Low-cost, Real-Time, Autonomous Water Quality Testing and Notification System

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Summary
Input Traditionally, water quality was tested by collecting the samples of water and experimentally analyzing it in the laboratories. However, in today's world, where time is the scarcest resource available and industrialization and economy is growing rapidly, the traditional method of water quality testing is not applicable anymore. To tackle the issue, several electronic (microcontroller and sensor based) water quality monitoring systems were developed in the past decade. However, as most of these systems were studied, besides their strengths, each of them have their own limitations to be taken into consideration. Therefore, an automatic, remote, portable, real time, and low cost water quality monitoring system has been developed. This system consists of a self-made Arduino microcontroller, multiple sensors, GSM module, LCD display screen, and alarm system. The water quality data is read from the physical world through the water quality testing sensors and sent to microcontroller. The data is then analyzed by the microcontroller and the result is displayed on the LCD screen on the device itself. Another copy of the sensor readings is sent remotely to the water quality monitoring user's mobile phone in the form of SMS. When an abnormal water quality parameter is detected by any sensor, the alarm system will turn on the respective red LED for that parameter and the buzzer will give warning sound. At the same time, the abnormality of the water parameter is reported to the user through SMS. The system has been designed so that it can be used for wide applications and by all kinds of users.

Key words:
Water quality monitoring, Microcontroller, Sensors, GSM module, Alarm system.

1. Introduction

Water is the primary need of all living beings and living without water is impossible. With the advancement of technology and industrialization, environmental pollutions have become a major concern. Water pollution is one of the most serious types of this environmental pollution. Our lives depend on the quality of water that we consume in different ways, from juices which are produced by the industries and we consume, to the water supply in our houses. Any imbalance in the quality of water would severely affect the humans' health and, at the same time, it would affect the ecological balance among all species. Water quality refers to the chemical, biological, radiological, and biological parameters of the water. The essential parameters of the water quality vary based on the application of water. For example, for aquariums, it is necessary to maintain the temperature, pH level, dissolved oxygen level, turbidity, and the level of the water in a certain normal range in order to ensure the safety of the fish inside the aquarium. For the industrial and household applications, however, some parameters of the water are more essential to be monitored frequently than the others, depending on the usage of the water [1], [2].

The traditional method for monitoring of the water quality is such that the water sample is taken and sent to the laboratory to be tested manually by analytical methods. Although by this method the chemical, physical, and biological agents of the water can be analyzed, it has several drawbacks. Firstly, it is time consuming and labor intensive. Secondly, the cost for this technique is very high due to the operation cost, labor cost and equipment cost, and it is difficult to make critical decisions in the real time [2].

To overcome the drawbacks of the conventional water quality monitoring methods, sensors can be used. Sensor is an ideal detecting device which can convert non-power information to electrical signals which can easily be processed, transformed, controlled, displayed, and transferred. Compared to the conventional water quality testing techniques, sensor based water quality testing has many advantages such as high sensitivity, good selectivity, speed, fast response etc [1].

In order to ensure the safety of the quality of water, it should be monitored in real time. To make the process of testing the real-time quality of water simple and easy for everyone, a remote, low cost, and portable water quality monitoring system is designed and developed. It is a user-friendly system which frequently tests the quality of water and sends notification and provides alarm to the user in case of any abnormality in any parameter of the water.

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2.Organization of The Paper

In this paper, firstly, a study of the existing water quality monitoring systems is done. Secondly, the proposed design is introduced and its features are elaborated. Thirdly, under the evaluation and discussion part, the characteristics of the main components of this proposed design is detailed and the results of the system are shown. Finally, the paper is ended by conclusion and a projection of the future expected work on this topic.

3. Related Work

To get a firm understanding of the current water quality monitoring solutions, some of the latest related researches

to this work were studied, as cited.

Khurana et al. proposed a water quality monitoring system which can analyse the quality of water and send an alarm signal to the authorized personnel through Wi-Fi on mobile if the water parameter is not a desired value [1]. This system provides an accurate measurement of the water parameters since in this system the pH sensor is double calibrated. However, this system is only able to monitor the pH level of the water and not any other water quality parameter.

M Deqing, Z. Ying and C. Shangsong, in [2], used GSM (Global System for Mobile Communications) with microcontroller and sensors to monitor the quality of water remotely. In their proposed system, the essential water quality parameters namely pH level, conductivity, dissolved oxygen, and turbidity are read from the water through the respective sensors and it is then analysed by the controller and if it is beyond the standard range, it is sent to the monitoring centre's and managements' mobile, in the form or SMS (Short Message Service), at the same time. The data is as well stored in a database for management to perform a backup, and it is plotted to a curve and displayed on a PC interface for further analysis. However, this system is only affordable for big water supplier companies or industries since it consists of expensive components. Therefore, common people cannot afford this product.

N. Vijayakumar and R. Ramya came up with an idea for the real-time water quality monitoring in the IoT (Internet of Things) environment. Their system consists of several sensors which is able to measure some essential parameters of the water such as temperature, pH level, conductivity, turbidity and dissolved oxygen level, and the data can be viewed on the internet using cloud computing. In this system, Raspberry PI is used as core controller; its disadvantage is that it is run on LINUX kernel using keyboard and monitor. It requires the users to input a command every time they want to know the sensors reading, or the sensors' value must be read at a set time interval only [3].

A.S. Rao, S. Marshall, J. Gubbi, M. Palaniswami, R. Sinnott, and V Pettigrove developed a water quality monitoring system using Arduino Mega 2560 microcontroller and respective sensors to monitor the temperature, conductivity, pH, dissolved oxygen, light and oxidation reduction potential of the water. Although this system is an accurate system and costs lower compared to some other proposed systems, it consists of complex wiring and requires a computer or an extra Beagle board-XM ARM processor for communication interface and operation [4].

Pradeepkumar M, Monisha J, Pravenisha R, Praiselin V, and Suganya Devi K proposed a water quality monitoring system for monitoring the essential parameters of water which are temperature, turbidity, and pH level, in IoT environment. They used Arduino Uno as core controller of the system with related sensors and Ethernet shield for the transmission of the data. The main drawback of this system is that it uses a separate receiver section with a PC server and UART in addition to the transmitter section which contains the microcontroller, sensors, and Ethernet shield [5].

L. Hongpin, L. Guanglin, P. Weifeng, S. Jie, and B. Qiuwei (2015) designed a real-time remote water quality monitoring system for aquaculture water quality. They developed a multi parameter water quality monitoring system to improve the aquaculture products in China. In this system, solar cells and lithium cells are used to supply the required power of the device. According to the needs of aquaculture industry, dissolved oxygen sensor, pH electrode, temperature sensor, and ammonia nitrogen sensor were used to test the respective parameters of the water. In this system, STM32F103 chip was used to process the data and GPRS (General Packet Radio Service) and ZigBee modules were used to transfer the data wirelessly to the monitoring centre where the data is displayed and stored. The system was also connected with aerator to detect the automatic control of the concentration of the dissolved oxygen. The system can shut down the aerator automatically if it detects that the dissolved oxygen's concentration is above the pre-set upper limit. In this system, the data is read out, collected, processed, analysed, saved, and displayed by Lab-view. The programming of the sensor nodes was performed by C language based on Kiel environment. This system is a good integration of ammonia, pH, dissolved oxygen, and temperature sensors with GPRS and ZigBee transmission

techniques for real-time remote monitoring of the quality of water for aquaculture industry. Since this system uses solar power for power supply, it is dependent of the environmental conditions. It will stop working if a cloudy weather lasts for a few days. Moreover, this system is unaffordable for average users in terms of cost [6].

4. Proposed Design

In our proposed method, an own assembled Arduino microcontroller is used as the core controller of the system. Once the code is uploaded to the microcontroller, no PC system, keyboard command, monitor is required to operate the system. The system functions automatically and independently according to the code uploaded to the microcontroller. The programming in used in this system is used C language. In this system, four sensors are used to measure the essential water parameters. As it was studied from the previous researches, the most essential water parameters needed to be monitored by the average users are water pH level, water turbidity (cloudiness), water temperature, and the water level which is a measurement of the amount of the water in a container. Therefore, four essential water parameters which are temperature, pH level, turbidity, and water level can be measured by this proposed system. Sensors' circuits are connected to the microcontroller and the probes of the turbidity, pH, and temperature sensors placed inside the water. A water proof temperature sensor is used to avoid any damage or electrical shock to the system and the user. An ultrasonic sensor is used to measure the level of the water in the container. The ultrasonic sensor is connected in the system such that it will be placed on the top of the water container. The ultrasonic sensor sends electromagnetic waves to the water surface and receives the wave back after touched the water surface. From the time taken to send and receive the wave by the ultrasonic sensor and the velocity of the electromagnetic waves, the distance which shows the water level in the container is calculated by the microcontroller. As the container dimensions are known, the amount of the consumed water can also be calculated for the applications where it is necessary. All sensors read the water quality parameters and send the data to the microcontroller in the form of electrical signals.

The microcontroller is programmed such that is will analyze the result and compare it with the standard ranges which are predetermined in the code. If any water parameter crossed the standard limit, the alarm system will turn on and the message will be shown on the device's screen and sent to the user's mobile as will. The alarm system is designed such that for every water parameter, there are one red LED (Light Emitting Diode). In case of any abnormality in a water parameter detected by the microcontroller, the respective red LED will turn on to indicate that the water is not proper for use. Besides the LED indicator, there is a buzzer which will create alarm sound and inform the user about the abnormalities in the water supply system.

To show the sensor readings (The water parameters) on the device itself, an LCD (Liquid Crystal Display) screen is used. The LCD screen is connected to the microcontroller, and through the wired connection, it receives the sensor readings from the microcontroller and displays them accordingly. If the water quality is not within the desired range, the LCD screen will display a message which indicates the quality of water being out of the desired range i.e. "Water temperature is high" and it displays the value of the readings as well.

In order to communicate with the users, who monitor the quality of water from a far distance, a GSM (Global System for Mobile Communications) shield is used. The GSM module is connected to the microcontroller and programmed so that it will receive a copy of the analyzed data from the microcontroller and sends it in the form of SMS (short message service) to the user's mobile. The message sent to the user's mobile include all the data readings of the sensors as well as the condition of the water quality compared to the standard ranges. Two mobile numbers can be registered in the system in order to avoid the problems caused by any interruption in the mobile service provider networks. The overall block diagram of the proposed system is shown in Figure 1.

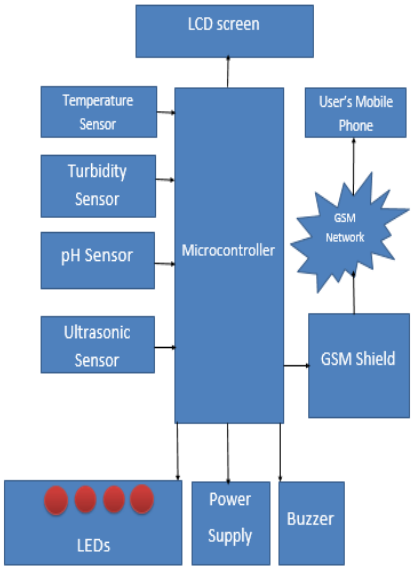

Fig.1 Overall block diagram of the proposed system.

5. Discussion and Analysis

To facilitate monitoring the quality of water, a portable, real time, low cost, and remote water quality monitoring system was proposed. As illustrated in the proposed design, the system consists of multiple sensors, microcontroller, GSM module, LCD screen, LEDs and a buzzer which work in synchronization to meet the objectives. Moreover, the LEDs are associated with each sensor. That is, each red LED turns on when the water does not support the required range for a particular parameter. The system can perform all-weather real-time monitor to temperature, turbidity, PH and the level of water. The design of the system is useful to manage water quality parameters and make a man-to-machine interaction via mobile phone.

5.1 Description of The Main Components

Water Quality Detection Sensors: The temperature sensor used in the system is DS18B20 from U.S. DALLAS semiconductor company. It can measure temperature from -55° C to +125° C. Its accuracy is ±0.5 °C from 10°C to 85° C and the power supply range is from 3.0V to 5.5V. it has the important properties which a sensor should hold. That is, it is fairly precise, nonreactive to salt water and it is a waterproof sensor. This digital temperature sensor uses one-wire interface and can work with any microcontroller [7].

Turbidity in water is the result of suspended solids which stop incident and scattered light. Therefore, turbidity is the measure of scattered light caused by suspended particles in water. Turbidity sensor used in our system is produced by DFROBOT operating at 5V DC voltage with less than 500ms response time. Moreover, less than 1NTU (Nephelometric Turbidity Unit) indicates a good water quality, 1-5 NTU indicates a fair water quality, and greater than 5 NTU indicates a poor quality of water [7].

The pH sensor used in our system is produced by DFROBOT company. It measures full range PH (1-14) with ±0.1Ph accuracy at 25°C. Its operating at 5V within temperature range of 0°-60°. To use the sensor, is first connected with BNC (A miniature quick connect/disconnect radio frequency) connector and PH2.0 interface is plugged into the input of the microcontroller [7].

Level of water is one of the four parameters that the proposed system is committed to evaluate. To reach the goal, we have chosen HC-SR04 sensor. It can measure from 2cm to 400cm with an accuracy of up to 3mm. There are 4 pins to be connected in various position. They are, VCC (power supply), trig (trigger), Echo (receive) and GND(ground) pins. Like other sensors in the system, it requires 5V power for operation [7]. The amount of water consumed and the water level in the container are measured from the time, taken to send an electromagnetic signal from the trigger and receiving it back by the receiver, and the velocity of electromagnetic waves (velocity of light). The distance calculated by the microcontroller from these velocity and time indicates the water level in the container.

GSM Module: GSM module is an information transmission module which is based on dual. The main components of GSM module are GSM baseband processor, Flash, GSM RF, power, antennas, and antenna jack. The module is produced by SIMCOM whose operating voltage ranges from 3.2V to 4.8V with low power consumption. Users control the module through standard AT commands. Moreover, it supports a frequency bandwidth of 900MHZ and 1800MHZ. Data and voice within the frequency bandwidth are transferred safely and fast. The GSM module carries two kind of SMS modes which are text mode and PDU mode. We chose to apply text mode, for the system sends digital messages. What is more, the dual band GSM/GPRS module has RS232 interface which permits one to connect PC as well as microcontroller with RS232 chip (MAX 232) [7].

The Microcontroller: Arduino belongs to a family of single board microcontrollers intended for easy build interactive objects and environments. It consists of 54 input/output pins, 16 analog inputs, 4 UARTs, a 16 MHZ oscillator, a USB connection, a power jack, an ICSP header and a reset button. The data collected by different sensor can be sensed by microcontroller in conjunction with programming code. Multiple languages can be selected to program Arduino mega board. As for our case, we have programmed it using Arduino commands which uses C language. In addition, AT mega 2560 board provides 256 KB of flash memory to store the code. The microcontroller can be powered either via USB connection or external power supply (battery). The recommended power supply range using an external power source is 7V to 12V. However, in the case of exceeding 12V, voltage regulator might overheat and damage the board. A safe power supply of 5V from a regulated source is ensured. Pins used for power supply are Vin, 5V, GND and IORF. The microcontroller provides communication with computer and other microcontrollers. Its software includes a serial monitor which allows textual data to be sent and received. The RX and TX LEDs will flash when the data is being transmitted or received respectively. To ensure the portability of the expected prototype, a self-made Arduino microcontroller with smaller size was assembled [8].

5.2 Results of The Proposed Design

The system was tested under different conditions and with different qualities of water. The output of the system was successful and in accordance with the research objectives. As mentioned, the sensor readings are shown on an LCD screen on the device prototype itself and it is also sent to the user's mobile through SMS. The results from both LCD screen and from the user's mobile are shown in Figures 2 and 3.

Fig. 2 Sensor readings from the LCD screen on the device prototype.

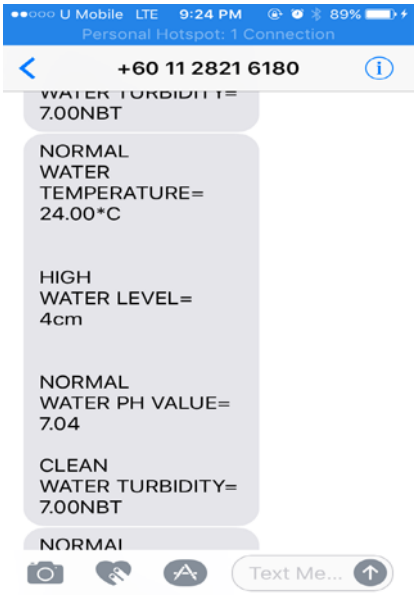

Fig. 3 The results in the form of SMS

6. Comparisons and Analysis

In the previous work done on the water quality monitoring methods, it was found that there are some issues with the applied approaches which have to be taken into consideration. Some of the previous publications proposed comprehensive but costly approaches whereas the others proposed low cost method but limited in terms of applications. For instance, the method proposed by Khurana et al. in [1], is a low-cost approach, however, the designed system can only measure the pH level of water. In the same way, Pradeepkumar et al. [5] and Hongpin et al. [6] developed water quality monitoring systems which are limited for a specific application such as aquaculture. In contrast, the systems proposed by Deqing et al. [2] and Rao et al. [4] can be used for a wide range of applications, but their disadvantage is high cost. On the other hand, some approaches to design and development of water quality testing are not user friendly. As an example, the design proposed by N. Vijayakumar and R. Ramya in [3] requires keyboard commands for reading the sensors' outputs. In today's world, with the great advancements in science and technology, the users look for the autonomous and user friendly devices which would be able to operate without interruption and human operators.

In our proposed method, most of the above issues have been taken into consideration. From the previous related work, it was estimated that there are four water parameters which are mostly needed to be monitored in almost all applications. Hence, the proposed design was developed to measure those water parameters which are temperature, pH level, turbidity (cloudiness), and the level (amount) of water, as shown in the results above. The beauty of our proposed system is that it is a compact autonomous device which can display the water parameters on a small screen in the device prototype, while at the same time, it can send the data remotely to the user as well. Moreover, low cost developed it, and it can provide the water quality measurements with acceptable accuracy. It can be further improved by adding more sensors and using water proof components in the future.

7. Conclusion and Future Work

In this work, the design and demonstration of a prototype remote, automatic, portable, real time, and low cost water quality monitoring system is described. In this system, low cost components i.e. microcontroller, GSM, LCD screen and other nonmain components are used to achieve the objectives of the proposed design with acceptable accuracy. Compared to the previous related works, the cost of the system prototype is considerably low. To

ensure the portability of the device, a self-made, small size Arduino microcontroller is used. The developed system was tested under different conditions, with solution of water with different impurities, and in different periods of time. The results of the test for all times have been successful. We conclude that all the objectives of the proposed system have been achieved. To test more parameters of the water quality for some applications, other sensors can be included in the system. The system has wide application and it is usable and affordable by all categories of users.

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