

The development of a real time, interactive water level monitoring system through SMS with AC load control

Jordan D. Buhion¹, Judelyn B. Buhion², Janice B. Ocon³

^{1,2,3}Public School Teacher III, Claver National High School, Surigao Del Norte, Philippines

jordan.buhion@deped.gov.ph, judelyn.buhion@deped.gov.ph,
janice.ocon@deped.gov.ph

Abstract. Flooding and water level rise is a constant problem Filipinos encounter every year. The Philippines has a reasonably well-defined rainy season due to the monsoons. To counter the adverse effects of this potentially disastrous phenomenon, modern flood monitoring and forecasting systems are indispensable. Thus, the utilization of a comprehensive GSM-based system for monitoring water level of streams, lakes, rivers and other bodies of water in areas prone to flooding is essential to effectively increase the people's awareness in real time. The system works by receiving water level update queries through text messaging from any cellphone number and texts back the accurate water level (in feet and inches) based on the actual reading from the system's sensor. The water level update can be done "on demand" or every 10 minutes. The system can analyze the water level patterns such as the rate of water level rising or receding and includes its observation on the SMS to be sent. It also has integrated anti-theft features such as intruder sensor and alarm and the system locator through GPS (Global Positioning System). They are designed to protect the system against thieves and intruders. The system is also capable of controlling an AC (Alternating Current) load. This allows the system to be used in various applications that require water monitoring and automatic control. It can control AC loads of up to 2000 watts. The control function can be "automatic" or through SMS (Short Message Service) depending on the application.

Keywords. disaster prevention, early warning, flood monitoring, flood detection

1. Introduction

The Philippines, being an archipelago is blessed with a large number of rivers, lakes and streams. Paradoxically, it is sometimes excessive abundance of water that spells trouble than the lack thereof. Especially relevant today than before the years of climate change, the occurrence of floods and other water related catastrophe seems to increase yearly. One can never predict what specific time of the year it occurs, and what extent of damage it can bring. Sound flood monitoring, forecasting and preparation is crucial in minimizing its damaging effects. A flood warning must be issued as soon as possible. The affected people can take the appropriate preventative actions if they have enough lead time.

Flood monitoring and forecasting has been one of the major concerns of the government especially during the monsoon season. The DRRMOs of almost every municipality

has been combatting this problem with little success. The lack of effective water level monitoring and flood forecasting tool can be attributed as one of the primary reasons why these type of calamity poses ever increasing risks in our community since river floods, flash floods, and coastal flooding all occur on a yearly basis.

River Flood

Heavy rains from monsoons, hurricanes, tropical storms, or winter melt increase the capacity of rivers and their tributaries, causing a river flood. Flooding can also occur when muck from landslides and other natural overgrowth obstructs the natural flow of the water body. River floods can also be caused by humans clearing too much vegetation from river banks.

Flash Flood

A flash flood occurs when the water level rises dramatically in a short amount of time. It is brought on by a sudden downpour of rain. In many countries, flash floods are a big issue. Because this type of flood occurs unexpectedly, there is no effective cure.

Coastal Flood

Coastal floods are the result of sea water entering the domestic area. This could happen as a result of low pressure combined with high tides or storms. In both circumstances, the sea level rises unnaturally, resulting in floods.

2. Statement of the problem

The project aims to develop a multi-purpose gsm-based water level monitoring system for various applications with the specific feature set as follows:

Will the device be able to:

1. Send outgoing SMS water level updates in real time (User and Administrator)?
2. Receive SMS commands and execute it in real time (User and Administrator)?
3. Filter out invalid SMS commands or unauthorized phone number?
4. Perform analytic algorithm to know the rate of water rising or receding?
5. Detect potential thief and notify the owner/administrator through SMS?
6. Send through SMS the longitude and latitude of the current location of the system to the administrator once the system is potentially stolen?
7. Turn ON/OFF an AC load connected to the system through administrator SMS command?
8. Precisely control a water motor pump (AC) that fills a tank/container with water?

3. Literature review

Manual water monitoring techniques were used in the past. People were sent to record levels of water on monthly basis, the improvements to technology makes it possible for water level monitoring to be done remotely. To record water level more regularly, telemetric devices were used. The data gathered was then sent to other devices over long distances which permits for greater response capabilities and simplicity of use. In addition, water level monitoring also brings a number of other advantages including increased efficiency and lessens human error. Various works related to flood monitoring systems have been conducted as follows.

"Real-Time Flood Water Level Monitoring System with SMS Notification"- Metropolitan Manila is one of the most flood-prone areas in the Philippines. The goal of this project is to construct a stand-alone flood water level monitoring system for the Kahilom Street neighbourhood in Manila. The Arduino Uno, GSM shield, and sensors are used to build the system, which will be powered by a solar panel and generator. The three LEDs placed to the wall will serve as an early warning device. The system will then send an SMS notification to the residents of the neighborhood [1].

"Development of Flood Detector System Using MC68HC11 Microcontroller"- This project entails the creation of a Flood Detector system that will identify the current water level based on the voltage generated by the detector. The collected data will be processed in a database to ensure that safety precautions are taken if the water level reaches the danger level. Hardware and software development make up the entire flood detecting system design. The most crucial hardware design is a microcontroller board for controlling the entire system, as well as a transmitter and receiver module for sending and receiving data [2].

"Video Surveillance System For Real Time Flood Detection And Mobile App For Flood Alert" – Typically, bridges are connected across seas, rivers, and other waterways, which are more prone to disasters such as flooding and tsunamis. In order to alert people affected by these disasters, an early detection and warning system is designed, with the flood range being detected using video streaming and warning information being provided if it exceeds a certain threshold. The flood information is distributed to the local population via a mobile app called "FLOOD ALERT," which was constructed using Android and Java and provides information about the location of the flood that occurred, as well as the related date and time. This system is capable of reducing undesirable consequences, such as bridge collapse due to flooding [3].

"Flood Transmission Based Protocol For Home Automation System Via Power Line Communication"- The use of power lines as a data transmission medium has been the subject of numerous studies and developments. Almost every room in the house has many power outlets. The power line is the most widespread network and infrastructure accessible. This project's goal is to use this architecture to design a home automation system. This paper describes a way for creating a Home Automation System that uses a proprietary built power line communication protocol to form a network between the main controlling unit and client units. Multimode simplex communication, flood transmission, and even parity error detection are all used in the protocol. The protocol has been successfully developed and tested in a Home Automation System that includes one main controlling unit, three client units, and data transmitted via power line to the appropriate device [4].

4. Design methodology

The system was designed with 3 different sensor inputs. The URM07 ultrasonic sensor, HC-SR04 ultrasonic sensor and the GPS module. All sensors were connected and controlled by the ARDUINO MEGA microcontroller. The GSM module serves as both input and output. It accepts text message commands from the users and relays it to the ARDUINO Microcontroller. Once the Microcontroller has interpreted the command, it then executes the command by reading the appropriate sensor/s and once again processes the data. It then communicates again to the GSM module passing on the data or information to be sent back to the user through SMS. All these components were connected to the Microcontroller that does all the data processing, calculation and communication.

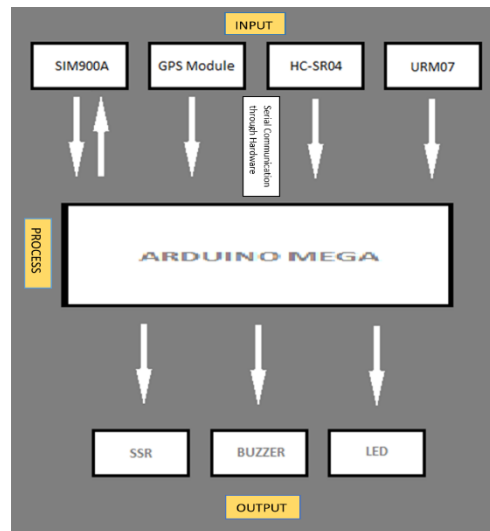


Figure -1: Block Diagram of the System

4.1 The Input System

The input system was primarily composed of sensors that provide data to be processed by the ARDUINO MEGA Microcontroller. The URM07 ultrasonic sensor serves as the main sensor that reads the water level. It produces an analog signal transmitted serially, representing the distance of the object (water) that is fed to the Microcontroller for processing and interpretation. The speed of sound travelling in air is greatly affected by the air temperature. The URM07 sensor has a built-in temperature compensation system making it read distance accurately even in environments with varying temperature.



Figure -2: Ultrasonic Sensors (URM07 and HC-SR04)

4.2 The Process

4.2.1 Initialization of water level reference

The moment the program is executed the first time, the “water level update” feature for both the users and administrator are still inactive. The sensor reads the distance but without a reference distance, the ARDUINO microcontroller would not know whether the succeeding water level updates indicate a rising level or a receding level, thus it must have an initial water level reference that would also serve as the normal water level status. This initialization should be done before the water starts to rise due to flood. The GSM module waits for a valid text message from the administrator number with a code “UPDATE” (not case sensitive). Once an SMS is received, the ARDUINO microcontroller analyzes the message for the validity of the code and the sender number (administrator). If the code is valid but the sender number isn’t, the ARDUINO microcontroller tells the GSM module to send an SMS to the sender number with a message “The administrator has not activated the system yet.”. Otherwise, if both the code and

the sender number is valid, a text message is sent to the administrator that the system is ready with the initial water level reference distance in FEET and INCHES.

4.2.2 Water level update for administrator and users

The water level update for the administrator number can be done in two ways. Right after the initialization process, the ARDUINO microcontroller tracks the time and the system sends an automatic water level update to the administrator number exactly 15 minutes after. The second method can be done through SMS query, by sending the code “UPDATE” (not case sensitive) to the system’s GSM module phone number. This method also applies to the users who want to receive a water level update. Once the SMS is received by the GSM module, it will pass the data on to the ARDUINO microcontroller for processing. If the code is valid, the microcontroller then stores the sender number and tells the GSM module to send the appropriate water level update. Otherwise, if the code is invalid, the system ignores the request and waits for another SMS queries.

4.2.3 Intruder detection, alarm and GPS locator

Intruder detection is mainly done by the HC-SR04 ultrasonic sensor. **HC-SR04 distance sensor** is usually paired with both microprocessor and microcontroller boards like Arduino, Raspberry Pie, ARM, etc.

The sensor is powered using a regulated +5V through the Vcc and Ground pins. The electric current used up by the sensor is not more than 15mA and hence can be directly connected to the on board 5V pins of the microcontroller board. The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the Arduino. To begin the measurement, a high signal is sent for 10uS to the trigger pin and then turned off. This triggers an ultrasonic wave at frequency of 40Hz from the transmitter. The receiver waits for the sent wave to return as echo. Once the wave is returned after it getting reflected by any object the Echo pin turns high for a specific amount of time that is equal to the time taken for the wave to return and received by the sensor. The time during which the Echo pin is high is computed by the Arduino as it gives the information on the time taken for the wave to return to the Sensor.

The microcontroller was programmed to trigger the buzzer if the HC-SR04 sensor detects intruder within a proximity of 2 feet (24 inches). If the sensor detects an intruder, the microcontroller calculates the distance. If the distance is less than 24 inches, the microcontroller activates the buzzer and sends an SMS to the administrator on the intruder and the exact distance of the intruder from the system. The microcontroller then stores the time and wait for another trigger from the sensor. If the sensor is triggered again, the microprocessor tests if the time of the new trigger is less than or equal to 2 seconds from the first trigger. If it is, the microprocessor increments a counter variable. If the counter reaches to 3, the microprocessor halts all the operation and sends the current GPS coordinates of the system to the administrator number and keeps tracking the system as long as the main power of the system is still on. This means that the system is in the possession of the intruder. All other function of the system should be halted to conserve energy that should be focused to the GPS module.

4.2.4 AC Load Control

The AC load in the system was designed to add versatility. The system can be used in various applications that need automatic control and handling of large loads like filling up reservoirs and tanks, dam emergency water release gates, filling up fish ponds and other related systems.

The system, through SMS command by the administrator number, can activate or deactivate any AC load with a maximum power capacity of up to 2000 watts that is connected to the AC outlet. This was done by manipulating the DC input of a 5v mechanical relay that is connected to the microcontroller. The DC and AC component of the relay is isolated by an opto-coupler built-in the relay. The output of the relay is connected to an external AC supply that powers the AC load. If a valid SMS with a code “ACON” (not case sensitive) is received by the GSM module, the microcontroller then tests the validity of the sender number. The only authorized person to make the command is the administrator and not the users. If both information is valid, the microcontroller turns “ON” the relay thus turning on the AC load and an SMS is sent to the administrator prompting that the AC load has been turned “ON”. Otherwise, if the code is valid but the sender is not the administrator, the microcontroller tells the GSM module to send out an SMS to the number who sent the command, prompting that the number being used to make the command is not authorized.

With the same process, the administrator can send an SMS command to turn the AC load “OFF” with a code “ACOFF” (not case sensitive). The microcontroller validates the code and the sender number. If the code is valid, the AC load is turned “OFF” and an SMS is sent to the administrator. If the code is valid but the number isn’t, an SMS is sent to the sender number and rejects the request.

4.3 The Output System

The output components used in the system were composed of the LED, active buzzer and the GSM module. Every time an SMS is sent by the GSM module, a LED is lit. This is to notify the user of the action performed. The active buzzer was used to send an audible signal to the intruder every time the HC-SR04 sensor was triggered. The buzzer is activated for 10 seconds but is deactivated after 3 consecutive sensor triggers within 2 seconds in between triggers. This implies a possible theft scenario so the buzzer is turned off and the GPS coordinates of the current location of the system is sent to the administrator. The GSM module sends outgoing text messages to either confirm or reject requests and to send water level updates.

4.4 Tank Filling Control System

This application of the system is an important function that adds versatility. With a flip of a switch, the user can change from water level monitoring application to tank filling control system. The program starts by the Arduino microcontroller reading the initial state of the tank (empty) the same way as reading the reference water level for the water level monitoring application and sends an SMS to the administrator of the distance from the bottom of the tank to the sensor. The microcontroller then turns the AC motor ON to dispense water and fill the tank up while keeping track of the current level of the water to know when it is already full. The microcontroller stops the motor and waits for the tank to be completely empty again before turning back the AC motor ON as shown in *table 1* below.

Tank State	Motor State
EMPTY	ON
HALF FULL (previously empty)	ON

FULL	OFF
HALF EMPTY (previously full)	OFF

Table -1: Truth Table of tank state against motor state

5. Experimental results









5.1 Functionality Testing

As shown in Table -2 below, the functionality testing was conducted with five trials. All functionalities were tested and accurately performed exactly as designed except for the sending of the GPS coordinates having 80 percent accuracy due to GPS signal unavailability. The test was conducted during a rainy day and the signal was affected by rain cloud coverage.

Tested System Component	T 1	T 2	T 3	T 4	T 5	ACCURACY
Sending of outgoing water level SMS updates	Blue	Blue	Blue	Blue	Blue	100%
Receiving incoming water level SMS queries from any cellphone number	Red	Red	Red	Red	Red	100%
Filtering of invalid SMS	Yellow	Yellow	Yellow	Yellow	Yellow	100%
Performing analytic algorithm for rate of water increase or decrease	Green	Green	Green	Green	Green	100%
Detecting potential theft	Cyan	Cyan	Cyan	Cyan	Cyan	100%
Sending longitude and latitude through SMS	Dark Green	Light Green	Dark Green	Dark Green	Dark Green	80%
Turning ON/OFF the AC load	Grey	Grey	Grey	Grey	Grey	100%

Table -2: Functionality Testing

Legend:

-  - SMS sent successfully
-  - SMS queries received successfully
-  - Invalid SMS queries detected
-  - Accurately measured water level
-  - Potential theft successfully detected
-  - Coordinates sent successfully
-  - Coordinates sending failed
-  - Load turned ON/OFF successfully

5.2 Sensor Reading Error Correction

Ultrasonic sensors are limited to flat and perpendicular (to the sensor) surfaces when it comes to accuracy. In real applications like flood however, the water could get rough and floating solid debris can also cause false readings to the URM07 sensor. This was solved with multiple iterations in the program. The microprocessor was programmed to read the sensor several times, not just one, and compared the values each time. The values with the same distance reading mean it is the closest to the actual reading, discarding those values that are too low or too high. The microcontroller was programmed to sample the sensor 10 times, with 300 millisecond delay in between samples. As shown in the table below, done in a simulation with actual flowing river water. After 5 trials, the system without iteration in the program (Distance 1) produced erroneous readings that are either too low or too high. These are false readings. After the iteration (Distance 2), it produced near to identical distance readings.

<i>No. of Trials</i>	<i>Distance 1 (Inches) Without iteration</i>	<i>Distance 2 (Inches) With iteration</i>
1	15	15
2	16	16
3	98	15
4	37	15
5	15	14

Table -3: Sensor Distance reading without and with iteration

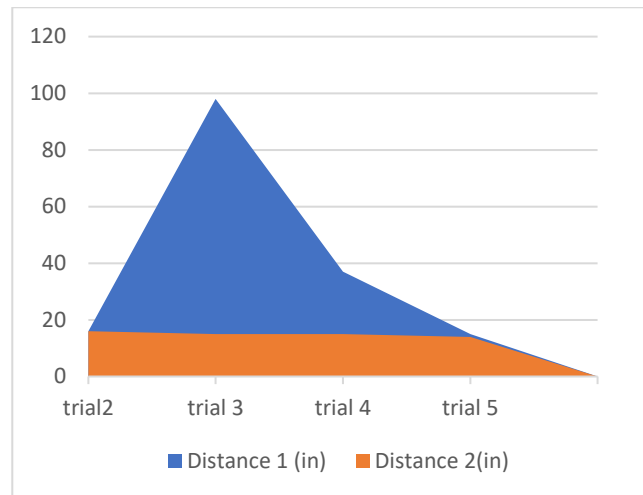


Figure -3: Sensor accuracy with and without iteration

6. Scope and limitation

6.1 Ultrasonic Sensor

The sensor being used to get the distance of the water from the system is ultrasonic type. Ultrasonic sensors use the concept of sound and echo to compute for the distance of an object. The sensor however is not capable of differentiating the type of object. It cannot distinguish water from solid objects floating in the surface of the water that can sometimes cause inaccurate distance measurement.

6.2 GSM Signal

The primary method of data transmission being used in the system is through Short Message Service (SMS) or text messaging. This mode of data transmission relies primarily on the GSM signal availability. The text updates will never reach its recipient if the GSM signal is poor or nonexistent.

6.3 Cellphone Load Credit

The system GSM module's SIM card should have load credits during operation since the system needs to send text messages and make a call if necessary. The user/administrator cellphone should also have load credits in order to make update queries and commands through text.

6.4 10-second Data Processing

Just like all microprocessors, Arduino Mega cannot perform two tasks at any given time. If the user/administrator sends an SMS to the system, the microcontroller processes the data in a time span of 10 seconds. This means that anybody sending queries/commands to the system within this 10-second time frame will not be received by the microcontroller. This is primarily because of the sensor's iteration to get a more accurate water level reading. Thus, in applications where false sensor reading is nominal, e.g. in areas having no strong water currents and floating debris, this problem will be minimized because the sensor doesn't need several reading repetitions thereby reducing the processing time significantly.

7. Applications

Aside from saving significant amount of time, remote water level monitoring can have a wide assortment of benefits to the environment, such as improved flood forecasting. Using water level monitoring systems, it is easier to deploy countermeasures rapidly in the occurrence of water levels becoming too high or low. Water level monitoring is frequently used in applications such as flood forecasting, wetland studies, study of tides and monitoring of surface water.

8. Conclusion

The efficiency of the interactive water level monitoring system through SMS with AC load control is a factor of good sensor system and sound programming. The sensors perform as expected and the data and results after thorough testing showed promising results. Solving the problem of early flood warning system is the most important goal this project has achieved but its versatility on certain other applications is just as significant. Overcoming the limitations such as GSM signal availability, cellphone load and ultrasonic sensor accuracy would certainly improve the system capabilities further.

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