GSM & web-based flood monitoring system

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GSM & web-based flood monitoring system

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Abstract. The purpose of this project is to develop a local real-time river flood monitoring and warning system for the selected communities near Mandulog River. This study focuses only on the detection and early warning alert system (via website and/or cell phone text messages) that alerts local subscribers of potential flood events. Furthermore, this system is interactive wherein all non-registered subscribers could inquire the actual water level of the desired area location they want to monitor. An estimated time a particular river waterway will overflow is also included in the analyses. The hardware used in the design is split into several parts namely: the water level detector, GSM module, and microcontroller development board.

1. Introduction
Residents from flat areas beside the mouth of Mandulog River were greatly affected by typhoon Sendong (2011) and Pablo (2012). This river had a waterway more than 50 kilometers long which serves as the main drain of the mountainous area which covers about 70,000 hectares of land as shown in Figure 1. The watershed covers hundreds of smaller rivers connected to Mandulog River and form a network of channels similar to the branches of a tree. It is the main trunk where most of the storm water collected by the mountain watershed passes through before reaching the sea (Iligan Bay).

Figure 1. Mandulog River Watershed Coverage.

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During periods of heavy rainfall, the stream network in the uplands collects rainwater and swell Mandulog River, generating a flash flood which sweeps away everything in its path. The river channels swell and form an overbank flow that encroaches on adjacent fields. During the typhoon Sendong, the river of torrent carried tons of trees and eroded debris cascaded toward the communities of Bayug, Upper Hinaplanon, Hinaplanon and Santiago in Iligan. Floodwaters 7 to 10 meters high rampaged beyond the banks of the river and wiped out villages with incomprehensible force.

This special project develops flood detection, emergency alert and monitoring system which will warn the residents of a particular community for a possible flooding along the Mandulog river banks. River watersheds are mounted with a water level detection device which has a GSM kit that will send signals to the server node. If system detected a warning status, the server will automatically send a text message to those recognized individual subscriber, and will continue to update until the water level detected returns to normal. Moreover, a monitoring device will automatically upload the current status to the internet through a website and other social media sites. Individual subscribers could also inquire the latest water level status of the particular area they wanted to monitor by texting a keyword which directs the text message to a specific node where the device is mounted. Additionally, a specific area could be monitored and predicted when to overflow depending on the volume of the watershed and amount of rainfall. This could be a great help to nearby areas in order to be prepared for a possible flush floods.

2. Other flood monitoring system
These last decades, lots of flooding risk technologies have been developed to minimize the danger of flood in inhabited areas. The current government development is the Project NOAH of the Department of Science and Technology’s (DOST). Automated rain gauges (ARG) and water level monitoring stations (WLMS) was installed along the country’s major river basins (RBs). This project will come up with computer models for the critical RBs through LiDAR technology, automate the process of data gathering, modeling and information output, and release flood forecasts.

Most of the technologies being developed commonly apply flood detection and monitoring system. They usually use a sensing device, flood modeling using software, internet and mobile technology. However, the applications are usually for one way communication only. In order to get information, the individual needs to access the website. However, in order to access the information, it requires mobile phone that has an internet feature, and most people could hardly afford to purchase one. In addition to that, individuals are busy doing their daily routine, to a point that monitoring activity cannot be their priority. These are the reasons why communities are blinded with the current status of the nearby river watershed. The unawareness led to the overflow of the watercourses of Mandulog River waterway and the subsequent inundation of various localities causing extensive damages to properties and human life.

As compared to other works, the proposed technology is personalized and designed for individuals who are directly involved within Iligan City and nearby communities along the Mandulog river waterway. This system is also a two-way topology where residents can interact and inquire the current status of the waterway.

3. Proposed research
This project builds a prototype that will detect the current water level across the watershed of Mandulog River and its surrounding areas through sensors. The geographical area of the river was sub-divided into areas where sensors were installed. Each sensor signifies a warning level. Once a sensor is triggered, an output signal will be relayed to a microcontroller which serves as a switch that triggers the connected GSM modem to send alert SMS message to the server. Then, the server will automatically send a text message to the numbers stored in the database. Also, the computer will then automatically relay the alert signal by uploading a warning post on a website or to social media sites like Facebook and Twitter. The process repeats as the water level continues to rise and triggers another
sensor. Once the water level reaches its critical point, it will relay a message giving warning to the nearby areas. Furthermore, communities could inquire by a sending message thru keywords.

4. Project elements
The basic hardware components used in the implementation of this project are as follows: float switch for water level detector, inverter, rain gauge, GSM module, and microcontroller development board. GSM is controlled using a water level sensor.

4.1. Sensors
For a specific watershed area, water level sensors are mounted depending on desired number of levels. The sensors used in the study are of float switch type. The purpose of a float switch is for it to open or close a circuit as the level of a liquid rises or falls. The float encases a sealed magnet which moves up and down the length of the stem as a fluid level rises and falls. As the magnet passes by the contacts in the encased reed switch, they touch and complete a circuit between the two lead wires.

4.2. GSM
The GSM module is used to transmit the data from sensors to the PC System through wireless transmission. In this project, Model 900 GSM/GPRS Modem Kit is used which is a physical add-on and usually mounted to the top of Arduino. It comes with a library to send/receive SMS and voice calls, and establish TCP communication over the broadly spread GPRS network. To upload sketches to the board, connect it to computer with a USB cable and upload sketch with the Arduino IDE. Once the sketch has been uploaded, you can disconnect the board from your computer and power it with an external power supply. Then, the GSM library handles communication between Arduino and the GSM shield. The majority of functions are for managing data, voice, and SMS communication.
To configure a GSM Modem, a HyperTerminal is used. RS232 Cable is also used to connect to the modem, and to the PC’s serial port as shown in Figure 3. A HyperTerminal utility should be installed in your PC. Additionally, Micro C is the tool used in PIC micros for the development of embedded systems without compromising its performance and control.

4.3. Rain gauge
The same concept is applied when the level of water droplets in the rain gauge increases - there is detection of change in the level of rain fall volume and this will trigger the GSM module to send an SMS. The rain gauge uses a measuring jug container calibrated in milliliters (ml) to measure the amount of rainwater collected. The measured amount is divided by the area of the funnel used in millimeters. This gives the amount of rain in millimeters that has fallen. Measured average rainfall volume is tabulated in Table 1. The formula used is:

\[
\text{Rain fall} = \frac{\text{Amount of rainfall in jug (mL)}}{\text{Area of the funnel (mm}^2\text{)}}
\]

Table 1. Rain fall volume.

<table>
<thead>
<tr>
<th>Level</th>
<th>Volume in mL</th>
<th>Area of funnel</th>
<th>Rain Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>7850 mm</td>
<td>6.36 mm</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>7850 mm</td>
<td>12.74 mm</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>7850 mm</td>
<td>19.11 mm</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>7850 mm</td>
<td>25.48 mm</td>
</tr>
</tbody>
</table>

4.4. Control unit
The basic operation of control unit is controlling GSM thru microcontrollers which are defined by the particular program. GSM module is connected to an output pin of microcontrollers by way of a switch circuit which is connected to a transistor. The collector of this transistor is connected to the switch circuit and the emitter is grounded. In the switch circuit, one diode is used for sending signal in one direction and one inductor is for opposing the change of current flow. The output of switch circuit is connected with GSM module. Control unit would perform depending on the water level detected by the microcontroller. When the microcontroller sends 0/1 volt to the base of the transistor then it becomes off/on and its emitter and collector becomes open/closed conditions. Then the GSM will get a closed path giving an OFF/ON condition, idle (no message sent) or sending status.

5. Operation description and complete circuit diagram
The operation of the main river water level detector is described through the block diagram shown in Figure 4. Other parts needed in the design are PIC16F9877A microcontroller, crystal oscillator, 2 capacitors with a capacitance 22 pF, LED, water basin, water level sensor, transistor, and some capacitor. The crystal oscillator is composed of two 22 pF capacitors which perform as an external clock generator to execute the instructions of the program.

The microcontroller is embedded with a program that will trigger the output with given input signals from the sensors. The power supply is regulated to 5 Volts. This is enough supply for the microcontroller to operate. The sensors that are placed into the bank of the river are composed of stranded wires, one wire for each level. One of the wires is connected to ground of the microcontroller which is in pin 12 or pin 31. That indicates Level 0. As shown in the Figure 4, the wire for the levels 1, 2, 3 and 4 are connected to the microcontroller through pins RE1, RA0, RA1 and RA2, respectively. Pins were assigned according to level defined as follows: Pins RA0 (Critical), RA1 (Warning), and RA2(Normal). On open connection or level 1 of the main river water level detector is not filled with water, the resistance is 100k\(\Omega\). A voltage drop can be measured across the resistor connected parallel to the wire for level 1. The voltage drop is about +4V-+5V. The microcontroller is programmed that if
the input voltage is greater than +4V, then the rain drops collected has not reached such level. When
the water level rises and immerses the wire for level 1, due to water conductivity, the wire for level 1
or of any level becomes connected with wire connected to ground. Then the microcontroller gets
ground signal (0v) to that pin of that level. Once the level 1 is grounded or 0V, this indicates that
the water level in the river has reached level 1, then the microcontroller sets the LED for level 1 to ON
and the information of what are the input voltages of the pins RA1, RE0, RE1 and RE2 are is passed
on to the Arduino Mega 2560 through the transmitter of the microcontroller which is the pin RC6 and
processed to be sent to the GSM module for wireless transmission. The same goes for levels 2, 3 and
4. But on the 3rd and 4th level, the alarm will be triggered for warning. Every change in the level of
the raindrops collected will be read by the microcontroller and goes on continuously. From the rain
gauge set-up, the same set up is applied in the main river water level detectors for the crystal
oscillator, power supply and ADC converter has been used.

![Figure 4. Circuit Design.](image)

**Table 2.** Experimental Result of Water Level Sensing Unit.

<table>
<thead>
<tr>
<th>Water Basin Input</th>
<th>RA0(LED 1)</th>
<th>RA1(LED 2)</th>
<th>RA2(LED 3)</th>
<th>Water Level</th>
<th>River Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>(0)EMPTY</td>
<td>LOW LEVEL</td>
</tr>
<tr>
<td>001</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>(1)50%*H</td>
<td>NORMAL</td>
</tr>
<tr>
<td>011</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>(2)75%*H</td>
<td>WARNING</td>
</tr>
<tr>
<td>111</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>(3)90%*H</td>
<td>CRITICAL</td>
</tr>
</tbody>
</table>

Each pins output will be display on the LED depending on the inverted signal from the
microcontroller. The water level could be varied depending on the physical characteristics of the basin.
The position or the height of the sensors where it is mounted will define the water level condition. In
this experiment, we defined Level as 50%, Level 2 as 75%, and Level 3 as 90% of basin’s height(H).
Likewise, RE1 pin of the microcontroller is used to detect the signal from the server. When pin gets
high, the LED’s will be turned ON which means there is a high signal received. This signal is a text
inquiry from the subscriber about the current water level condition. If high signal is received, it sends
a signal to the controls of the whole circuit and sends back a message to the subscriber thru the GSM
module of the current level condition of the water.

6. Mandulog river prototype and measurements
The prototype replicating the Mandulog River is developed as shown in Figure 5. To simulate the
behaviour of the Mandulog River, main riverand branching waterway were built. Initially, the amount
of water filled is just below level 1 for the main river and also for the branching rivers. Upon
simulation, River 1 is filled with water as an assumption that water from the rain added volume to the
water in the river. The float switch rises up and there has been detection for level one. As the water
level continues to rise up and it reaches level 2, there is detection for level 2 and so on for level 3. The
same scenario occurs in river 2. On the main river, besides from the captured rainfall, water level also
rises as water from rivers 1 and 2 are continually rising. As a result, there is an increase in the water
level in the main river and that will trigger the water level detector. For every change in the water
level, the GSM module will send an SMS of the change in water level.

![Mandulog River Prototype](image)

**Figure 5.** Mandulog River Prototype.

To calculate the amount of time each area will overflow, the basic formula in getting the volume of
a rectangular solid, which is \( V = LWH \), is used. By differentiating both sides of the equation, we can
come up with a general equation for computing the speed of change of water level height at any given
amount of pressure or flow rate \( \frac{dV}{dt} \) and length and width of a particular terrain, that is:

\[
\frac{dV}{dt} = L \times W \times \frac{dH}{dt}
\]

From the basic equation, the time could be computed since the following parameters are available:
\( \frac{dV}{dt} \), which represents the flow rate measurements from the design rain gauge; \( H \) (height), \( L \) (Length),
and \( W \) (Width) of a particular area. Moreover, take note that for the main river, the computation for
branching waterway should be included.

Actual time in hours of testing is performed in order to analyze the time variation at each point of
time. The tabulated time delay of operation shows the actual time of sending the generated commands
from the mobile phone until loads are activated.

**Table 3.** Time delay response of the device.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Main River</th>
<th>Water Way 1</th>
<th>Water Way 2</th>
<th>Rain Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.7s</td>
<td>2.4s</td>
<td>3.4s</td>
<td>1.7s</td>
</tr>
<tr>
<td>2</td>
<td>3.3s</td>
<td>1.8s</td>
<td>2.7s</td>
<td>3.2s</td>
</tr>
<tr>
<td>3</td>
<td>2.5s</td>
<td>2.9s</td>
<td>2.3s</td>
<td>2.4s</td>
</tr>
<tr>
<td>Average</td>
<td>1.83s</td>
<td>2.36s</td>
<td>2.8s</td>
<td>2.43s</td>
</tr>
</tbody>
</table>
7. Website
The website has different interactive GUI as shown in Figure 6. You can view where sensors are mounted and its height for the water level indications. It was linked to a Google map, to locate specific area where the device is mounted. Facebook and Twitter users can also follow in order to monitor and get updated with the current water level status of Mandulog River. A 7-day weather forecast for Iligan City is also included. The current status of all areas monitored and mounted with the device is displayed in the server webpage as shown in Figure 7. Additionally, the histories from the previous dates of the real-time captured data of the water level activity are saved. Thus, you can still review the events and use this data for any purpose.

![Figure 6. Web Page Design.](image)

![Figure 7. Server GUI.](image)

8. Results and discussion
The data from the water level monitoring hardware were successfully transmitted using GSM sim900 and Arduino Mega 2560 and was successfully received by the computer system using GSM USB Dongle. The researchers have achieved the objectives of the study, which is to integrate different water level detectors from remote areas into one system. It is quite efficient for it has wide area coverage since it uses the cellular network that is used in mobile phones. The wireless communication set up that the researchers used is already web-based, given that there will be a dedicated IP Address. Since dedicated address is only issued to commercial entities, this study will just be limited to the use a local host to present the data received from the hardware. The local host is used as the server and if given a dedicated IP Address, the data in the system can be broadcasted live to anyone in the internet. One of the best examples of establishment that have a dedicated IP address is MSU-IIT (http://my.iit.edu.ph). Moreover, the system made has the ability to handle more data provided that the hardware that transmits the data works well and it is within the coverage of the module. Since cellular networks are used in module, the system could cover the whole country. Data can be obtained from the devices located anywhere in the Philippines. The prototype was successfully designed to have a simulation which is the same as in the real situation in the Mandulog river.

In terms of efficiency, a test was conducted by recording the time delay of the detection of the water level to be transmitted and recorded or updated in the website. The record time tabulated in 3 shows that it is efficient and reliable enough to operate via wireless. Through this system, the information could be available to anyone who could access the internet once the website will be given a domain and can be broadcasted live in the internet. Aside from the people near the river who would be alarmed once the water level will be of critical level, those who are away will also be informed of the current situation. With that, necessary preparations and safety measures can be done. It could be a help to prevent or lessen the damages that flood may bring.
9. References

