The Design and Implementation of a Wireless Flood Monitoring System

Yasir Hashim, Abdul Hafiz Bin Mohd Idzha and Waheb A. Jabbar
Faculty of Engineering Technology, Universiti Malaysia Pahang,
26300 Gambang, Kuantan, Pahang, Malaysia.
yasirhashim@ump.edu.my

***Abstract*—Floods and excessive rainfall are unavoidable phenomena that can cause massive loss of people's lives and destruction of infrastructure. The impact of floods on human lives can be avoided by the Flood Monitoring Systems (FMS). There are many systems used in practice by disaster management agencies for monitoring flood levels. However, most of these systems are very costly and sophisticated to be used and maintained. Most of the conventional floodgates in water canals are manually-operated and suffer from the lack of real-time monitoring of water levels which might lead to overflow in the canals and flash floods. Therefore, in this paper, we have developed an innovative, cost-effective, and user-friendly water level measurement system. The developed system exploits ultrasonic sensor with Arduino microcontroller to measure the water level and identify the situation whether it is safe, cautious or dangerous based on the predefined levels. The implemented prototype alerts individuals and/or authorities separately via SMS using GSM module or Bluetooth. Our system has been tested as an individual unit and the results were very promising. It can monitor the water level accurately and show visual alerts using a LED, in addition, it can send messages via Bluetooth and Cellular networks. In the future, we are going to implement multiple units of the developed system to work as a wireless network for flood monitoring.**

***Index Terms*—Arduino; Flood Monitoring System; Microcontroller.**

I. INTRODUCTION

Electronics devices play an important role in our modern lives, especially the automated based electronics devices [1]. Advances in electronics devices towards Nano-dimensions leads to improve microcontrollers architecture and its ability in processing data [2]. Climate changes are one of the major issues that have mind boggled the world leaders, it effects thinning of the ozone layer which causes melting of the polar ice cap that raises the sea level which leads to weather abnormality [3-7]. Abnormality such as a mega hurricane which caused billions of dollars of property damage and thousands of life casualties have struck few nations of the world.

Flash floods are one of the minor abnormalities that also causes damage, but the impact on human lives is preventable. As the name given, flash flood rises rapidly without any signs of the flood struck, while humans are in their vulnerable state and the probability of casualty is considered highly plausible.

In Malaysia, floodgates in water canals are traditionally operated manually, which needs the operator to constantly supervise the water level if any abnormal circumstances occur. However, sometimes the operator isn’t available or unaware of the water level which may lead to a halt of river flow that would cause overflow in the canal. This scenario is rather preventable by the presence of a monitoring system.

In some developed countries, a similar system is applied, but the range of the information that can be received by the public is limited, it is usually relayed through meteorology agencies or department then passed through to response team that involves in rescuing civilians.

This paper demonstrates the complete system that aims to provide an alert for the locals living in the flood-prone area for them to react first while waiting for the response team to arrive. The proposed system alert consists of three aspects, alerting through visual alerts, audible alerts, close proximity alert (i.e. via Bluetooth interface through a smartphone) and long-distance alert (i.e. via short message system (SMS)). These alerts would be helpful to the residents whether they are indoor or outdoor.

The remaining part of this paper is structured as follows: The next section discusses the background of flood monitoring system and their benefits. Section 3 introduces an overview of the proposed system and the adopted methodology and materials. The results and discussion are introduced in Section 4. Finally, a conclusion is drawn up and the future work is highlighted in Section 5.

II. THE PROPOSED FLOOD MONITORING SYSTEM

Figure 1 and Figure 2 show the system block diagram and the Flowchart of Flood monitoring system and explain the working principle of the system by transmitting and receiving the ultrasonic pulses to enable the system identifying the water level. The ultrasonic sensor will emit the ultrasonic signal from (Trigger) pin and receive the pulse to (Echo) pin. (Echo) pin and (Trigger) pin sends a digital reading to Arduino microcontroller module to be computed.

The ultrasonic sensor which enables the detection of solid and liquid materials will be utilized to detect the water level. The digital reading that is received from (Trigger) pin and (Echo) pin will convert to time duration after the pulse is transmitted using formula [8]:

$$Time = \frac{Distance}{Speed} \tag{1}$$

where: *Speed*=340 m/s for sound through air.

Normally, the levels of the waters could be classified based on the passing ability of the vehicle as shown in Figure 3. The three ranges of levels of water that will be the parameters which manipulate the system are represented the height of water, the first range of water, which is the default for the system is the safe level ranging from 0cm–30cm height. The cautious level range between 31cm–49cm and the crucial condition which is the danger level above 50cm about the height of an average adult knee. Each of the conditions has its reaction upon the system which is based on Table 1.

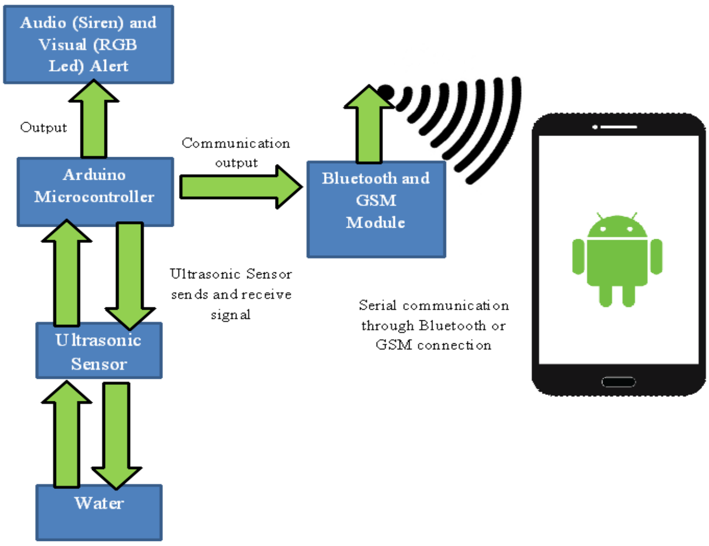

Figure 1: Flood Monitoring system block diagram

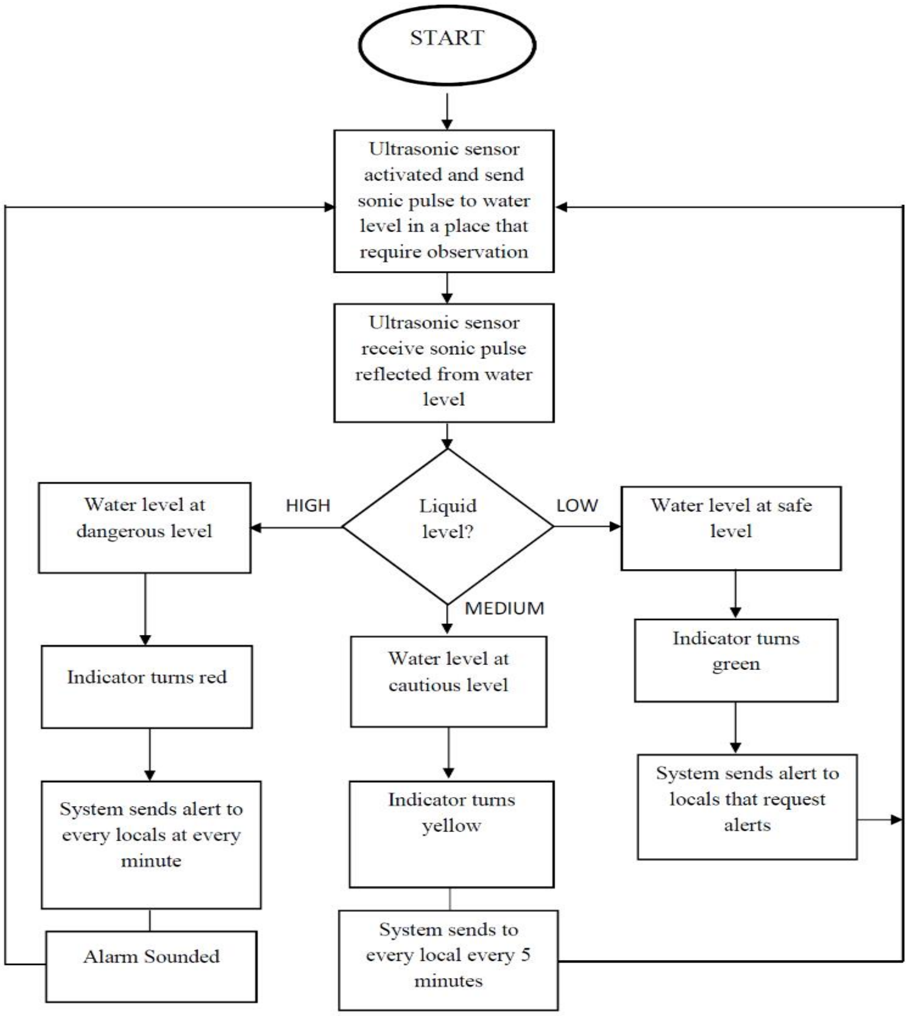

Figure 2: Flowchart of Flood monitoring system

Table 1
Conditions and response for the FMS

Conditions	Flood Level	Response		
		System	GSM Module	Bluetooth Module and Android app
Secure	<30 cm	LED green	Idle	Sends reading
Cautious	<50cm, >30 cm	LED yellow	Send alert to civilians	Sends reading
Dangerous	>50 cm	LED red, siren sound	Send alert to civilians	Sends reading and sounds an alarm

From Figure 4, the flood monitoring system is fitted to the beacon for the deployment of the field. The beacon's design is fulfilled by using a UPVC pipe with a diameter of 8inch as the properties of the material is suitable for the application as it is able to withstand the harsh weather conditions throughout time. From Figure 5, the beacon is designed to a perforated cylinder shaped, the perforated made to enable the water to fill the cavity of the cylinder and to eliminate any disturbance for the reading to be accurate.

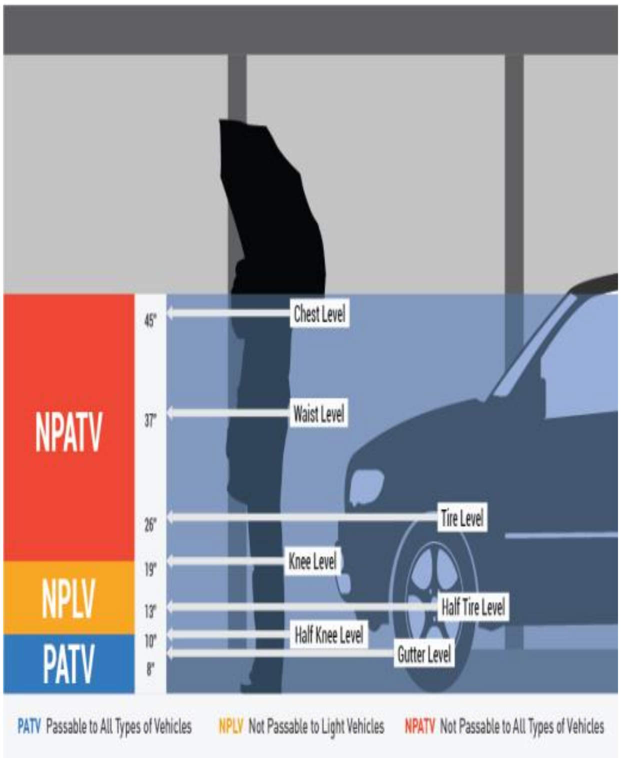

Figure 3: Water level height based on the passing ability of the vehicle

Figure 6 shows the Android application that was built to display the water level and cautious status from the FMS remotely from the Android phone at a proximity range. Since the FMS comprises of Bluetooth module the range is limited to about 10meter in radius to the beacon. The addition of GSM module to the system will increase the range to be unlimited if there is mobile network signal in the location of the receiver.

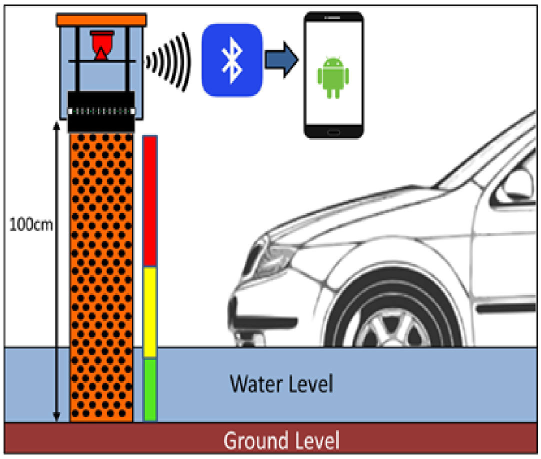

Figure 4: FMS beacon on field

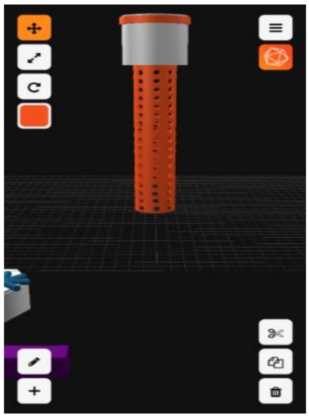

Figure 5: 3D drawing of the mainframes

Figure 6: The Android application interface

The microcontroller is the heart of the system, as all the control signals pass through and are processed by the microcontroller. The Arduino Nano microcontroller unit is a computer on a chip that is programmed to perform almost any control, sequencing, monitoring and displays the function. Because of its low cost, it becomes the natural choice for the designer. Its great advantage is no other external components are needed for its application because all necessary peripherals are already built into it. Thus, save the time, space and cost which are needed to construct low-cost devices. Table 2 shows the Pin configuration of Arduino Nano microcontroller unit and Figure 7 illustrate the connection of circuit diagram.

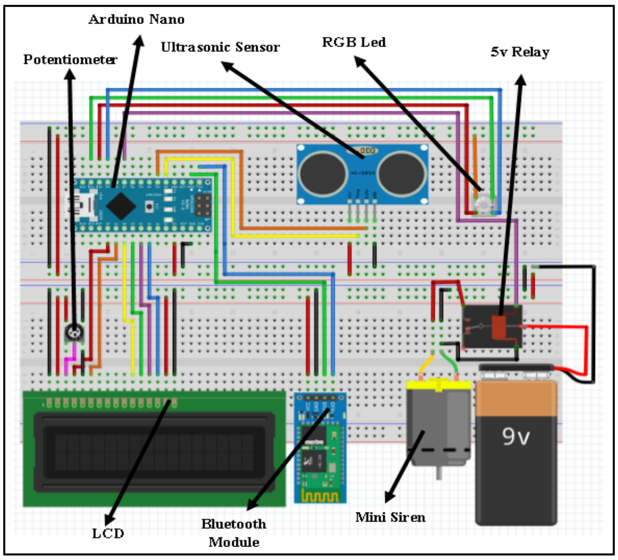

Figure 7: Flood monitoring electrical circuit diagram.

Table 2
Pin configuration of Arduino Nano microcontroller unit.

Arduino Pin	Connected Pin	Description	Component
A0 (Analogue In)	RS	Register Select	LCD Display
A1 (Analogue In)	E	Enable	
A2 (Analogue In)	D4	Data pin	
A3 (Analogue In)	D5		
A4 (Analogue In)	D6		
A5 (Analogue In)	D7		
0 (RX)	TX	Transmitter pin	Bluetooth
1 (TX)	RX	Receiver Pin	
2	TRIG	Send Ultrasonic pulse	Ultrasonic
3	ECHO	Receive Ultrasonic pulse	
7	RELAY	Connect to the normally open of the relay	Relay
9 (PWM)	BLUE	PWM controls the blue cathode pin of the LED	RGB LED
10 (PWM)	RED	PWM controls the red cathode pin of the LED	
11 (PWM)	GREEN	PWM controls the green cathode pin of the LED	

Sensor selection is a significant action to be considered in any system design [9,10], as it will have an incredible effect on the process of the system performance during its whole life and could even have outcomes related to the quality of the product. To design the flood monitoring system that is different than other systems. Application of ultrasonic sensor applied to monitor levels of the flood water. Ultrasonic sensor [11,12] able to detect any types of obstacles it has the angle of detection of 15˚ and the ranging module HC-SR04 provides 2cm until 400cm non-contact measurement function yet the ranging accuracy can reach to 0.3 cm. The modules include receivers, ultrasonic transmitters, and a control circuit. The ultrasonic sensor has four pins which are Vcc pin, Trigger pin, Echo pin and Ground pin. Liquid crystal display is used as an interface for the user to read out the height of flood level, the LCD can be used to calibrate the accuracy of the water level while on the field.

The Bluetooth module HC-06 Bluetooth Module is used to send signals from the microcontroller to the Android devices, by sending signals. The module has a built-in transceiver to transmit and receive signals to the Android device, working at 9600 baud rate and ability to be accessible at a distance remotely about 10meter.

The mini siren (MS-190 Mini Motor Siren) functions as the audio output to alerting the locals if the monitoring reached the dangerous state, other than the visual alert or by the Android application. The mini siren theoretically is operated by forcing the air from an array of fan blade through opening design to create a high sound pressure that could reach about 120db of sound pressure it is equivalent to the thunderclap at a close distance. The low voltage consumption of the mini siren should be enough for this application as the audible output, working voltage as minimum as 5 V to the maximum of 12 V it is a relevant choice component of the system [13]. RGB LED is required as a visual alert for the nearby locals to notice whether the flood conditions.

The RGB LED is controlled by using the Pulse Width Modulation (PWM) of the Arduino Nano board which could control the brightness and the color of the LED by mixing the three lights of the diodes (Red, Green, and Blue). The voltage rating of the LED strip is about 12 V and recommended input current is 2 A, which can be provided by using the rechargeable battery which will provide 2200 mAh (milliampere per hour) and the voltage can be boost using a DC booster to step the voltage from 9 V to 12 V. The system can be powered with 9 V rechargeable battery and be increase or decrease by using DC buck-boost converter to be regulated suitable power rating of each component. The use of solar panels will provide the system with renewable energy continuously for a few months until the rechargeable battery needed to be changed.

The design of the system needs to comply with a few properties for the system to operate properly. As the system needs to be put in the water environment areas and able to withstand harsh weather, waterproofing the beacon is a priority. Water could easily fill any cavity of the circuit compartment that would lead to short circuits. Using custom HDPE container as the circuit compartment eliminate the problem of humidity and water reaching into the circuit compartment as it tightly sealed enabling it to be water-proof. Threaded rod and aluminum sheet are used to withhold the circuit in place of the compartment which makes the built sturdier than other material.

III. RESULTS

The flood monitoring system achieves its aims to act as an early warning or a real-time alerting system as its properties can assist the civilians to be alerted to the flood level that endanger them. But in some circumstances the system has its pros and cons that needed to be taken into consideration, that can be improved in the next version of the system. The advantage of this system that it uses a modular circuit enables the user to modify without changing the whole system. The electronic component is interchangeable with better quality component if it is necessary.

The system could be integrated into a vast network of FMS beacon placed in strategic places, flood-prone places, or industrial area that need to be alerted when flood rises. The use of radio frequency to transmit the signal between beacons and the main hub can be utilized as it is covered faster than the mobile network. Data logging of water level in the river could be used for flood forecasting which will be more useful as civilians can prepare for flood earlier rather than unexpectedly confronting the flood. The beacons can improve by having an energy saving plan that would minimize unnecessary power output, for instances, the system turns on only when the temperature drops down or barometric pressure changes, and humidity increases. These are all the conditions that could verify the weather when it is starting to rain so that the system would be on alert when necessary rather than turned on all the time.

IV. CONCLUSIONS

This research paper is aimed to minimize or further extinguish the possibility of human casualties during flood seasons. The system is easy to use, to install and can be used by anyone, civilians or government agencies. This system would be an improvement to the previous system that limited the information to the civilians by having it on demand and in any conditions, they are in. The aspects of the system mainly have been designed to enable the civilians to be alert in any way possible to them, the audiovisual, the close proximity, and the long-range alert.

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