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Development of Water Quality Monitoring for Smart Aquaculture System

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Abstract: Water quality monitoring for smart aquaculture system is a device that helps to describe the water quality parameter such as pH, turbidity and temperature of the water. It will monitor the process of sampling and analysing the water condition. This project is focused on local aquaculture species. Water quality monitoring for smart aquaculture system is designed to allow fish farmers to monitor and control their fish in the pond much more easily than before. It will help fish farmers to understand more about the water quality parameter that needed for their fish. It is equipped with an early warning detection that can help fish farmers monitoring their pond. The data collected will be transmitted to the cloud server and user will get notifications regarding the condition of their pond by using push notification services to their smartphone. This can enhance the productivity of the fish pond because user can always monitor the level of water quality that suitable with the fish. This study proposed a monitoring system with the ability to measure temperature, pH, turbidity and water level. The ability of the system to provide information and notification proven when the system sent a notification from Raspberry Pi board to smartphone where the pH level of the water beyond the allowable range. User also, able to control water pump to control the water over wireless connection using Blynk platform. Finally, the system successfully embedded new technology to help to revolutionize the aquaculture industry with the help of internet of things technology.

Key words: Monitoring system, water quality, sensor, aquaculture, temperature, pH, Raspberry Pi

INTRODUCTION

Water covers two-third of the Earth's surface with over 97% presents in the oceans and <1% in freshwater streams and lake. Water is an essential habitation for fish and other marine lives. The source and quantity of water available are the most important factors to consider when choosing a site for an aquaculture facility. Many undesirable chemicals and environmental factors associated with certain fish farms can be traced to lack of background information on the source of water used before the final site for a new farm is selected a thorough investigation of the quality and quantity of water must be considered by the producer (Zakaria, 2006).

Wolpe (1980) defined aquaculture in many ways. It has been called as the rearing of aquatic under controlled or semi controlled condition underwater agriculture. The other definition of aquaculture is the art of cultivating the natural produce of water, the raising or fattening of fish in enclosed ponds. Aquaculture can be potential means of reducing organism for commercial products it can mean an increased number of jobs, enhanced sport and commercial fishing and a reliable of protein for the future.

As described by Bartram and Ballance (1996) water quality depends on the various chemical where it dissolved in the water. Good water quality level is determined by all attributes present in the water at an appropriate level and not outside tolerable range. Often aquaculture water quality does not equal to environmental water quality. Therefore, different parameters are used in monitoring aquaculture farm as compared to environmental water quality. Good water quality condition differs from species to species.

Bhatnagar and Devi (2013) mentioned that the physical, chemical and biological properties are interrelated and it affects survival, growth and reproduction of aquaculture. Aquaculture can also have reverse effect to the environment as aquatic organisms

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Table 1: Tolerable range of parameter

Parameters	Catfish	Tilapia	Carp
Temperature	18-27°C	23-34°C	18-27°C
Dissolve oxygen	>1.5 mg/L	>5.0 (Peferred) 3.0-4.0 (Tolerable)	>1.5mg/L
pH level	6-8	6-8	6-8

consume oxygen and produce by products, carbon dioxide and ammonia. Important water quality parameters to be considered are temperature, salinity, pH, DO, ammonia, nitrite/nitrate, hardness, alkalinity and turbidity.

In most of the aquaculture industries, manual water quality monitoring has been employed in order to assess the water quality of the pond. Due to the importance of maintaining the water quality for better production, the aquaculture farms normally perform daily physical monitoring on the ponds. The workers need to manually observed the water condition at the pond. This activity is very time consuming and it lacks of automated alert system for the owners. As mentioned by Kayalvizhi *et al.* (2015) the problem also related to the requirement of manpower to perform manual activities and need to be minimized the researchers also proposed a monitoring system in their research.

Thus, this study aims to present the details of the design and implementation of a remote water quality monitoring for smart aquaculture system. This system has been designed to allow fish farmers to monitor and control their fish in the pond much more easily than before. The system is also equipped with an alert feature to inform the farmers on the degradation of water quality via. smartphone notifications. This include the introduction of cloud monitoring and the internet of things element in the system. The four criteria that has been identified to monitor and to detect water quality changes are water temperature, pH level, water level and turbidity. Table 1 shows summarizes tolerable range of chosen water quality parameter for several species of fish.

Litreature review: As part of the literature review process, several works by other researchers on water quality by Simbeye and Yang (2014), Haron *et al.* (2009), Kayalvizhi *et al.* (2015) and Rao *et al.* (2013) have been analysed and compared to identify the suitable component and methodology to be used in the project. Simbeye and Yang (2014) in their study described the communication method used was through wireless sensor networks through Zigbee from ATmega16L microcontroller to the base station host and use Global System for Mobile (GSM) module for user notification. The parameter transmitted were temperature, dissolved oxygen, pH and water level.

Haron *et al.* (2009) mentioned in their method focused on leveraging on wireless sensors in detecting the water quality. Short Message Service (SMS) has been employed as a method to deliver alert to the farmers upon detection of degradation of the water quality. The parameter measured same as Simbeye and Yang (2014) but without the water level information. The research by Haron *et al.* (2009) only focused on water quality for single species, prawn.

Another related work by Kayalvizhi *et al.* (2015) measured dissolved oxygen, pH and temperature parameter. Kayalvizhi *et al.* (2015) used ATmega8 processor to sense the parameter value and sent the data to Raspberry Pi. Raspberry Pi connected to the router using LAN cable. The ATmega processor has been used to perform Analog to Digital Conversion (ADC) before transmit to Raspberry Pi.

Rao *et al.* (2013) described in their research that Arduino Mega 2560 has been used to perform the ADC conversion on temperature, pH and light parameter. The parameter data sent to a base station (computer) using Universal Serial Bus (USB) port. The data then saved on MySQL database server for further data analysis.

Based on the works done by researcher by Simbeye and Yang (2014), Haron *et al.* (2009), Kayalvizhi *et al.* (2015) and Rao *et al.* (2013) the literature review from data sheet of the related electronic components and other sources there were many methods available to transmit the water quality parameter. The research also, discussed on ADC process. Different methods on providing user notification can be used such as SMS. The parameter data also can be stored as online or offline source for further water quality analysis. Thus, gives the motivation and the direction towards the proposed system as described in the next section.

MATERIALS AND METHODS

Figure 1 illustrate the basic design of the system. The hardware module received the input from the sensors and analysed the data and exchange it with the cloud server. The basic hardware controller platform for this project based on Raspberry Pi 3 board. This board powered by Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit System on Chip (SoC). It is also equipped with 1GB RAM. This board also, WiFi and Bluetooth enabled board. That will provide flexibility on data transmission. This hardware also, provides several feature such as I2C controller to communicate with I2C based sensors and displays.

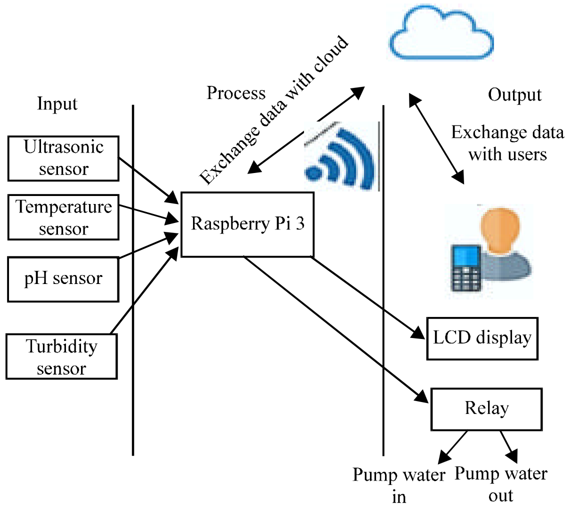

Fig. 1: Block diagram for the whole system

After the data of the water quality had been collected and analysed it sent the data to the Blynk server. From there, the Blynk cloud messaging has been used to send the data of the water quality by notification to the fish farmers. Upon receiving the data user able to control the water valve system from their smartphone. Communication of the board and the cloud server is through WiFi controller available on the Raspberry Pi 3. The cloud server will store the data and relay the notification from the board to the user using WiFi and existing telecommunication network.

Raspberry Pi 3 board act as a controller that controls the whole system, Fig. 2 shows the flow for overall system in the board. There is a setup configuration for all the sensors then it will check the parameters and make a comparison for the water quality parameters. After that, a notification will be sent to fish farmers and the mobile apps based on Blynk continuously updated. The tools used to develop this system comprise both software and hardware.

Hardware parts: The following devices has been used in the proposed system.

Temperature sensor: For temperature sensor, DS18B20 has been used to measure the level of the temperature of water quality. DS18B20 is a waterproof sensor that can be submerged into the water. It is a digital one-wire based input.

Turbidity sensor: Based on theory, turbidity is the level of cloudiness or haziness of the water. Turbidity sensor

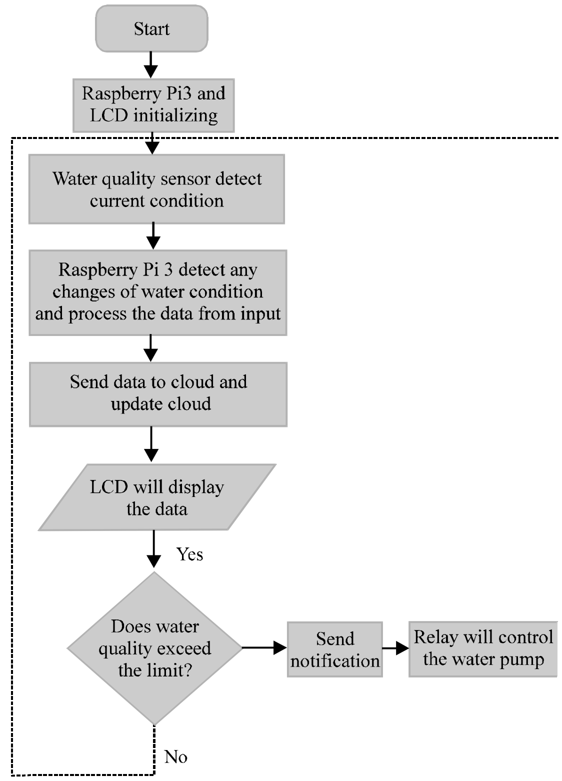

Fig. 2: Process flow of the overall project

was used to measure the amount of light receive in the water to make sure the level of cloudiness of the water is always in a good condition.

pH sensor: pH is negative log of the activity of the hydrogen ion in an aqueous solution. It ranges from value of 0 until 14. Solution that <7 are acidic, >7 are basic or alkaline and 7 is neutral. Basically voltages that produce by pH sensor was very small, 59 mV for each pH value. The value will be amplified to fit the range for Analog to Digital Conversion (ADC). The analog voltage reading has been collected and converted into digital value.

Ultrasonic sensor: An ultrasonic sensor is a device that can measure the distance to an object by using sound waves. It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back it is possible to calculate the distance between the sonar sensor and the object. This sensor was used to detect the water level of the pond.

Raspberry Pi 3: Raspberry Pi 3 will function as a controller that controls the whole system. All the system required for warning, request or for setting up the sensor will be upload to the board and the system script based on Python language.

Relay: Relay was used to control the water flow into the pond. It has been used together with electric pump to control water flow. When the quality of the water outside the tolerable limit the water in the pond will be replace with the water in the reservoir.

Inch TFT touch screen LCD: The 3.5 inch TFT touch screen LCD has been used in the system provide direct view of the water quality parameter value. It provides the realtime offline data viewing on the water quality parameter data at the pond.

Software design

Blynk platform: Blynk platform has been used as part of the system. Blynk is a mobile application platform where the users can manipulate and control the hardware remotely via. internet of things. It enable users to control their Arduino, Raspberrry Pi, ESP 8266 and other WiFi enabled boards through internet. This platform has its own server where the smartphone and the hardware are all connected. From here, a lots of features can be implement on the hardware and also on the smartphone in order to perform specific task. The application provides widgets where the interface of the hardware occurs. These widgets can be connected via. virtual pins and also the hardware built in ports and I/O. Communication between smartphone and hardware created via. Blynk cloud server where all the data from the hardware such as digital value and analog value can be send and receive. From here, the data can be manipulated, so that, the Blynk can perform other new task to the hardware.

Flask web server with SQLite database: Flask is a micro web framework. Flask has been used in order to displaying real time value during the running process of sensor and also plotting a graph based on the data that have been save in the SQLite database that had been setup before. All of the web development are using python language and HTML for the web page layout. All the information hosted within the Raspberry Pi using Flask.

RESULTS AND DISCUSSION

Figure 3 shows the overall prototype for this project while Fig. 4 shows the overall circuit connection in development for the project. The hardware and software analysis phase in this project involved the result obtained through overall system test. It helps to study the pattern of data with regard the system inputs. Based on the information gained it will help to model the data for specific condition of the water in the pond for future prediction. In this phase the data obtained was compared with the actual device such as thermometer, digital multimeter and pH meter. This to ensure the accuracy of the input supplied to the system. Table 2 and Fig. 5 shows the comparison value for pH while Table 3 and 4 Fig. 6 shows the comparison value for turbidity reading.

Fig. 3 : Overall prototype for overall project

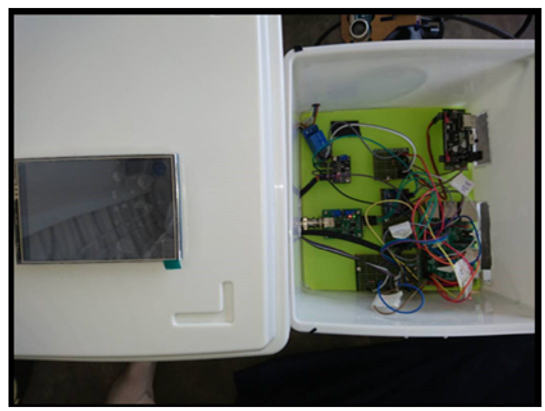

Fig. 4 : Overall circuit for hardware connection

Table 2: pH meter reading value

pH water condition	pH sensor value (x)	pH meter values
pH 2.5 (Vingar)	27331	2.5
PH 4.0	24505	4
pH 6.9	22476	6.9
PH 7 (Plain water)	20300	7
pH 8 (pH sensor liquid)	19204	8
pH 9 (Baking soda)	19000	9
pH (Bleach)	13500	12

Table 4: Temperature reading value

Water condition	Thermometer temperature	Sensor values
Hot water	56.6	108
Room water	26.0	90
Cold water	14.7	46

Table 3: Turbidity reading value

Water condition	Turbidity sensor value	Turbidity level	Turbidity multimeter (mV/V)
Clear water	30917	5	4.00
Water+Soil (1 spoon)	17100	4	2.12
Water+Soil (2 spoon)	9300	3	1.12
Water+Soil (3 spoon)	5200	2	0.60
Water+Soil (4 spoon)	2900	1	0.38

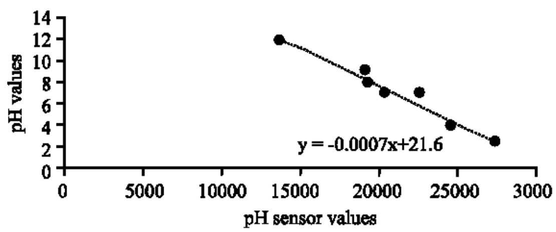

Fig. 5: Plotting graph for pH reading value

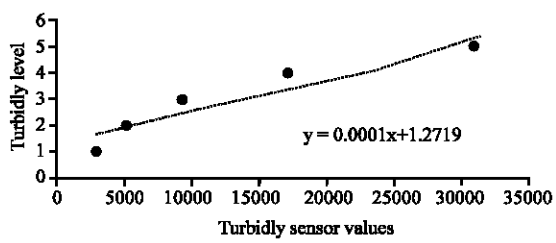

Fig. 6: Plotting graph for turbidity reading

Blynk apps notification: Figure 7 illustrates the notification output sent to user's smartphone when the abnormal water quality occurred. Figure 8 displayed the value of sensors reading on the Blynk Apps in users smartphone while Fig. 9 shows the button on or off for pump for user control the water pump from smartphone. User will be able to control the pump over the internet to perform the necessary action based on water condition displayed on the mobile apps.

Onsite data visualization: Figure 10 illustrate the water quality parameter displayed on the 3.5-inch LCD. It displayed realtime data. The webpage on Fig. 11 shows the water quality parameter data displayed on a web browser accessed locally in the local WiFi network. The webpage displayed the value obtained from the sensor and analysed by the Raspberry Pi. When the sensor measured the values, the data sent to the web server and display in a HTML file that is created with the Flask. The web page reloaded every 10 sec to display the current sensor automatically.

The Flask web server got the data from the SQLite database using SELECT statement and display all the data selected in the HTML file created. The sensors data stored to the database every 1 min with using Crontab

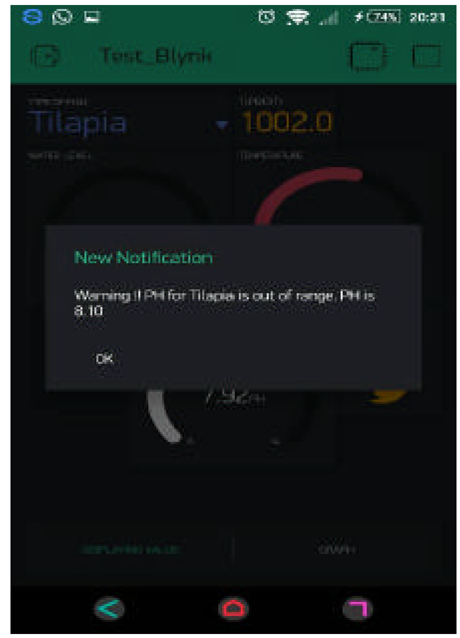

Fig. 7: Notification out of range of pH value at Blynk Apps

Fig. 8: Detected value sensors displayed on Blynk Apps

in Raspberry Pi. Crontab is the job scheduler used in the Raspbian and other Linux based system. It has been set to run the Python code file to save data into database and execute the code every 1 min.

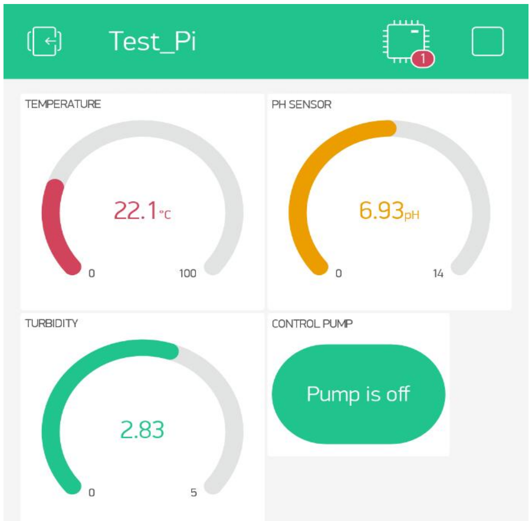

Fig. 9: Click button pump on or off to control water pump

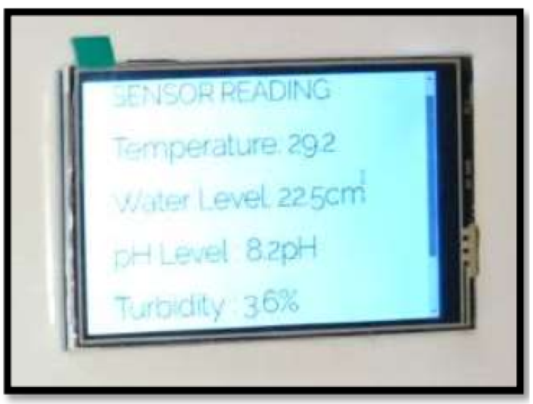

Fig. 10 : Water parameter on the LCD

Hardware: The proposed system is a system capable to monitor the current condition of the water quality for a fish pond. This prototype proven to be able detect the current conditions of the parameters for the local aquaculture species. There are 4 types of sensors that suitable with the water quality parameter. The level of range for every parameter was set for the aquaculture species. The system powered using Raspberry Pi 3 which act as the microcontroller to process the detected data from the sensors and control the data acquisition process for all the sensors. Each of the sensors coding were uploaded into the Raspberry Pi 3 board. Initial setup for Raspberry Pi 3 has been completed by using laptop via. Virtual Network Computing (VNC) by using VNC viewer. All the process to upload the Python scripts and board configuration processes done through the remote connection, VNC. The operating system, Raspbian has

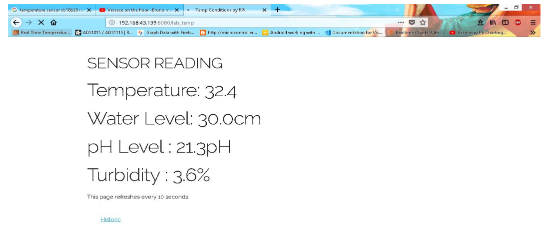

Fig. 11: Web interface for displaying all sensors values hosted by flask

been used and installed on the micro SD card and plugged to Raspberry Pi board. Raspberry Pi 3 board powered by a supply from the laptop and USB power adaptor where the board only requires 5 V to operate.

There were 4 main sensors used in the prototype. The first sensor is DS18B20 this sensor is one wired temperature sensor that have the waterproof sensor features. Then, the ultrasonic sensor that used to measure a water level also a digital sensor. There were two analog sensor used in this project which is pH sensor and turbidity sensor. Analog to digital converter ADS11115 was used in the system to extend the capabilities of the Rapsberry Pi to read the analog sensor value through inter-integrated Circuit (I2C) interface. It is because Raspberry Pi 3 does not have built-in ADC interface. Thus, the board needs external analog to digital converter such as ADS11115 to make it work with analog sensors. ADS11115 provide 4 channels to read from 4 different analog sensors (Fig. 11).

Software: Blynk is the platform we use for the internet of things in this project. This platform is suitable since it matches the description for the cloud and notification system. The Blynk platform was applied for displaying the sensor value from the application itself and sends notification via. wireless for the condition of the water whether it is in good or bad condition. By using the push notification, the user can receive the water condition based on the set time interval. The Blynk application also functions as a display for all sensors including graphical data of the current time as illustrated in Fig. 8 and 9. Using widgets that are connected to virtual pins all the data from the Raspberry Pi can be displayed on the interface provided. For the push notification, the menu widget has been used in order for the user to set the optimum sensor value for the specific fish and it will compare to check if the sensor detect the condition of the water is out of range of the optimum value. The push notification has been used to notify user when the sensor detect beyond the suitable range as illustrated in Fig. 7 based on configuration in Table 1. After the mobile application

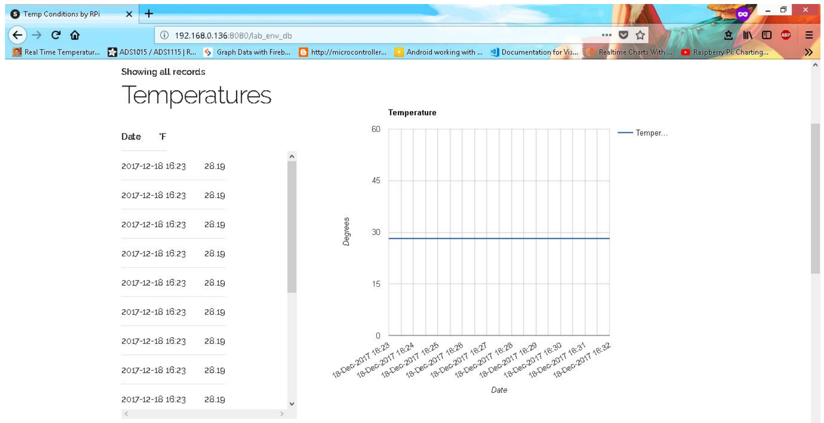

Fig. 12: Displaying graph for temperature sensor from the SQLite database

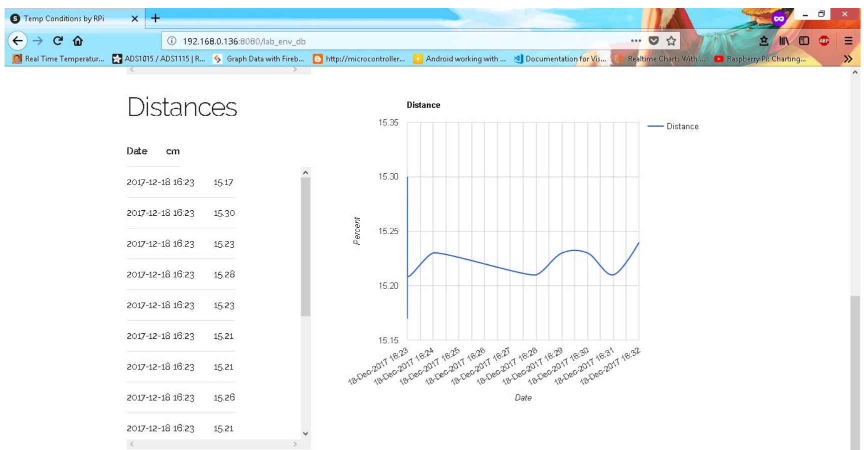

Fig. 13: Displaying graph for ultrasonic sensor from the SQLite database

is installed on the user's smartphone, the Raspberry Pi 3 also need to be connected to the internet via. Wi-Fi. Uploading the code to the Raspberry Pi 3 completes the vital steps in applying the Blynk application which is connecting hardware with the Blynk cloud server. The interface created using Blynk also provide the ability to control pump at the site manually as illustrated in Fig. 9. Current reading of the water quality parameter can be observed through physical view on 3.5-inch LCD as illustrated in Fig. 10. Figure 11-13 illustrate the another capability of the system where the user able to view the water quality parameter through web browser in where the user in the same wireless network.

CONCLUSION

At the end of this project after all the things considered the objectives mentioned earlier in a previous chapter has been achieved successfully where this project was able to help entrepreneurs of fish pond in urban areas and especially in rural areas to keep abreast of the latest technology in the hope that it can cause the labour cost to be minimized. Moreover, this system also may enhance the water quality monitoring process which can reduce the use of time and energy. Besides that, this project will give the big contribution to the fishing industry in order to improvise the rearing and breeding process for the aquaculture species. This project also was equipped with the notification warning systems from the smartphone applications via. the cloud, so that, if anything occur or any changes of the condition of water quality that will harm the fish detected, fish farmer will be informed as soon as possible and they are able to effectively control the problem. Specifically, this system also allows the user to control the water level and monitor the current condition of water quality in the pond even with they are far away from the pond. All relevant information in this project can be utilized in the process of project improvement in the future in the hope that the next generation will generate more useful projects for the community.

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