Earthquake Disaster Awareness System

Ahmad Zaki bin Hj Shukor, Gopalasamy, Muhammad Fahmi bin Miskon, Fariz bin Ali@Ibrahim
RIA Group, Center of Robotics and Industrial Automation, FKE, Universiti Teknikal Malaysia Melaka, Malaysia.
zaki@utem.edu.my

***Abstract*—Earthquake is type of natural disaster which is usually very fast and unpredictable. When this kind of disaster happens, people will usually panic and exit or run away from the facilities. Without proper guide and safety instructions, this might result in unwanted consequences, such as accidents, injuries or leaving behind family members or officemates. Due to this problem, a disaster (earthquake) awareness system is being developed. The system will at first calculate the amount of vibration in the soil of the earth. This calculation will be approximated to the Richter scale and if it is significantly large, will send safety instructions in the form of messages displayed at LED signboards available at important locations in the vicinity of the building. With this awareness system, if an earthquake happens, people will know what to do and where to go even if they are not trained with the disaster drill exercises.**

***Index Terms*—Accelerometer; Awareness System; Earthquake Alert; LED Messaging.**

I. INTRODUCTION

Recently on 5th of June 2015, Malaysians faced an unforgettable moment which is a strong magnitude of earthquake with moment measure 6.0 Richter scale at Ranau, Sabah, East Malaysia at 7.15am [1]. It was the strongest earthquake in Malaysia since 1976 which measured 5.8 Richter scale at Lahad Datu. On the same day in the evening, three aftershock earthquakes happened measuring 4.3 Richter scale for first two and 2.8 Richter scale for the third shock [2]. Even though the earthquake was a medium range natural disaster, 18 casualties, many injuries and property damages were recorded [3-5].

Until now, Malaysia is still not fully prepared in earthquake disaster management since the earthquake that happened in 1976 and many thought that Malaysia is a place where earthquake is impossible. Thus, Malaysians have least precaution on earthquake or don't know what to do if an earthquake happens. Public will get panic over earthquake and the situation will turn to chaos. This also may cause loss of lives as some people might fall down and others step on them during chaos. People inside buildings may die or get seriously injured due to the fall of heavy concrete. Not only in Malaysia, in many developing countries like recently in Nepal, there are in total more than 8000 deaths [6]. In the last 25 years, earthquake combined have caused deaths of 680,000 people in Haiti, China, Pakistan, Iran and India Ocean [3].

II. RELATED WORK

Researchers F. Finazzi and A. Fassò [7] developed an Earthquake Network project of a world-wide network of smartphones for real-time detection of earthquakes. Each smartphone mounts an accelerometer sensor which, can measure the wave of a quake plus they measure accelerations induced by a large number of sources. Nonetheless, the acceleration data collected by all the smartphones can be gathered together and analysed in order to distinguish real quakes. A classic control chart is thus used to detect if the acceleration exceeds a threshold. When this happens, the event is reported to the cloud along with the spatial position of the smartphone and additional information on the event. Each smartphone also reports its state to the cloud every 30 minutes. This allows to have an estimate of the number of smartphones that, at a given time, are enabled to detect vibrations and thus a possible quake.

R. Khudabadi [8] developed Google Cloud Messaging (GCM) which is phone application using Internet is a system used to send disaster messages earlier to all area users through phone. GCM is to intimate users with area specific early disaster warning, GPS senses user's location dynamically and a centralized server will store the information. If the administrator knows that disaster is going to happen, it is their responsibility to send warning to users. Moreover, the administrator has to define evacuation area nearest to the user position and which is not affected by the disaster. The victim's device location from GPS will be determine and reported to the administrator via server application.

M. S. Bin Bahrudin, R. A. Kassim, and N. Buniyamin [9] develped a fire alarm system which is a real time observing system that sense the presence of fine material or smoke in the air due to fire. It also captures images via camera installed when a fire occurs. The system will able to remotely send an alert when fire is detected. If fire happens, short message service (SMS) will be report to fire fighters after the user's confirmation. A low cost single-board computer, the Raspberry Pi, combined with a microcontroller board; the Arduino Uno is used to implement this fire alarm system. When sensor detects any abnormality in the air, the image of the environment is captured using webcam.

B. Soediono [10] studied the Richer Scale of the earthquake with the approximate acceleration approximate Mercalli Equivalent, which will be used in this research.

Our work is different from [7] and [8] because we do not use smartphones as displays and use LED message board displays to alert people within the vicinity of a workplace or institution. This is because the alert message should be seen by many and during earthquakes, people tend to panic and want the instructions to be seen quickly in viewable areas. Some workplace or institutions do not allow mobile phones in the vicinity due to safety and security reasons.

Table 1
Richter Scale with correspond Acceleration [10]

Richter Scale	Approximate Acceleration	Approximate Mercalli equivalent
3.5	$2.5\ cm/s^{2^2}$	II
4.5	$10\ cm/s^2$	IV
6.0	$150\ cm/s^2$	VII
7.3	$500\ cm/s^2$	X
8.1	$780\ cm/s^2$	XI
>8.1	$980\ cm/s^2$	XII

III. METHODOLOGY

A. System Flowchart

The idea of the system is to send the message of the earthquake detection and safety instructions to a display device, such as an LED board display system or even a High Definition Monitor. Referring to Figure 1, once there is medium range earthquake, the sensor (accelerometer) of the system will detect it. Once the sensor detects the vibration more than the threshold value, the controller will send the output (precaution) message to a display device(s) remotely. The receiver controller will display the content of the message in LED display in order for the viewer to take safety measurement. The display devices might not only be one device, but multiple devices placed at several locations.

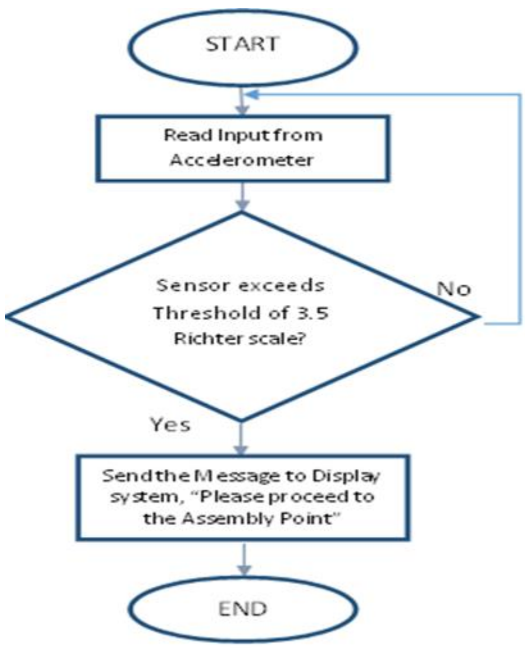

Figure 1: System flowchart

B. Raspberry Pi

Raspberry Pi is a single board computer designed and developed by Raspberry Pi Foundation in England. Debian and Arch Linux ARM distributions are provided by the foundation for download. Python is the main programming language for Raspberry Pi and it is already available as tool. The primarily operating system of the Raspberry Pi is using Linux-kernel equipped with a 900Mhz quad-core ARM Cortex-A7 architecture CPU, having 1GB RAM. It is also featured with 4 USB ports and an Ethernet controller. It is able to handle full HD 1080 playback and using onboard VideoCore IV graphics processor unit (GPU).

This controller will be used to send messages to display device(s). A picture of the controller is shown in Figure 2.

Figure 2: Raspberry Pi

C. Sensor (Accelerometer)

This sensor is the key component to detect the medium range equipment. The Accelerometer is a dynamic sensor and one of the common inertial sensors capable for the vast range of sensing. The common accelerometer can measure acceleration in one, two or three orthogonal axes. Proper acceleration is measured using accelerometer. On the other hand, the accelerometer at rest will evaluate an acceleration g= $9.81m/s^2$ straight upward at top of the earth. Thus, a free fall orbiting accelerometer will measure zero accelerating due to the gravity of the earth. The ability of the sensor to detect acceleration in different axis helps detect the vibration of the earthquake which is not fixed in one direction every time an earthquake happens.

D. Hardware Connection

The accelerometer is connected to Raspberry Pi 2 by using simple male to male jumper wires. Since the output reading from the accelerometer is in analog form, an analog-to-digital converter (ADC) is needed to convert the analog signal from accelerometer before sending it to Raspberry Pi as the input. The Ethernet port of the Raspberry Pi is plugged into with Local Area Connection cable to enable internet connection. The ports of Raspberry Pi are used to connect with accelerometer as shown in the Figure 3.

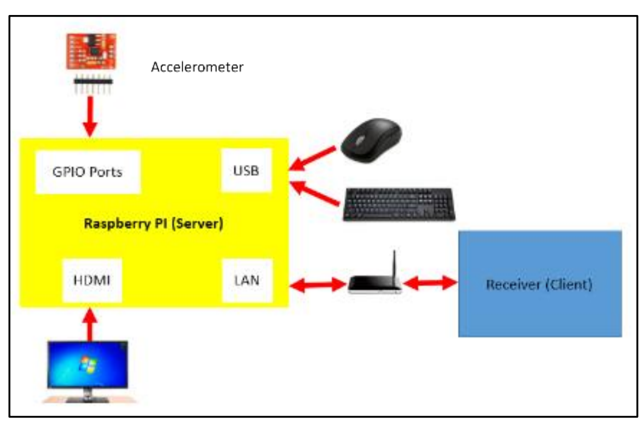

Figure 3: The block diagram (hardware) of the system

The converted signal from the sensor will be processed by the Raspberry Pi. Moreover, port 2 and port 6 of the Raspberry Pi will supply voltage of 5V and ground respectively.

A LED Display is connected at the receiver of the Raspberry Pi in order to display the information and safety guidelines once an earthquake occurs and it has received the information.

A monitor, an USB keyboard and an USB mouse were used for developing the software in the Raspberry Pi.

The block diagram of the system shown in Figure 3. The HDMI cable is used to connect monitor from HDMI port of the Raspberry Pi while USB port of raspberry Pi used to connect keyboard and mouse.

E. Software

The Raspberry Pi uses a Linux-Based operating system. Raspbian Wheezy is the operating system (OS) used in this project. The OS image is extracted to an SD card by using Win32 Disk Manager. The configuration of the OS such as login details and IP address setting was done.

The system uses WhatsApp desktop application to send the information which is commonly used in smartphones. By installing Yowsup library into Raspberry Pi, WhatsApp application can be accessed. Yowsup is a Python library that allows user to login and use the WhatsApp service and provides user with all capabilities of an official WhatsApp client, allowing user to create a full-fledged custom WhatsApp client. Python programing language is a high level programing language chosen for witting the OS application program for the system.

F. System Description

The sensor is placed in the center of the container which is filled with sand and soil. The value of the output voltage will change when the gravity force acts on the 3 different axes. The output value will be in analog form and the threshold value will be calculated by referring to data sheet of the accelerometer.

Since accelerometer has 3 axis, two axes is selected for this project since earthquakes happens in these two axes. For axis Y and axis X, two different ports of the Raspberry Pi is needed as both will give different readings. Accelerometer is connected to the port of the Raspberry Pi which was defined as input and always sends input to it. It will inform the Raspberry Pi the current status. If any of the output from this two axis surpass exceeds the threshold value, it will trigger the Raspberry Pi to send precaution message through WhatsApp to receiver Raspberry Pi which is connected to a display system. This is needed to receive the alert remotely.

The receiver Raspberry Pi connected to the LED Display will then echo the received information or message on the LED display.

G. Experiment 1: Accelerometer Testing with Threshold Value

The accelerometer pins are connected to the Arduino pins GND, 5V, X and Y acceleration analog values to Arduino INPUT pins and Arduino OUTPUT to LEDs to indicate over threshold values.

The accelerometer is tested to give output whenever the output will surpass the threshold value. Thus, two different LEDs are connected to output of X-axis and Y-axis respectively. In initial stage, this experiment is tested using Arduino Uno.

H. Experiment 2: Convey messages from controller to WhatsApp client using Raspberry Pi

The purpose of this experiment is to send WhatsApp messages via software from Raspberry Pi to the clients (LED displays or smartphones). Through the use of a Linux WhatsApp program called Yowsup, messages can be sent from the operating system in Raspberry Pi to other clients (such as smartphones and LED displays equipped with internet). In this experiment, the desktop (Raspberry Pi) has to be registered in Yowsup as a WhatsApp identity as any registered mobile number. To register, SMS will be sent to the mobile number and then the registration code can be entered in the Yowsup software for Raspberry pi to act as the mobile number. After successful registration, the test echo program could be run to make sure that the desktop successfully emulates the mobile number.

IV. Results and Discussion

This section shows the results for the experiments conducted. In experiment 1, the container is shaken in three different conditions; in X-axis only, in Y-axis only and in diagonal direction of the X and Y-axis.

Before using the accelerometer, it is desired to know the analog values that correspond to positive and negative acceleration (gravity). The analog values will be converted to digital by the Analog to Digital Converter (ADC) available in the controller. Next, the corresponding Richter scale can be approximated to its digital value.

By assuming that Rx is the gravity acceleration at first, we can calculate its corresponding ADC value by letting V0g as the voltage at zero acceleration (gravity) and Vref as the reference voltage. These values are obtained from the sensor's datasheet.

Calculation of digital output for Rx = 1g

$$\begin{aligned} adcRx &= (Rx \times Sensitivity + V0g) \times 1023 \div Vref \\ &= (1g \times 0.33V/g + 1.65) \times 1023 \div 3.3 \\ &= 613.8 \end{aligned}$$

This calculated value of 613.8 (or approximately 614) is the value of 1g which is 9.81 m/s. We then calculate the value of the same magnitude of acceleration, but in the opposite direction.

Calculation of digital output for Rx = -1g

$$\begin{aligned} adcRx &= (Rx \times Sensitivity + V0g) \times 1023 \div Vref \\ &= (-1g \times 0.33V/g + 1.65) \times 1023 \div 3.3 \\ &= 409.2 \end{aligned}$$

The approximate value of 409 represents acceleration of 9.81 m/s in the negative direction. Next, we need to calculate the gravity force for a Richter Scale of 3.5 = 0.025 $\frac{m}{s^2}$ [10]

$$\begin{aligned} Rx &= 1g \div (\tfrac{9.81}{0.025}) \\ &= 0.00255g \end{aligned}$$

A. Experiment 1: Accelerometer Testing

Table 1
ADC Value of the accelerometer read by the controller

Shaking Test		1	2	3	4	5	6	7	8	9	10
		Digital Output Reading (points)									
Parallel to X-axis	X-Axis	514	516	501	501	501	501	501	501	501	501
	Y-Axis	497	485	505	504	504	504	504	504	504	504
Parallel to Y-axis	X-Axis	502	499	503	501	501	501	501	501	502	503
	Y-Axis	505	521	503	504	503	502	502	503	502	503
Diagonal	X-Axis	514	549	515	439	502	503	503	502	502	502
	Y-Axis	506	534	512	499	507	506	506	506	506	506

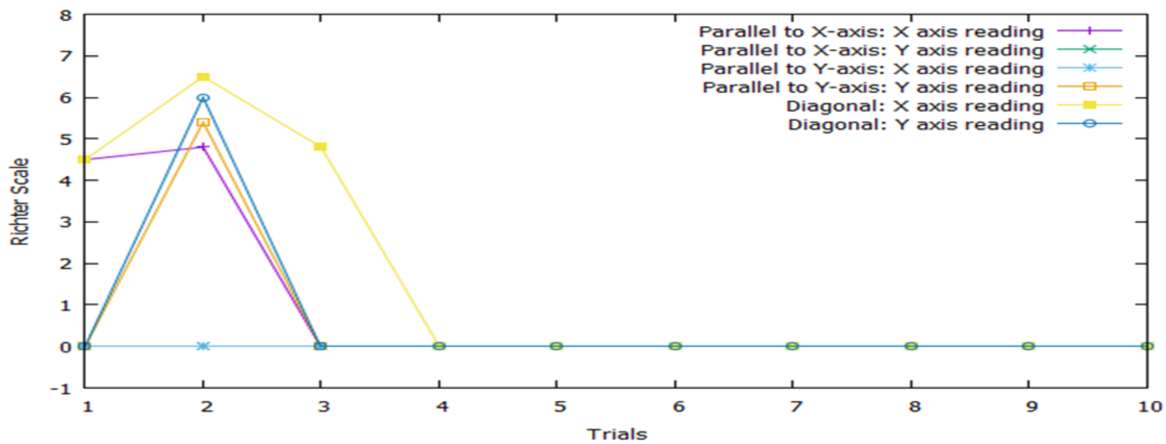

Figure 4: Corresponding Ritcher Scale to Trials

This value is then used in the Analogue to Digital conversion equation to determine its approximate digital value.

Calculation of digital output for 0.0025g

$$adcRx = (Rx \times Sensitivity + V0g) \times 1023 \div Vref$$
$$= (0.0025 \times 0.33V/g + 1.65V) \times 1023 \div 3.3V$$
$$= 511.76$$

For a Richter scale of 3.5, the corresponding digital value that will be read is 511.76 or approximately 512. Then the corresponding acceleration (g) value of a Richter Scale of 6.0 = 1.5 $\frac{m}{s^2}$ is determined.

$$Rx = 1g \div \left(\frac{9.81}{1.5}\right)$$
$$= 0.153g$$

Its respective digital value is then calculated. Calculation of digital output for 0.153g

$$adcRx = (Rx \times Sensitivity + V0g) \times 1023 \div Vref$$
$$= (0.153 \times 0.33V/g + 1.65V) \times 1023 \div 3.3V$$
$$= 527.15$$

We now have the upper limit value/threshold (6.0 Richter Scale) and lower limit value (3.5 Richter Scale) thus the threshold value can be set as a limit in order to give an output signal from the controller whenever the threshold value is exceeded. The threshold value points for an earthquake 3.5 Richter Scale is 511.76 whereas for earthquake 6.0 Richter Scale is 527.15. These values are used in the program of the system.

Table 1 shows the ADC value of the sensor read by the controller in 10 different trials. While Figure 4 shows the Richter scale respect to ADC value reading from the accelerometer from table 1. Between trial 1 until trial 4, some of the reading exceed threshold value set by the Arduino. Figures 5 to 7 shows the three different axis of shake.

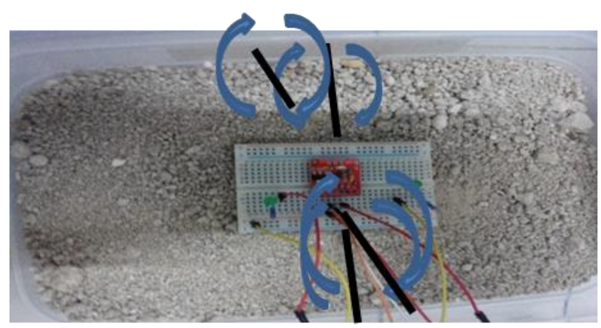

Figure 5: Shaking Parallel to X-axis

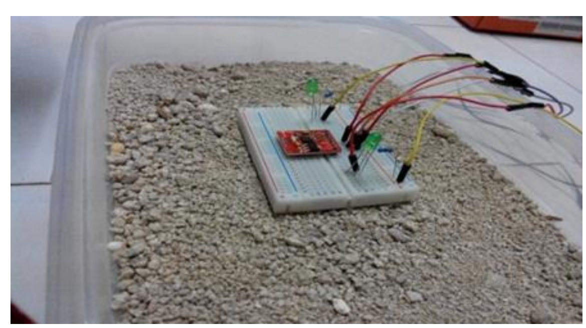

Figure 6: Shaking Parallel to Y-axis

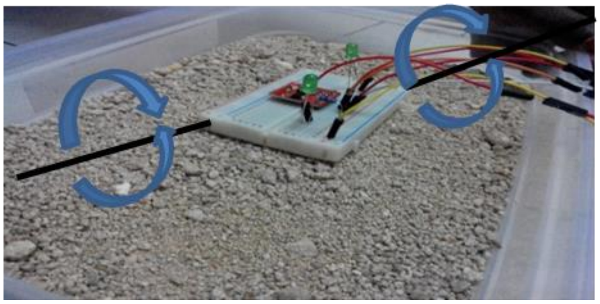

Figure 7: Diagonal Shaking

B. Experiment 2: Convey messages from controller to WhatsApp client using Raspberry Pi

The Yowsup library has been installed in Raspberry Pi to access WhatsApp smartphone application. Once it was installed, the messaging system can be used to communicate remotely. Basically, for message sending and receiving, both use same Yowsup library. Figure 4 shows that the 6 digits code has been requested to register the WhatsApp as an official client. Figure 7 shows the message sent using Raspberry Pi to a number. After the registration in Raspberry Pi, the messaging function through it is enabled. In this project, WhatsApp is used to send the precaution alert message once the output values from the sensor surpass the threshold value. The precaution alert message will be received by receiver and displayed on LED display.

Figure 8: Message Sent from Raspberry Pi

V. CONCLUSION

This paper presented an earthquake disaster awareness system using accelerometer to sense the earthquake. This simple system display an alert message on LED display to make people aware of the earthquake and take necessary action to save their lives. Since this system is small and compact, it can be installed in many areas to detect earthquakes. Moreover, it also a relatively cheap system, thus, to employ this system in large volumes is possible. It has many advantages compared to current using seismometer which measure earthquake in Richter Scale. Indirectly, this system can also reduce number of casualties when earthquake happen.

Further improvement can be done, for example addition of web camera to capture the image and send that image information. Image could explain the situation of earthquake better.The manuscript article should be written in English in the font of Times New Roman, which includes the following: abstract, introduction, literature review, objectives, research methodology, theory, testing and analysis, results and discussions, conclusion, acknowledgement and references. Manuscript should be prepared via the Microsoft Word processor. Do include the duplicate hardcopy and softcopy to the editor.

ACKNOWLEDGMENT

We will like to acknowledge University Teknikal Malaysia Melaka for providing the fascilities and support in general, the Center of Excellent in Robotics and Industrial Automation and also the research group of Robotics and Indstrial Automation. Authors would also like to acknowledge UTeM research grant PJP/2014/FKE(11D)/S01339.

REFERENCES

[1] Rilek1Corner "6.0 Trembler Rattles Sabah West Coast," *The Borneo Post*. 2015.
[2] Amanda Lee "M5.2 - 28km N of Ranau, Malaysia," *United State Geological Survey*, 13-Jun-2015.
[3] Goh Chiew Tong "Sabah quake update: 8 Singaporeans dead, 2 more missing," *Channel News Asia*, 07-Jun-2015.
[4] S. Sokial, "Authorities release names of Mount Kinabalu Qauke victim," *The Rakyat Post*, 07-Jun-2015.
[5] M. f. Darwis, "11 Bodies found at Mt Kinabalu, say Sabah Minister," *The Malaysia Insider*, 07-Jun-2015.
[6] R. Sanches, "Death toll in Nepal earthquake tops 8,000," *CNN*, 10-May-2015.
[7] F. Finazzi and A. Fassò, "Earthquake monitoring using volunteer smartphone-based sensor networks Data acquisition Earthquake detection," pp. 1–4.
[8] R. Khudabadi, "A Recent Study on Early Disaster Warning & Evacuation System on Mobile Phones Using Google Cloud," vol. 02, pp. 501–503, 2015.
[9] M. S. Bin Bahrudin, R. A. Kassim, and N. Buniyamin, "Development of Fire alarm system using Raspberry Pi and Arduino Uno," *2013 Int. Conf. Electr. Electron. Syst. Eng.*, pp. 43–48, 2013.
[10] B. Soediono, "Earthquake Magnitude, Intensity, Energy and Accleration," *J. Chem. Inf. Model.*, vol. 53, p. 160, 1989.