very large impact from main destruction of ground motion and secondary destruction from building rupture. By providing early warning system, secondary disasters caused by the earthquake, such as fire due to gas leakage, electric shock or loss of important personal data, can be prevented. This research designs an early warning system against earthquakes, where the sensor used was 3d accelerometer-based OMRON D7S vibration sensor. A warning is also sent to personnel or web-server via GSM communication. The system calibrated with a standard tool MEISEI G401 owned by Indonesian Earthquake Agency (BMKG). Test showed that early warning system have accuracy value of 74.32%. From the testing that has been done, the time delay in sending data is greatly influenced by the state of the surrounding environment. Data is sent and stored to an SQL-based database, with an average delivery delay of 1.7 seconds. This system successfully provides an early warning using the buzzer alarm as desired. The percentage of success of the buzzer turns on as desired is 100%.

1. Introduction
Indonesia is an archipelago located between three tectonic plates namely the Indo-Australian Plate, the Eurasian Plate and the Pacific Plate. This makes Indonesia prone to earthquakes, the shifting of these plates can cause tectonic earthquakes. Not only flanked by three plates at once, Indonesia is also surrounded by a ring of fire (Ring of Fire) so that volcanoes in Indonesia are very active, which can cause volcanic earthquakes [1]. Earthquake is one of the natural disasters caused by vibrations that occur on the surface of the earth caused by the release of energy suddenly, thus creating seismic waves caused by disturbances that occur in the earth's crust, such as faults and shifts of earth plates and activities volcano.

According to the National Disaster Management Agency (BNPB), during 2018 there were 17 destructive earthquakes. As an illustration of the earthquake in Lombok and Sumbawa caused damage and losses of Rp 17.13 trillion, and caused 564 people died and 445,343 people were displaced [2]. Based on the impact of the death toll, of course, making the earthquake is a very frightening specter. But efforts to reduce losses can still be made if information about the epicenter of the earthquake can be disseminated, so that people who are close to that point can make an effort to save themselves as soon as possible.
Therefore, we need a tool that can provide earthquake early warning in real time. Seismic data is collected and stored to a database. The database used will be integrated with the web server, in order to make it easier to determine the epicenter by using the triangulation method.

In research conducted by Alif Ghifari, namely "Design of Earthquake Detection Devices Using Vibration Sensors" [3]. Vibration sensor used is 801S sensor. The disadvantage of this research is that the intensity of earthquake strength is based on the ADC value, which does not correlate directly with earthquake intensity. In this study the vibration sensor used was OMRON D7S. This sensor can issue Peak Ground Acceleration (PGA) values from a vibration. Taiwan has researched accelerometer-based network sensor which placed in schools as early warning system [4]. Earthquake sensor based on social engineering, which using tweet of people who sense earthquake movement, cannot provide reliable reading rural and remote areas [5]. This research designed low-cost early warning system for residential and commercial building.

2. Background

2.1. Earthquake intensity scale

Earthquake intensity scale is a scale that states the impact caused by an earthquake [3]. Quantification due to the earthquake continues to grow and only spread more widely after the 10-scale earthquake intensity was set by Rossi-Forel in 1883 (RF Scale). This scale was later developed by Mercalli, an Italian seismologist and volcanologist in 1902 to 12 on the scale. Then developed again by Seiberg (1912,1923), the next version is the Mercalli-Cancani-Sieberg Scale (MCS Scale) used in Southern Europe in 1932. In 1931 an English-language earthquake scale was published by Wood and Nueman. This scale was later developed again in 1956 by Richter which was later called Modified Mercalli Intensity or MMI which is still used today.

Peak ground acceleration or Peak Ground Acceleration (PGA) is the maximum ground acceleration that occurs during an earthquake. This scale is denoted by "g" (acceleration of gravity) [4]. The maximum ground acceleration can also be represented in m / s², where 1 g is equal to 9.81 m / s² [5].

| No | Richter Magnitude | Modified Mercalli (Imm) | PGA (%) | PGV (cm/dt) |
|----|------------------|------------------------|---------|-------------|
| 1  | 1                | I                      | <0.17   | <0.10       |
| 2  | 1.2              | II                     | 0.17 – 1.4 | 0.1 – 1.1  |
| 3  | 2-3              | III                    | 0.17 – 1.4 | 0.1 – 1.1  |
| 4  | 3                | IV                     | 1.4 – 3.9 | 1.2 – 3.4  |
| 5  | 4                | V                      | 3.9 – 9.2 | 3.4 – 8.1  |
| 6  | 4-5              | VI                     | 9.2 – 18  | 8.1 – 16   |
| 7  | 5-6              | VII                    | 18 – 34  | 16 – 31    |
| 8  | 6-7              | VIII                   | 34 – 65  | 31 – 60    |
| 9  | 7                | IX                     | 65 – 124 | 60 – 116   |
| 10 | 7-8              | X                      | >124     | >116       |
| 11 | 8-9              | XI                     |         |            |
| 12 | 9                | XII                    |         |            |

To determine the value of earthquake intensity, this study uses the Modified Mercalli (Imm) intensity scale with the following formula [6].

\[
Imm = 3,66 \log(PGA) - 1,66
\]
The formula is developed by Wald et al. (1999), with an estimated intensity range between V ≤ Imm ≤ VIII. Because when conducting the research, Wald et al. do not have the Intensity data ≤ IV, then use the following equation [6].

\[ Imm = 2.20 \log(PGA) + 1 \]

Where is PGA in cm / s^2.

2.2. Vibration sensor
Vibration sensor is a device that can read a vibration, where the vibration will be converted into an electric voltage. The concept of the vibration sensor is to read the value of the acceleration of the vibration which is read using an accelerometer. An accelerometer is a sensor used to measure the acceleration of an object. Accelerometer measures dynamic and static acceleration. Dynamic measurements are measurements of acceleration in moving objects, while static measurements are measurements of Earth's gravity. To measure the tilt angle [7].

3. Methods
This earthquake detection system is designed so that the system can provide accurate earthquake information using a timestamp from GPS, timestamp in the form of Coordinate Universal Time (UTC), and provide information in the form of coordinates in the form of longitude and latitude, by utilizing the features possessed by the SIM7000E communication module. In this earthquake early warning system uses the OMRON D7S-A0001 vibration sensor as an earthquake vibration detector that is connected to the Arduino Nano microcontroller. To display the data needed, a serial monitor from Arduino IDE and a database server is used to display the data sent to the database. A block diagram for the design of an early warning system in general is shown in Figure 1.

4. Result and discussion

4.1. Vibration sensor testing
This test is performed to display the PGA value that is read by the OMRON D7S sensor and the MEISEI G401 Intensity meter when a vibration occurs. Following are the MEISEI G401 Intensity meter specifications:
- Sensitivity : 640mV/G
- Measurement range : ± 6 G (maximum gravity is ± 5 G maximum)
• Measurement accuracy : Measured value ± 10%
• Component : Three axes (X, Y, Z)
• Control element : Calculate PGA, MMI, 5 Hz PGA.

![Figure 2. Graph of vibration sensor test results.](image)

Based on Figure 3, a graph is presented which is a representation of the reading of the PGA value of each test tool. If the G401 intensity meter in this test is considered as a reference, it can be concluded that the D7S sensor has a weak accuracy but has a good level of precision. This is represented by the form of a graph that is near constant.

Based on vibration sensor testing that has been done. The average PGA value read by the MEISEI G401 Intensity meter is 0.1651g. And the average PGA value read by the OMRON D7S sensor is 0.1227g. So that the average error value can be calculated using the following formula.

\[
\%Error = \frac{Xr - X'r}{Xr} \times 100\%
\]

\(Xr\) = Actual average value
\(X'r\) = Predicted average value

By using the formula above, where the average PGA value read by the MEISEI G401 Intensity meter as an actual value in this test. And the average PGA value read by D7S is the predicted value. Then the average PGA error obtained in testing 30 vibration sensors was 35.68% with an accuracy of 74.32%.

![Figure 3. Comparison results graph.](image)

Based on Figure 4 it can be concluded that the OMRON D7S vibration sensor always detects vibrations in each experiment with an intensity of 6 MMI scale. This is influenced by the PGA value not less than 0.0920g and not greater than 0.1800g when testing. While the MEISEI G401 Intensity meter can read vibrations with a vibration range of 3 MMI to 8 MMI. With the smallest PGA value 0.0107g, and the largest PGA value 0.3399g.
4.2. Vibration sensor testing with earthquake simulation tool

Based on tests conducted using earthquake simulation tools. The earthquake simulation tool performs earthquake simulation with an MMI intensity scale 5. The simulation shows when indoors or in mode 2. The monitor describes the situation where furniture items fall, and the floor cracks. Meanwhile, when outdoors or in mode 1, the state of the road cracks, trees sway and the street lights collapse. Description of the damage caused is in accordance with the description due to damage caused by an earthquake with an MMI scale of 5.

![Figure 4. MMI value graph when simulation.](image)

Figure 4 shows, the results of tests conducted when mode 1 shows the average MMI that is read is 5. The results of tests conducted in mode 2 get an average MMI that is read is 5, with some data showing the intensity scale of MMI 4.

![Figure 5. PGA value graph when doing simulation.](image)

Figure 5 shows the results of tests conducted using earthquake simulation tools. The results of this test have a range of PGA values that read between 0.0280g to 0.0879g. Based on the PGA value that is read the lowest PGA value occurs when the simulation is in mode 2. And the highest PGA value occurs when the simulation is in mode 1. Because the simulation tool performs a simulation on an MMI intensity scale of 5, the PGA range needed is between 0.0390g to 0.0920g. In mode 2 there is an MMI value of 4, this can be caused by the weight of the earthquake simulation tool has increased. This was caused by visitors to the geological museum who were riding the simulation tools during the test. Because according to Newton's law 2 "The acceleration of an object is directly proportional to the total force acting on it and inversely proportional to its mass. The direction of acceleration is the same as the direction of the total force acting on it ".

\[
\sum F = m \cdot a \\
\Rightarrow a = \frac{\sum F}{m}
\]
Where, $\Sigma F$ is the force acting during the simulation, $m$ is the mass given during the simulation and $a$ is the acceleration obtained during the simulation.

5. Conclusion
The conclusion that can be drawn from the results of testing and analysis that has been done is that the system has an accuracy percentage of PGA reading of 74.32%, when compared to BMKG's Intensity Meter. Data is sent and stored to an SQL-based database, with an average delivery delay of 1.7 seconds. The system succeeds in giving an early warning via an alarm buzzer according to its function with a success rate of 100%.

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