SMS BASED FLOOD MONITORING AND EARLY WARNING SYSTEM

Sheikh Azid, Bibhya Sharma, Krishna Raghuwaiya, Abinendra Chand, Sumeet Prasad, A Jacquier
The University of the South Pacific, Suva, Fiji
E-Mail: azid_s@usp.ac.fj

ABSTRACT

This paper demonstrates the design process, implementation and experimental verification of an SMS based Flood Monitoring and Early Warning system. With tools such as credit top-up and storing contact numbers will be done via SMS. Updates on the height of the water level would be texted upon users' request. The system provides timely information and alerts at-risk or threatened populace and relevant authorities by means of SMS when the level of water surpasses the user defined threshold value. The Global System for Mobile Communications (GSM) module is used for sending the mobile text messages while the Arduino Uno microprocessor is used to read in the input from the pressure sensor and then calculate the height of water. This simple yet effective warning system is deemed to be one of the fastest and cost effective method of alerting the relevant authorities and the vulnerable residence.

Keywords: arduino uno, barometric pressure sensor, GSM module, SMS.

INTRODUCTION

Climate change due to global warming has caused an increase in unpredictability of weather patterns in the world today. It has brought tremendous impact on the high mountainous glaciers resulting in large discharge of water. Global warming has caused rise of sea levels due to melting of snow and ice and with an ever-increasing regularity of flood damage, a definite need has emerged for an early warning system for people in the regions deemed to be 'at high risk' from flooding. High level of damage to properties and loss of lives are the underlying factor in the development of such an early warning system.

Fiji has a history of tropical cyclones and frequent flash flooding. It has been seen that short periods of heavy downfall has led to severe flooding in low-lying areas. [1] Residents and authorities have been caught off guard and as a result properties are damaged and human lives have been lost. This is invariably due to the absence of a proper flood monitoring system that can provide correct and timely information via communication channels that are operational at the time. Radios and TVs, although available in most households, may not be effective due to the power cuts. Although there are many evacuation centers and authorities on alert upon times of flooding, many people are not able to escape or save their stocks on time. There is a need for a fast, convenient and reliable Flood Monitoring and Early Warning System to alert residents and authorities when water level reaches a critical height.

Currently the South Pacific Metrological center uses the satellite to find out the average rainfall in the area and then predict the weather [2]. The GIS hydrological model in China uses of satellite to read the water level and then subtracts the surface elevation to get the height of flood [3]. Satellite is also used to gather data of different sensor systems and the collected data was analyzed to get information on the flood. The image sensor system consisted of Landsat, SPOT, and ERS [4].Most of flood level systems depend on satellite to predict the flood data however, there was a need of a system which automatically reads the live data rather than predicting in the threatened area instantly send alerts.

The idea of an SMS based warning system was proposed because mobile phones have become a popular communication device amongst people all over the world. While there are fewer than 7.2 billion people, the number of active mobile devices currently stands at 7.22 billion [5]. SMS is the most widely used form of communication around the world with more than half of world's population [6].

The concept of smart home, smart classroom, eLearning have all integrated SMS within their functionality. For example in the smart home the user was able to control lights and appliances at home remotely. [7]. An SMS based remote metering system shown consisted of various remote meters and a central server designed for electricity billing of industries and residences [8]. The technique was developed to provide an automated means of obtaining data in order to avoid corruption and human error, which could occur during data collection.

All mobile phone are able to communicate because it comprises of a GSM. GSM is a standard cellular network developed to describe protocols for networks used by mobile phones. It is a modem which operates over a network via SIM card and its range is up to 35km [9]. The range is further increased by the use of cell phone towers (base stations). The mobile phones communicate with each other and with other fixed phone networks using radio waves via the base stations. The base stations transmit the incoming signals to the main telephone network either by telephone cables or by using higher frequency links between the antennas located at the base stations and another wired to the main telephone network [10].

Contribution

This paper presents the idea of alerting flood threatened residence and relevant authorities by the means of SMS. An Arduino microprocessor is used to control the whole system. It is interfaced to GSM modem and pressure sensor. The water level height is measured by a

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pressure sensor and the Arduino microcontroller is used to calculate the height value of the water using Pascal's Law. The water level calculated would then be compared with the set threshold and if the level is more than the set value, the microcontroller would enable SMS to be sent to residence to alert them via the GSM module. The system is independent it even does not need any external power supply while the recharge of sim-card and storage of contacts would be done via text message. If the battery is low anyone can top up the system and also any authorized person can know the status at any time. The entire system is solar powered and its chargeable batter can last for about a week.

Design Overview

The pressure sensor is mounted at one end of the pipe and is placed in the control box together with the other electronic components as shown in Figure 1. Air would be trapped inside the pipe when the setup is lowered in the water because of one closed end. Rise in water level would cause the air trapped inside the pipe to compress which would causes an increase in pressure in the air trapped inside the pipe. Hence the pressure measured by the sensor is then converted to height by Arduino. The threshold height value set would be chosen by the user with prior knowledge of the flood height in the particular area. This threshold value would vary with different locations where the system would be placed in.

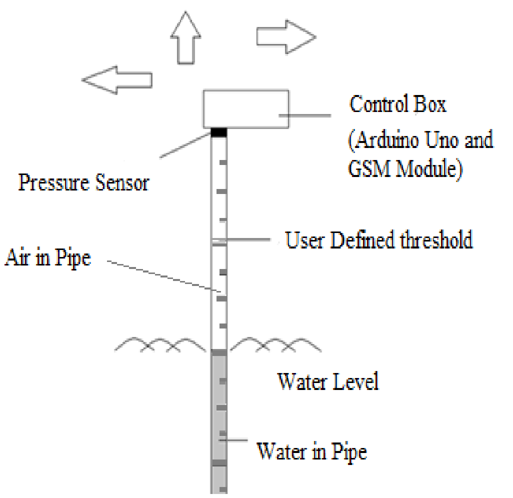

Figure-1. System Setup [11].

When the water level exceeds the threshold value set, emergency alert message would be sent to numbers stored in the phonebook of the sim which would contain numbers of people and contact of relevant authorities' disaster management committee. These committees' could quickly open up evacuations centers and carry out necessary steps to facilitate evacuation process and alert other relevant authorities such as fire authority, Red Cross and other aid agencies.

Design Overview

The ultimate aim is to make the system independent. Three significant area of programming from the past publication from the authors [11] are automatic credit top up, updating the resident numbers and feedback the current status to any authorized user. The system is programmed such that the first two characters would be same always except the last. The different functions are as follows:

*123- Updating the phone book, this phone book is used to alert the at-risk residents. The number 3 will verify that the 7-digit number written after this is to be stored as contact in the phone book.

*124- This is used for Credit top. The 12-digit number written after this code is the recharge pin which needs to be extracted and sent to 132 (If using Vodafone sim) for sim top up.

*125 – Feed back to user. This will SMS the user the current water level and temperature.

As seen below, the read pressure and temperature loop is done first. Within this loop, the critical level is checked and an SMS is sent to the user if the critical level is reached. A snapshot of the Arduino code for comparing pressure is given below. The manufacturer of the pressure sensor had already provided the codes for reading and calculating the pressure. This is a separate function and is called when needed.

```
///////////////////////////////////////////////////////
pressuredifference = (pressure-100717);
if (pressuredifference<=0)
{
  levelheight=0;
  Serial.println("Zero");
}
   else if (pressuredifference>0)
  {
      levelheight = (pressuredifference/8084.00);
      Serial.println(levelheight);

    if (levelheight >= critical_height)
    {
      Extract();
    }
    }
 //////////////////////////////////////////////////////
```

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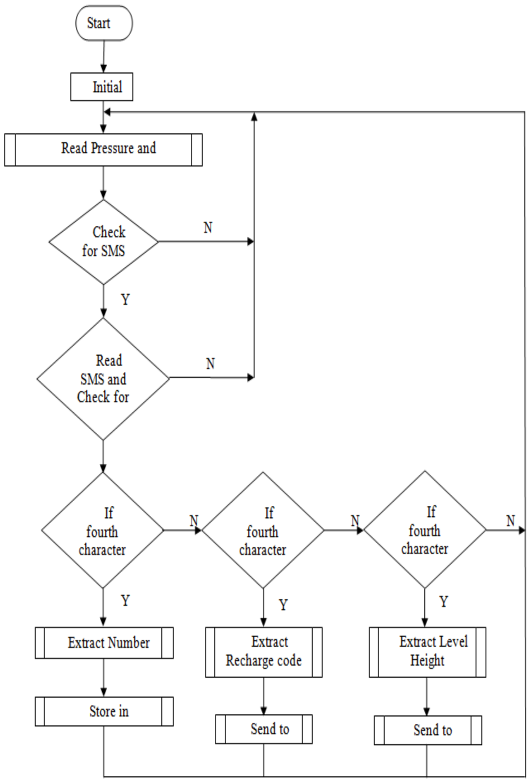

Fig. 2. Program Flowchart (modified from [Azid and Sharma, 11])

Figure-2. Program Flowchart (modified from [Azid and Sharma, 11]).

Since the GSM module only responded to AT commands, These AT commands were also incorporated in the programming. The Arduino programming language is based on C/C++. Table-1 explains the most common AT command used for the system programming.

Table-1. AT Commands.

AT Command	What it Does
AT+CNMI=3,3,0,0	Enable GSM to direct all incoming data to Arduino terminal
AT+CMGF=1	Setting Message mode to text mode
AT+CMGS=<"number" ><text> (ctrlz)	Sending an SMS to a particular phone number
AT+CPBR=<index>	Display the contact stored at a particular position specified by the index.
AT+CPBW=<index>,<" number">,129,< "name"	Store a number at a particular position in phonebook. The index specifies the destination of the phone number. The number 129 identifies the contact as a phone number and not an email contact.

Source: AT Command Datasheet[10]

```
////////////////////////////////////////////////////////////////////////////////
void SMS()
{

  delay(10000);
  cell.println("AT+CMGF=1");
  delay(200);
  cell.print("AT+CMGS=");
  cell.print(34,BYTE);
  cell.print(number);
  cell.println(34,BYTE);
  delay(500);
  cell.print("ALERT!! THE WATERLEVEL HAS REACHED CRITICAL HEIGHT. PLEASE EVACUATE TO HIGHER GROUNDS!!");
  cell.println(26,BYTE);
  delay(5000);
}

////////////////////////////////////////////////////////////////////////////////
```

Figure-3. Sending SMS AT Command.

The sending of SMS mostly dealt with the AT commands. All that was required was to print the AT commands to the cell so that it could be recognized by the GSM module. Delays were placed to give time for the GSM module to process information. The ending of the SMS code is signified by 26 which is the ASCII equivalent of the character CTRL+Z.

The void Clear ( ) function was written so that unwanted data coming from GSM module could be removed. When AT commands are sent to the GSM module it replies with OK or +CME: Error. The void Clear ( ) function enables this data to be extracted and displayed which allows the memory to be cleared for continuation of the execution of the rest of the programme. If this function is not incorporated in the code then the program will get stuck when unwanted data is received by Arduino.

Hardware Model Pressure Senor

Different types of sensors such as level sensors and ultrasonic sensors were also researched The problem with ultrasonic and level sensors is that a low power consuming sensor has a very small measuring range, for example a 5V ultrasonic sensor typically has a ranges from 2cm to 3m. During severe flooding, water level reaches far beyond 5m from usual water level. If such sensors are used then they would be place about 3m above normal water height and hence will not be a perfect monitoring system. A level sensor to measure heights of more than 5m requires AC input as these are mostly high power industrial based sensors. The system will no longer be considered as a standalone if it is connected to the grid. It will also not be logical if the system is to be placed in a remote area as extra cost will be incurred for connecting it to the national grid. Problems will also arise if the nearest power supply is kilometers away. The barometric pressure sensor used consumes very little power and at the same time has high resolution of 0.2Pa and high range 3kPa to 110kPa. It requires a 3.3V input and comprises of an inbuilt analog to digital converter. A cylindrical pipe can be used to trap the air. Using a longer pipe will allow for a larger range of water level to be measured. The pressure changed can be used to calculate the water level height.

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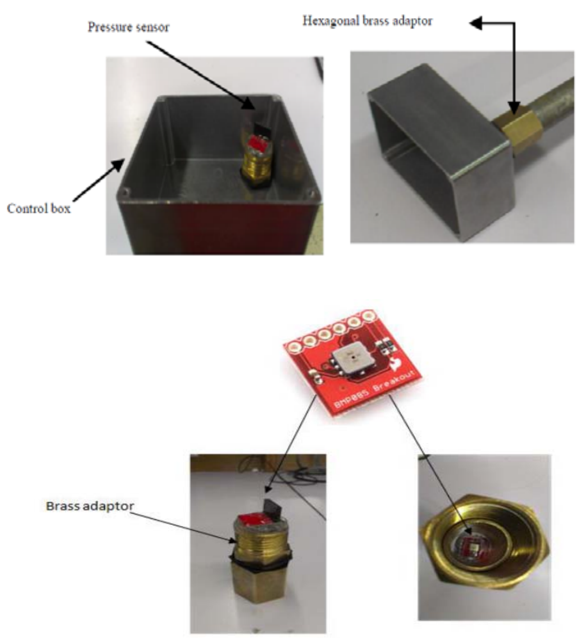

Figure-4. The barometric pressure sensor (SM5100B) is fixed at one end of the pipe facing downwards so that air pressure in the pipe could be measured.

Housing and structure

The pipe of the system could be 5m long so that rising water level does not submerge the control box. The entire electrical system is in the control box which is made of aluminum housing, this housing is weather proof and resistant to corrosion.

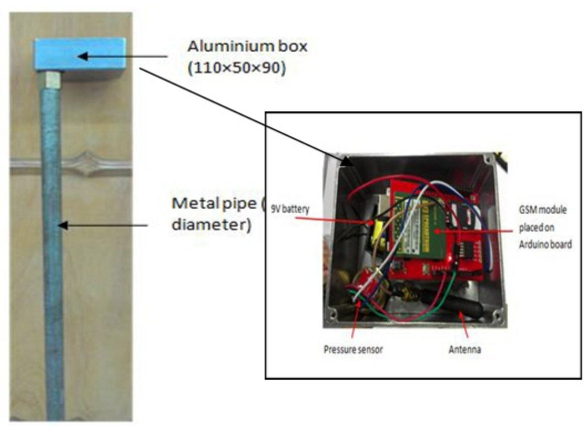

Figure-5. The completed setup. An aluminium box is used to house the circuit components requires an external support such as a column of a bridge or a dedicated concrete support. Figure-5 is an Autocad drawing of the possible installations.

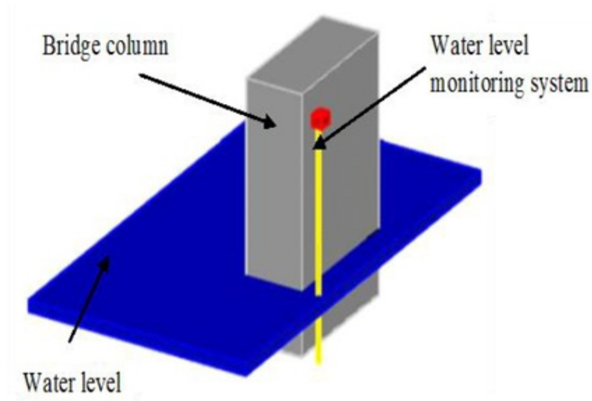

Figure-6. System with a bridge column for support.

RESULTS

The first step was to calibrate the entire system. This was done by achieving a relationship between the water level change and the air pressure change inside the pipe. The pipe was marked at 0.1m height intervals and was lowered in water. The pressure value after each 0.1m interval was noted till 0.9m of the pipe was in the water. Four samples at each height level was taken and averaged out as shown in Table-2.

Table-2. Pressure vs Height Values.

Pressure (Pa)					
Height (m)	0.0	0.1	0.2	0.3	0.4
Sample 1	100727	101589	102457	103288	104110
Sample 2	100 718	101583	102427	103284	104069
Sample 3	100709	101604	102376	103287	104048
Sample 4	100715	101570	102442	103259	104014
Average	100717	101586.5	102443	103279.5	104060.3
Height (m)	0.5	0.6	0.7	0.8	0.9
Sample 1	1048.3	105697	106556	107308	108063
Sample 2	104905	105685	106547	107263	108012
Sample 3	104953	105633	106479	107296	108018
Sample 4	104923	105648	106442	107266	108000
Average	104896	105665.7	106506	107283.3	108021.8

A graph of Pressure Vs Height was drawn to see the relationship and deduce a method of getting the water level height value by using the pressure information. As seen from Figure-6, the relationship is linear and the gradient equation obtained from the graph was

$$y = 8084x + 100717 \text{ (Initial Pressure).} \quad (1)$$

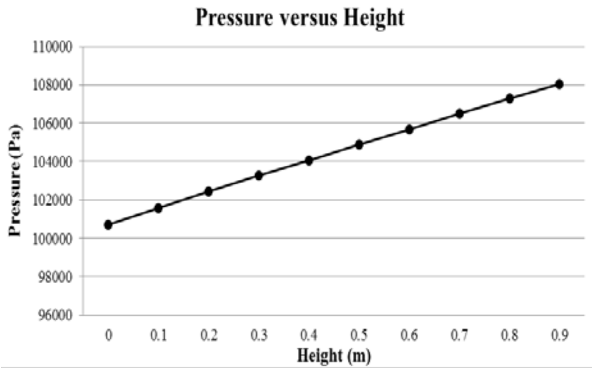

Figure-7. Pressure vs Height Graph.

As seen above, the graph of pressure versus height is linear. This made it possible to obtain different water level height information from measured pressure. From the graph the level height is obtained as

Level Height = Pressure – 100717Pa /8084 (2)

Inserting the current pressure reading value in the equation will give the value of level height. The y-intercept of the gradient equation which is in this case 100717 Pa would need to be changed always to the initial pressure value of the location the system would be setup in.

CONCLUSIONS

This paper presents the design of a SMS Based Flood Monitoring and Early Warning System and discusses its implementation. It successfully verifies the use of pressure sensors in a water level monitoring system as the relationship between the pressure and water level height is a perfect linear.

One problem in the system may develop if the network provider makes changes to the network. The GSM module cannot upgrade itself.

The system is further improved by make it independent by incorporating a solar battery charging system. This can be supported by the GSM module. GSM module has a feature that enables it to check the battery level at any time. Since the setup will be in a remote area, the solar charging system will allow for the battery to be constantly charged. The user can also check the battery status through the GSM module. The module should be able to feedback the battery level to the user via SMS. Further remote top-up, adding resident numbers are also incorporated to make the system fully efficient.

Finally, this monitoring system is fast, cheaper and reliable hence it helps prevent the loss of lives damage to properties.

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