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Design and Development of Flood Monitoring and Early Warning System

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ABSTRACT

Flood is a natural disaster caused by the rise of water levels, typically in urban areas. This phenomenon can cause damages to properties such as buildings and landscapes. Moreover, it also can cause death among humans and animals. Malaysia is among the country that has rainfall throughout the years alongside monsoon seasons. Therefore, this country is prone to floods that are not predictable that causes the public to be unprepared to face potential floods. Although the authorities have taken some measures, such as the installation of the monitoring system, it is not efficient, expensive, and difficult to maintain. Hence, this study aims to design a low-cost flood monitoring system comprising a rainfall sensor, temperature sensor, humidity sensor, controller (Arduino), and GSM modem. The system will monitor the rainfall rates alongside temperature and humidity in deciding for the potential occurrence of flood. The data will be sent to a host PC with Graphical User Interface via GSM modem. The developed prototype aims to be installed at a selected location for monitoring and testing.

1. INTRODUCTION

Malaysia is among the country that has rainfall throughout the years alongside monsoon seasons. Therefore, this country is prone to floods that are not predictable that causes the public to be unprepared to face potential floods. Although there have been some measures taken by the authorities, such as installing a monitoring system, it is inefficient, expensive, and difficult to maintain.

What is a flood? A flood can define as an overflow of water in a certain source such as sea, river, and drain, which is extremely dangerous to the community [1]. A flood is a phenomenon of one of the most severe threats in natural disaster. According to the report, about forty percent of total loss is due to flooding [2]. Modern and developed countries like Malaysia are exposed highly to floods as they have high population densities, bringing disastrous effects to the communities. This statement is supported by United Nations studies in 2010 state that about fifty percent of the world population is living in the cities [3]. Moreover, the flood becomes the phenomena in Asia compared to various types of disaster, which is the highest among other disasters [4].

Artificial Neural networks (ANN) have been used in prediction and forecasting in the past few years. This is because it can examine and used historical data to predict future data. The satisfactory result produces by ANN for the ability to solve complex nonlinear systems without physical knowledge makes itself one of the most popular applications for prediction and estimation in different areas [5]-[7]. The upstream river level was measured by each station built near the upstream, and the real-time water data is available at the website (www.water.gov.com). Supervisory Control and Data Acquisition System (SCADA) is used to measure the water level by the Department of Irrigation and Drainage Malaysia (DID) [8]. The data is measured every 10 minutes and then used for training and testing for the model. Thus, these data are well utilized for upcoming flood occurrences soon [9]. Artificial Neural network (ANN) and Neural Network Autoregressive Model with Exogenous Input (NNARX) is different because ANN solves complex nonlinear systems. At

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the same time, NNARX is more advantageous to knowledge-related concepts [10]. Several places used this system, such as Kedah and Kuala Lumpur. This study was done in Kelang river in Petaling Bridge of Kuala Lumpur. The three upstream of Termeloh river were measured by using Supervisory Control and Data Acquisition (SCADA) system, and real-time water level samples were provided by the Department of Irrigation and Drainage Malaysia (DID) [5]. Furthermore, the sample data are tested, with reliable training, validation, and testing sample, and taken from 6 February till 21 October 2010 in meters for 3 or 7 hours to get good performance. Each data has 10 minutes' interval, and all these samples are used when the flood occurs, thus providing an excellent model to upcoming floods [11] [12].

There was a study conducted at the Itajai Valley where the system first introduces in that area since the flood often occurred in the region. Since 1984, the monitoring and alert flood system of basin Vale do Itajai is introduced to operate in the area to give feedback in monitoring and alert Itajai Valley flood. Hydrometeorology is related by the team scientific research developer in addition to the system. The alert system comprises a telemetric network installed in the city of the Vale do Itajai. The information that are recorded will be transmitted automatically by using the GPRS transmission system. All the data sent are received by the computer of an admin, which is responsible for handling and compiling the information received from the transmission system. The forecast information and condition of the basin will give by the Civil Defence agencies and the media [13].

Additionally, the study in [14][15] design a system capable of alerting the citizen and center of flood and flood risk emergencies comprised of three inputs: pressure sensor, accelerometer sensor, and Fluvial pollution detector. The system will monitor the water level at the runway and river, and the data will be sent to a host PC with Graphical User Interface via GSM modem. If someone comes or goes near the monitoring point, will assess the situation of the runway and river at the selected area

There was a study conducted in Metro Manila, Philippines, where the flood causes heavy traffic and destroys property and live [16]. The researcher created a flood detection system using Arduino to monitor the rising water of residential areas comprising of ultrasonic sensors, Arduino, and network data transmission to send SMS to the Local Government Unit and residents of Barangay Marulas Valenzuela City, Philippines This system work by using the ultrasonic sensor to determine the height between the sensor and the floodwater. The update from the flood water will be texted to the rescue team (Local Government Unit) and residents for them to view the level of the level water from time to time. A power bank powers the sensor and Arduino for continuous water height detection and network data transmission. This system is the fastest method to monitor floods and will be helpful to avoid the problem when the flood occurs [17].

A flood occurs almost every year in Malaysia and faces the most severe climate-related natural disaster, especially during the monsoon season [1]. According to Malaysia Meteorological Service (MMS), November and February is the highest flood potential which occurs the same time as the monsoon season [4]. In Malaysia, the east coast of Terengganu receives heavy rainfall that always causes a flood especially during the end of year. The flood caused by several factors such as the lower land and distant from the main source of water, which are the river and sea coast area, apart from the rainfall received during northeast monsoon season [1]. Another enormous flood in Malaysia of flood disaster history, striking several neighborhoods in the east Malaysia state of Sabah, Johore, Malacca, Negeri Sembilan, and Pahang, was flooded because of the same situation Terengganu due to the northeast monsoon season. Among the five states, Johore is the worst affected country, representing more than 30 000 evacuees [18 -20].

Flood monitoring and early warning system is mainly designed to observe and alert people about the incoming flood in the area. The system consists of hydreon optical rain sensor, temperature humidity sensor, GSM modem, and an Arduino Uno for this project. The project's main purpose is to create an effective way to monitor the weather and warn the people in the affected area. The system triggered when the raindrop sensor and temperature humidity sensor detect at a certain level cause the microcontroller, Arduino, to spread message to the selected location affected by using GSM modem. This chapter comprises of problem statement, objective, significance, scope and limitation of the project.

The project's significance is to develop the system according to the issue that the community has to face, which is the flood. Flood monitoring and early warning system is a system to predict whether the location will have affected by flood or not. If the system detects that the area will be flooded, the microcontroller of the system will deliver the warning message through SMS to the people of the selected region. However, more work and studies required to increase the efficiency of this prototype such as alarm system and additional sensor.

In this project, the system comprises of rainfall sensor, temperature sensor, humidity sensor, controller (Arduino), and GSM modem. Moreover, the components inside this project can be replaced easily for maintenance or upgrades. This project can be improved further by adding more sensors to gather more accurate data. As that being said, the scope then can be expanded and can be used at mostly anywhere of affected places. The limitation of this project is that this area of the case study will be concentrated in Malaysia. Thus, the respondent will be the community in a particular area of the country.

The remaining sections of this paper are organized as follows: Section 2 describes the particular study area or activity focused on in this project and implemented to achieve the goal. This section presents the workflow chart, schematic diagram, and steps to follow: Section 3 presents the result and discusses the project. Section 4 summarizes the overall work.

2. METHODOLOGY

2.1 System

The block diagram of the project shown in Figure 1. Meanwhile, Figure 2 illustrates the system flow chart.

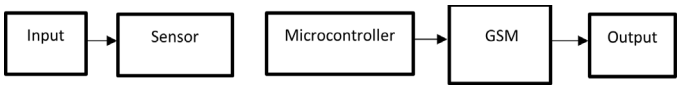

Fig. 1. Block Diagram

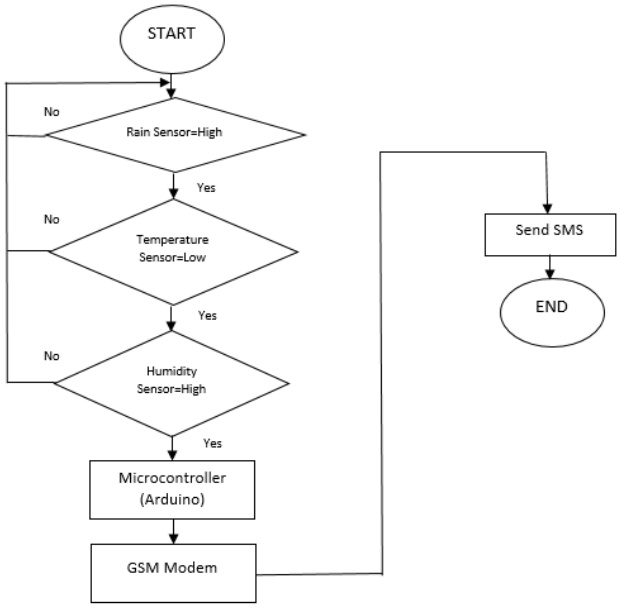

Fig. 2. Flow Chart

When the rain sensor detects the raindrop and the temperature-humidity sensor detects, the data from the sensor will send through the SIM900 shield. To fulfill the condition to send message to the register user, the sensor must reach its specific limit as instructed in the microcontroller (Arduino UNO). From there, the controller conducts the data gathered from the sensor and then applies coding and programming to create the desired feature. The data then be sent to the GSM modem, where the GSM modem will send the notification to the user.

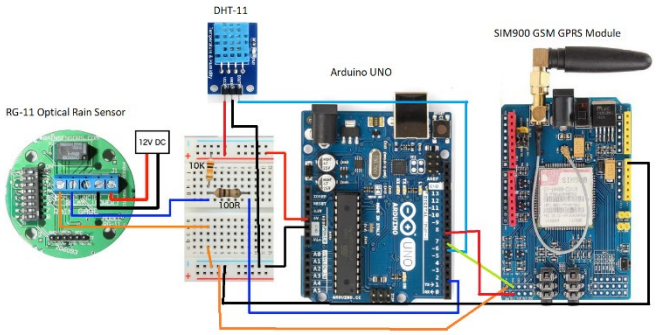

Fig. 3. System schematic.

The output of the rainfall sensor is connected to the Normally OPEN (NO) because when it is rain, the digital production NO will become Normally CLOSE (NC) while the digital input will be going to the ground. Then, the rain sensor collects data and sends the data to the Arduino (port 2). The 100-ohm resistor is used to prevent the microcontroller from damage. This is to limit the flow of the current. Meanwhile, it will send data to the microcontroller for the temperature and humidity sensor if the condition is applied to it. The program that had been conducted to the microcontroller will instruct the GSM modem to transmit data to the user by using the same frequency but then dividing the frequency band into multiple time slot which in other word, it will give message for the registered user.

2.1 Components

The system components are listed inn Table 1.

Table 1. Components

Component	Specification
Arduino Uno	Microcontroller ATmega328P – 8-bit AVR family microcontroller Operating voltage 5V Input voltage 6-20V Analog Input Pin 6 (A0-A5) Digital I/O Pins 14 (Out of which 6 provide PWM output
DHT-11 Temperature Humidity Sensor	Power supply 3.5V to 5.5V Output both temperature and humidity through serial data No connection and hence not used Connected to the ground of the circuit
Rain Sensor (RG-11)	Input voltage 12V-30VDC Max load 1A, 24VDC Reverse Polarity protection 50V Operating temperature Range -40ºC to +60ºC
Jumper Wires	22 American wire gauge (AWG) 150mm (6") long Male-Male connectors (pin to pin)
	Compatible with Arduino Working power is 5V/2A Quad band support: 850/900/1800/1900MHz
Sim900 Shield GSM GPRS Module	Full control via AT commands set: Standard - GSM 07.07 & 07.05 and Enhanced - SIMCOM AT Commands. Support TCP/UDP protocols Low power consumption: 1.5mA (sleep mode)
Sim Card	

The RG-11optical rain sensor shown in Figure 4 is optical, which is not mechanical, chemical, or conductive but with more rugged, sensitive, and reliable than any other technology. This sensor includes a DIP switch that allows it to be set up for the mode of operation, such as tipping bucket, "It's raining," condensation sensing, wiper control, irrigation control, and drop detection. In this study, the RG-11 optical rain sensor sense water hitting the surface of the lens by using an infrared light beam and used the same principle as rain-sensing windshield wiper control to collect the rain data.

Fig. 4. Rainfall Sensor

RG-11 has been designed with a DIP switch which programs the mode of operation:

[1] Tipping bucket

Tipping bucket is replaced with low maintenance alternative

[2] "It's Raining"

The sensor will normally close when a skylight at the first sign of the rain, normally open when the rain stops

[3] Condensation Sensing

Continuously monitors the clarity of the sensing surface.

[4] Wiper control

Control the wiper from off through intermittent and steady-slow speeds.

[5] Irrigation Control

Measure both rain accumulation and rain intensity

[6] Drop Detection

The mode used for external data interpretation.

The DIP switches must be set so that the RG-11 rain sensor will behave according to the instructions given in the instruction manual. Controls such as 5, 6, and 7 set the overall mode operation, and other switches (1, 2, 3, 4, 5) adjust the behavior within the modes. Also noted that RG-11 could not drive 120/240 VAC load without an external relay because it requires only low voltage AC/DC supply and prevents directly powered from the 120/240 VAC grid, which could cause damage to the sensor.

3. RESULTS AND ANALYSIS

The system test of this flood monitoring and early warning system can be divided into multiple categories, the DHT -11 sensor test, GSM modem test, Rg-11 optical rain sensor test, and the entire system test within the microcontroller. This project will also be testing the cost of per SMS and the difference between default current and current transfer per message. The system test also consists of the software and the hardware design. The prototype developed is shown in Figure 5 and Figure 6 respectively.

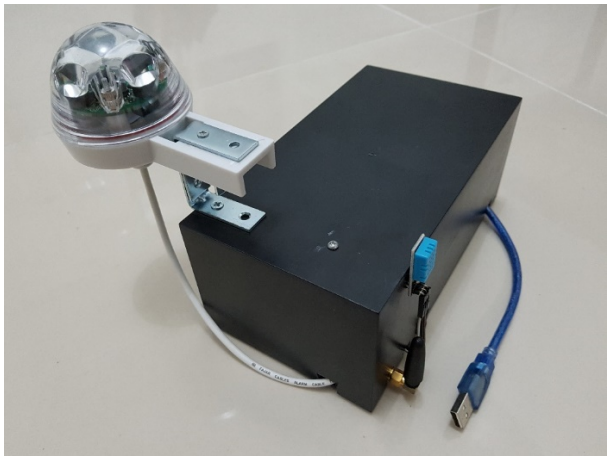

Fig. 5. Top-side view

Fig. 6. Top-front view.

These were an early stage of the prototype that been developed during the installation of hardware. This prototype was not ready to test at the actual site because of lacking waterproof material used. After several research on the material used in the project, the complete prototype was built. The changes that had been made were the placement of the DHT-11 and GSM module and the metal stand of the RG-11 optical rain sensor. The DHT-11 and GSM module was inside the project box's body because both components and hardware were not waterproof. Besides that, the metal stand was removed to prevent any conductor flow through the system during the thunderstorm while conducting at an actual site.

Figure 7 shows the final output of the project. The project's output sends the message to the register user as the input of the sensor meets the condition. The system is tested several times to confirm the accuracy and effectiveness of the data provided to the registered user. The result was given through the mobile phone and show the warning system to the user. The future works planned are to add more input sensors to gather more accurate reading and realistic prediction results on the selected area's water level. The pressure sensor is an excellent example of a sensor to add to this project. This is because the pressure sensor detects the pressure of the water. The higher the water level, the higher the pressure. Therefore, pressure sensor is highly recommended to test with this project.

Additionally, the GSM module will be replaced with IoTs (Internet of Things) platform such as "BLYNK" app. It is simple and easy to use which it can remotely control the hardware, displaying data, store data, visualize and many more. Furthermore, Blynk server can communicate all the communication between hardware and smartphone.

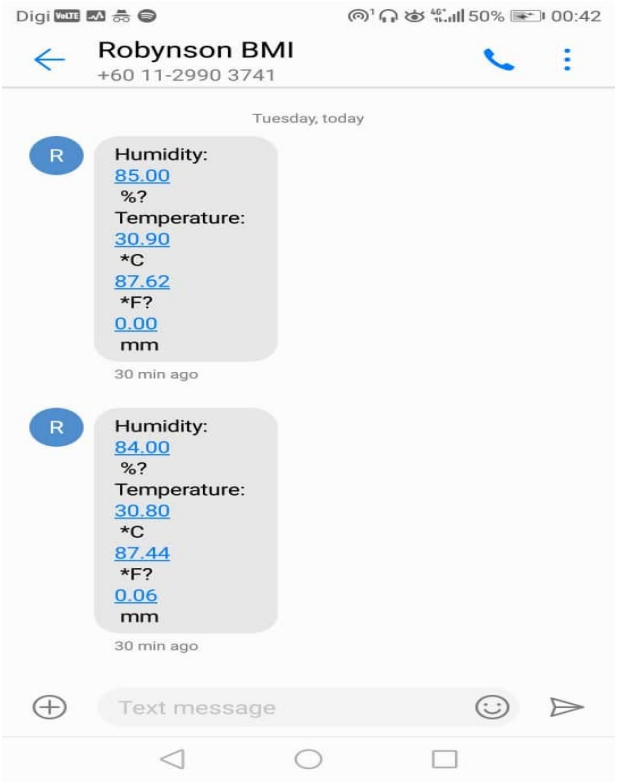

Figure 7. Final test system result

4. CONCLUSION

In conclusion, a low cost flood detection was developed. The system capable to measure rainfall intensity and predict the potential occurance of flood. The system will send a warning message to registered user by text messaging.

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REFERENCES

[1] D/iya, S. G., Gasim, M. B., Toriman, M. E., & Abdullahi, M. G. (2014). Floods in Malaysia: Historical Reviews, Causes, Effects and Mitigations Approach. International Journal of Interdisciplinary Research and Innovations. https://doi.org/10.5897/AJBx10.009

[2] Ruslan, F. A., Samad, A. M., Tajjudin, M., & Adnan, R. (2016). Flood water level prediction modeling using NNARX structure for Sg Pahang basin. In Proceedings - 5th IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2015. https://doi.org/10.1109/ICCSCE.2015.7482245

[3] Latif, A. A., & Arshad, N. H. (2014). A review of flood management governance framework in Malaysia and selected countries. In Proceedings of the 6th International Conference on Information Technology and Multimedia. https://doi.org/10.1109/ICIMU.2014.7066626

[4] Jaafar, K., Ismail, N., Tajjudin, M., Adnan, R., & Rahiman, M. H. F. (2016). A review on flood modelling and rainfall-runoff relationships. In Proceedings - 2015 6th IEEE Control and System Graduate Research Colloquium, ICSGRC 2015. https://doi.org/10.1109/ICSGRC.2015.7412484

[5] Ruslan, F. A., Samad, A. M., Zain, Z. M., & Adnan, R. (2014). Flood water level modeling and prediction using NARX neural network: Case study at Kelang river. In 2014 IEEE 10th International Colloquium on Signal Processing and its Applications. https://doi.org/10.1109/CSPA.2014.6805748

[6] Adnan, R., Ruslan, F. A., Samad, A. M., & Zain, Z. M. (2013). New Artificial Neural Network and Extended Kalman Filter hybrid model of flood prediction system. In Proceedings - 2013 IEEE 9th International Colloquium on Signal Processing and its Applications, CSPA 2013. https://doi.org/10.1109/CSPA.2013.6530051

[7] Rahman, I. 'Izzati A., & Alias, N. M. A. (2011). Rainfall forecasting using an artificial neural network model to prevent flash floods. In 8th International Conference on High-capacity Optical Networks and Emerging Technologies. https://doi.org/10.1109/HONET.2011.6149841

[8] Adnan, R., Ruslan, F. A., Samad, A. M., & Md Zain, Z. (2012). Flood water level modelling and prediction using artificial neural network: Case study of Sungai Batu Pahat in Johor. 2012 IEEE Control and System Graduate Research Colloquium. https://doi.org/10.1109/ICSGRC.2012.6287127

[9] Ruslan, F. A., Zakaria, N. K., & Adnan, R. (2013). Flood modelling using Artificial Neural Network. In Proceedings - 2013 IEEE 4th Control and System Graduate Research Colloquium, ICSGRC 2013. https://doi.org/10.1109/ICSGRC.2013.6653287

[10] Ruslan, F. A., Samad, A. M., Tajjudin, M., & Adnan, R. (2016). Flood water level prediction modeling using NNARX structure for Sg Pahang basin. In Proceedings - 5th IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2015. https://doi.org/10.1109/ICCSCE.2015.7482245

[11] Rohaimi, N. A., Ruslan, F. A., & Adnan, R. (2017). 3 Hours ahead of time flood water level prediction using NNARX structure: Case study pahang. In 2016 7th IEEE Control and System Graduate Research Colloquium, ICSGRC 2016 - Proceeding. https://doi.org/10.1109/ICSGRC.2016.7813309

[12] Ruslan, F. A., Samad, A. M., & Adnan, R. (2017). 3 Hours flood water level prediction using NNARX structure: Case study Kuala Lumpur. In Proceedings of the 2016 6th International Conference on System Engineering and Technology, ICSET 2016. https://doi.org/10.1109/FIT.2016.7857537

[13] Adnan, R., Samad, A. M., Zain, Z. M., & Ruslan, F. A. (2014). 7 hours flood prediction modeling using NNARX structure: Case study Kedah. In Proceedings - 4th IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2014. https://doi.org/10.1109/ICCSCE.2014.7072758

[14] De Souza, D., Cardoso, I. F., & Momo, M. R. (2015). Tool-Based Mobile Application Applied to the Monitoring System and Flood Alert. In Proceedings - 2015 9th International Conference on Complex, Intelligent, and Software Intensive Systems, CISIS 2015. https://doi.org/10.1109/CISIS.2015.51

[15] Silva Souza, A., De Lima Curvello, A. M., De Souza, F. L. D. S., & Da Silva, H. J. (2017). A flood warning system to critical region. In Procedia Computer Science. https://doi.org/10.1016/j.procs.2017.05.453

[16] Asmara, W. A. H. W. M., & Aziz, N. H. A. (2011). SMS flood alert system. In Proceedings - 2011 IEEE Control and System Graduate Research Colloquium, ICSGRC 2011. https://doi.org/10.1109/ICSGRC.2011.5991822

[17] Aziz, I. A., Hamizan, I. A., Haron, N. S., & Mehat, M. (2008). Cooperative flood detection using GSMD via SMS. In Proceedings - International Symposium on Information Technology 2008, ITSim (Vol. 4). https://doi.org/10.1109/ITSIM.2008.4632045

[18] Guzman, E. D. E., Cuadra, V. S., & Luna, A. G. D. E. (2016). Flood detector system using arduino. International Journal of Management and Applied Science.

[19] Baharum, M. S., Awang, R. A., & Baba, N. H. (2011). Flood monitoring system (MyFMS). In Proceedings - 2011 IEEE International Conference on System Engineering and Technology, ICSET 2011. https://doi.org/10.1109/ICSEngT.2011.5993451

[20] M, A., Ashikin, N., Shaari, B., Muchtar, A., Bahar, A., Adriansyah, D., Hayashi, T. (2014). Flood Impact Assessment in Kota Bharu, Malaysia: A Statistical Analysis. World Applied Sciences Journal. https://doi.org/10.5829/idosi.wasj.2014.32.04.422