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PRE-FLOOD WARNING SYSTEM BASED ON USER MOBILITY

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ABSTRACT

The occurrence of flood causes millions of Ringgit in damages, along with the loss of life and property, and the devastation of agricultural and livestock. Therefore, an effective pre-flood warning system must be developed to mitigate flood losses and lessen the flood effects. However, when developing a warning system for flood disaster, limited communication during the occurrence of floods and the availability of electricity supplies should be taken into account. Thus, this paper proposes a conceptual framework with three (3) main stages: monitor water level, alert flood victims on flood danger status and inform flood victims to relocate to the nearest relief centre with regards to their mobility. This is done by leveraging on the Mobile Telephone Switching Office (MTSO), where warning SMS is broadcasted only to the cellular numbers logged at the affected base station. A system architecture has been designed and a prototype system is developed. The prototype system is made up of a medium sized aquarium tank, a hand pump, HC-SR04 ultrasonic sensor, Arduino UNO R3 and IComsat GSM shield. To validate the proposed prototype system, an experiment with controlled water rising effect is conducted in a lab scale setup. The results prove that the proposed prototype system is reliable as it is able to measure water level accurately and broadcast warning SMS immediately to flood victims. Thus, by having an effective real time pre-flood warning system, immediate action can be carried out in order to save lives and minimize the damages caused by flood disaster.

Keywords: flood warning, early warning system, location based warning.

INTRODUCTION

In Malaysia, floods occur nearly every year during the monsoon season and are considered as a regular natural disaster in the country. Given its geographical location, we face a heavy and regular rainfall during the local tropical wet season from October to March each year and flood is a natural result of this cyclical monsoons [1]. Due to the climate change that is followed by recurrent heavy rainfall, Sarawak and the Peninsular Malaysia have experienced 40% rainfall, which increased from 30% in the past [2] . As mentioned in the Borneo Post by the environment scientist and also the Deputy Minister of Natural Resources and Environment, Datuk Seri Dr James Dawos, the sea level had increased by 22 cm as of the present-day due to global warming and the highest king tide was estimated at 6.3 meters [3]. Dawos concluded that there is no stopping to floods and things could be worse if no implementation of long-term solution is taken to counter the problem.

Therefore, in order to mitigate flood losses and lessen the flood effects, it is important to come out with an early warning system [4]. According to [5], an early warning system should be able to provide timely warning of imminent dangers, which gives the local authorities ample time to prepare for effective response and act accordingly to avoid it. Unfortunately, there is a lack of concern in the substantial of an early warning system even though the technologies are widely available [6]. Warning might fail to reach the local authorities and sometimes it may not be understood due to ineffective and unsuitable alert tools of communication channels. Moreover, the 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. Thus, this paper focuses on performing a comparative study of flood disaster in Malaysia and the existing flood warning systems, developing a prototype system model for the proposed pre-flood warning system and validating the proposed prototype system model through experimentation.

In the real world implementation, the proposed system will be using an HC-SR04 ultrasonic sensor that is installed at a riverbank to measure water level. The sensor will be connected to an Arduino UNO R3 microcontroller, which will then process the collected data before sending it to IComsat GSM shield. As proof of concept, the project is scaled down to only a lab scale aquarium tank with controlled water rising effect. The GSM shield is connected to the nearest base station and warning SMS is broadcasted only to the cellular users that are logged within the flood affected base station. This can be done by requesting the dynamic list of cellular users from the Mobile Telephone Switching Office (MTSO) as the MTSO maintains records of users' mobility changing between base stations in specific geographical area [7]. To save operational cost and ensure reliability of the system during power outage, solar cell is used to ensure the system works when there is no electricity supply to power up the sensors at the affected sites.

The following sections of this paper will discuss on the literature review, design and project modelling, results and discussion, and conclusion and recommendation.

LITERATURE REVIEW

It is addressed in Introduction that this paper focuses on performing a small-scale study of flood disaster and the existing flood warning system. Thus, this section discusses on how this paper is related to the work of others and what can be improved based on the identified gaps in the literature.

Flood disaster in Kelantan, Terengganu, Pahang, Perak and Johor

The floods that hit the country from 15 December 2014 till 3 January 2015 has resulted in a total of 210,116 victims in Kelantan, Terengganu, Pahang, Perak and Johor were relocated to safety [8]. Based on the news reported in The Star Online, the north-eastern state of Kelantan recorded the worst hit with the number of people displaced making up to 70% of the total, followed by Terengganu and Pahang at 14.9% and 11.5%. During the flood occurrence, the communications have become even more challenging as access by road is limited due to waters that submerged many of the main roads, until at one point, the electricity supply had to be cut off to ensure the victims do not get electrocuted [2]. Referring to the news of flood disaster in Malaysia, particularly in Kelantan, Terengganu, Pahang, Perak and Johor, it is obvious that something needs to be done in order to prepare for the catastrophic flooding. Therefore, there is a need to improve the existing flood forecasting and warning system to become more efficient in order to mitigate flood losses and lessen the devastation of property and lives [9].

Related work

1) Automated photonics flood warning system (Flood-SMS)

Flood-SMS is a lifesaving flood warning system that alerts people through Short Message System (SMS) once the water level nearby starts to rise. The system utilizes photonics sensors to detect three (3) levels of flood warning (i.e. flood occurrence, flood alert and flood at dangerous level). Warning signals are sent from a GSM modem in the form of SMS only to those who have subscribed to receive the warning. The system operates by using batteries to ensure it is free from any electrical shocks arising from short circuits [10].

2) Cooperative flood detection using GSMD via SMS

This project focuses on detecting water level remotely using water level sensor when flood disaster happen. Visual Basic and C# is used to implement the software with the ability to control, sense and perform the measurement of water level. Ozeki Message Server-6 is used as the SMS gateway application that sends warning SMS from the web application direct to the subscribers through their mobile phone [6].

Gaps found in the literature and way forward

Although it was clearly shown that Flood-SMS and the cooperative flood detection using GSMD via SMS are both beneficial, it is nevertheless inefficient due to the fact that they are sending the warning SMS only to subscribed users and both system did not state the location of the nearest evacuation centre for the victims to go. Moreover, the use of water level sensor is inefficient in terms of its capability in measuring different types of water level. Therefore, the development of the proposed system in this paper aims to broadcast warning SMS to all residents, passers-by and local authorities that happen to be within the affected area with regards to their mobility. This can be done by utilizing the information recorded by the MTSO that controls the base station. The information contains the location of logged users in a specific geographical area, thus introducing a more efficient and hassle-free pre-flood warning system. By leveraging on this technology, users are not required to subscribe manually in order to be notified because eventually when flood happens, users will get the warning SMS.

Communication channels used in disaster warning

In this project, short messages services (SMS) plays an important role for broadcasting messages simultaneously to multiple users. SMS is a service available on most digital mobile phones that permits the sending of short messages between mobile phones, other handheld devices and even landline telephones.

Table-1. Comparison between communication channels used in disaster warning [6].

Channel	Advantage	Disadvantage
Electronic Sirens	Capable of reproducing warning signals and voice announcements.	Power failures always occur during emergencies.Cannot disseminate a detailed message.
Radio and Television	Widespread.	Take time to get warnings.
Telephone (Fixed and Mobile)	Messages can be delivered quickly.	Authenticity issues. Does not reach non-users. Network congestion.
SMS	Information can be broadcasted simultaneously.	Characters limit. Does not reach non-users. Network congestion.
Internet or Email	Interactive multiple sources can be checked for accuracy of information.	Not widespread.
Amateur or Community Radio	Excellent for rural, poor and remote communities.	Not widespread.

Based on the comparison in Table 1, SMS has the most advantage to be used as a communication channel in disaster warning because information can be broadcasted simultaneously to multiple users in a short time. This suits the second need of this proposed project, where immediate warning notifications on the water level status are required to be given to the residents, local authorities and passers-by to give them ample time to take immediate action.

Moreover, in the United States, SMS notification is proven to help save lives during tornados that happen in the months of April, May and June. A testimonial article reported that one of the victims of tornados disaster mentioned that he lives in an area where tornado sirens cannot be heard, therefore text alerts was the only mode of communication that has helped him to seek for shelter immediately [11]. As a conclusion, SMS will be used in this project as the main communication channel to broadcast alert that notifies users on the occurrence of flood disaster and at the same time act as a warning.

Comparative study on application of 2G-GSM and 3G for SMS technology

Table-2 shows the comparative study between 2G-GSM and 3G technology.

Table-2. Comparative study on 2G-GSM and 3G technology.

Area of Difference	2G-GSM	3G
Definition	Global System for Mobile communication as an open digital cellular technology that transmits mobile voice and data services (Mobithinking, 2014).	The third generation of telecommunication hardware standards and general technology for mobile networking (Shehan, 2013).
Data Transfer Rate	9.6 kbps.	Up to 14.4 Mbps on the downlink and 5.8 Mbps on the uplink.
Features	Digital voice service. Advanced messaging. Global roaming. Circuit-switched data.	Always-on connectivity. Global roaming. IP-enabled.
Pros	Ability to roam and switch carriers without switching phones (Shehan, 2013). Wider coverage in rural areas and major cities.	Offers much faster data transfer. Offers powerful multimedia services and applications.
Cons	Not suitable for web browsing and multimedia applications. Require longer time for download activity.	Expensive but limited. Some area does not have 3G coverage especially rural areas.

Based on the comparative study in Table 2, 2G-GSM has the most advantage compared to 3G. Moreover, GSM technology is needed to allow messages to be broadcasted and delivered to the receivers in a short time so that immediate action will be taken right away. Thus, the GSM technology is chosen as a medium to broadcast warning SMS from the IComsat GSM shield after receiving instructions from the microcontroller.

User mobility

Cellular network is divided into many cells and each cells has a base station to provide signal coverage. This base station detects the mobile users' cellphone numbers while the users are logged in the cell and these numbers are stored in the Mobile Telephone Switching Office (MTSO) database. User moves from one cell to another cells. Therefore, when user moves to another cell, the user's cellphone number in the previous cell is removed and logged into the new cell [7]. By leveraging on this technology, we can trace the presence of mobile users in a cell and actively alerts users when they are in the flood affected area. Consequently, only users who happen to be within the area of flood disaster will be notified to evacuate the area immediately.

Ways to measure water level

Table-3 shows a comparative study between ultrasonic sensor and water level sensor.

Table-3. Comparative study on ultrasonic sensor and water lever sensor to measure water level.

Area of Difference	Ultrasonic Sensor	Water Level Sensor
Ranges	0.33-3, 0.33-12,1-48 ft.	0-3, 0-15, 0-30, 0-60, 0-120, 0-250, 0-500 ft.
Resolution	0.009, 0.035, 0.141 inch.	Infinitesimal (Analog).
Accuracy	Better than 0.5% of range at constant temperature; affected by temperature gradients, target echo strength and speed of sound in vapors.	± 0.1% of full scale at constant temperature. ± 0.2% over 1.37°C to 21.1°C range.
Transducer Type	Ruggedized piezoelectric.	-
Update Rate	50 ms.	125 ohms.
Output	4-20 mA (4 mA is minimum water level and 20 mA is maximum water level).	4-20 mA or 0.5 to 2.5 VDC.

Based on the comparison in Table-3, ultrasonic sensor is chosen as it can be triggered as fast as every 50

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ms or 20 times per second while providing precise, non-contact distance measurements from about 2 cm to 400 cm. The principle of ultrasonic distance measurement is the same as radar and sonar and it is ideal to be used for level monitoring or linear motion monitoring applications. As illustrated in Figure-1, the ultrasonic sensor measures the distance between transducer and water surface.

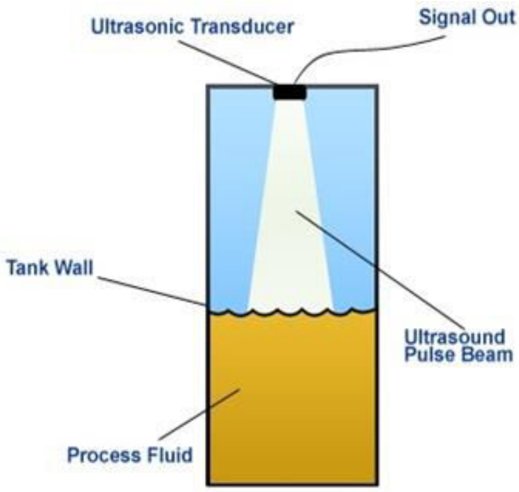

Figure-1. The operation of ultrasonic transducer, adopted from (Kevin Hambrice, 2004).

The ultrasonic sensor consists of a transmitter and receiver. The transmitter transmits electromagnetic signal in pulses towards the water surface. The signal is reflected once it touches the water surface and collected by the receiver. The sensor then records the travelling time taken for the signal to propagate from the transmitter towards the water surface, and reflected back towards the receiver [12].

Microcontroller

A microcontroller is required to integrate the ultrasonic sensor with the GSM shield. The microcontroller will process the input data gathered from the sensor before it is passed as the output data to the GSM shield. The calibration between the ultrasonic sensor and the GSM shield is done by uploading instructions code to the microcontroller.

Table-4 shows a comparison between Arduino UNO R3 and Raspberry Pi.

Based on the comparison in Table-4, Arduino is chosen as it operates on ATmega328 that allows direct access and control to the programming of the microcontroller. It can be powered up with a USB cable or an AC-to-DC adapter or battery. The chip comes with crystal oscillator design to generate low frequency and phase jitter, which is recommended for USB operation [13].

Table-4. Comparison between Arduino UNO R3 and raspberry Pi.

Specifications	Arduino UNO	Raspberry Pi
Processor	Atmel ATmega328	700 MHz ARM 11
Chip	16 MHz crystal oscillator	Broadcom BCM2835
Flash Memory	32 KB	-
Inputs	6 analog	HDMI, DVI, Composite or SCART
Interface	14 digital I/O pins	Broadcom Video Core IV
Operating Voltage	5 V	700 mA
SRAM	2 KB	-
EEPROM	1 KB	-
Clock Speed	16 MHz	-

Solar cell

Solar energy is chosen to supply power for the pre-flood warning system to ensure that the system works even though when there is no electricity supply during the occurrence of flooding. Moreover, with the use of solar energy, large amount of money can be saved and it keeps our climate livable as it causes no pollution and makes no noise.

DESIGN AND PROJECT MODELLING

As illustrated in Figure-2, the pre-flood warning system consists of three main systems; data processing, data presentation and data broadcast.

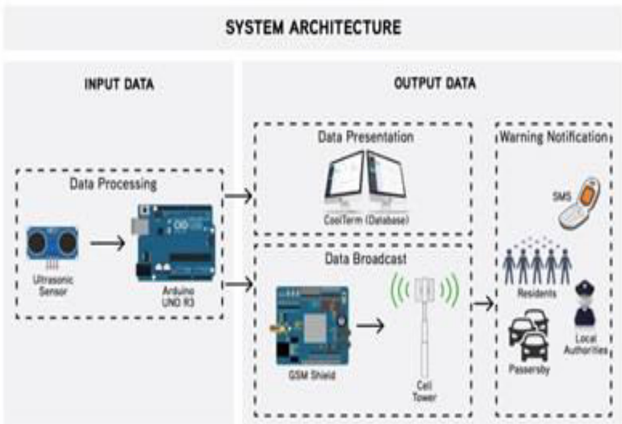

Figure-2. System architecture for pre-flood warning system.

Data processing involves collection of data from ultrasonic sensor, which will be installed at riverbanks to measure water levels. Data gathered from the ultrasonic sensor will be sent to a microcontroller that compares the water levels (i.e. low, medium and high) with a pre-determined threshold value shown in Table-5.

Table-5. Threshold value for water level indicator.

Water Level	Distance between Water Surface and Ultrasonic Sensor
High	1.1 cm to 8.0 cm
Medium	8.1 cm to 15.0 cm
Low	15.1 cm to 23.0 cm

The threshold value is determined by dividing the aquarium tank into three (3) equal partitions, which indicates three (3) level of water namely high, medium and low. Once water level exceeds the threshold, the microcontroller will instruct the GSM shield to broadcast warning SMS. Data flow diagram in Figure-3 shows the algorithm flow of the code that has been programmed into the microcontroller via the Arduino Software IDE.

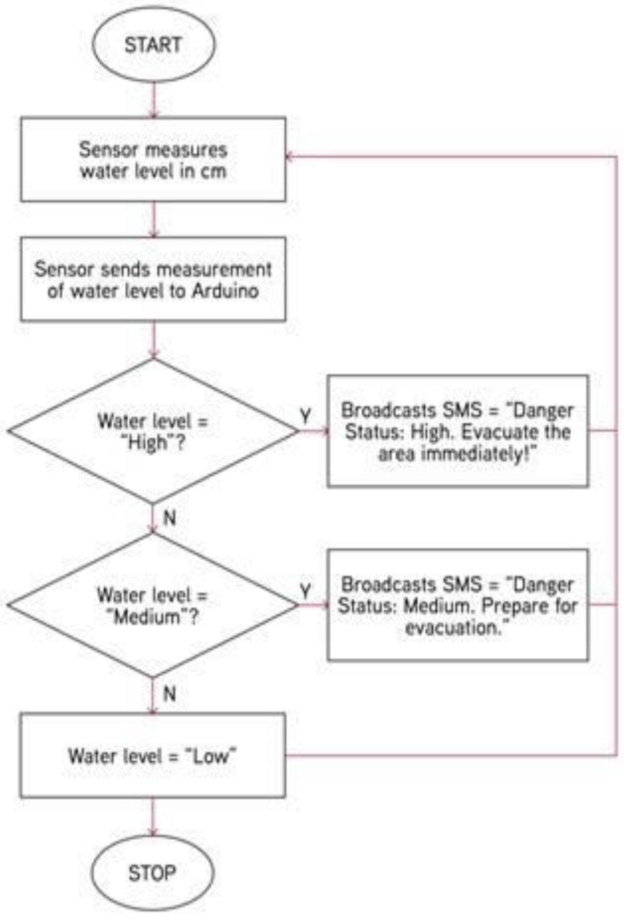

Figure-3. Data flow diagram of pre-flood warning system.

RESULTS AND DISCUSSION

An experiment with controlled water rising effect was conducted to validate the prototype system for the proposed system architecture. Thus, this section discusses on the results from the conducted experiment, which consists of experiment setup and prototype testing.

Experiment setup

The prototype model is made up of a medium sized plastic aquarium, a hand pump, a 5.5 cm x 8.5 cm breadboard, HC-SR04 ultrasonic sensor, IComsat GSM shield and GSM antenna, Arduino UNO R3 and an unlocked SIM card.

Step-by-step assembly instructions

1. Insert an unlocked SIM card to the SIM cardholder of the GSM shield and assemble the GSM antenna.
2. Place the jumpers of digital pins receive (RXD) and transmit (TXD) to D2, D3 as shown in Figure-4.

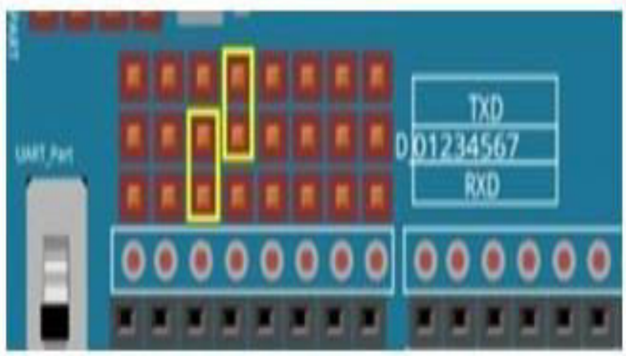

Figure-4. GSM shield software serial pins positioning.

3. Plug the GSM shield into the Arduino socket.
4. Upload sketch, which contains the instructions code that controls the functionality of Arduino into the Arduino board.

For validation purposes, three (3) tests were conducted namely accuracy testing, performance testing and system testing.

Test 1: Accuracy testing

The purpose of conducting this test is to determine the accuracy of data collected from the ultrasonic sensor. Test is executed in an indoor environment with default setup shown in Figure-5.

Figure-5. Default experiment setup.

The accuracy of data collected from the ultrasonic sensor is determined by comparing its measurements with manual measurements using a 30 cm clear plastic straight centimeter ruler. According to the measurements recorded from the graph in Figure-6, out of the 30 trials that have been performed, it appears that the shortest distance measured by the sensor is 7 cm, while the actual distance recorded 7.2 cm.

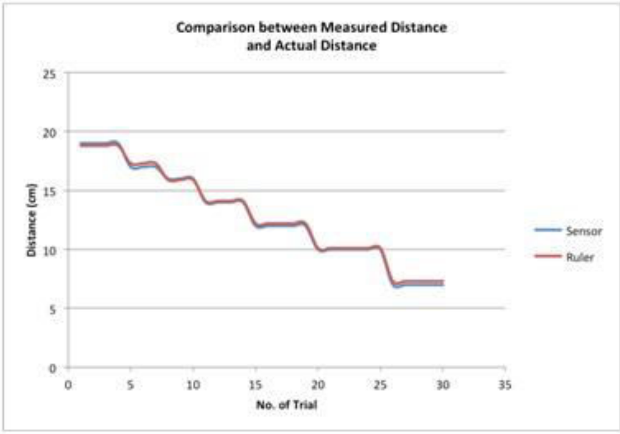

Figure-6. Comparison between measured distance and actual distance.

Nevertheless, the line graph in Figure-6 shows not much gap between the reading recorded by the ultrasonic sensor and the ruler. This shows that the ultrasonic sensor is accurate as it always recorded distance within 1 cm. Moreover, based on the bar graph shown in Figure-7, the average accuracy is calculated at over 93%. 27% out of 93% has actually recorded 100% accurate measurement with less than 0.1 cm of error, which results in registration error percentage of 7%. However, these results are all within an acceptable precision range within ±0.2 cm.

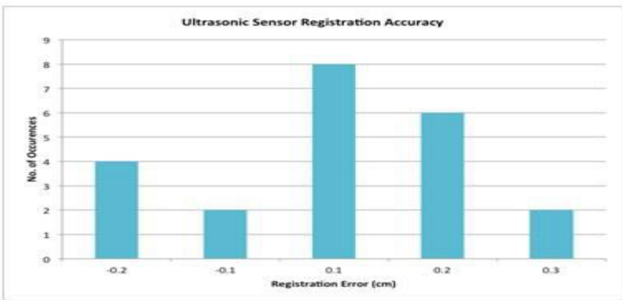

Figure-7. Ultrasonic sensor registration accuracy.

In conclusion, the results proved that there is a very good correlation between the distance recorded by the ultrasonic sensor and the actual distance measured with a ruler. Therefore, it is safe to conclude that the ultrasonic sensor does provide accurate reading with 93% to 100% success rate.

Test 2: System testing

The purpose of conducting this test is to calculate the average velocity of water rising. The velocity will be used to forecast a specific time frame to broadcast warning SMS to the victims. Test 2 is performed in an indoor environment as shown in Figure-8.

In order to calculate the velocity of water rising, the aquarium tank is set to receive free flow of water coming in and out from the tank. The time delay to retrieve new data from the ultrasonic sensor is set to an interval of 30 seconds.

Figure-8. Experiment setup with free flow of water inlet and outlet.

Table-6 shows a list of value gathered from the experiment, in which the value represents the following parameter. The value is used to calculate the average velocity of water rising. It is important to get good estimation on the time frame to ensure ample time is given to the victims to evacuate the event area before the flood becomes worse.

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Table-6. Value recorded from Test 2: System testing.

di	df	Δd (m)	ti	tf	Δt (s)	v(av) = Δd / Δt (ms)
0.23	0.19	- 0.04	595	657	65	- 6.15
0.19	0.17	-0.02	787	852	65	-3.08
0.19	0.17	- 0.02	852	917	65	-3.08
0.17	0.15	- 0.02	986	1047	61	-3.28
0.17	0.16	- 0.01	1047	1112	65	-1.54
0.15	0.16	0.01	1112	1177	65	1.54
0.16	0.14	- 0.02	1177	1242	65	-3.08
0.16	0.14	- 0.02	1242	1311	69	-2.90
0.14	0.12	- 0.02	1437	1502	65	- 3.08
0.14	0.12	-0.02	1502	1567	65	- 3.08
0.12	0.10	- 0.02	1762	1827	65	- 3.08
0.12	0.10	- 0.02	1827	1902	75	-2.67
0.10	0.07	- 0.03	2152	2217	65	-4.62
0.10	0.07	- 0.03	2217	2285	68	-4.41
0.07	0.05	- 0.02	2477	2541	65	-3.08

Legend:
di: Initial Distance of Water Surface to Ultrasonic Sensor in Metres
df: Final Distance of Water Surface to Ultrasonic Sensor in Metres
Δd: Change in Distance in Meters
ti: Initial Time of Water Rising in Seconds
tf: Final Time of Water Rising in Seconds
Δt: Change in Time in Seconds
v(av): Change in Water Rising Velocity in Meters per Seconds

From the calculation of change in water rising velocity from Table-6, a velocity against time graph is plotted. The graph in Figure-9 shows negative velocity, which means the water level is moving backwards in a negative direction. This indicates that water keeps rising towards the ultrasonic sensor. However, there was one time where water level is recorded to be reducing, hence the positive velocity. This may have happened due to water level that changes rapidly as water is flowing in and out almost simultaneously from the aquarium tank.

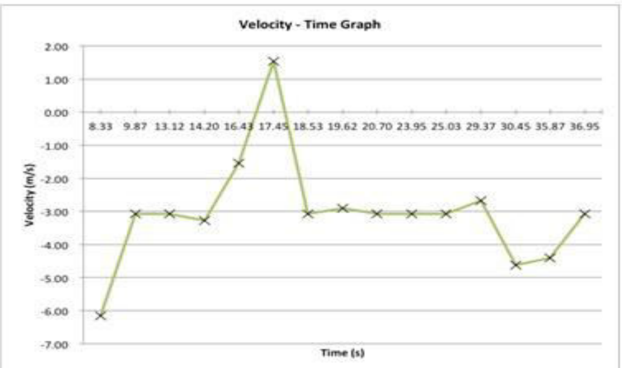

Figure-9. Velocity against time graph.

Based on the results, negative velocity implies that the water level is moving towards the ultrasonic sensor as water level increases. During the event of flooding, water level in the river changes quickly and thus, warning SMS need to be delivered early to the victims.

Test 3: Performance testing

The purpose of conducting this test is to measure the stability and reliability of the pre-flood warning system. This is done to ensure the system can perform well in measuring water level accurately as well as sending warning SMS immediately. Similar setup to the setup of experiment in Test 2 is used.

The reliability of the system is measured by comparing the number of serial monitor displaying SMS status *Sent* with the number of SMS that is actually received by the recipients. The stability of the system is measured by looking at the consistency of data collected by the ultrasonic sensor.

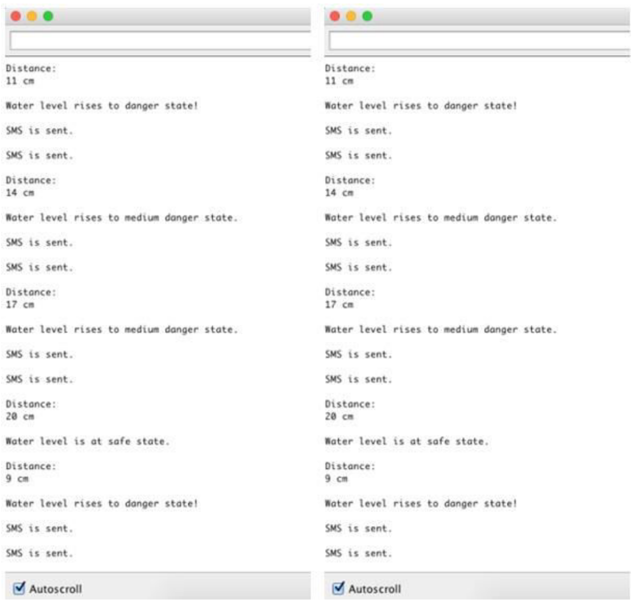

Figure-10. Output displayed on serial monitor.

Output displayed on serial monitor in Figure-10 matches the number of warning SMS delivered to recipients' mobile phone as shown in Figure-11.

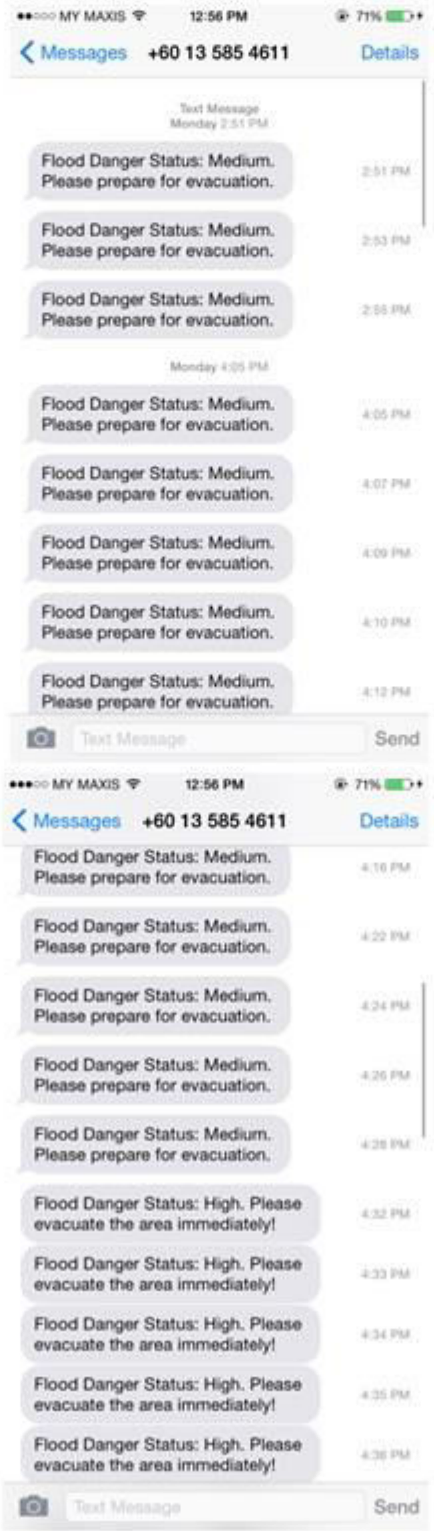

Figure-11. Actual SMS delivered on recipient's mobile phone.

However, during the first test, out of 30 trials, two (2) warning SMS actually failed to reach the recipients but the status on serial monitor displayed it as Sent. This may have happened due to network congestion or other factor that affects the performance of the GSM shield in broadcasting warning SMS. Nevertheless, the second test is completed and the result is summarized in a line graph shown in Figure-12.

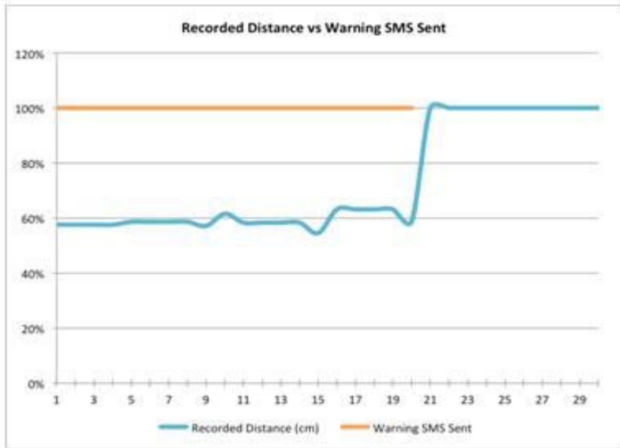

Figure-12. Recorded distance against warning SMS sent.

From the graph in Figure-12, the system managed to broadcast warning SMS for all recorded water level status of medium and high, with 100% success rate. The reading of water level collected by the ultrasonic sensor is also consistent until the water subsided to the extremely low level.

Based on the results, the system is already stable in recording water level distance accurately. The system is also reliable as it is able to broadcast warning SMS as soon as water level increases to the medium and high danger phase.

CONCLUSION AND RECOMMENDATION

The three main objectives of this paper have been successfully met. A successful analysis of comparative study on the existing work has been finalized by conducting a critical analysis between the available technologies based on the gaps identified in the literature. The second objective is met with the successful development of a prototype system that detects three (3) stages of water level (i.e. high, medium and low) and broadcasts warning SMS immediately. Therefore, the third objective of validating the prototype system through experimentation is achieved by conducting three (3) tests (i.e. accuracy testing, performance testing and system testing). The results from the experiment conducted show that the proposed prototype system is working as intended and with 96% to 100% success rate, the ultrasonic sensor is proven to be able to measure water level accurately.

By having an effective pre-flood warning system, immediate action can be carried out in order to save lives and minimize the damage caused by flood disaster. With warning SMS that is broadcasted simultaneously based on user mobility, it is guaranteed that the information is delivered to the communities and passersby that reside within the affected area, which at the same time helps local authorities to accelerate the process of evacuating flood victims to the relief centre. Moreover, with the presence of an effective pre-flood warning system, the process of monitoring water level become automated, allowing proper management plan to be carried out before, during and after the occurrence of flood disaster.

For future recommendation, it is best if the concept of Fuzzy Logic from Artificial Intelligence is applied. This allows the system to acquire the capability of self-learning and forecasting. With uncertain weather conditions, this concept will be able to accurately predict the flood risk level based on the water level measured by the ultrasonic sensor.

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REFERENCES

[1] Floods in Malaysia. 2015. Wikipedia, the free encyclopedia.

[2] The Star Online. 2014. Disaster first response impeded.

[3] N. W. Chan. 2015. Impacts of Disasters and Disaster Risk Management in Malaysia: The Case of Floods. Resilience and Recovery in Asian Disasters, ed: Springer. pp. 239-265.

[4] Rogers, D., and V. Tsirkunov. 2011. Global Assessment Report on Disaster Risk Reduction– Costs and Benefits of Early Warning Systems. United Nations. pp. 1-16.

[5] I. M. Dokas. 2014. Ontology to Support Knowledge Representation and Risk Analysis for the Development of Early Warning System in Solid Waste Management Operations. Environmental Software Systems. Vol. 7, pp. 109-119.

[6] I. A. Aziz, I. A. Hamizan, N. S. Haron, and M. Mehat, Cooperative flood detection using GSMD via SMS. 2008. International Symposium on in Information Technology (ITSim 2008). pp. 1-7.

[7] Y. Xiong, Y. Deng, W. Wang, and J. Ma. 2014. Phoenix: a collaborative location-based notification system for mobile networks. Mathematical Problems in Engineering, vol. 2014.

[8] Klse-online.blogspot.com. 2014. Malaysia's Flood Disaster: Assessing the impact. [online] Available at:http://klse-online.blogspot.com/2014/12/malaysias-flood-disaster-assessing.html

[9] B. Balis, M. Kasztelnik, M. Bubak, T. Bartynski, T. Gubala, P. Nowakowski. 2011. The urban flood common information space for early warning systems. Procedia Computer Science. Vol. 4, pp. 96-105.

[10] News.utm.my. 2015. UTM SMS Based Flood Device Minimizes Loss | NewsHub. [online] Available at: http://www.news.utm.my/2015/01/utm-sms-based-flood-device-minimizes-loss/ [Accessed 12 Nov. 2015].

[11] A. Media. 2014. Alert Media | Disaster Notification System is Essential during Tornados. [online] Alertmedia.com. Available at: http://www.alertmedia.com/disaster-notification-system-are-essential-during-tornados

[12] K. Hambrice and H. Hopper. 2004. A Dozen Ways to Measure Fluid Level and How They Work. Available:http://www.sensorsmag.com/sensors/leak-level/a-dozen-waysmeasure-fluid-level-and-how-they-work-1067.

[13] C. Cheung and M. Kjar. 2005. Using the 16 MHz Crystal Oscillator. Freescale Semiconductor Application Note. Rev 1, pp. 1-8.