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Xbee Pro S1 Based Wireless Data Acquisition System for Landslide Monitoring

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Abstract: Landslides are disasters that occur due to the shifting of land. To detect it, we need a system that can monitor it in real-time. Therefore, in this study, a wireless data acquisition system based on the Xbee Pro S1 module was built for monitoring landslides so that the community quickly responded in the event of a disaster. Testing the range of the module is very important to ensure that data communication between the transmitter and receiver can take place. The test carried out in this study was to take the plate distance data on the extensometer by adding a load and then detected using an ultrasonic sensor. The Xbee transmitter sends data to the Xbee receiver in real-time. From the test results, the maximum range of the Xbee Pro S1 module is 150m outdoors with an average delivery time of 15s from the transmitter to the receiver.

Keywords: landslide; wireless data acquisition system; Xbee module

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Introduction

Landslides are one of the natural disasters that often occur in Indonesia. High rainfall is the main triggering factor in many cases of landslides (Yuliza et al., 2016). One area that is prone to this disaster is the island of Lombok. The head of the Public Works Department and the NTB Regional Disaster Management Agency stated that landslides had occurred in several areas such as Sembalun in East Lombok, Pusuk in North Lombok, and Sekotong in West Lombok. The disaster has caused damage to public facilities and human life. The National Disaster Management Agency stated that a landslide had occurred in West Lombok and left four people dead and five people injured. Therefore we need a disaster mitigation system that can detect the potential for landslides in several disaster-prone areas on the island of Lombok.

Landslide disaster mitigation is an effort to minimize the fall of human victims and or property losses due to events or series of events caused by nature, humans, and by both that result in casualties, human suffering, property loss, damage to infrastructure, public facilities, and causing disturbance to the life and livelihood of the community. The stages of landslide disaster mitigation are mapping, investigation, inspection, monitoring, and socialization (Cobum in Somantri, 2008).

When conducting ground shift monitoring, a wireless data acquisition system is required to facilitate the monitoring process. Data acquisition begins with a physical phenomenon on an object to be measured. Real-time data acquisition systems require connection or installation to a computer. The computer must be active when collecting data (Husein, 2010). In the study (Ronchi et al., 2015), the data acquisition and pre-analysis program was written with LabVIEW software

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and was able to control the spectrometer wavelength, PMT power supply, data acquisition, and storage.

To monitor data in real-time, software that can visualize the data is needed. In research (Mizrah et al., 2015) used LabView-based software to control testing, data registration, and loading of test programs into system modules. LabVIEW stands for laboratory virtual instrument engineering workbench. LabVIEW serial communication with Arduino requires several functions. These functions are VISA configure serial port, VISA writes, VISA read VISA close, and VISA bytes at the serial port. These functions can communicate with each other using strings (Artanto, 2012).

A previous study (Hanto et al., 2012) has developed a wireless data acquisition system using a potentiometer based on Xbee Pro S1 to monitor potential landslides. The system uses serial data communication. The Xbee module can communicate with logic and voltage compatible with UART (Universal Asynchronous Receiver-Transmitter) via the serial port (Digi Internatonal, Inc., 2009). UART is a piece of computer hardware that translates between parallel data bits and serial bits. A UART is usually an integrated circuit used for serial communication on a computer or the serial port of a peripheral device.

In research (Wirawan et al., 2016) has developed a wireless data acquisition system using the SIM900 Quad-band GSM/GPRS module for wireless data communication in testing ground shift detectors. Information on ground shift data to identify potential landslides and is displayed on a website. The research still needs development in monitoring soil shifts. Therefore, the data acquisition system should be located directly at the monitoring post.

In this study, the researcher designed a wireless data acquisition system based on the Xbee Pro S1 module for landslide monitoring. The advantages of this module are low power consumption and the long-range of 1.6 km.

Method

The stages in this research begin with hardware design, software design, tool testing, monitoring of measurement results, and analysis. The hardware system consists of Arduino Uno, Xbee Pro S1 module, and ultrasonic sensor. The system work process in the following diagram

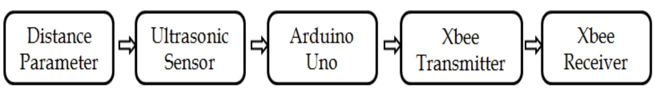

Figure 1. System work process flow

The first process of the designed system is to determine the variables to be measured. Furthermore, the ultrasonic sensor is connected to the Arduino Uno and the Xbee module to detect the system measurement results. The Xbee transmitter will send the measurement data to the Xbee receiver.

Sensor calibration

The first step is to calibrate the sensor before use. Calibration is done twice by comparing the value of the standard tool to the read value detected by the sensor. The following is the regression equation obtained from the first calibration:

$$x = \frac{y - 0.077}{1.032} \quad \text{............................ (1)}$$

Use equation (1) in the form of an Arduino instruction program for the final sensor calibration. Retrieval of object distance data to the sensor using the Arduino instruction program. This process is called inversion. The inversion process is done by iterating several times to reduce the error value. Iteration is a process of recalculation of data entered in the same mathematical function repeatedly to obtain the desired result (Loke in Kurniawati, 2011).

Xbee module testing

The second step is to configure the XBee module. Configuration process to differentiate Xbee transmitter with Xbee receiver. Xbee module range testing uses ultrasonic sensors to determine how far the module can communicate.

The ultrasonic sensor is then paired with an extensometer. Then the tool is connected to the Xbee transmitter in the following figure

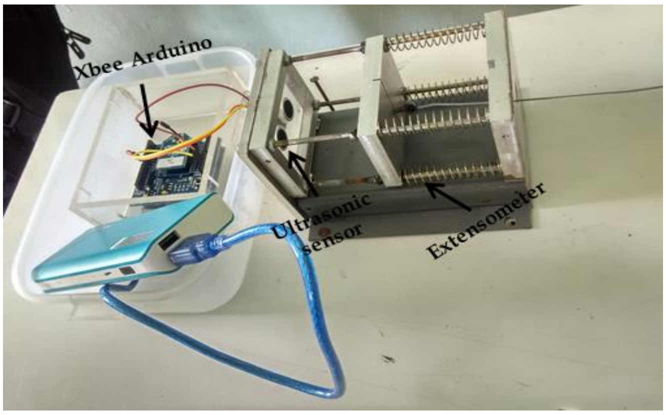

Figure 2. Sensor and prototype extensometer

An extensometer is a simulation tool for detecting ground movement with the addition of a test load. The use test loads in this study were 5N, 10N, 15N, 20N, 25N, 30N, 35N, and 40N. Each additional test load causes the plate on the extensometer to move so that it changes position. Simulation of plate movement indicates ground shift.

The Xbee receiver is integrated with Arduino and connected to a laptop with LabVIEW software as shown in the following figure.

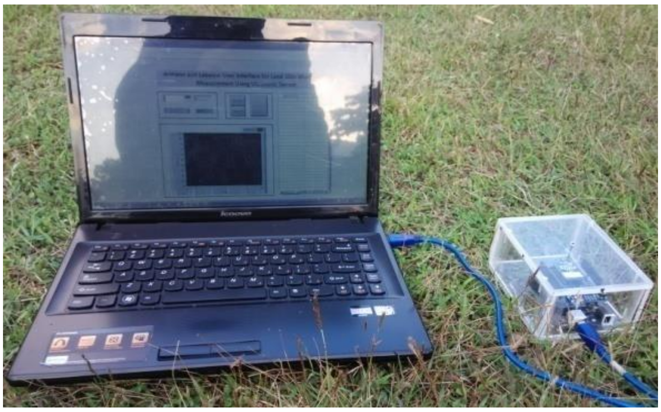

Figure 3. Xbee receiver

The design of the LabVIEW program so that the laptop can communicate serially with Arduino. In this programming, various functions are used for serial communication such as VISA configure serial port, VISA writes, VISA read, VISA close, and VISA bytes at the serial port. The following is the blog diagram of the LabVIEW display used in this study.

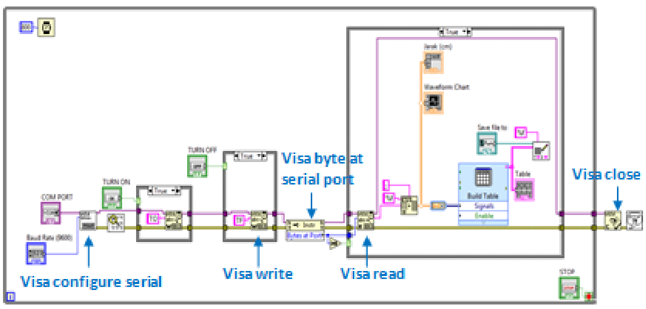

Figure 4. LabVIEW diagram blog

The design of System

The third step is to combine all components into a data acquisition system for simulation of ground displacement. The overall scheme of the system design is in Figure 5.

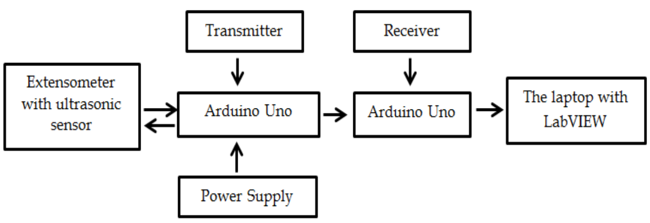

Figure 5. Wireless data acquisition system design schematic

Result and Discussion

Sensor calibration results

Sensor calibration is to compare the sensor value with the standard tool value. The ultrasonic sensor is a distance sensor, so the calibration uses a distance measurement tool, namely a ruler calibrate the readable distance. The calibration results are in the following figure.

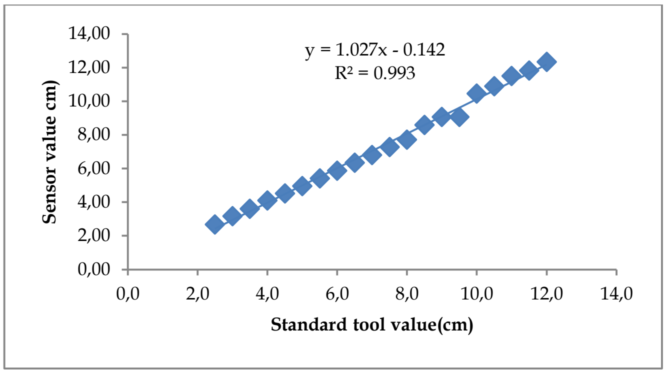

Figure 6. Sensor calibration

Figure 6 shows the comparison between the value read by the sensor and the calibration distance read by a standard tool is linear. Based on the graph, the standard deviation of the sensor readings is 0.142 the sensor sensitivity is 1.027 cm per centimeter. The Standard tool value is 1 cm away it means the sensor will read a distance of 1,027 cm. while R^2 is 0.993. The sensor has a relative error of 0.030%.

Xbee module test results

Testing the Xbee module communication to find out how far the communication range from this module is. This test using a test sensor (LM35DZ) and an ultrasonic sensor. The results of the distance reading by the sensor will be sent wirelessly through the Xbee transmitter in the monitored area to the Xbee receiver at the monitoring post. The range of the Xbee Pro S1 module with two sensors outdoors is in Table 1.

Table 1. Xbee module range distance

No	Distance (m)	Data Delivery Status
1	20	Sent
2	40	Sent
3	60	Sent
4	80	Sent
5	100	Sent
6	120	Sent
7	140	Sent
8	150	Sent
9	160	No response
10	180	No response
11	200	No response

Testing the maximum communication range of the Xbee Pro S1 module is 150m. the distance is not by the specifications module, which is 1.6 km. A previous study (Irpan, 2011) stated that testing the distance between the transmitter and receiver is 200m using an external antenna. While in this study using a small chip-type antenna. For better results, you can use other types of antennas, namely integrated whip and RPSMA connectors.

Wireless data acquisition system

The following is a picture of a wireless data acquisition system in the field. The system is for monitoring ground shift using a simulation of the addition of a load.

Figure 7. Transmitter system

This system simulates ground displacement using an extensometer and test load. If there is a shift in the ground, then the plate on the tool will shift. In this study, the extensometer was equipped with a test load to simulate ground displacement. The test loads used are 5N, 10N, 15N, 20N, 25N, 30N, 35N, and 40N. Each additional plate load will shift. The sensor then detects the shift distance on the plate. The results will be sent through the XBee transmitter from the monitored area to the XBee receiver at the monitoring post. The following is a picture of the wireless data acquisition system in the field. The system is for monitoring ground shift using a simulation of the addition of a load. LabVIEW display for monitoring data recording in figure 8

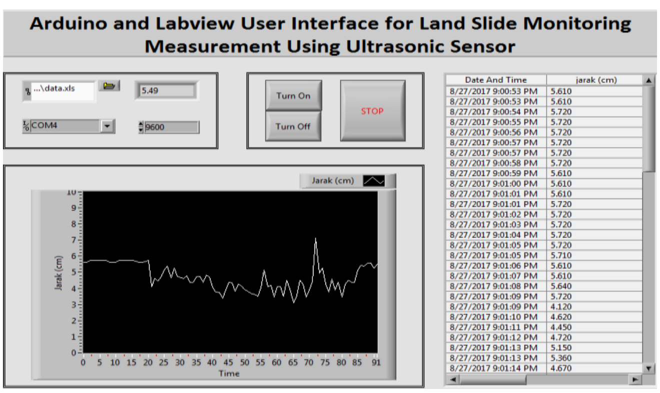

Figure 8. Execution file display

The results of testing the wireless data acquisition system using a simulation of adding a load with five repetitions are in Figure 9.

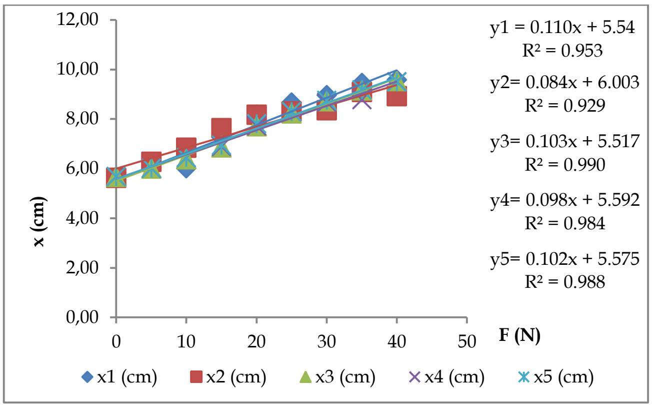

Figure 9. Graph of relationship between load (N) and distance (cm)

The graph shows the relationship between load and distance is linear. The greater the addition of the test load, the greater the detected plate distance. In other words, the bigger the landslide bigger the ground shift. This simulation uses a test load to pull the extensometer plate.

Based on the graph of five repetitions produces five regression lines. There is one line that deviates, namely the line in the second repetition. The five lines show that the measurement of each repetition is very close in value. Except for the second repetition slightly deviates from the value of the other four repetitions. The regression equation and the coefficient of determination (R2) are almost the same and close to the value 1. From the graph, there is a deviation from the average value. From measurements were obtained with five repetitions. There results of the distribution of the average deviation value with the addition of load.

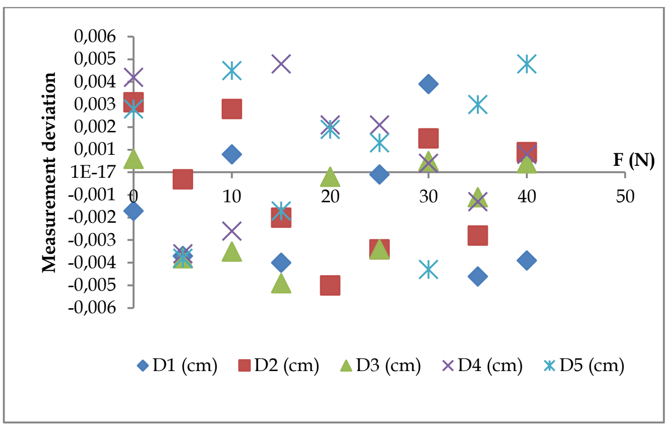

Figure 10. Distribution of the average deviation value

Figure 10 shows a graph of the distribution of the average deviation of the measurement value based on the addition of load. Graph interprets the distribution of deviation points from the measurement results in graph 9. Based on the graph maximum mean deviation value of the measurement is 0.004 cm and the minimum average deviation is -0.005 cm. The measurement deviation is the deviation from the mean value. From the average deviation value, the relative error with five measurements is 1%.

In the monitoring process, the most important thing is to know the time lapse between sending and receiving data. The following is the result of system testing using the data transmission interval between the transmitter (Tx) and receiver (Rx) with three repetitions at different times.

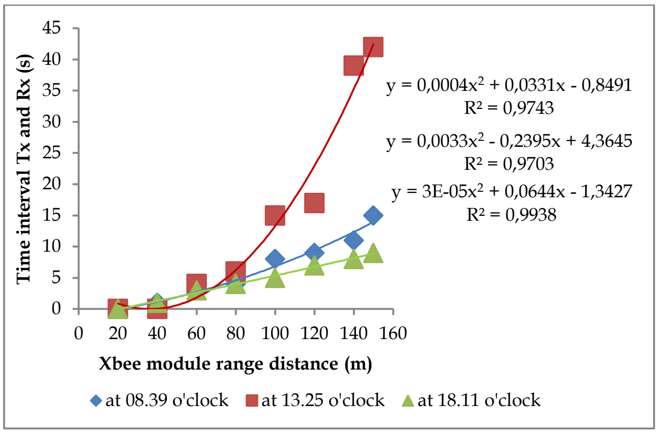

Figure 11. Time-lapse relationship graph with xbee modul module distance

Figure 11 shows a graph of the time-lapse between Tx and Rx to the range distance. This graph is non-linear (a polynomial of degree two). There is no time lapse at a distance of 20m and 40m because they are very close. While at a distance of more than the time-lapse is getting bigger. These results generally indicate that the longer the range, the greater the data transmission time interval. The reason is the speed of data transfer affects the distance between the transmitter and receiver (Wibawa, 2011).

The curve shape of the graph above is an open half parabola with the same pattern at three different times. In the morning at 8.39 and the evening at 18.11 have temperatures ranging from 280C - 290C. There is the time interval between Tx and Rx is small compared to during the day. The reason during the day at 13.25 have temperature is hot, which is around 330C - 340C. The test results show that temperature can affect the data transfer speed of the Xbee Pro S1 module. On the datasheet, the module works at temperatures of -400C-850C on an industrial scale. In field-scale testing, the results show that if the Xbee Pro S1 module works above a temperature of 300C, the data transfer time interval will be greater. It means that the data received is hampered. At high temperatures, the noise in the Xbee signal becomes large so that the Xbee signal will be covered with noise and cause data transfer from the transmitter to the receiver to be hampered.

Conclusion

The design of the Xbee Pro S1 module-based wireless data acquisition system was successful. The system consists of two parts, namely transmitter (Tx) and receiver (Rx). The Xbee transmitter functions to send data to the Xbee receiver while the Xbee receiver functions to receive data from the Xbee transmitter. The test of the wireless data acquisition system was successful at a maximum range of 150m, by simulating the addition of a test load. The test uses the distance of ultrasonic sensor readings sent from the monitored area (transmitter) to the monitoring post (receiver) with an average time interval of 6s (morning), 15s (afternoon), and 5s (afternoon), the relative error of measurement of 1% and sensor precision of 98.4%. It means that the tool is precise and can use for landslide monitoring.

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