Water Level Meter for Alerting Population about Floods

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***Abstract*—The most important thing immediately before, during and after a disaster occurs is the dissemination of information, a deployment of devices enabled by IoT (Internet of Things) could bring benefits in terms of giving to people information opportunely for making decisions in face of this disaster. In this paper, we present a sensor to measure water level in rivers, lakes, lagoons and streams. For such purpose and to prove our concept, we designed a pilot project through a micro-model that is constructed with a water level measurement sensor based on a simple open circuit that closes when in contact with water and experimentally tested into a water container under a controlled environment. This micro-model is performed on the basis of a programmable electronic board (Netduino Plus 2), an electronic circuit connected to electrical resistances that are located at a specific height, within a water container; when the water level rises and reaches the resistors, varies the impedance, this shows the actual water level and so on for different heights. The information from water level sensor is transmitted via WiFi to a laptop, then this information is also seen in smartphones, where users can see the water level in rivers. Finally, the micro-model is tested by experimental tests under a controlled environment and satisfactory results are obtained.**

I. Introduction

There exist several types of natural disasters, it is known that flood is one of the most dangerous since they have enough destructive power to change the course of rivers, sweep away and destroy whatever is in their path.

Our motivation for this work is based on all damages caused in our region due to floods, this natural disaster has caused many people to suffer damage to their homes and losing their belongings. Heavy rain caused flooding and damage to homes, inhabits from Tabasco have been warned against taking to the water without proper preparation following record heavy rainfall across the state. Tragic floods happened in Tabasco, Mexico in 1999 and 2007. In 2007, the homes of as many as half million people were destroyed and damaged by massive floods. Torrential rain pounded the region giving rise to widespread flooding by several rivers burst their banks.

There exist encouragement for researching preliminary solutions in this kind of disaster to mitigate and help in rescue operations. A variety of options there is for creating systems capable of warning vulnerable populations about an imminent threat of floods.

It is important to understand deficiencies in methods and processes for measuring water level in rivers. CONAGUA[1] currently monitors river levels in an automated fashion on their website, hence visible for everyone at any region, but especially for those living near riverbanks. However, it is known that monitoring is not automatic since a gauge performs this task by measuring river stages with a limnimetric rule, then, the data collected are captured manually and are is displayed on the CONAGUAs website.

However, the above brings deficiency in the measurement process because the data may not have been accurately captured and brought to where this information could be too late for help or planning a rescue strategy.

The fact that the data collection of levels of water bodies is executed by a person and it carries dangers and delays in the dissemination of information. One of these risks is endangering the person who comes to take action, as torrential rains access to the measuring points are extremely complicated, and in cases of possible flooding these delays are crucial to salvaging belongings and especially the lives of people living in areas at risk.

Because of the expensive cost of gauges to measure water level and the importance of developing warning systems for measuring levels in rivers that contribute to safeguard lives of citizens who inhabit regions in danger of flooding, we present a water level sensor based on water conductivity.

II. Background

Very recently it appeared the concept of Internet of Things (IoT) as a topic emerged in the wireless technology field. IoT describes the pervasive presence of a variety of devices such as sensors, actuators, and smartphones or mobile phones that through unique addressing schemes, are able to interact and cooperate with each other to reach common goals [1]. In [2] is mentioned Internet of Things is a paradigm as a result of the convergence of three different visions: Internet-oriented visions (middleware), things oriented (sensors) visions and semantic-oriented (knowledge) visions. In previous works dealing with this term [3], [4]. Hence, it is possible to use the concept of IoT to provide communication capabilities to

[1]CONAGUA stand for Mexican National Water Commission, http://www.conagua.gob.mx/

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a device that could alert opportunely to a population before a natural disaster occurs.

Before using sensors integrated into IoT (”Things”-oriented vision) some works have been proposed to disaster situations [5], [6], [7], [8]. Specifically ”Things”-oriented vision works like [9], [10] where RFID technology is used. However, we are especially interested in those applications centered in disasters by floods. For example, a system for flood detection is ALERT [11]. This system uses remote sensors to transmit environmental data to a computer system. Various kind of sensors deployed in the ALERT system is rainfall, water level, and weather sensors. These sensors supply information to the centralized database system. Another example is found in [12], it is a landslide detection system using a WSN (Wireless Sensor Network). This system has enabled a more convenient early warning system and provides a system able to learn about the phenomena of natural disasters.

Current emergency management and disaster recovery systems usually involve several parts such as a communication infrastructure and an information management system [13].

Forecasting flash flood by the overflowing of rivers is able to process, analyze (by means of rain gauge and stream gauge) and remotely sensed data to detect the occurrence of a flood. This system is the ideal solution, but it is expensive. A variety of hardware, software (including computer applications and programs), and communication capabilities are required to support and maintain this water level measurement system. Several studies have designed river level sensors using databases, processing raw data, extracting information and sending wirelessly this information to users. [14], [15],[16]. Another more previous works have studied similar issues such as [17], [18].

Because of climate change extreme rainfall is becoming more frequent often, therefore it causes heavy flooding. This causes the need to monitor constantly the river level, so these measurements must be safe and to have reliable sensors are essential. According to location characteristics, different measuring principles can be used.

A water level measurement enables to know the amount of water that have a river, it also to know what level it can become dangerous because it may cause an overflow, therefore, cause floods. Saving level values can make predictions for future levels and behaviors in the water level of rivers, lakes, lagoons, ponds, and dams.

A. Water Level Meters

Different types of water level measurement systems are used in industry and research which is shown in Figures 1, 2, 3, and 4. These can find directly measuring the height of the liquid by drawing up to reference line, other measuring hydrostatic pressure, some more which are based on a float system whose displacement caused by the same liquid is quantified or also those that exploit the electrical properties of a liquid.

Traditional systems for measuring water level have existed for decades. Next, we present the most typical ones.

1) Limnimeter Rule Meter: Rule for graduating that is set in a river and used to read the fluctuations of the water levels. (See Fig 1).

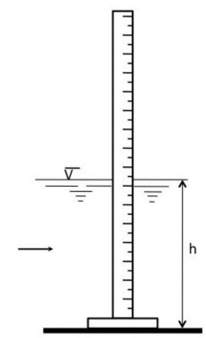

Fig. 1. Limnimeter rule

2) Liquid Level Meter: This device measures directly the height of liquid taking into account a reference of level measurement of a container. (See Fig. 2).

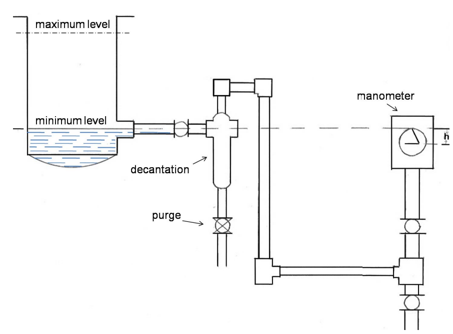

Fig. 2. Liquit meter (Manometer)

3) Sounding Line Meter: It is a rod or ruler which is inserted into a reservoir, the water level is determined directly by measuring the length that is wetted by the liquid. (See Fig 3).

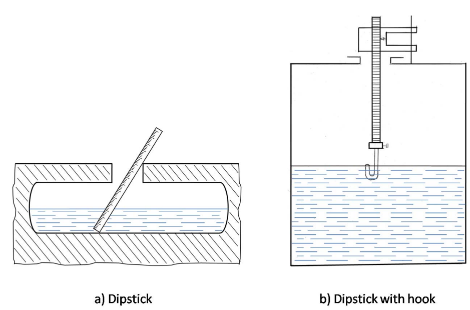

Fig. 3. Sounding line meter

4) Mechanical Float Meter: It consists of a float located in the tank connected to the outside showing the liquid

level with graduated scale. The connection can be direct, magnetic or hydraulic. (See Fig. 4).

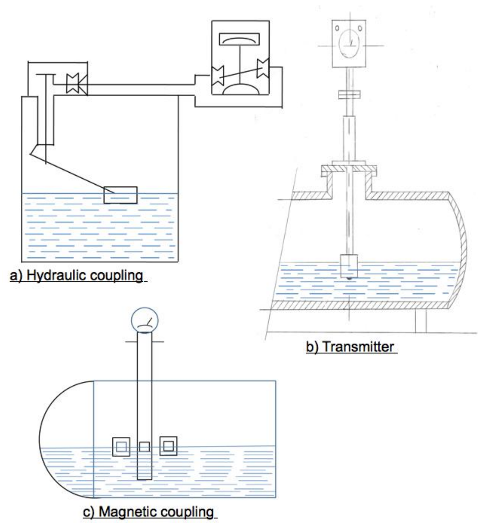

Fig. 4. Float meter

B. Water Level Measurement Sensors

Right now exists sophisticated early warning systems capable of providing some protection from floods. These systems can be from heavy rain event detection via satellite sensors, rainfall gauge networks, radar networks, or some combination of the three, until atmospheric fine-scale models, to forecast the risk of flooding in rivers or water bodies a short time in the future.

Currently, there are many modern level sensors to measure levels of water such as stated in the previous paragraph. Some kinds of sensors are shown In Table I.

TABLE I
LEVEL SENSORS DETECT THE LEVEL OF LIQUIDS

Point level detection of liquids	**Point level detection or continuous monitoring**	**Continuous level measurement of liquids**
Magnetic and mechanical float	Ultrasonic	Magnetostrictive
Pneumatic	Optical interface	Resistive chain
	Microwave	Magnetoresistive
	Capacitance	Hydrostatic pressure
		Air bubbler
		Gamma ray

III. Structure and Description

To test the performance of our water level measurement system, we have created a micro-model based on a prototype. In this way, we avoid waiting for torrential rains to watch how the water rises in a river. It seems an absurd idea to test our prototype directly on a river.

Basically, the prototype has as function to be a flood alarm system, that consists in a water level meter connected to an audible alarm device in 24-hour operation. When the water level reaches the level marked a speaker alert (Siren) is triggered. The prototype also sends information about water level from the container to a web server and smartphones as well.

As mentioned, there are different models and types of water level meters, including sensors based on different technologies. At this time, we design a solution based on a simple open circuit that closes when in contact with water that takes advantages of existing sensors, so we think that an implementation of water level system can send alert signals toward a web server or a software application installed on smartphones.

When carrying out this water level system, we took into account the physical properties of water, hence, take to determine the levels of liquids. Water has the ability to conduct or transmit heat, electricity or sound. We believe that the conductivity feature of the water could be a simple and economical solution for measuring water level, based on this idea, our work focused on studying changes in impedance or resistance of some devices when they are covered by water. Although there are other alternatives for measuring water levels, such as acoustic sensors, it was quite difficult to acquire for use with the Netduino technology, leading to deciding to monitor the levels with water resistivity.

A. Water Level Design

To validate the idea and realize a Proof of Concept (POC), as noted earlier, we have designed a micro-model that emulates how the river stage rises. This micro-model consists of a water container, an electronic circuit, a Netduino board, an Access Point, a laptop, and a smartphone.

We must take into account the water level system protection, it must have a waterproof coating to avoid get damaged when water exceeds the maximum level and sensors get dirty due to high solids in the water, hence, a measurement is recommended in a controlled environment.

It is convenient to use an automatic level measurement and wireless data transmission, connect the device to a server.

B. Equipment and Materials

In order to design the prototype the following materials and equipment were used. All parts and elements are shown in Figure 7.

1) Access Point D- LINK Dir-600.- To wireless communication.
2) LED colors - three colors (color code) (See Fig. 5):
   - Green: Moderate Alert
   - Yellow: Caution Alert
   - Red: Maximum Alert
3) Water Container.- It enables to emulate a controlled environment.
4) Netduino Plus 2 board (See Fig. 6).- Netduino Plus 2 is an electronic platform to create our prototype since it calculates measurement and stores readings of levels. This board has the following features:
   - STMicro 32-bit microcontroller

- Speed: 168 MHz, Cortex-M4
- Code Storage: 384 KB
- RAM: 100 + KB

5) 9 resistors (10 ohms).- To cable data input to Netduino plus 2.
6) Micro USB cable (1 m).- To connect the data transmisin from the Netduino Plus 2 board to the Web.
7) Copper wires .- For cabling all circuit and connecting to the Netduino Plus 2 board.
8) Water (5 liters).- To fill the container.
9) Speaker Alert (Siren).- To emit a loud sound when water is rising the red level.
10) 1 Laptop .- A computer to execute Microsoft Visual C# and interact with Netduino Plus 2.
11) Microsoft Visual C# 2010 Express:.- Programming Language for running the water level system.
12) Smartphone .- To receive advices when the water level is changing.

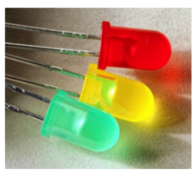

Fig. 5. LEDs in three different colors to indicate the water level.

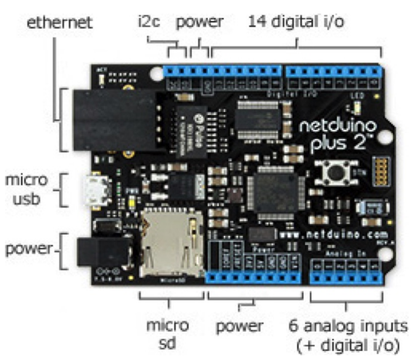

Fig. 6. Netduino Plus 2 board

C. Architectural Design

Our water level measurement architecture is shown in Fig. 7, all parts are integrated and put it all together, in this Figure is shown the architectural design, it has three open electric circuits, the terminals or ends (green, yellow and red wires) of these circuits are placed inside the water container (3 and 8), these terminals are connected into three pins of the Netduino board (7 and 4), these circuits go through a breadboard where connections are organized. Terminals are located in different heights allowing water to determine three levels (8), it is assigned a color to each level to identify more clearly, where the LED in green color is the lowest level, yellow LED is intermediate and red LED is the highest one.

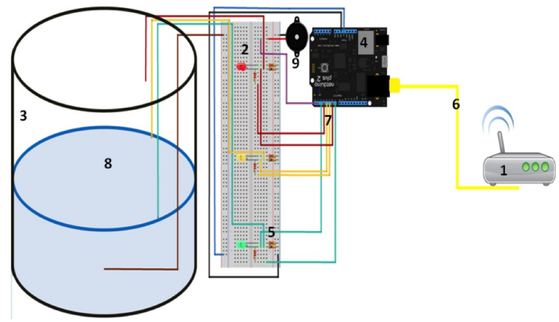

Fig. 7. Water Level Architecture

The brown wire is the neutral pole of the circuit and this pole is permanently in the bottom of the container when the electrical energy flows through the circuit, then it remains open until the water level reaches the first terminal indicated by the green color. The liquid serves as a conductor of electricity but with a resistance value so that a short circuit is not present. If there is a change in circuit current, the breadboard has a LED color connected to this circuit, then it has reached the first level (green), and so on (See Figure 7). At the same time, the circuit also triggers the speaker alert.

D. Measurement and interpretation of obtained values during sensing

The water level is measured by means three phases or layers, That is, green alert, yellow alert, and red alert.

1) A device emits a signal to the respective sensor to measure the water level.
2) The value obtained from the sensor becomes in alert levels.
3) In case of failure to comply with the higher criterion than one (> 1), return to step 1.
4) Using a dynamic IP address AP with mobile devices where readings transmitted data is connected.
5) A measurement in degrees is added, together the date and time when transmitting a signal to the sensor.
6) It is stored into the memory card.

IV. Testiing and Implementation

Netduino apps are written using C# language and many of us are already familiar with the Visual studio IDE for development from Microsoft. The same Visual studio IDE can be used to create, run and debug the Netduino apps.

Assuming we also already have an installed visual studio lets look at other components that need to be installed in order to start programming Netduino apps. Below in Figure 8 is shown the three parts involved in the prototype, after compiling the Netduino programming code, put water in the container, the prototype is ready to be tested.

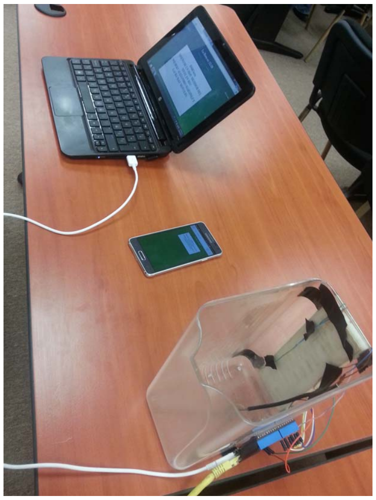

Fig. 8. Sensor working and sending alert mensaje to a smartphone

Testing prototype

As mentioned, a water container with three wires inside and a neutral pole were placed within a container, that was filled with water in three stages and while the container was filling, the prototype was sending warning messages to smartphones.

How we tested the prototype proposed in this paper is described in detail as follows:

1) The container (empty and dry) was filled with water up to the level of the first wire (green terminal). (See Fig. 9a.).
2) Immediately the computer program installed on the laptop triggered an audible signal and a message of green alert was displayed, at the same time in the Smartphone is shown the same alert message. (See Fig. 10).
3) We continued pouring water into the container up to the level of the second wire (yellow terminal). (See Fig. 9b.).
4) Similar to the previous case, the application on the Laptop triggered an audible signal and a yellow message was displayed, same happens in the Smartphone, a yellow message was displayed on a screen. (See Fig. 11).
5) Finally, we continued filling the container with water that was in the yellow state level, the water reaches the third and final level (red wire). (See Fig. 9c.).
6) PC application immediately sounded the siren and green warning message was displayed on the monitor, while in the smartphone was displayed the same red alert message, indicating that the population should evacuate. (See Fig. 12).
7) The prototype worked in reverse order when the water was removed from the top level, the application changed automatically to yellow alert and green alert respectively.

In this way we tested our prototype once slowly being filled with water the container; if the water level rises, warning messages are sent to both the laptop and the smartphone.

As a result, if the amount of water poured into the container is constantly maintained, then it is possible to calculate the time remaining until the water reaches the next level mark and so on until the threshold.

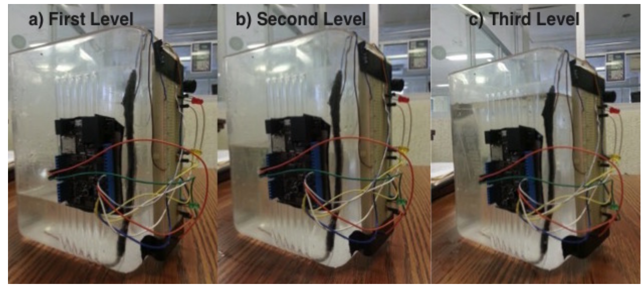

Fig. 9. a) Water level up to the first level (green LED), b) Water level up to the intermediate level (yellow LED), c) Water level up to the last level or threshold (red LED)

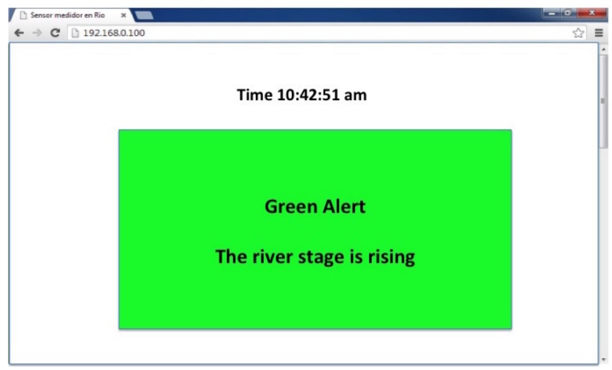

Fig. 10. Green Alert Message

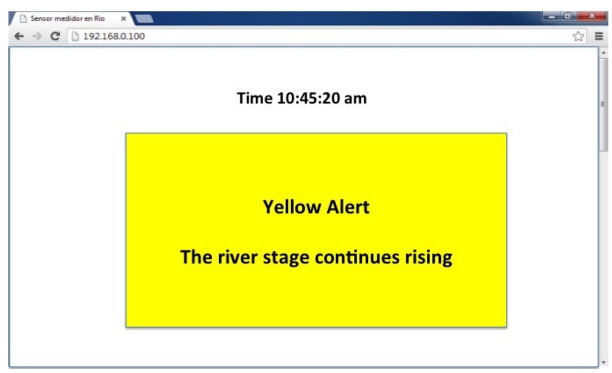

Fig. 11. Yellow Alert Message

V. Conclusion

According to definitions of IoT, if we consider a sensor as an element of IoT which enables to communicate its current status and be published on Internet, then our proposal is very

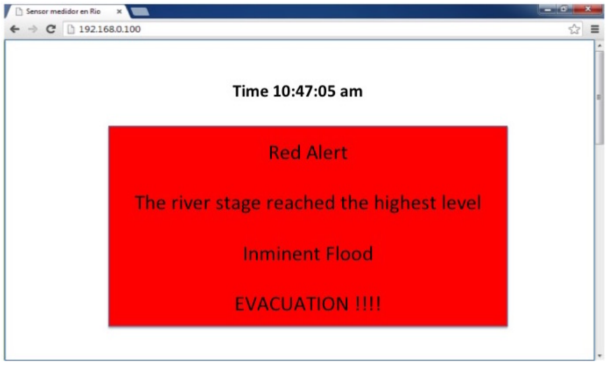

Fig. 12. Red Alert Message

close to what we are intending to achieve within the concept of Internet of things.

Nevertheless, the real intent of the proposal is to achieve a flood early warning system. So far, we have only built a micro-model through a prototype, that sends an audible signal and graphical messages towards smartphones about the water level into a container.

This micro-model was developed based on a programmable electronic board (Netduino Plus 2), where some electrical resistors were connected to three heights into a water container, the rising water levels covering the resistance so that cause variation in the impedance, this fact indicates what is the water level, and so on for the three different heights. This information was transmitted to a web server via WiFi. After, this information can be accessed by mobile devices, users can graphically see the data, these data show the values of water levels.

Subsequently, the prototype tests were conducted into a controlled environment, these tests consisted in measuring the water level in a container with water, different filling levels were tested, such testing showed the expected results.

Given these facts, if it is known the time when rising the water level up to the threshold while the water level passes each level mark, it is possible to know exactly these calculations in a real scenario like a river.

Hence, people can be opportunely informed when rising river levels, so inhabitants can make a decision and start preparing to evacuate their homes if necessary. So now we can consider a really warning system to alert residents of low-lying areas about changes in rivers.

Acknowledgment

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