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Development of Flood Notification System

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Abstract: The present of natural disaster such as flood causes loss of life, property, devastation of livestock and agriculture. It costs a million of Ringgit to reconstruct, repair and provide shelter for victims. Flood is known as yearly disaster in Malaysia because of the monsoon season that will cause heavy rain in certain states. Therefore, a system that provide an effective flood notification system that give early warning need to be develop to reduce the loss of property and helps people that live around the affected area. Before developing a flood notification system for the flood disaster, communication system available during the occurrence of flood must be studied. Hence, a system that works in three stages is propose. First stage: monitor water level based on height of water, second stages: calculate the time for flood to occur and third stage: alert victims about flood status and suggest the nearest relocate center using their mobile device. The notification is done by taking advantage of GSM network as the coverage of GSM network is widespread and mostly available in any places in Malaysia. The notification messages will be send to cellular of logged user which are head of the village, police station and nearest safety agencies. The developed system will be using an Ultrasonic Sensor, Arduino UNO R3 and GSM shield as the main components in the prototype. Arduino UNO acts as the microcontroller of system that will perform various actions such as observing the height of water, perform calculation of water level and send SMS through GSM shield. In order to validate the accuracy of proposed system, an experiment is conducted using small scale prototype to simulate the real flood conditions. The system is expected to provide real time and reliable measurement of water height with an additional feature of sending SMS notification.

Keywords: Flood System; Notification of Flood System; SMS based system; GSM System.

1. Introduction

Every year in Malaysia, flood disaster occurred mostly during the monsoon season. It is a regular disasters that occur from month of October to March each year that cause heavy rain and regular rainfall at certain geographical location. Therefore flood is a result of this cyclical monsoons. Sarawak and Peninsular Malaysia have experiences 40% rainfall that was 30% in the past due to climate change that followed by recurrent heavy rainfall [1]. Based on research of environment scientist, Datuk Seri James Dawos, due to global warming the sea level has increased by 22 cm and the highest tide recorded is 6.3 meters [2]. He concluded that there is no stopping to floods and it could be worse if there is no improvement or technology implementation to prevent and counter the problem. Hence, it is important to come with an flood notification system in order to reduce flood losses and notify victims of incoming flood disaster [3]. An early warning system should be able to provide real-time warning that provide local authorities time to act and prepare for effective response in order to avoid the disaster [4]. Unfortunately, there are lack of system that take advantage of available technologies to create an effective and responsive flood warning system to benefit people [5]. Warning might fail to reach their destination and sometimes it may not be understood due to ineffective and unsuitable alert tools of communication channels. Moreover, existing warning system lacks the basic abilities to monitor water level, to give immediate and real-time warning notifications and to offer a well-organized coordination during evacuation process. The propose system focuses on designing a system that overcomes the existing flood based on comparison study from previous system [6-7]. Then a prototype system model for the proposed design flood notification system will be

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developed [8]. The system is simulated using experimental setup to determine the accuracy and reduce system errors. For real life implementation, the proposed system would be using Ultrasonic sensor (HC-SR04) that will be installed at riverbank to measure height of water or water level [9]. The microcontroller for the system is Arduino UNO R3 that is connected to sensor and GSM shield module [10-12]. The Arduino will collect data from the sensor and perform calculation to determine the flood occurrence and the data will be send to GSM network using GSM shield module. A standard SIM card is used to send the messages through network operator that will apply cost for each messages sent by the system. However, as a proof of concept, the rsearch work is scaled down to only lab scale setup [13]. A few test will be conducted through experimentation that can control the rising of water to implement the real situation. In order to save the operational cost and ensure reliability of the system during power outage, battery is used to ensure the system works when there is no electricity supply to power up the system [14]. Furthermore, the system only used small amount of power, therefore battery source is enough to power up the system [15]. The power source and others component will be placed in a special design box or casing to prevent short-circuit during the rainy condition. Seasonal heavy continuous rains in Malaysia from 26 December 2016 caused flooding in two states: Kelantan and Terengganu. The flood temporarily displaced about 25000 people and have rendered some villages inaccessible due to damaged bridges and blocked roads. Besides that, rains after 23 January 2017 caused flooding in six states: Johor, Kelantan, Pahang, Perak, Selangor, and Sabah. Johor and Pahang got the worst-hit where water rose 1.5 metres in certain areas [12]. The flood affected a total of 14903 people. Most of the victims are moved to nearest relief centres or family members who don‟t get affected by flood. The latest flood occurrence is from 20 to 26 of February 2017, where torrential rains caused the Baram and Limbang rivers in Sarawak to overflow causing evacuation of 830 people [13].

2. Background and Literature Review

Flood is common natural disasters that can occur at any time at any place. There are three types of flood that is coastal flood, river flood and surface flood. Coastal flood occur in area on the coast of sea, ocean or large body open water [14]. It is usually caused by extreme tidal condition [17] caused by severe weather. River flood occurs when excessive rainfall over an extended period of time causes a river to exceed its capacity and causes flood to nearby or lower ground. Surface flood eventually caused by heavy rainfalls creates a flood event independent of an overflowing water body [15]. It can happen in urban area caused by intense rain overflow drainage system and flow into streets and nearby structure and run-off or flowing water from hillsides. River flood is commonly occurs in this country despite the rainy season. Certain places that have lower geographic ground will be flooded with water. The residential area is the most affected area by the massive water. Flood causes loss of property and people will suffer the consequences [6]. The present water level indicator do not really accurately determine time of flood. Therefore in this rsearch work, a flood notification system will be developed to help the villagers [18-20]. The system using mobile phone as output to inform users. This will help users to prepare and move their belonging to safe place.

Existing flood warning system such as water level indicator is not able to notify people of incoming flood. The lack of tool and research cause flood to occur without better prevention method. Therefore, improvement and innovation need to be done to make sure the loss and safety of people in village or city. As people nowadays has their own mobile device, why not we make use them? Therefore this system takes the advantages of mobile device to inform people about incoming flood via messaging.

2.1 Flood Disaster in Malaysia

Flood is the most intense natural disaster experienced in Malaysia. Flash flood and Monsoon flood are two vital type of flood that occurred in this country. The monsoon flood occurs from Northeast monsoon which occurs from the month of October to March causing heavy rain to east coast state in peninsular, northern part Sabah and southern part of Sarawak [7]. Based on the history, one of the worst flood disasters that happened in this decade is cause by monsoon rain. The flood affects the east state of Malaysia including Perak and Johor. Duration of flood occur from 15 November 2014 until 3 January 2015. This worst flood affected 200,000 people and caused a total of 21 deaths. Table 1 shows the statistic of evacuate people of affected area. Floods not only cause loss of lives but also severe damage building and public facilities such as school, train railway and hospital. During flood occurrence, the communications have become challenging as access by road is submerges by water. At certain places electricity had to be cut off to prevent electric shock [9]. The reported damages would cost state government over RM1 billion to recover all the facilities [27-28].

2.2 Previous Related Works

Related research work of other researchers are being study to make improvement based on identified problem or adapt with system requirement needed for this rsearch work. Some previous system using the same sensor, microcontroller and transmission medium is cited as guidance to design the proposed flood notification system. Flash Flood Warning System in Risky Area [14]. Y. Chonbodeechalermroong and S. Chuenchooklin from Naresuan University, Thailand has created a flood warning system based on GPRS system to reduce the risk of flash floods in valley and rivers. If the heavy rain occurs at the river it takes about two hours for the river to overflow. The system contain siren that will notify on the warning level and the microcontroller will send data through messages to person in

authority. Then the officer will send the SMS to officer who governs area for preparation of flood. The system divided into two parts, transmitter on upstream area and receiver at low stream. The transmitter composes of instrument such as water level sensor, rain gauge, sensor and SMS GSM module. The power will be supplied by solar cell and battery. The receiver has SMS receiver tool, solar cell, battery and microcontroller. The water levels are divided into three phase that are low, medium and height, where each level has different duration of alarm sound. The design of flash flood warning system. Design and Construction of Early Flood Warning System Through SMS Based on SIM300C GSM Modem [15], a group of researchers from University of Pelita Harapan, Indonesia has design and construct an early flood warning system. These system objectives are to measure threshold height of water and send warning message to client. The system must detect three phase based on the height of water and calculate time for flood to occur. SMS will be send to inputted recipient number using GSM network. The system will be tested using a small scale prototype design to determine the accuracy and calibrate the error [16]. The three phase levels are prone to flooding, flooding and safe condition which the height of each level is predetermined in the design. The system of early flash flood warning system. SMS Based Flood Monitoring and Early Warning System [6] S. Azid, B. Sharma. K. Raghuwaiya from The university of the South Pacific, Fiji has developed a SMS based flood monitoring and warning system. This system demonstrates the design process, implementation and experimental works for a SMS based flood warning system [17]. The system will update the height of water level to contact number via SMS upon user‟s request. The system provide real-time alert when level of water surpasses defined threshold value that is set in the system. This system used GSM module for sending the text messages while Arduino Uno act as microprocessor that used to read input from pressure sensor and calculate height. The sensor detects the water level and the height is determined using Pascal‟s Law. Battery with attached solar panel will supply power to the system and the battery can last about a week. The design of water level detection method and housing for sensor. Flood Warning System Based on User Mobility [5], the system objective is to send warning messages to cellular number that has been logged at the affected base station [18-20].

2.3 Gap Found Between Literature Review and Way Forward

Table 1 describes the advantages and disadvantages of previous flood detection system compare to my propose system.

Table 1 – Advantages and Disadvantages of previous system

Author	Advantages	Disadvantages
Y.Chonbodeechalermroong and S. Chuenchooklin	Has administrator - checking information before spread the message.	Solar cell - cost a lot for maintenance [21-22].
E. Kuantama, P. Mardjoko, and M. A. Saraswati	Water level request - User can send request message to know level of current water. Waterproof casing - to prevent short circuit	Solar panel - cost a lot for maintenance [23].
S. Azid, B. Sharma, K. Raghuwaiya, A. Chand, S. Prasad, and A. Jacquier	User request message - User can send message using predefined format to obtain information about current water level. Aluminum housing – Weather proof and resistant to corrosion.	Pressure Sensor - Complex formulation needed to calculate height of water using Pascal‟s Law and low sensitivity [24].
F. A. Mastor, I. A. Aziz, N. S. Haron, J. Jaafar, N. N. Ismail, and M. Mehat	Three water level notification - Low, medium and high level but only send notification if the level reach medium and high level only.	GSM module at base station – wired connection from sensor to base station may cause short circuit if flood occur [25-26].
Propose system	Detect three levels but only notify Caution (medium) and Danger (high) level only. GSM shield design in a water-resistance casing together with sensor and Arduino to prevent short circuit. The power supply of system using battery to reduce cost.	

3. Research Methodology

The SMS flood notification system in this thesis focuses on performing a small-scale study only. The system is divided into three main parts that are the digital input system in the form of ultrasonic system, data processing system in the form of microcontroller (Arduino UNO R3) and output system in the form of GSM modem (SIM9000 GSM Shield) .The proposed system can be easily installed on the riverside. As for the main controller of the overall system, the microcontroller has several important roles to do such as controlling the ultrasonic sensor used for measuring the water height, calculating the height of the water, and sending the water level data which is measured from the ultrasonic

sensor and send to the GSM modem in the form of SMS. In the main system, the ultrasonic is an input subsystem which will continuously measure the water level. This process is controlled by the microcontroller. When the water level reached the flood-prone, flood or safe boundaries, the ultrasonic will send the data coding which provides current condition. Then the microcontroller will command the GSM modem to send a short message to the client. All communication between the client systems via done by using SMS in accordance with the predetermined SMS delivery format. The processes start with ultrasonic sensor sending out a signal to measure the height of the water. The data gathered from the sensor will be forwarded to the Arduino for data processing. The Arduino will analyze and compares the recorded data with previous cases as reference. If the Arduino detect the water level has reach Caution level, it will send first warning messages to the users through GSM modem to the GSM network. In real-time situation when the user receive the warning message, they will have to prepare if worse condition occur. If the water level is in Normal level condition no messages will be send to user. After sending the first messages, the system will continuously measure the height of water. If the water level reaches Danger level, the system will once again send warning message with estimated time for flood to occur. This is to ensure people knows the exact time for them to leave the danger area and will be well prepared. If the water level does not increase the system will reset and measurement will start from first stage. Furthermore, in the proposed flow diagram, the user will receive two warning notification messages if flood occur. The Caution notification will only notify about the condition while Danger notification will send message with condition together of the estimated flood time and nearest relief center. This addition condition of the proposed system is an improvement from previous system to increase efficiency of flood system.

3.1 Proposed Flood Notification System Architecture

The flood notification system consists of three phase; data recording, data processing and data broadcasting. Fig. 1 illustrate the propose system architecture of the system.

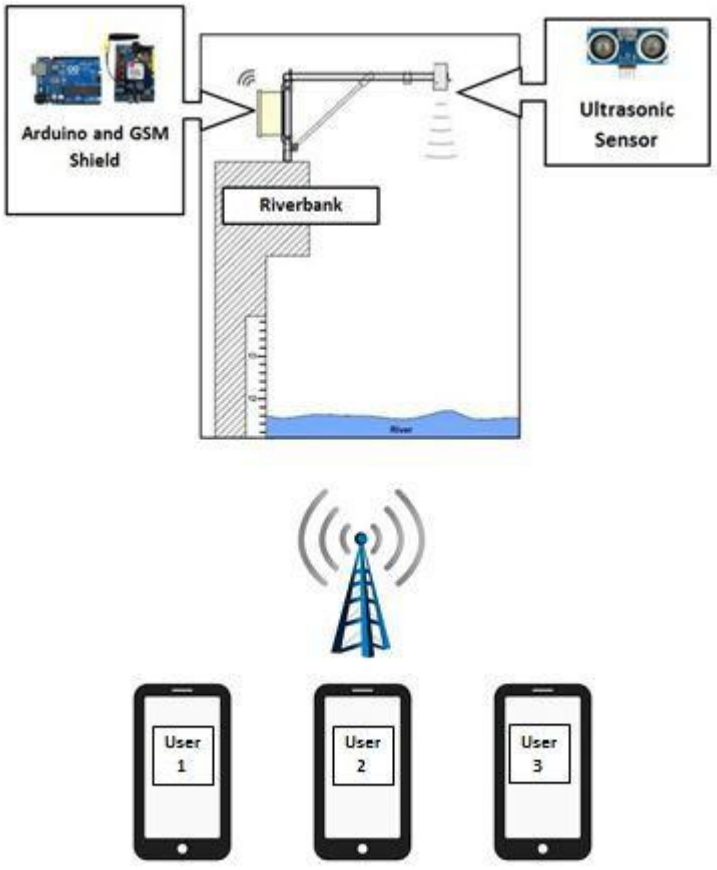

Fig. 1 - Propose of system architecture design.

3.2 Flood Measurement Data Recording

The ultrasonic sensor measure water level and send the data to Arduino. The sensor transmits high-frequency sound pulse and record how long it takes for the sound pulse to reflect back. The speed of sound transmitted is approximately 341 meters per second in air. The sensor then used time difference between sending and receiving sound pulse to determine distance as shown in Fig. 2, Fig.3 and in Fig. 4.

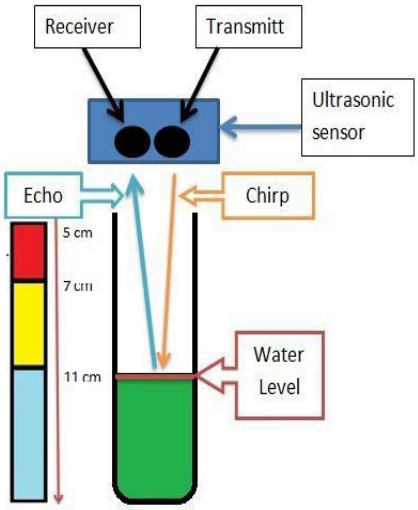

Fig. 2 - Mechanism of ultrasonic sensor for Normal level.

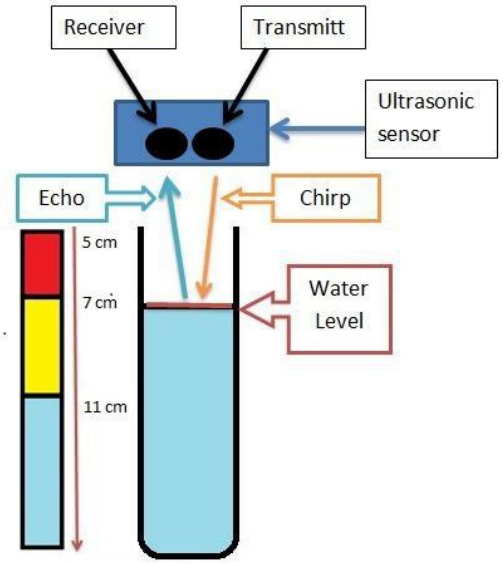

Fig. 3 - Mechanism of ultrasonic sensor for Caution level.

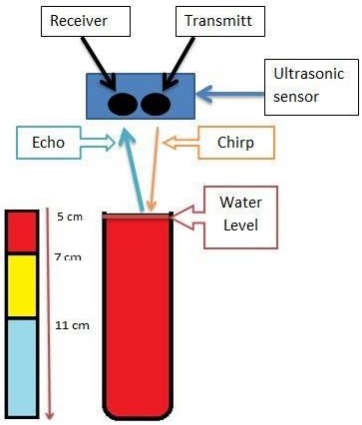

Fig. 4 - Mechanism of ultrasonic sensor for Danger level.

3.3 Flood Measurement Data Processing

The data obtain from ultrasonic sensor is then receive by the microcontroller which is Arduino UNO R3. The microcontroller will perform the calculation to determine the status of flood based on height of water with reference of past cases. The system obtain two type of notification level: caution level and danger level. Each level has its own range height of water based on previous flood occurrence .The reference is shown in Fig. 5

KELANTAN : Water Level On-Line Stations

Station ID	Station Name	District	River Basin	Last Update	River Level (m)	Normal	Alert	Warning	Danger
6019411	Sg.Golok di Rantau Panjang	Pasir Mas	Sg.Golok	3/12/2016 02:01	8.54	5.00	7.00	8.00	9.00

Legend
Alert Level
Warning Level
Danger Level
-9999 : Data is out of range (error)

Fig. 5 - References level of flood in Sungai Golok, Kelantan.

As the system is conducted only in experiment, the system size is reduce to suitable scale but maintain the actual condition. In the system, the height of water is scaled down to 1cm : 10cm ratio, with reference from water level of Sungai Golok, Kelantan as shown in Fig. 5.

3.4 Flood Measurement Data Broadcasting

The processed data is then sent to Global system for GSM module in the form of SMS to be broadcasted to all users registered in the system to inform regarding flood condition in the area. There are two type of warning design, first warning is named as Caution that ranged from 7-11 cm from ultrasonic sensor and second is Danger level ranged from 5-7 cm from ultrasonic sensor. Fig. 6 illustrated the visual of the system.

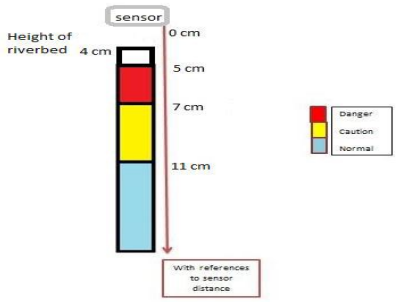

Fig. 6 - Distance measurement of height of water from sensor.

3.5 Flood Notification System Design

The system design involves designing the circuit and prototype of the proposed system. For circuit design, simulation of circuit need to be perform using software and for prototype coding need to be written and upload to the Arduino for system testing. During programme design, debugging is expected to occur because of error that may arise from the coding design.

3.6 Block Diagram of Flood Notification System

The block diagram show how the system works from start until the end. The system start with the sensor detecting the height of water and then send the data to the microcontroller. The microcontroller will send the data to GSM Shield. Then the GMS shield will transmit message via GSM network until it reach the user. Fig. 7 shows the block diagram of proposed flood warning system.

Fig. 7 - Block diagram of propose system.

The connection between GSM Shield and Arduino. Pin 3VR of GSM Shield is connected to pin 2 (D9) Arduino and pin 3VT is of GSM Shield connected pin 3 (D10). These connections allow the system to communicate using serial library in the IDE software. Then, pin ground is common for both GSM and ultrasonic sensor.

4. Results and Discussion

It includes the measurement, testing, calibration of sensor and functionality of hardware and software. The result obtain from the experiment is evaluation of the functionality of the proposed system after calibration to ensure data obtained is accurate and represent the real situation.

4.1 Sensor Measurement Data

The most important parameter in this system is to measure the distance sensor. In order to measure the height of the river, Ultrasonic sensor is used to measure the distance of water relative to the height of sensor. Ultrasonic sensor will act as the references point for the system where the initial value is zero (0) and increase until the sensor reflect the signal where this represent the height of water to be stored in the system.

4.2 Ultrasonic Sensor Coding to Measure Distance

The coding algorithms above is used to measure distance of water from sensor and stored the data into Arduino for microcontroller to make decision based on height of water level. The output of the sensor is display in serial monitor as shown in Fig. 8.

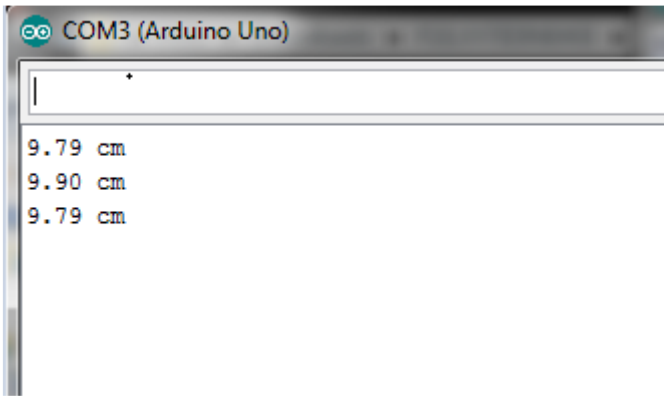

Fig. 8 - Output of ultrasonic sensor reading

Measurement is done by comparing the value obtain from serial monitor of Arduino IDE software and manual measurement using ruler to determine height of water from sensor. The sensor reading is perform three times to determine the precision of the sensor. Fig. 9 shows how measurement is taken manually.

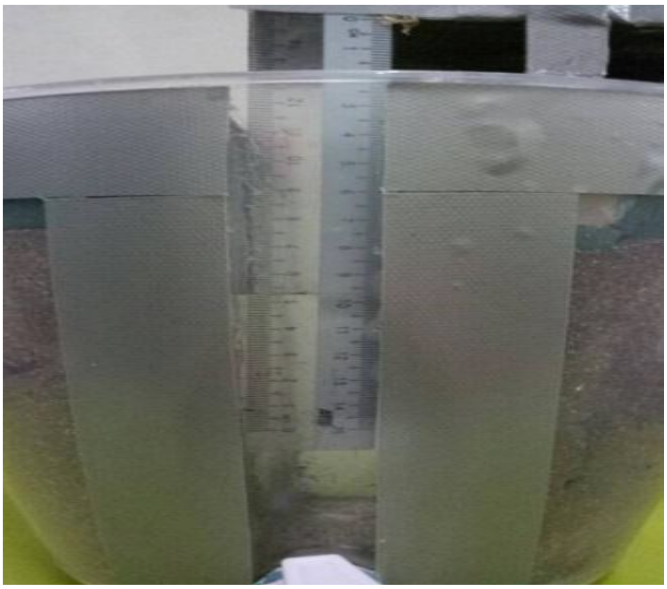

Fig. 9 - Manual measurement using ruler

Based on Fig. 9, the value for average reading is quite close or similar with reading obtain for reading 1, reading and reading 3. It shown that the ultrasonic sensor used in this system is reliable and quite precise. In this system, the reading is only taken at distance 2cm because ultrasonic sensor can only detect distance from 2cm to 400cm. 13 cm is the last measurement because that distance already reach the normal water level condition in this system, where the normal water condition is about 11cm - 13cm from sensor.

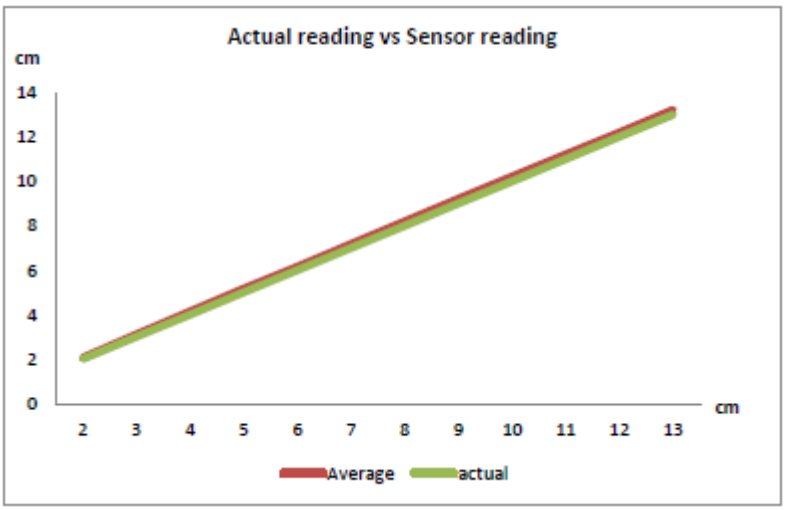

Fig. 10 - Graph plot for average reading of sensor

From Fig. 10, percentage error of sensor reading is decrease over increase of distance. It shows that the sensor has increase its efficiency as the distance increase ,which means it is reliable to be used in this system. The error in the measurement occurs because of air humidity and temperature during the reading is taken. These factors can affect the speed of signal transmitted from the sensor and eventually cause the result to vary and not constant for each measurement [19].

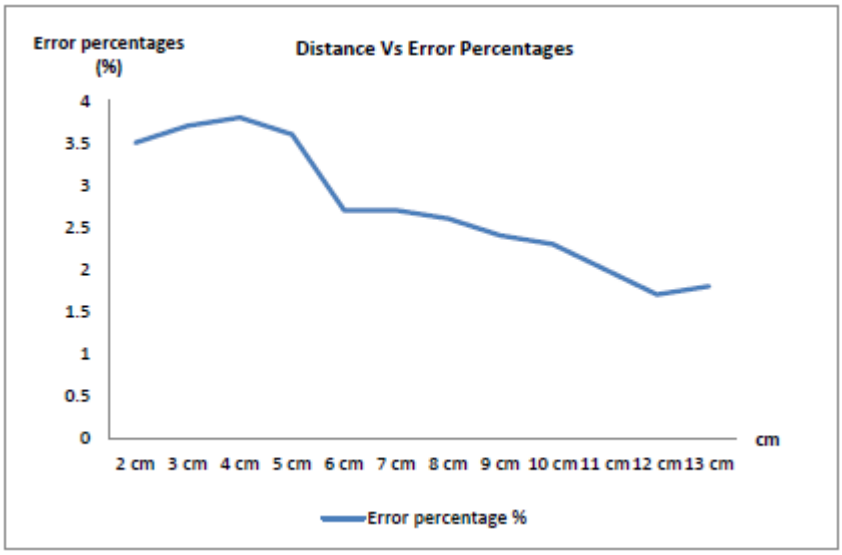

Fig. 11 - Error percentage plot of sensor reading

4.3 Time Taken to Transmit the Message from System to User

The GSM system used in this system is text message using network service provider in Malaysia region. The message that is send to receiver will be charged according to data rate applied by the service provider. In order to test the transmission time for the receiver to accept the message from the system, a few test message will be send to the receiver to measure the time taken for the message to arrive. The written coding above is used to send message from output Arduino to user. The coding used is AT commands to order Arduino to send messages via telecommunication network. The telephone number of user is required to be included in the coding to enable the connection to the user mobile phone. Fig. 12 shows messages receive by user.

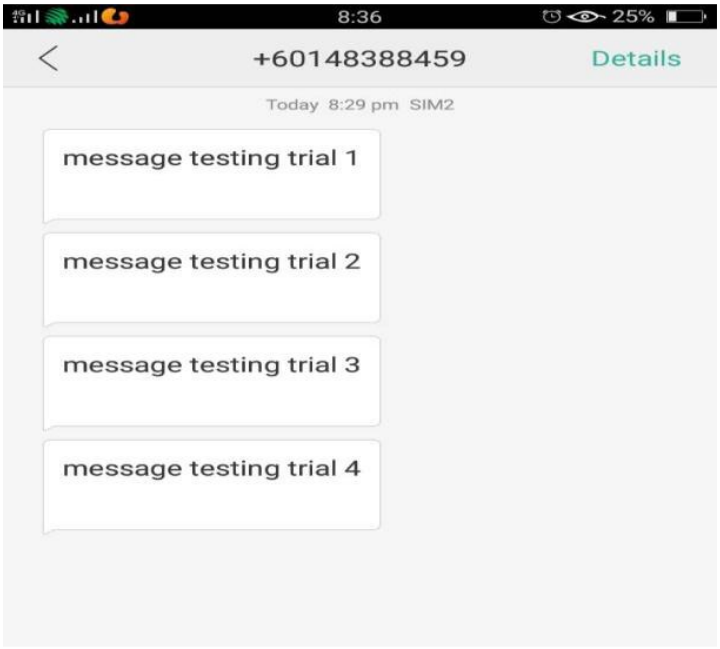

Fig. 12 - Sending message test

4.4 Performance of Flood Notification System

The result of system is determined by a few aspects involving system stability, and number of message receives by the users. It also includes the prototype design of the system to perform real situation that may cause flood to occur. The main objective is that the prototype can show the increase or decrease of water. In order to increase the volume of water, water is manually poured into the river.

4.5 Proposed Mechanism for System Stability

System stability is determined after considering the error that occurs from sensor used in the system. In order to ensure the system provide precise and accurate message to user based on height of water, the system used time delay to compare or check a conditions to ensure the system is performing the right task. When the system detect the height of water already reach the caution or danger level, the system will re-measure the height of the river again after 10 second of delay. If only the water level for the first and second measurement is in the same level then the system will send the messages. The result obtained from system is displayed in Fig. 13 obtained from serial output of system. The output shows two value of height that is 5cm and after 10 second that is also 5cm. If only the first and second measurement are in the same water level then, danger message will be send to user. This condition is created to prevent unforeseen condition which likely to occur at the river in real life situation such as water column or driftwood that may interfere the sensor reading and create a signal that does not represent the real flood situation. The reading of water level of the system is quite accurate based on the result obtained. The number recipient to receive the message is display in the system to ensure the message will be received by the user.

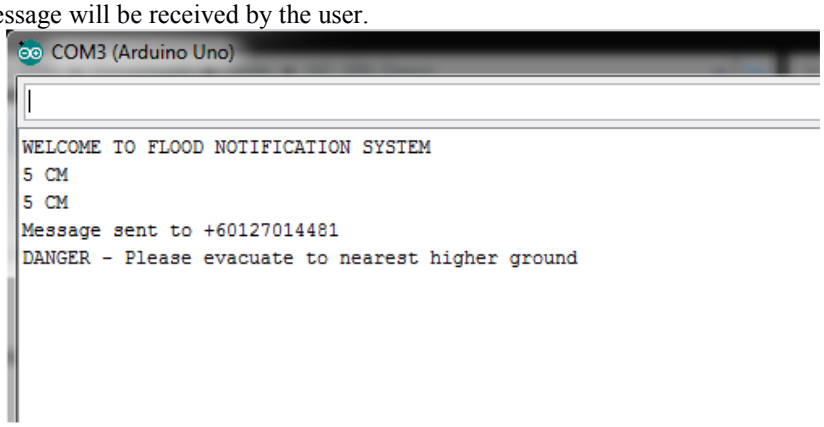

Fig. 13 - Example of action if condition is true

4.6 Output of Flood Notification System

Fig. 14 shows the message received by user for 3 conditions of flood notification system.

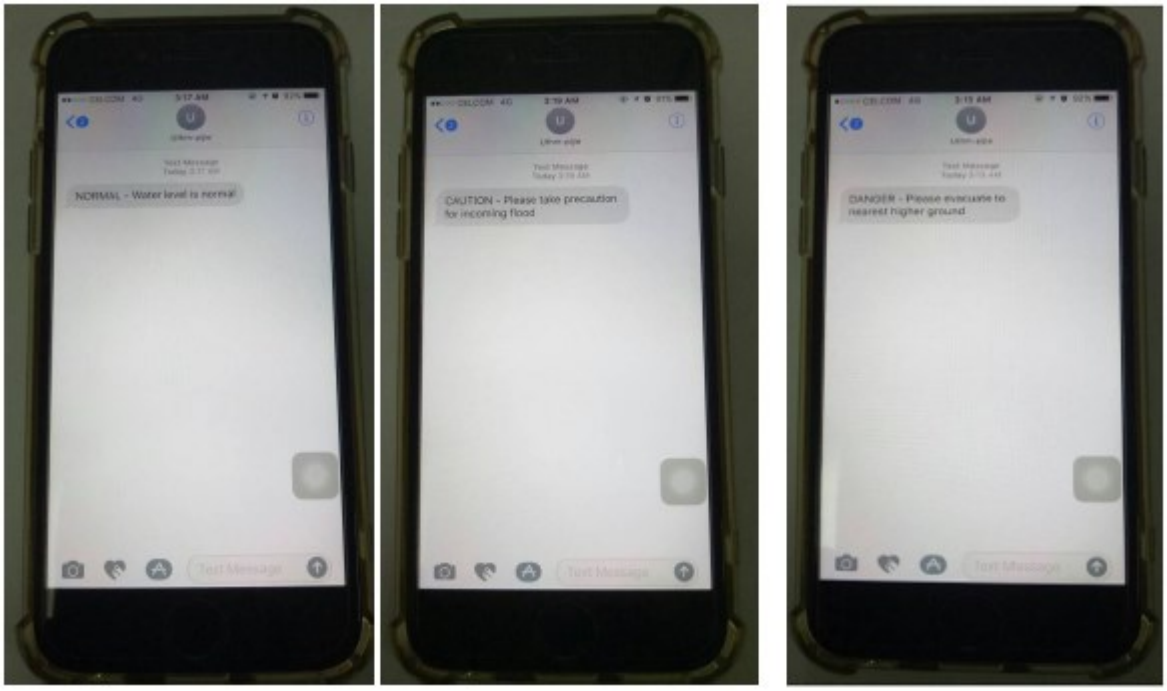

Fig. 14 - Output message receive by user for different water level
a) Normal message for normal water level b) Caution message for caution water level c)

5. Conclusion

Based on the result of studies that have been done on the flood notification system, all objective of this rsearch work have been achieved regardless of error occur because calibration is made to increase the efficiency of system performance. Each of part and module developed in the system are properly functioning. Ultrasonic sensor module work brilliantly to measure height of water and GSM module is also properly integrated with Arduino UNO module to perform the message sending task. In addition, the system is able to prevent accidental input that may occur by providing the right coding to the system. This made the system reliable and produces trustable output for user. The second objective is to test the system by experimental setup is also success where the result of the system is similar to the expected result to be achieved by system.

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