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Optimized parameters of wastewater treatment system using fuzzy control

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ABSTRACT

This paper aim is to design an education kit for wastewater system that can maintain the standard parameters of neutralized wastewater by maintaining the suitable pH (Potential Hydronium) level and temperature of the wastewater from industry by using fuzzy controller. This study is capable to control the unwanted bacteria by automatic regulatory and monitoring the temperature, pH and water level. Fuzzy logic method is use to control and monitor pH level as well as the temperature during clarifying process because pH control process is a complex physical-chemistry process of strong individuality of time-varying and non-linearity properties. Pumps used in the prototype need to be controlled precisely to enable either acid or base to be pumped into mix tank of the wastewater treatment. The control and monitoring system, which has been designed through LabVIEW front panel will ease end user in inspection of the parameters involve in wastewater treatment. The entire system output could be observed remotely in Data Dashboard application in smartphone or tablet. The GUI was designed and interfaced with the prototype constructed to carry out the process of controlling and monitoring the required parameters. Few tests were conducted repetitively to analyse the performance of the system parameters. It was found that the controlled set point fixed within the range of pH 7.6-8.4, temperature 25-29.44 Celsius and water level of 20cm in this research that was effectively achieved in the entire test conducted. In addition, the wastewater system accuracy and performance is 96.72% and 90.22% respectively.

Keywords:
Fuzzy logic control, Neutralization, pH, Wastewater system

1. Introduction

Waste water is an enormous concern in industrial safety. pH is one of the waste water parameters that needs to be controlled. Acidic or alkali waste water is tremendously dangerous. It could be the root to mutation in human cells, which commonly called cancer. Long-term exposure to acidic or basic environment can cause illness and unhealthy life to living beings in the world. Control difficulties

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in the process industry are subject to non-linear and time-varying behaviour, many inner loops, and much communication between the control loops. A water quality model is essential for water quality simulations and planning, and identifying its parameters is important to applications. By determining the appropriate parameter values, we can improve the accuracy of water quality modelling and forecasting. Natural ecosystems and human society essentially depend on water resources, so it is essential to the sustainable development of society that they are supported.

Many methods were presented to control wastewater treatment process in past, and have been used in some countries. Many processes in chemical and biotechnological industries are described by multiple sets of differential and algebraic equations. As such they are difficult to control and optimize during transition between different set-points.

The most challenging part of this project would be the control of temperature and pH level computations due to the nonlinearity characteristics as they are done by logarithmic calculations and requires continuous monitoring. Some of the earlier approaches were simulation based that provided good results. Moreover, graphical user interface (GUI) designation is very important which gives an ability to the user to check present parameters with the past parameters. Some of the offered systems may include autonomous control but their structures are nonflexible and cannot be modified or adapted simply by operator. The other fully autonomous systems prices are not reasonable because of it uses expensive components. In addition, the system would be delayed due to using many components. These research systems have been implemented by using Wireless Sensor Network (WSN), which is energy intensive because networking protocol (ZigBee) cannot support traffic types wider range for applications wherever upper data rates are significant. The ZigBee disadvantage is related to the maximum possible operational area of the network. Therefore, the research is done by remotely control and monitoring of water parameters, which is connected wirelessly via LabVIEW.

2. Literature review

Simulation of Fuzzy and PID Controller to water level system using LabVIEW is proposed to solve the problem of water level controlling system [1]. The fuzzy controller is further enhanced compared to PID as it has no overshoot (OV), respectable strength and lower settling time (Ts=105s) and rise time (Tr= 29). Furthermore, an absolute and squared error of fuzzy controller is 45.6% and 53.9% less than PID controller respectively. Conversely, without practical implementation in real time, system efficiency cannot be concluded based on simulation but this present research will include implementation and testing. In contrast, the WSN structure proposed by [2] that monitoring of a fish farm requires a specialized staff by using temperature and pH sensors. This system is to detect immediate changes with enough periodicity though measurements will not be feasible to perform manually. If the threshold value of any of the parameter changes, the indicator indicates it and ZigBee module programmed like a coordinator will receive the sensor data wirelessly. Data received from the sensor node are sent to the computer protocol and data received is displayed in GUI. Due to the difficulty of acquiring environmental factors data of water quality, water quality environment monitoring system via WSN has been suggested by [3]. The system has received excellent result practically but the users cannot get the previous water quality environmental data to compare with present data. In the present research, user can check present parameters with the past parameters at the same time. Besides that, fuzzy based control is a beneficial option for difficult control applications since it offers a suitable way to construct non-linear controllers by experimental information usage. Researcher [4] proposed that water parameters are transferred electronically to internet server who analyses, responds and stores the information using ZigBee and A51 computer program. The online water observation and interactive devices permits the water parameter to be sent to the user on an everyday basis without the necessity to travel. The result has shown that monitoring the water quality by needed parameters has controlled perfectly. However, the system lacks the user to check present parameters with the past parameters while present research can check both at the same time. Moreover, there are set of rules that include the fuzzy logic quantifications of the specialist's skill on explanations of how to realize superior control of water parameters and provide correct value.

3. Methodology

For the proposed research, several objectives have to be met and the objectives will include design and develop an automatic Fuzzy Logic based system to control pH level to prevent unwanted bacteria with a low cost prototype in Fig. 1. Secondly, the wastewater parameters need to be monitored and controlled by GUI. Thirdly, evaluate and simulate remotely controlling and monitoring of water parameters such as temperature and pH level controlled wirelessly via LabVIEW. The proposed system is microcontroller based which is programmed to execute the system operation with the interference on LabVIEW to display the control and monitoring parameters for GUI purpose.

The microcontroller of choice for the prototype is the Arduino ATmega328p microcontroller. This is an open source programmable controller meaning there is sufficient and active resourceful information available on its usage. It is also a low cost controller and consumes low power. This controller allows for easy interface between the input sensors are and the host PC.

Besides, pH sensor is a device that is used to measures the acidity or alkalinity levels of a solution [6]. pH can be measured using indicators, digital and analogue pH electrodes. In this project, the BNC probe analogue type sensor is being used which provides continues analogue read value upon 5V logic. It is compatible to the controller in terms of interfacing and power consumption. It can read from pH 0 - 14 having an accuracy of ±0.1pH and has a response time of less than 2 minutes.

In this project the DSB18B20 temperature sensor is used as it lets designer precisely measure temperature in the wet environment with a simple 1-Wire interface. It can be easily install in small scale prototypes compare to thermocouple and it is ultra-low-cost digital sensor as well. Thermocouple is good for high temperatures such as exceeding more than 200ºC and it cannot provide connection to many devices but DSB18B20 can accompany as many as 127 devices on only 1-Wire line. Additionally, a digital level sensor is utilized for determining the water level in this aquarium as its output will take one of the two states which will be translated to high/low water level. Also ultrasonic sensor could be used to meet the same objectives, but such a device will require more extensive signal processing capabilities. Furthermore, the pedestal pump is to be used to circulate the water across the system. The submersible pumps are quieter and the seal prevents dust and moisture from interfering with the operation. However, they require higher investments and have lower life spans compared to pedestal pumps which are more economical and easy to maintain.

Also to calibrate the pH sensor, calibration solutions with pH 4, 7, 10 will be used. At initial phases domestic liquids will be used as reagents such as colorex and chlorine. Since chemicals are involved the tank's material must be not reacted with the chemicals. Hence glass and HDPE rated materials are suitable for tank design, either one of these will be chosen to design based on availability and ease.

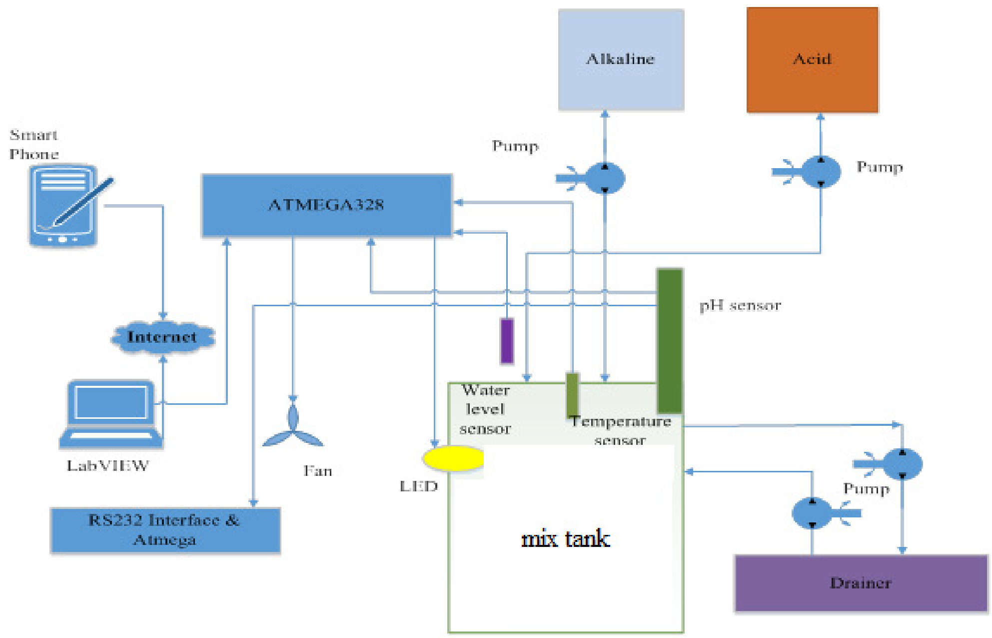

Fig. 1. Hardware components interfaced with LabVIEW

In order to send the data to the database, a wireless connectivity need to carry out such a chore. The controlling, monitoring and communication remote can be done by the microcontrollers. The microcontroller will use the serial communication via USB cable to the laptop. LabVIEW [6] will provide the serial communication via VISA driver. The Arduino will read the data from the sensor and provide the data to the LabVIEW via serial communication. For remote controlling and displaying the GUI over the phone, the internet web browser will use the router access to able to show the data remotely. Essentially, the design principals involve the calculation which could be used in the material and component selection.

3.1. pH

In the pH measurement, some factors have to be considered such as the reagents mixing in the tank should have uniform ions distribution and the temperature must be maintained at 25^{0}C to obtain an accurate pH reading. Voltage output from pH electrode linearly changes in proportional to changes in pH and temperature.

$$NaOH + HCL \rightarrow H_2O + NaCL \quad (1)$$

The aquarium chemical reaction in (1) has shown that NaOH and HCL are reacted which results in forming saltwater. From (1), based on stoi-chiometry relationship, the substance has a mole ratio of 1:1 and therefore the (2) can be deduced.

$$V_A C_A \propto V_B C_B \quad (2)$$

where, Acid: V_A = Volume, C_A = Concentration, and Base: V_B = Volume, C_B = Concentration

Essentially, pH is described as a negative decimal logarithm (log) of hydrogen ion (H+) action [5]. It is significant that aH^+ signifies the activity in adulterate solutions (< 0.1mol.dm^{-3}) as shown in (3).

$$pH = -\log 10[aH+] = -\log 10[H+] \quad (3)$$

This value is closer to the concentration.

3.2. Temperature

All the commands and data are transformed least significant bit first by 1-Wire bus. When the sensor obtains a reading, converting the data starts for creating 2-bytes with the capacity. The process is taking up to 750ms. The temperature reading in its useful form is derived using (4).

$$T = ((HighByte << 8) + LowByte) \times (0.0625) \quad (4)$$

A "0.0625" multiplier is the coefficient among sensor's internal value with actual temperature based on 12-bits resolution where every layer on the sensor's range translates to 0.0625°C.

3.3. Pump

In order to controlling the specific amount of the liquid injecting in the container, the specific measurement will be carried out by turning ON the pump for 1ms and measure how much liquid amount is being pumped within that specific time period of time. By measuring this volume, the operation time can be determined which will allow the motor to pump in the correct volume of water where the pump is controlled using pulse width modulation (PWM).

PWM is a generated digital signal by the microcontroller to make an analogue output. Wherever the R-C low pass filter is intended to ensure the load resistance and capacitance does not adjust any F_c through the input signal. Based on data sheet, the Arduino's PWM frequency supposed to be occurring at 49Hz, F_c can be represented in (5).

$$F_c = 1 \div 2\pi RC \quad (5)$$
$$R = 1 \div 2\pi F_c C = 1 \div (2\pi\,(50)(1\mu F)) = 3.183k\Omega$$

Thus F_c can be reduced with the resistance value of 3.183k Ω. Also the PWM concept is based upon the totally time period for turn ON and OFF which shown in Fig. 2.

3.4. Water level

Basically, the water is touching the two electrode of the sensor, they let the current pass through the electrode indicating the water level has been detected. With the sensor fixed at the top of the aquarium, the level can be determined as (7):

$$DutyCycle = PulseWidth \times (100 \div Period) \quad (6)$$
$$DutyCycle = 50\%(20ms) = 0.5s$$

$$L = Tank's\ Height - Distance \quad (7)$$
L = 450-150 = 300 mm

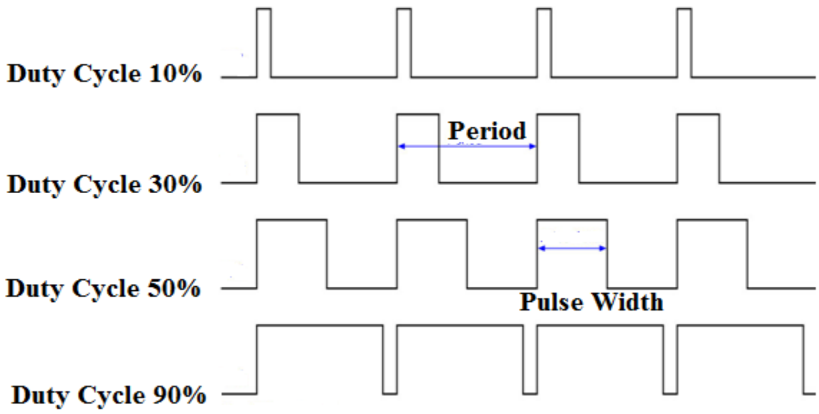

Fig. 2. PWM concept based on time period

3.5. Volume Measurement

The volume (V) measurement is done based upon the container shape where height in cylinder case will be obtained from the level sensor. If the tank is a cylinder, the volume can be calculated using the equation (8). Table 1 shows the summary of calculation.

$$\text{Cylinder}: V = \pi r^2 h \tag{8}$$

$$V = \pi (50\text{mm})^2\ (450\text{mm}) = 1125000\pi\ \text{mm}^3$$

Table 1
Calculations summary for the system

No	Design considerations	Estimated calculation
1	Volume measurement of Cylinder	$1125000\pi mm^3$
2	Volume measurement of Cuboid	$91125mm^3$
3	Water level	30cm
4	Duty Cycle	0.5
5	Resistor	3.183 kΩ

4. Results and discussion

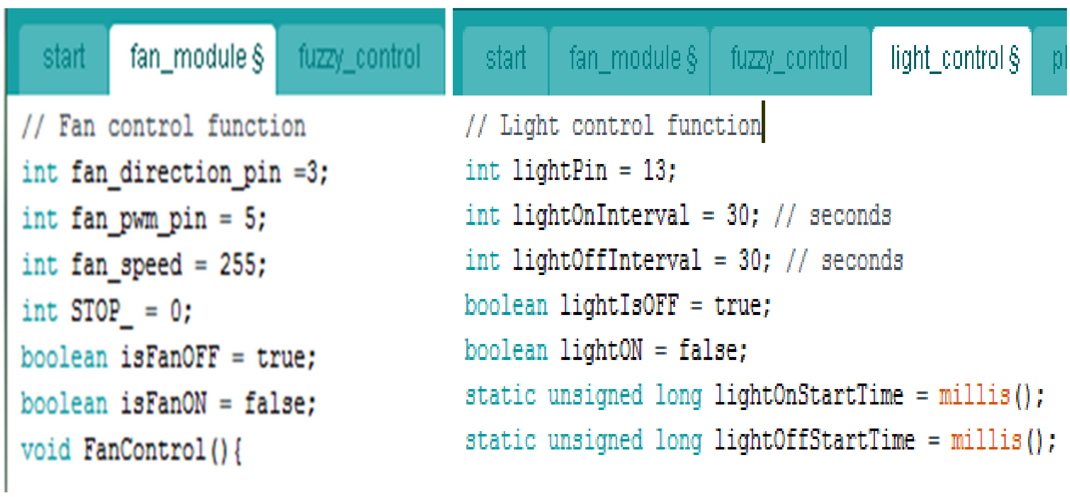

Fig. 4. Mixer code initialization

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The initialization codes had been programmed to initialize the libraries for the Arduino using coding language. The stated libraries such as the serial marginal interface are used for the connection port. It requires the serial monitoring, controlling and interface mechanism using data line for the data transmission during the sensor readings. Also it has been declared as the system ultimately should be interfaced to the LabVIEW. In order the Arduino can send and read the information from the PC based software, the library should be declared as shown in Fig. 4 and 5.

Moreover, by sorting out the three sensors commands, the microcontroller can sort out the evaluation otherwise it only shows one of the sensor reading as the input has been shared. Additionally, the output pins should be defined with respect to the assigned port. Also, the initializing code need to be designed in LabVIEW to enable the PC to receive and transmit by interfacing to the Arduino. Fig. 6 shows the block diagram.

start | fan_module § | fuzzy_control | light_control § | ph_monitor | pump_control | send_d

```
#define SensorPin A0            //pH meter Analog output to Arduino Analog Input 2
#define Offset 0.00            //deviation compensate
#define LED 13
#define samplingInterval 20
#define printInterval 800
#define injectionInterval 5000
#define ArrayLenth  40    //times of collection
int pHArray[ArrayLenth];   //Store the average value of the sensor feedback
int pHArrayIndex=0;
int phThreshold = 8;
static float pHValue,voltage;
static unsigned long startAlkalineInjectionTime = millis();
static unsigned long startAcidicInjectionTime = millis();
float currentPh;
```

Fig. 5. pH initialization

The PC based software initialization to be interfaced with the controller has been defined by the initializing function where the block diagram has to set the PC-COM port that the Arduino to be connected. Also the board use type to interface with the software, baud rate between the serial connection and communication type should be initialized. The Virtual Instrument Software Architecture (VISA) is required by LabVIEW to communicate with the controller over the serial port (RS-232). VISA presents the programming interface between the software and hardware. In order to obtain the raw data from the microcontroller, the analogue read functionality has been set upon the analogue broadcast data from the microcontroller. The raw data only could be received from the analogue pin that has been set. Furthermore, a close function has been set to end the connection data upon the connection closure between the software.

4.1. pH sensor reading verification

In the Arduino programming language, the sensor has been programmed to read analogue input and store into the pH array. Analogue reading need to be converted to voltage and then this voltage will be converted to pH value [7]. Continuously, this value will be set to the variable pH and then the sampling time will be obtained [8]. The learning of the pH neutralization process system model helps to predict the control technique [9]. The simulation results are evaluated for step and random acid instabilities, which shows that the controller controls the pH within the required limits with less mean square inaccuracy.

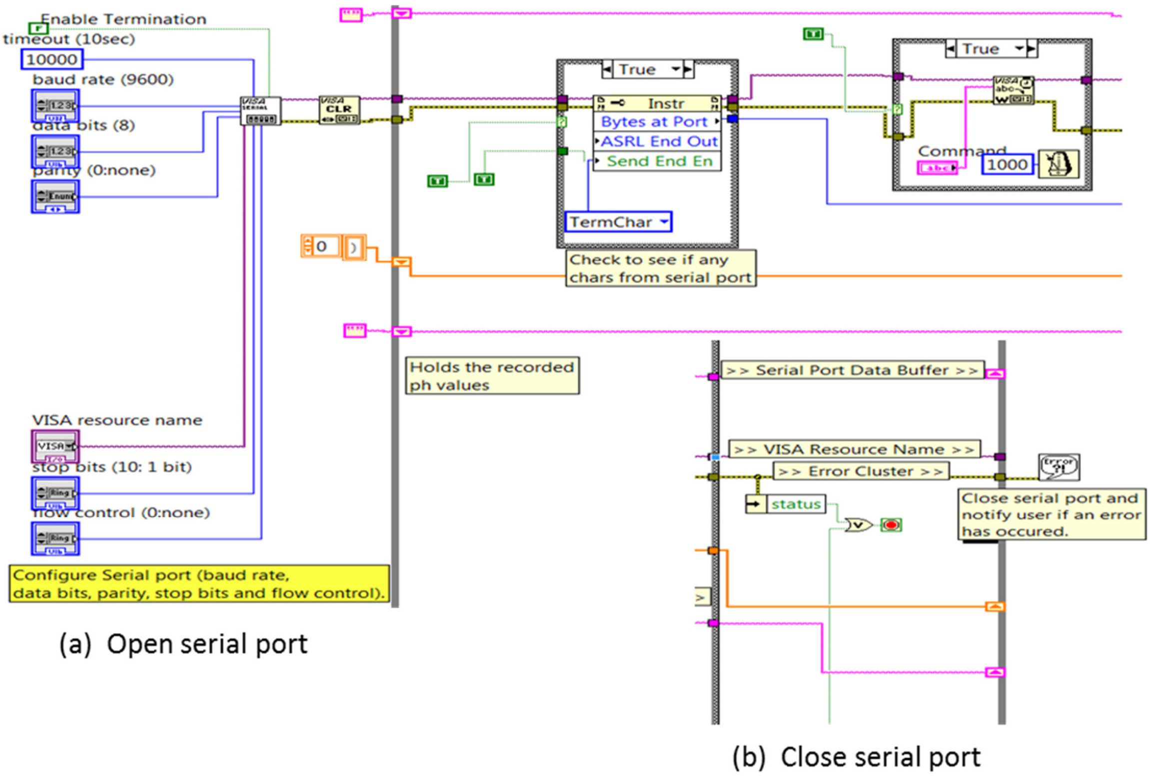

Fig. 6. Block diagram of Arduino interfacing

5. Conclusion

The parameters can be monitored throughout the monitoring system, which had been designed with the system implementation using the PC and Smartphone based software LabVIEW with the interfacing Arduino. The system can be monitored in both the ways either to be offline/online. The data transfer required 5 seconds delay time as the ration of 9/10 for the connection successful rate. It was found that to control pH of 15Litrs saltwater, it takes minimum 90 seconds and to control temperature, it takes less than a minute. In short, the mechanism has a connectivity accuracy at the rate of 96.72% to the data line connections.

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