Development of a low-cost automatic water level monitoring system

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Abstract: Water is a very important factor in agricultural production and is a key of our quality of life as well. Monitoring water level of a water source, such as dams, water tank or bore-well etc., plays a key role in agricultural management and development. If a water level drops below the threshold level for pumping in a water body, the pump motor may get damaged due to dry running. In such case monitoring water level becomes necessary task. Water engineers and other disciplines that study water, rainfall and so many other things related to water resources especially rivers, seas, lakes are faced with the challenge of acquiring quality and accurate data which is one of the motivations of this research. This work aimed at development of a low-cost automatic water level monitoring system (WLMS). The major components used for the development of the WLMS were Arduino board, ultrasonic sensor, Xbee transceiver and personal computer. The automatic water level monitoring system was realized using an ultrasonic sensor attached to an Arduino Uno to process the analog signal coming from the sensor into a useable digital value of distance. The level of the water was determined by the sensor's height with respect to the river bed minus the sensed distance between the sensor and the surface of the river. Changes in the water level was displayed on a personal computer. The developed system was effective. With the Arduino River level recorder developed, water level data can be easily accessed from rivers, lakes and oceans.

Keywords: automation, development, monitoring-system, water-level

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1 Introduction

Fluctuations in the level of some water resources like lakes, rivers and oceans are very important to document whether they result from floods, droughts, or normal water year. The properties of lake and river shores are often seriously affected by fluctuations in the level of the lakes or rivers such as flooding damage, drought-related access problems, and aesthetics. Having in mind the history of lake or river levels can help people living around the shores and others who use the lake or river to accept and cope with the natural changes in the level of the river primarily because of changes in precipitation (rain and snow), or human activities such as construction, operation of a dam, or from beaver activities (Department of Natural Resources, 2011; Heidi, 2013). Historical data from lake level fluctuations are very important in the development of computer simulations of lake fluctuations; they are also used in estimating flood levels. The flood levels are very vital in the establishment of a low-floor elevation for construction. The historical river or lake level data can be used by watershed managers and planners to prepare local water management plans and to model water quality characteristics on lakes and rivers (Department of Natural Resources, 2011; Zhang and Hu, 2009). Different methods has been used to measure water level in lakes, rivers and reservoirs such as the use of calibrated vertical staff, inclined gauges, and wire-weight gauges.

This study is about the design and development of an Arduino-based automatic water level recorder and its monitoring system that can be used in hydrology to detect digitally the level of water in a streams, lakes, or rivers.

1.1 Measuring water level

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Different methods have been applied in the measurement of water levels in rivers, lakes and reservoirs. These different methods are being classified as contact/contactless methods or Recording/Non-recording methods. In this work, they will be classified into recording /non-recording methods.

1.1.1 Non-recording gauges

In this type of gauge, the level of water can only be sensed and read off with the human eyes. Some of the common types of non-recording gauges include

a) Calibrated vertical staff

b) Inclined gauges

c) Wire-weight gauge installed on a structure above the water body

1.1.2 Recording Gauge

Some gauges are been used to record the readings gotten from the fluctuating levels of water. They are mostly classified based on either their mode of actuation or mode of recording. They include

a) Bubble gauges

b) Hydrostatic gauges

c) Non-contact gauges

These are considered the modern ways of gauging the level of water in a lake, reservoir or river. Air is being pumped at a programmed interval at the surface of the water body through a hollow tube. During this period, the absolute air pressure sensor detects the pressure of air in the hydrometric tube, and the atmospheric pressure. The level of water using this method is calculated as the difference between the air pressure and the atmospheric pressure. Similar method is being used in the Hydrostatic method of water level measurement. The contactless method of water level recorder can be achieved using either the radar or the ultrasonic method (Valery et al., 2009). The sensor emissions are perpendicular to the surface of the water and the reflected signal will be used to detect the distance by interference effect (Terzic et al., 2010). The exact distance between the sensor and the water body is calculated by the processor. It can be mounted on a bridge or other hydraulic objects.

1.1.3 Calculating exact distance using contactless method

The distance is being calculated using the speed of sound in air

$$\text{Distance} = \frac{\text{Time (s)} \times \text{Speed of sound in air(340 m s}^{-1})}{2} \quad (1)$$

With this equation, the processor can be programmed to calculate the level of water. One of the advantages of this method is that it senses the slightest differences in water level, making the readings very accurate (Reza et al., 2010).

Advantages of the hydrostatic gauges and the bubble gauges are that they can be used for any range of measurement (from 1 to 100 m), they can be used even during winter freeze-ups, and compared to the no-recording gauges they are easier to maintain since it can been checked once in six months. The contactless methods on the other hand are more accurate when compared to the hydrostatic and the bubble gauges, they also can measure up to 300 meters. They (using ultrasonic sensors) are easier to maintain and relatively cheaper to install. Most works on water level monitoring systems have just a data logger that stores information on the different levels of water over a period of time, but in this work, the system doesn’t just store the data, it transmits and displays the information to the base station and displays it on their screen. Also, it has an LCD that easily display the water level should one decide to go to the site to collect data (Edwin et al., 2016). This will provide adequate water level information of any water body for people who rely on the water body as a means of livelihood, hydrological research, and then for water managers, engineering projects in the coastal regions, such as the construction of bridges, docks, etc., that requires the engineers to observe fluctuating levels of the water body around the site. It will also help in scheduling projects that has to do with the construction, demolition or movement of large structures in advance in areas that has a record of wide fluctuations in water levels (Loizou and Koutroulis, 2016). Habitat re-establishment projects also involve accurate knowledge of water level and current conditions. The study also compares the measurements obtained using this system with the conventional method of water level measurement. A block diagram of the proposed Arduino based water level monitoring system is as shown in Figure 1.

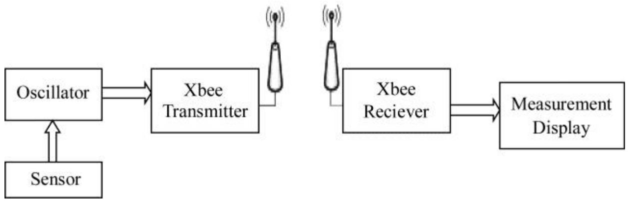

Figure 1 A block diagram of the proposed Arduino based contactless water level monitoring system

2 Materials and methods

The materials used for this work are an Arduino uno board, Ultrasonic sensor Module, a 16×2 LCD, a bread board, a 12 volt battery, Xbee transmitter and receiver, and connecting wires, a rod, and a wooden platform. The system block diagram is shown in Figure 1 above. The whole system is controlled from one power button which when switched on, supplies power to the Arduino board which starts carrying out its operations based on the interval codes. After the whole system is fully set up, the LCD display automatically starts showing the level of water at that time. The system detects the slightest fluctuation in the level of water. The device uses a 9V DC battery which should be replaced from time to time. Since the device is placed in a structure above the water, it doesn't have any contact with the water.

2.1 HC-SR04 Ultrasonic sensor

This sensor is used to measure a distance ranging from 2 cm to 400 cm, having an accuracy level of 3 mm. this sensor is made up of the receiver, the transmitter and the control unit. With this sensor, a very high level signal is sent using the trigger. The module automatically sends eight 40 kHz signals and then checks whether the pulse is received after being reflected by the obstacle it encounters. If the signal is received, the sensor will have the time it took for the pulse to be sent and reflected back to the receiver by the obstacle. The ultrasonic sensor module as shown in Figure 2, works on the natural principle of echo of sound.

Figure 2 Ultrasonic sensor

The idea behind using the ultrasonic contactless methods is to measure distance between transceiver and the sensor can be calibrated by measuring the distance from the sensor to the base of the water body. Some short ultrasonic pulses were transmitted through the sensor, and the travel time of that pulse from transceiver to liquid and back to transceiver was measured. Due to change of density of ultrasonic pulse travel medium, ultrasonic pulse will bounce back from liquid level (ultrasonic pulse first travelled through air and bounced off water with higher density than air). The program for the sensor was written with Arduino C-language. The system will become functional when the user activates it and then water level is detected by the distance over the ultrasonic sensor. The sensor sends a signal to the microprocessor circuit and the water level will be displayed, it will continue to update changes in the water level at an interval of say one second depending on what the program says. The process repeats as the level of water in the river continues to either rise or low.

2.2 Arduino-uno Board

This is a micro-controller board based on the ATmega328P datasheet. It has a 14 input/output pins as can be seen in Figure 3. Six of the fourteen pins can be used as outputs for PWM (pulse width Modulation), it has six analog pins and a 16 MHz quartz crystal, a USB port and a power jack, it also has a reset button and every other thing needed to support a microcontroller it can be powered using a battery or an AC to DC adapter. Other types of Arduino can also be used.

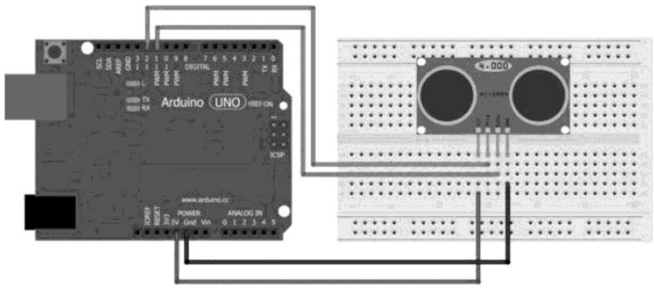

Figure 3 A schematic of the connection of the sensor to Arduino board

2.3 Xbee transmitter and receiver

This is a shield that allows Arduino to communicate wirelessly with the use of zigbee. It is based on Xbee module Maxstream with a communication distance of 100 feet indoors and 300 feet outdoors. There are other capacities of Xbee transmitters and receivers available depending on the distance you want to transmit from. The transmitter is connected to the device in the field, while the receiver is attached to either a system at the base station, or any other mode of display. The Xbee transmitter and receiver do not have a high power requirement.

2.4 A 16×2 LCD

This is an electronic display module that has a wide range of application. In this work, a 16×2 Liquid crystal display (LCD) as shown in Figure 4 was attached to the device in the field to enable someone in the field to also monitor the water level with his eyes if need be. A flow chart of the system is shown in Figure 5.

From the circuit diagram in Figure 6, the echo and the trigger pins were connected directly to pins A5 and A4 respectively (Pins A1 to A5 represents analog pins). The LCD was connected to the Arduino board in four bit mode, with control pin RS, RW and en are connected directly to pins 2, GND (ground) and pin three respectively, and the data pins D4 to D7 (Digital Pin series) were connected to pins four, five, six and seven in the Arduino Uno board. When the ultrasonic sensor is triggered to transmit a signal, the signal is being reflected when there is an obstacle. The Arduino processor reads off the time between the triggering and the time the echo was received. Knowing the speed of sound in air to be 340 m s^{-1}, system will then calculate the distance with the equation (1) above. It is right to note that the distance it measured is the distance between the sensor and the surface of the water. During the initial calibration of the system, the distance from the water bed to the sensor should be determined. So that the program will subtract the distance from the surface of the water to the sensor from the distance from the water bed to the sensor, so as to get the level of water at any point in time. These calculations are done and displayed in split seconds depending on the time of display set in the Arduino C-program. The accuracy level can be set also.

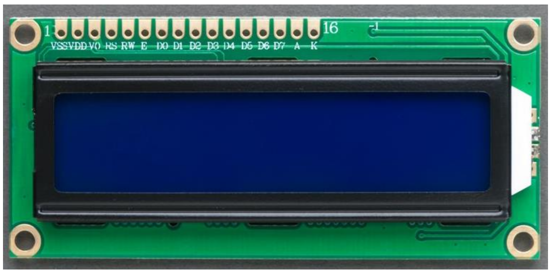

Figure 4 A 16×2 LCD

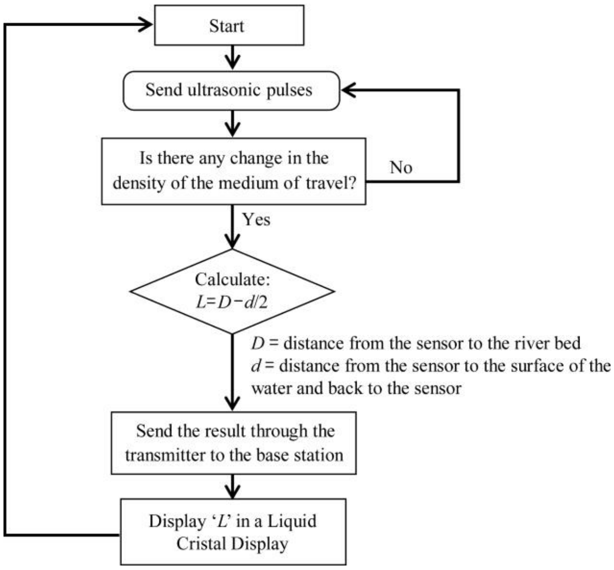

Figure 5 Flow chart of the system

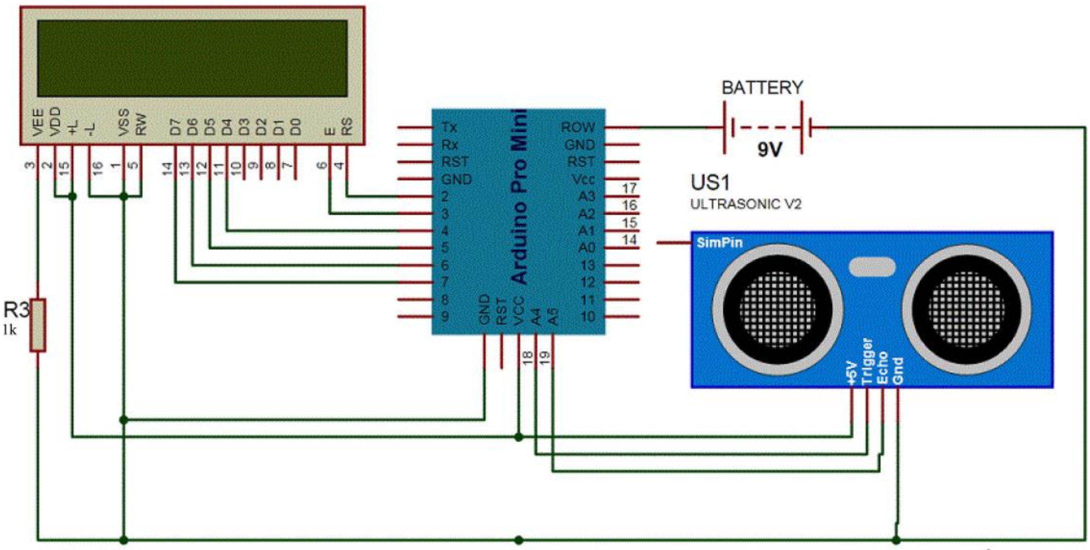

Figure 6 The circuit diagram of the connections

3 Experimental results

The technique of contactless method of water level sensing finds its application in nearly all fields dealing with fluids. This work stands as one of the techniques of contactless method of water level sensing. The experiment was conducted in a much related scenario, we tested the technique in an open pond where the level of water was varied using the outlet of the pond. The sensor was fixed at a known distance from the surface of the water and the calculations for the program were done bearing this in mind. The results were very fascinating as there was little or no error in what the sensor is sensing as the level, relative to the readings from a meter rule. This shows that in a river, lake, dam or any water body, this technique can be used to measure the level of water without the sensor or the expert coming in contact with the water. The technique gives real time readings of the changes in water level. The turbidity of the water was varied to check the effect of turbidity on the accuracy of the readings sent by the automatic level sensor. The system was programmed to send readings every two seconds and we tested for fourteen different levels with the sensor, we measure out the reading with the meter rule and check what the sensor sends too as the reading. Below is a plot of the readings for different levels with meter rule and the ultrasonic sensor. The turbidity of the water was recorded as 5.79 NTU. A graphical representation of the result gotten is shown in Figure 7.

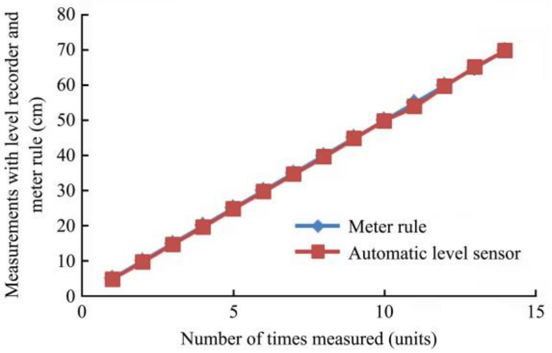

Figure 7 A plot of the readings from measurements with both the level sensor and the meter rule, turbidity of water = 5.79 NTU

The turbidity of the water was then changed with the addition of clay particles, making the turbidity of the water rise to 256 NTU after which the process was repeated and the plot of the results from the measurement is as shown in the Figure 8.

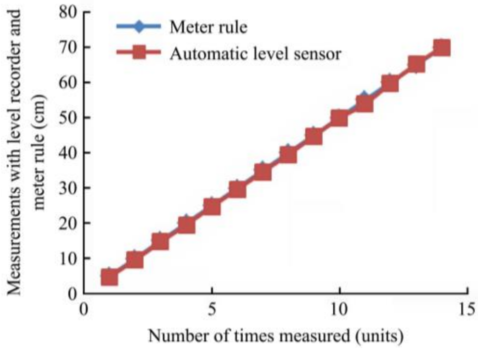

Figure 8 A plot of the readings from measurements with both the level sensor and the meter rule, turbidity of water = 256 NTU

Figure 9 shows the system set up for carrying out the test experiment using the Arduino based water level recorder and a screenshot of the result is shown in Figure 10.

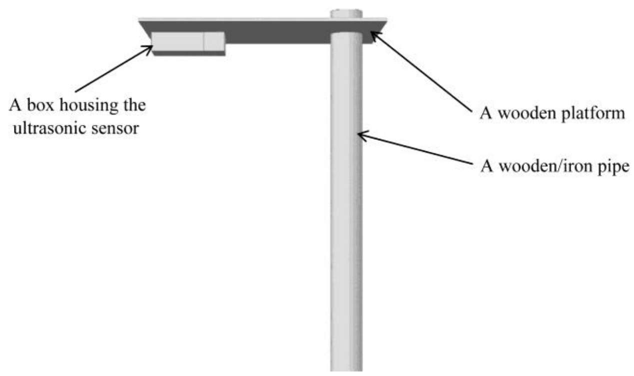

Figure 9 A sideview of the sensor platform that enables the sensor be placed 90º to the surface of the water

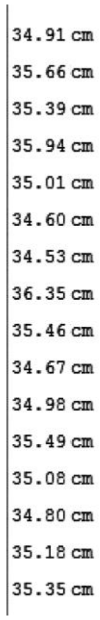
34.91 cm
35.66 cm
35.39 cm
35.94 cm
35.01 cm
34.60 cm
34.53 cm
36.35 cm
35.46 cm
34.67 cm
34.98 cm
35.49 cm
35.08 cm
34.80 cm
35.18 cm
35.35 cm

Figure 10 Some screenshots from the results sent to the computer from the sensor at level 35 cm

4 Conclusion

An automated water level monitoring system was brought to use, supplemented by the significance that it is not only automatic but also the values can be transmitted within a predefined distance. The model used for testing had some added features to fit for all the possible factors that can influence the readings. It can also be seen that one can well replace the meter-rule based method of monitoring with this device to sense the changes in the level of water in the river, lake, pond, or any other water body. From the results gathered, it can be seen that the differences in the values from the meter rule and the device is very negligible, showing that the device can comfortably replace the ancient method of river or lake level measurement. It can also be seen that the sensitivity of the device is not affected by the turbidity of the water, since we are getting almost the same values with changes in turbidity. Being that the device will be used in an outside environment, the sensor was shielded from rain by inserting it in a box made with fibre glass. This project has achieved the main objectives. This work involved designing and development of automatic water level monitoring system, it made use of a better software and hardware architecture that blends together for the interfacing purposes. The system used advance sensing technology to detect the water level.

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