System Design of Controlling and Monitoring on Aquaponic Based on Internet of Things

Adrian K. Pasha
Department of Electrical Engineering
UIN Sunan Gunung Djati Bandung
Bandung, Indonesia
adriankemal.akp@gmail.com

Edi Mulyana
Department of Electrical Engineering
UIN Sunan Gunung Djati Bandung
Bandung, Indonesia
edim@uinsgd.ac.id

Cecep Hidayat
Department of Agrotechnology
UIN Sunan Gunung Djati Bandung
Bandung, Indonesia
cephidayat62@uinsgd.ac.id

Muhammad Ali Ramdhani
Department of Informatics
UIN Sunan Gunung Djati Bandung
Bandung, Indonesia
adriankemal.akp@gmail.com

Opik T. Kurahman
Department of Informatics
UIN Sunan Gunung Djati Bandung
Bandung, Indonesia
opik@uinsgd.ac.id

M. Adhipradana
Senior Engineer Sale Stock Indonesia
Indonesia
opik@uinsgd.ac.id

Abstract— **In the aquaponic's system, maintenance water temperature and water value of pH is very important to make sure fish and plant grow well. The purpose of this research is to make a monitoring system of water temperature and water value of pH in aquaponic's system. It also adds controlling system to keep aquaponic's environment stable and to feed fish automatically through Internet of things. This research is prototype of monitoring and controlling system that applicated in aquaponic and can be access from web interface.The result of this research are water value of pH, water temperature monitoring system and controlling system that use websocket's framework to keep the system running in the real time operation. Two Arduino devices are used as the data taker and the executor in controlling system. Meanwhile a Raspberry Pi device is used as a web server and the gateway, so it can be accessed in web interface.**

Keywords—Arduino, aquaponic; Internet of Things (IoT),raspberry Pi; web interface

I. Introduction

An aquaponic is a bio-integrated food system which allows for the production of both plants and animals for consumption without requiring arable land. Aquaponics defined as the integration of hydroponics, growing without soil, and aquaculture, fish farming [1]. The environment is a significant factor in maintaining the quality of life for every living being[2]. The problem that arises with an Aquaponics system is the amount of data needs analysis and manipulation to optimize results.Post this, the numerous environmental factors such as air temperature, water temperature, humidity, pH, light intensity etc. and other variables such as water level, water flow etc. also need to be monitored and any change in any of these variables requires a change in the environment[3][4]. This becomes a massive task, and is quite difficult for any person to manage 24 hours a day, 7 days a week [5].

Consequently, it is very necessary to design a smart monitor and control system, especially for people who travel frequently.The rapid development of sensor, Internet, communication and computer technology, the smart life style will become a popular trend in our future life [6]. So new smart things should be created which can process information, self-configure, self-maintain, self-repair, make independent decision, eventually even play an active role in their own disposal. Things can interact, they exchange information by themselves. So the form of communication will change from human-human to human-thing to thing-thing [7].

IoT (Internet of Things) based aquaponics system allows remote monitoring and control of the water parameters. The various parameters are constantly measured through specified sensor nodes [8]. The ability to analyze these vast and complex amount of data is making it possible for accurate planting, visual management, and intelligent decision for agricultural production [9]. The research in integrating of IoT and aquaponic has begun. Jamisola, in his research conducted monitoring of water temperature, pH level, Dissolved Oxygen (DO) and many of aquaponics parameter [10]. Jamisola also created graphical user interface (GUI) with raspberry pi. In other side, Nikhil Agrawal has already finished his research that combine raspberry pi and Arduino as microcontroller [11]. Raspberry pi acts a central coordinator and end devices act as various router. Hardware components connected to each other to run the control and monitoring process[12].

In this paper, especially in controling side, the use of websocket was applied due the characteristic of the protocol and also needs of aquaponic system. The WebSocket API defines a simple protocol to transfer information, and provides a method for creating secure connections which is beneficial for authentication purposes [13]. Again we must consider that the required communication protocol should be websockets, thereby Tornado within the library websocket was used to perform this function, although in this case taking into account the limitations of use for unsupported browsers as unlike Socket.io this library does not have multiprotocol function [14].

II. Methodology

In this section will be explained about system requirements and system design as a whole that became the target of research. The system specifications developed to the end of the study are as follows:

- Web-based monitoring
- The system is able to control the lights and water pumps through the web
- The system is able to monitor water temperature, water pH level, and water level
- Can be accessed by various types of smartphones, as well as various browsers
- Sensor data is shown in web page in specified time margin

978-1-5386-6163-5/18/$31.00 ©2018 IEEE

- Sensor data is stored in the database

A Raspberry Pi device is used as the gateway of sensor readings and controlling of those read by Arduino. Raspberry Pi is also used as a database storage center to store data that can be monitored directly or remotely by users who connected in a network. For example connected in a similar hotspot. Features that exist in the web browser is water temperature monitoring data, water pH, water level and feed control system using websocket technology as its framework.

DS18B20 is used to measure water temperature. Meanwhile, DFROBOT analog pH meter is used to measure water pH level. For water level, Arduino water level sensor that have analog value is used. Raspberry Pi on the server side using tornado websocket protocol, MySQL Database, and Apache web server. And the user side, the monitoring software is a web-based application so that they can access the application through a web browser on their computer or smartphone that connected to the network.Fig. 1 shows the diagram of the system created.

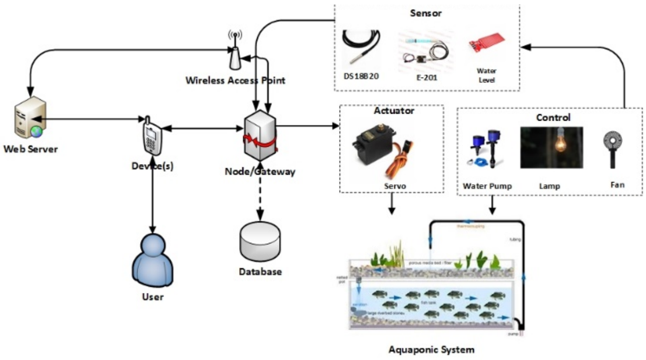


Figure 1. System Design

All sensors connect to the Arduino device and the communication between Arduino and Raspberry pi device is done by the python program. It is also threading data from Arduino device to Raspberry pi database with help of pyfirmata libraries. The websocket protocol controls the servo who used to feed the fish. Meanwhile water pump, lamp and fan were controlled automatically by the value of the sensor. All the data that have been received are stored in database, except the indicator of websocket protocol. It can be seen only in the command prompt and in the web page.

The implementation of the hardware is shown in figure 2 below.

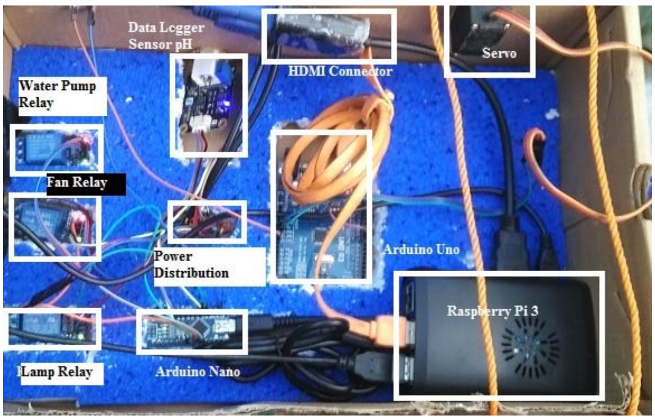


Figure 2. Hardware Implementation

In this research two Arduino devices are used, as shown in figure 2 above, the one is an Arduino Nano to control and the other is an Arduino Uno to monitor. The wiring connection is shown by Table 1.

Table1Wiring Connection

Pin Sensor/Module	Controller Pin	Function
Vcc, Water Level	5 V, Arduino Nano	Voltage,Water Level
GND, Water Level	GND, Arduino Nano	Ground,Water Level
In, Water Level	A1, Arduino Nano	Input, Water Level
Vcc, DS18B20	5 V, ArduinoNano	Voltage,DS18B20
GND, DS18B20	GND, ArduinoNano	Ground,DS18B20
In, DS18B20	D5, ArduinoNano	Input,DS18B20
Vcc, pH level	5 V, ArduinoNano	Voltage, pH level
GND, pH level	GND, ArduinoNano	Ground,pH level
In, pH level	A0, ArduinoNano	Input,pH level
Vcc, Servo	5 V, Arduino Uno	Voltage,Servo
GND, Servo	GND, Arduino Uno	Ground,Servo
In, Servo	D9, Arduino Uno	Input,Servo
Vcc, Relay 1	5 V, ArduinoNano	Voltage,Relay 1
GND, Relay 1	GND, ArduinoNano	Ground,Relay 1
In, Relay 1	D6, ArduinoNano	Input,Relay 1
Vcc, Relay 2	5 V, ArduinoNano	Voltage,Relay 2
GND, Relay 2	GND, ArduinoNano	Ground,Relay 2
In, Relay 2	D7, ArduinoNano	Input,Relay 2
Vcc, Relay 3	5 V, ArduinoNano	Voltage,Relay 3
GND, Relay 3	GND, ArduinoNano	Ground,Relay 3
In, Relay 3	D8, ArduinoNano	Input,Relay 3
Vcc, Buzzer	D9, ArduinoNano	Input, Buzzer
GND, Buzzer	GND, ArduinoNano	Ground, Buzzer
Vcc, Arduino Uno	USB Port,Raspberry Pi	PowerSupply,Arduino Uno
Vcc, Arduino Nano	SB Port,Raspberry Pi	Power Supply,Arduino Nano

III. Result and Discussion

There are 3 aspects tested in the research, They are sensor testing, websocket protocol testing, and web page testing. In the sensor testing, the value measured by the sensor will be compared to the measurement results by using measuring instruments. There are 3 parameters to be compared, water temperature, pH level, and water level. The python script will work and threading the real time data from the sensor in specified delayed time. The Websocket Protocol will be tested by running the python script program and run the specified web page in other device and the Raspberry Pi device as the web server. Last, web page will be tested by accesed it from another device that in same network. It will show all the sensoring data in form of table.

A. Sensor Measuring Test

After the system is successfully implemented and running, the sensor is tested by taking 20 samples of comparison results from water temperature and pH level reading values using sensors and measuring instrument. Water temperature is measured by DS18B20 and measuring instrument used is a thermometer. Meanwhile pH level is measured by Analog pH meter for Arduino and measuring instrument used is a digital pH meter. For the better accuracy, measurement devide by two times, in the morning and the afternoon. Figure. 3-6 show measured value using sensor and measuring instrument.

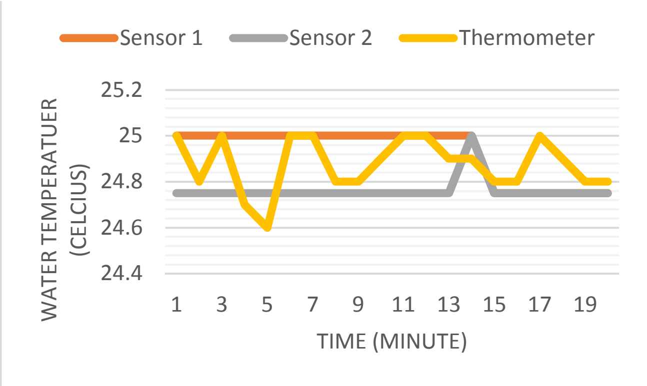


Figure. 3. Water Temperature Measurement in the morning

Based on the figure 3 above, it can be seen that water temperatur measurement in the morning are variables, between 24,8^{o} celcius and 25^{o} celcius, and the average water temperatur value is 24,74063^{o} celcius. There is a dropping water temperatur value after 4 minutes more and less that exceeds 24,8^{o} celcius. It drops until 24,6^{o} celcius. After 5 minutes, then, the water temperatur increases and back to between 24,8^{o} celcius and 25^{o} celcius. At this testing, the sensor 1 temperatur is 25^{o} celcius and the sensor 2 temperatur is 24,8^{o} celcius.

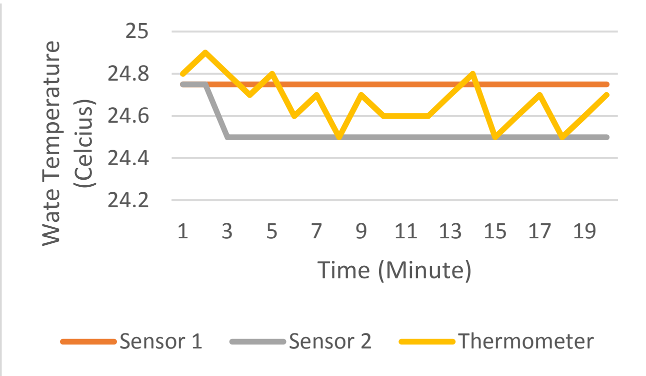


Figure 4. Water Temperature in The Afternoon

Water temperatur in the afternoon testing, can be seen in figure 4 above. The water temperatur have still variable values, between 24,5^{o} celcius and 24,9^{o} celcius, and the average water temperatur value is still 24,74063^{o} celcius. At this testing, the sensor 1 temperatur is 24,75^{o} celcius and the sensor 2 temperatur is at 24,5^{o} celcius.

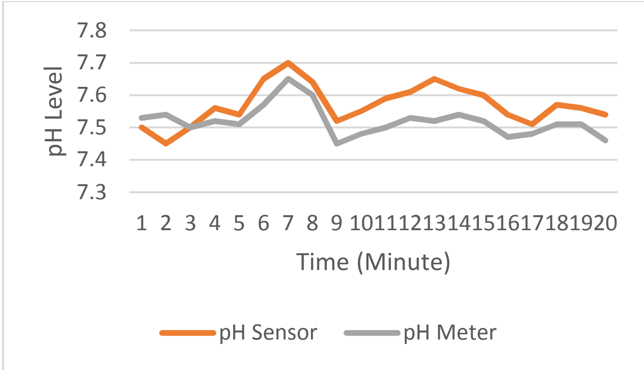


Figure 5. pH Level Measurement in the morning

Based on figure 5 above, there is a diffrence between pH level value measured by pH Sensor and pH Meter. At the first three minutes, pH meter device have some higher values than pH Sensor. After 3 minutes, pH Sensor then increases exceeding the pH Meter value and goes on through the end. The average value of pH level from pH Sensor is 7,64125 and the average value of pH level from pH meter is 7,5975. The pH sensor dominates the higher pH level value than pH sensor . This testing is carried on in the morning.

In the afternoon, the diffrence between pH level value as shown in figure 6 below.

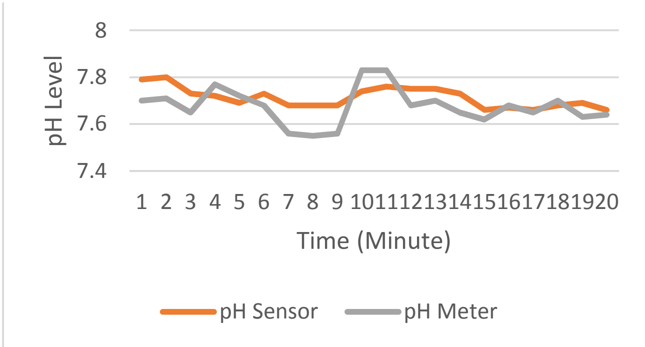


Figure 6. pH Level Measurement in the afternoon

Based on figure 6 above, the pH Sensor and the pH Meter devices undergo higher level and lower level than each other. The average value of pH level from pH Sensor is 7,64125 and the average value of pH level from pH meter is 7,5975. This average testing value is the same as the testing value in the morning as mention above. But in the afternoon testing, the pH meter has the highest and the lowest pH level value.

B. Websocket Protocol

After the sensor node works properly, the next tested aspect is Websocket Protocol. In this system, websocket is installed in Raspberry pi 3 model B especially Tornado Websocket. The Websocket Protocol is tested by showing the message received by Raspberry pi as the web server. The test is shown in Figure 7 below.

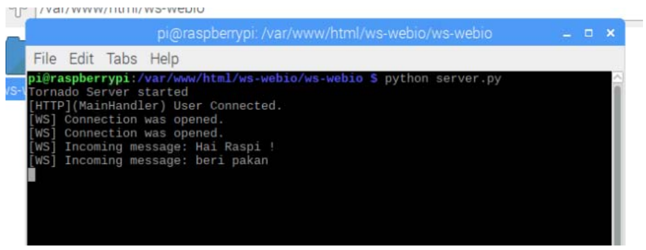


Figure. 7. Messages Received in Raspberry pi via Command Prompt

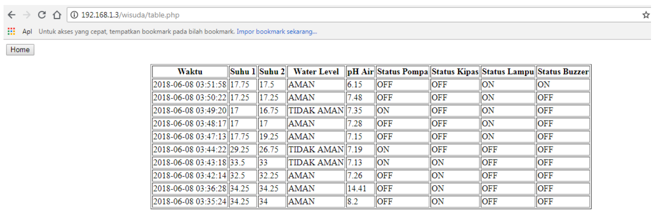
After the broker receives the message correctly, the next test is the Websocket Protocol synchronization with the web page. If the Websocket protocol works properly, the messages that sent from the web page wil be the same as the the messages that Raspberry pi received. Then if the user hit the "keyword", web page will automatically reply and it will do the specified order, in this case is rotating servo. Figure. 8. shows how web page will reply the "keyword" message.

Figure 8. The Replied Message from Web page

The keyword is "feed". If the user sent anything except "feed", the web page will automatically replied with the exact message that users sent. Otherwise, if user sent the keyword, web page will not show the exact message but "Server : has been fed" as the indicator that user hit the correct keyword.

C. Testing the Web Page

Data from each sensor node will be displayed in a web page. The web page is designed to be able to look after some limited data. In this case only shown the last 10 of data that Arduino sent to Raspberry pi. The number of data shown in the web page can be setting in the python script. Figure. 9. will show how the table of monitoring data looks like.



Waktu	Suhu 1	Suhu 2	Water Level	pH Air	Status Pompa	Status Kipas	Status Lampu	Status Buzzer
2018-06-08 03:51:58	17.75	17.5	AMAN	6.15	OFF	OFF	ON	ON
2018-06-08 03:50:22	17.25	17.25	AMAN	7.48	OFF	OFF	ON	OFF
2018-06-08 03:49:20	17	16.75	TIDAK AMAN	7.35	ON	OFF	ON	OFF
2018-06-08 03:48:17	17	17	AMAN	7.28	OFF	OFF	ON	OFF
2018-06-08 03:47:13	17.75	19.25	AMAN	7.15	OFF	OFF	ON	OFF
2018-06-08 03:44:22	29.25	26.75	TIDAK AMAN	7.19	ON	OFF	OFF	OFF
2018-06-08 03:43:18	33.5	33	TIDAK AMAN	7.13	ON	ON	OFF	OFF
2018-06-08 03:42:14	32.5	32.25	AMAN	7.26	OFF	ON	OFF	OFF
2018-06-08 03:36:28	34.25	34.25	AMAN	14.41	OFF	ON	OFF	OFF
2018-06-08 03:35:24	34.25	34	AMAN	8.2	OFF	ON	OFF	OFF

Figure 9. Web Page Interface

The table show water temperature from two DS18B20 sensor, water level, and pH level. Its also show information abaout water pump, lamp, fan, and the buzzer. Which is being active or not. The web page compatible in many browser from many devices as shown in Table 2.

Tabel 2 Compatible Table

Device(s)	Browser	Controlling	Monitoring
Xiomi Mi4i	Default Browser	Compatible	Compatible
	Chrome	Compatible	Compatible
iPhone 5c	Safari	Compatible	Compatible
Laptop Acer Travelmate	Chrome	Compatible	Compatible
	Internet Explorer	Compatible	Compatible

IV. CONCLUSION

The developed system allows displaying multiple Aquaponic parameter in specified delayed time. The parameters to be monitored include the water temperature, pH level, and water level. It also shows the information abaout water pump, lamp, fan, and buzzer. The information contains data is being off or activated. The information table showed in web page that can be accessed from various web browser in various type of devices. The system designed very simple to monitor and control. However, it can be developed to monitor more parameter and control more devices.

ACKNOWLEDGMENT

This research was supported by the electrical engineering department of Science and technology Faculty and Research and Publishing Center UIN Sunan Gunung Djati Bandung, Indonesia

REFERENCES

[1] B. Rieger, "Designing an Aquaponic Greenhouse for an Urban Food Security Initiative," Worcester, 2015.

[2] Y. Suryani *et al.*, "Effect of Propolis Coating on the Quality of Eggs: Microbial Contamination and Haugh Unit," *Res. J. Pharm. Biol. Chem. Sci.*, vol. 8, no. 2, pp. 1776–1784, 2017.

[3] N. Fajrin, I. Taufik, N. Ismail, L. Kamelia, and M. A. Ramdhani, "On the Design of Watering and Lighting Control Systems for Chrysanthemum Cultivation in Greenhouse Based on Internet of Things," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 288, no. 1, p. 012105, 2018.

[4] L. Kamelia, M. A. Ramdhani, A. Faroqi, and V. Rifadiapriyana, "Implementation of Automation System for Humidity Monitoring and Irrigation System," in *IOP Conference Series: Materials Science and Engineering*, 2018, vol. 288, no. 1, p. 012092.

[5] A. Nichani, "Environmental Parameter Monitoring and Data Acquisition for Aquaponics," *Int. J. Emerg. Technol. Comput. Sci. Electron.*, vol. 24, no. 9, pp. 29–34, 2017.

[6] S. Charumathi, R. M. Kaviya, J. Kumariyarasi, R. Manisha, and P. Dhivya, "Optimization and Control of Hydroponics Agriculture using IOT," *Asian J. Appl. Sci. Technol.*, vol. 1, no. 2, pp. 96–98, 2017.

[7] L. Tan, "Future internet: The Internet of Things," *2010 3rd Int. Conf. Adv. Comput. Theory Eng.*, pp. V5-376-V5-380, 2010.

[8] M. Odema, I. Adly, A. Wahba, and H. Ragai, "Proceedings of the International Conference on Advanced Intelligent Systems and Informatics 2017," vol. 639, 2018.

[9] O. Elijah, I. Orikumhi, T. A. Rahman, S. A. Babale, and S. I. Orakwue, "Enabling smart agriculture in Nigeria: Application of IoT and data analytics," *2017 IEEE 3rd Int. Conf. Electro-Technology Natl. Dev. NIGERCON 2017*, vol. 2018–January, pp. 762–766, 2018.

[10] R. Jamisola and A. M. Nagayo, "Cloud-based Wireless Monitoring System and Control of a Smart Solar-Powered Aquaponics Greenhouse to Promote Sustainable Agriculture and Fishery," no. June, 2017.

[11] N. Agrawal and S. Singhal, “Smart Drip Irrigation System Using Raspberry Pi and Arduino,” *Int. Conf. Comput. Commun. Autom.*, pp. 928–932, 2015.

[12] W. Vernandhes, N. . Salahuddin, A. Kowanda, and S. P. Sari, “Smart aquaponic with monitoring and control system based on iot,” *2017 Second Int. Conf. Informatics Comput.*, pp. 1–6, 2017.

[13] A. Wessels, M. Purvis, J. Jackson, and S. (Shawon) Rahman, “Remote Data Visualization through WebSockets,” *2011 Eighth Int. Conf. Inf. Technol. New Gener.*, pp. 1050–1051, 2011.

[14] G. Carro Fernandez, E. Sancristobal Ruiz, M. Castro Gil, and F. Mur Perez, “From RGB led laboratory to servomotor control with websockets and IoT as educational tool,” *Proc. 2015 12th Int. Conf. Remote Eng. Virtual Instrumentation, REV 2015*, no. February, pp. 32–36, 2015.