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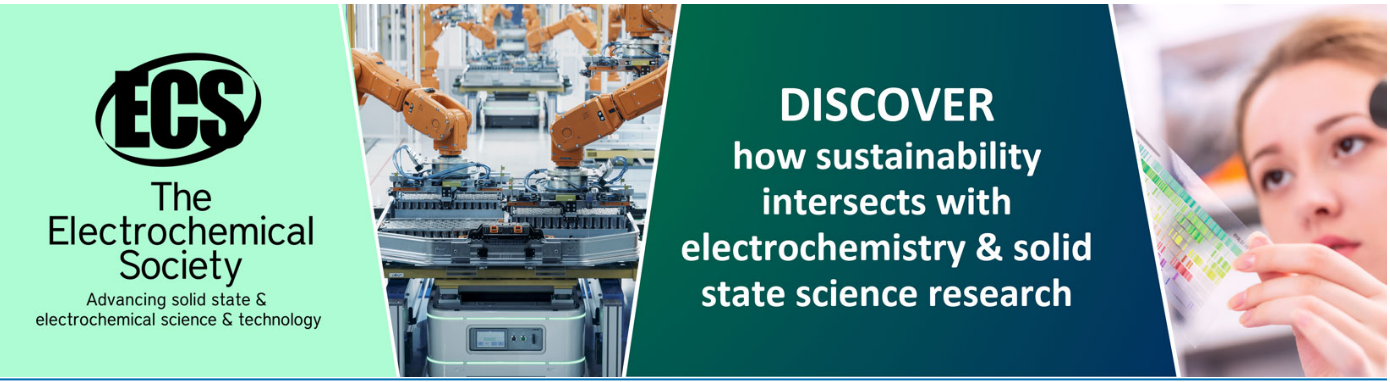

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Smart aquaponic system based Internet of Things (IoT)

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Abstract. Getting appropriate water source for fish and plant cultivation seems difficult. Moreover, the agricultural production is decreasing due to narrower lands so that land- and water-saving technology combined with a variety of vegetable is important to produce maximum yield. Aquaponics is a sustainable agriculture system in a symbiotic environment by combining aquaculture and hydroponics. This water system should flow on the planting medium periodically to ensure the plants get the nutrients, while the water can be filtered properly by the medium. This research designed a smart aquaponics system that could control and monitor the degree of acidity, water level, water temperature, and fish feed that were integrated with internet-based mobile application. In this system, there was a sensor installed to retrieve data, which was then transmitted to Ubuntu IoT Cloud server that could be accessed in real time through the internet network. Thus, the quality and water circulation were well-preserved. Results showed that the success rate of measurement for ultrasonic sensor was 99.94%, pH sensor of 92.35%, and temperature sensor of 97.91%. The temperature and pH water pool that were suitable for aquaponics ranged between 20-30^{0}C and 7-75 and the monitoring system proceeded as expected.

1. Introduction

In accordance with 2016 agricultural statistics, agricultural lands are always exposed to a land conversion annually from food to non-food utilization. The area of the lands has been decreased due to The fact that of many settlements and industries as a response to the increase of Indonesian population.

Table 1. Agricultural Lands in 2016 [1]

No.	Lands	Land Area (Ha)	Percentage
1.	Rice fields	8,087,393%	21.83%
2.	Plantation areas	11,846,954	31.97%
3.	Farms	5,172,502	13.96%
4.	Empty lands	11,945,726	32.24%

The rate of change in agricultural land into non-agricultural utilization in Indonesia reaches 100 thousand hectares per year [2]. The necessities of using lands for the sake of city development are larger than the existing lands, in which the situation makes agricultural land sacrificed and get smaller land areas. Sometimes, some stakeholders involved in the land clearing do not understand the importance of agricultural land such as rice fields. Besides having economic value as a buffer for food needs, rice fields also take important function in ecology such as regulating water system and carbon absorption [3]. To cope with that existing phenomena, one of the recent innovation in plant cultivation technology is hydroponic cultivation techniques combined with aquaculture techniques in a simple container using water recirculation process from fish to plant cultivation [3].

Aquaponics has been investigated by several researchers [4-8]. However, the researches mentioned have not discussed the automation of the aquaponics system. This paper proposed a smart aquaonics system so that the aquaponics system is easier and more efficient for the farmers. A smart aquaponics system is then designed by integrating mobile application with internet network in real time that functions to automatically control the aquaponics system without having often observations. In this system, there are many sensors installed to retrieve data that are then transmitted to the Ubidots IoT Cloud server that can be accessed in real time via internet network.

2. Methodology

2.1. Smart Aquaponics System
Smart aquaponics system is the development concept of bio-integrated farming system combined with internet of things-based electronic technology. This technology is designed to utilize water containing excess feed nutrients from aquaculture ponds or containers as a source of nutrition or hydroponic growing medium. Thus, the efficiency and effectiveness of feed and plant nutrition can be conducted[9]. Plant used in this present research was lettuce (Lactuca Sativa L.) and tilapia as the fish. This research used aquariums and pipes that had been modified as a place to plant.

2.2 Internet of Things
Internet of Things (IoT) can be divided into some layer architectures. The first layer is the perception layer, which functions to read and collect information from the physical environment. Then, the data will be used in the application layer. The perception layer is responsible for converting data into signals sent through the network so that it can be read by the application layer, for instance, the use of barcodes by minimarkets. In the barcode, there are data such as name, price, and stock of goods[10].

2.3 *Quality of Service (QoS)*
Quality of Service (QoS) is a method measuring how well the network and attempted to define the characteristics and properties of a service. In QoS, there are several parameters namely throughput, packet loss, and latency [11].

2.4 *System Design*
Based on Figure 1, the system design consists of several system components covering microcontroller, sensor, Android and web interface, local display, back up water, pump, fish feeder, notification, and emergency source.

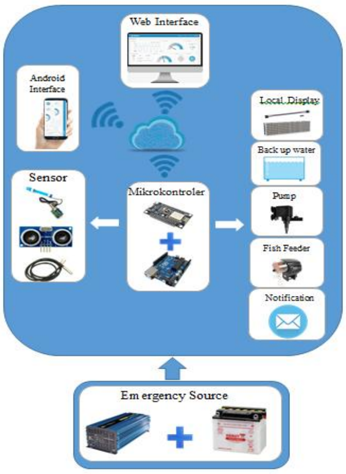

Figure 1. System Design

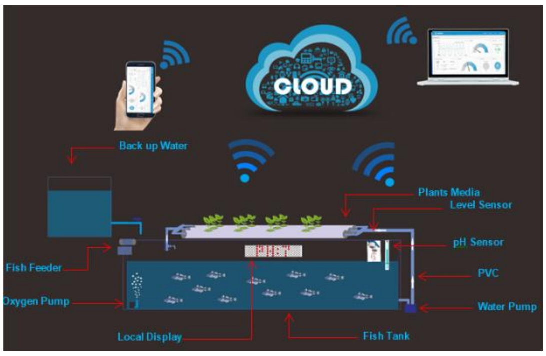

Figure 2. General Overview of the System

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3. Results and Discussion

3.1 *Testing of Ultrasonic Sensors*

This test aims to adjust the measurement results of ultrasonic sensors with the measurement results of manual procedures using a ruler. Moreover, this test proposes to find out the error value generated by reading ultrasonic sensors on changes in water levels in the aquarium.

Table 1. Results of Ultrasonic Sensor Testing

No.	Measurement (M)	Water Level (cm)		Success (%)	*Error* (%)
		Ultrasonic Sensor	Manual		
1	M 1	8	8	100	0
2	M 2	11	11.5	99.57	0.43
3	M 3	13	13	100	0
4	M 4	16	16	100	0
5	M 5	19	19	100	0
6	M 6	24	24	100	0
7	M 7	27	27	100	0
8	M 8	5	5	100	0
9	M 9	6	7	99.86	0.14
10	M 10	9	9	100	0
Average (%)				99.943	0.057

The results of ultrasonic sensor testing can be seen in Table 1, which shows that the biggest error value is 43% and the smallest error is 0%. Meanwhile, the average error is 57% with an average success of 99.943%.

3.2. pH and Temperature Sensors Testing

This test is done by inserting a probe from the sensor of pH meter into water with different degrees of acidity (pH). This test aims to calibrate the pH sensor and to determine the value of the acidity of the aquarium or container water. The results of the sensor readings are then compared to the digital pH meter. At the pH sensor, there is also a water temperature sensor which is used in the test simultaneously.

Table 2. Results of Acidity Testing (pH)

No.	Voltage	Acidity Level (pH)		Success (%)	*Error* (%)
		pH Meter Sensor	Digital pH meter		
1	2.08	6.61	6.6	99.85	0.15
2	2.08	6.62	6.6	99.97	0.3
3	2.08	6.60	6.6	100	0
4	2.07	6.61	6.7	98.7	1.3
5	2.08	6.63	6.7	98.95	1.05
6	2.20	7.02	7.8	88.89	11.11
7	2.19	7.01	7.8	88.74	11.26
8	2.19	7.00	7.8	88.58	11.42
9	2.19	7.00	7.8	88.58	11.42
10	2.18	6.99	7.7	89.85	10.15
11	2.20	7.03	7.9	87.63	12.37

No.	Voltage	Acidity Level (pH)		Success (%)	*Error* (%)
		pH Meter Sensor	Digital pH meter		
12	2.20	7.02	7.8	88.89	11.11
13	2.21	7.02	7.8	88.89	11.11
14	2.14	7.02	7.8	88.89	11.11
15	2.20	7.02	7.8	88.89	11.11
Average (%)				92.353	7.67

Based on Table 3 the results of testing the pH sensor for the value of acidity (pH) meter in 15 tests with a span of one minute in each test show the largest error value of 12.37% and the smallest value of 0%, meanwhile the average error of 7.67% and average success of 92.353%.

Table 3. Results of Temperature Testing

No.	Voltage	Temperature (^oC)		Success (%)	*Error* (%)
		Tempt Sensor	Digital Thermometer		
1	2.08	28	28.1	99.65	0.35
2	2.08	29	28.1	96.8	3.2
3	2.08	29	27.9	96.1	3.9
4	2.07	28	27.9	99,65	0.35
5	2.08	28	27.9	99.65	0.35
6	2.20	29	27.8	95.7	4.3
7	2.19	29	27.8	95.7	4.3
8	2.19	28	27.8	99.3	0.7
9	2.19	29	27.8	95.7	4.3
10	2.18	29	27.8	95.7	4.3
11	2.20	28	27.8	99.3	0.7
12	2.20	28	27.7	98.92	1.08
13	2.21	28	27.7	98.92	1.08
14	2.14	28	27.7	98.92	1.08
15	2.20	28	27.6	98.6	1.4
Average (%)				97.907	2.09

The temperature values in 15 tests with a span of one minute in each test can be seen in table 4. The biggest error value is 4.3% and the smallest value is 0.35%, whereas the average error amounted of 2.09% and the average success of 97.907%

3.3 *Server Testing*

This study uses one of the IoT platform servers namely Ubidots. The process of sending data to the Ubidots server are conducted by an account id in the form of token via a WiFi network. In this study, only one device with 4 variables was used. Every data sent from NodeMCU is further stored in one variable. Since each sensor has different variables, the data sent sensor will not be confused by the remaining data sensors as seen in figure 3 and 4.

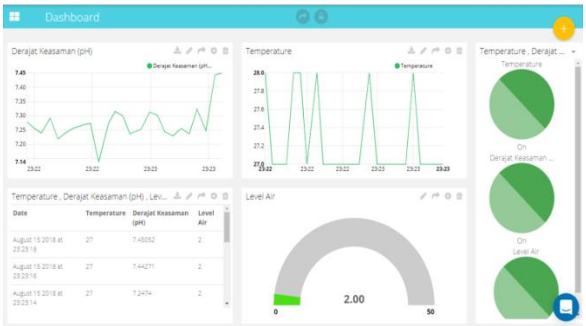

Figure 3. Dashboard Ubidost Interface

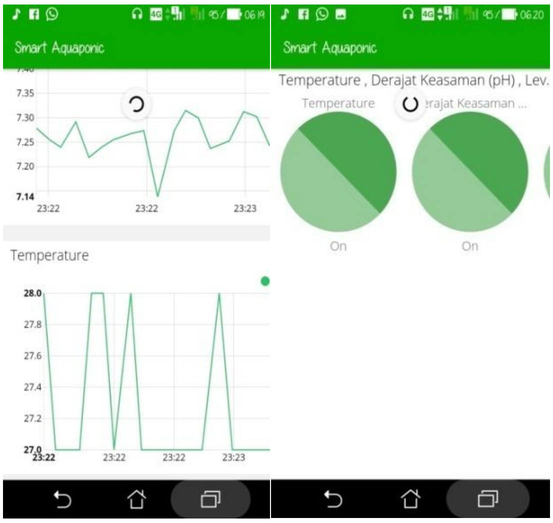

Figure 4. Android Interface

3.4. Testing of Quality of Service

The Quality of Service parameters used in this study are throughput, delay and packet loss. Of the three parameters will be tested on each data sensor transmitted to the server via a WiFi network. Calculations are done manually by analyzing the data transmitted on the serial monitor and received on the server. The calculation results are compared with the categories of each parameter tested to draw conclusions on the good or bad of a monitoring system (see **Table 4**)

Table 4. Results of *Quality of Service* Testing

Sensors	**Ultrasonic**	**pH**	**Temperature**
Throughput (Kbps)	8.2	8.2	8.2
Index	1	1	1
Packet Loss (%)	0	0	0
Index	4	4	4
Delay (ms)	2000	2000	2000
Index	1	1	1

3.5 Plant and Fish Growth

Based on Figure 13, the growth rate of lettuce is slightly slow that can be generally seen from few occurring leaves and the plant height also increases from 1 to 2 cm every week, and only reaches 5 cm at 4 MST (1 month) . the lettuce growth is hampered due to the influence of high temperatures on Madura Island so that many lettuce plants experience evapo-transpiration.

According to Karsono et al (2003), plant growth will be inhibited if the air temperature is high and evapo-transpiration runs continuously [12]. In addition to temperature, the factors that can influence the production of fish feces and pH of water, which are not suitable and do not meet the needs of plants. The number of leaves and plant height have increased for 4 MST even though the increase is only one strand (see figure 10). The lettuce growth can be seen in figure 5 to 8.

Figure 5. Lettuce 1 MST

Figure 6. Lettuce 2 MST

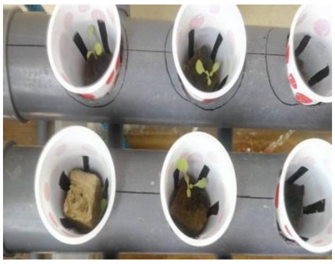

Figure 7. Lettuce 3 MST

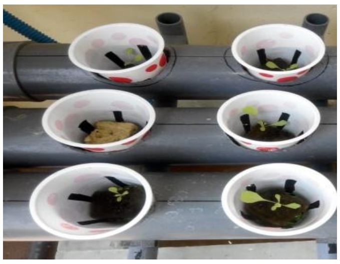

Figure 8. Lettuce 4 MST

Tilapia placed on aquaponics is those with the same average age, which is about 1 week with a dense amount of 30 tails. Feeding intensity is carried out 3 times a day (morning, afternoon, and evening). Figure 14 shows the growth of tilapia, in which the results show that the average fish growth goes well and continues to increase every week with the length of the fish parameters increasing by around 1-2 cm per week from 1 week of maintenance (1MP). Besides, the body size of the fish always shows positive growth except the weight because of the limitations of the tool. Henceforth, the parameters used are only the length of the fish. Figure 9 to 12 portray the tilapia growth.

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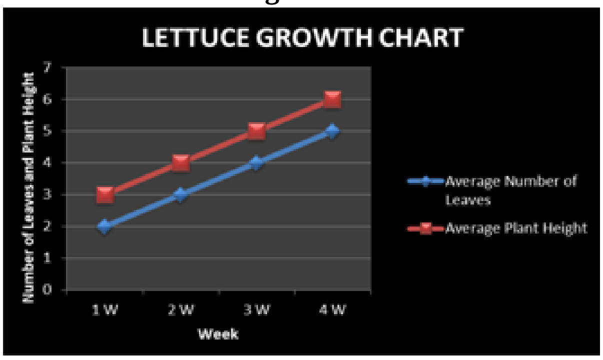
Figure 9. Tilapia 1 MP **Figure 10.** Tilapia 2 MP

Figure 11. Nila 3 MP **Figure 12.** Tilapia 4 MP



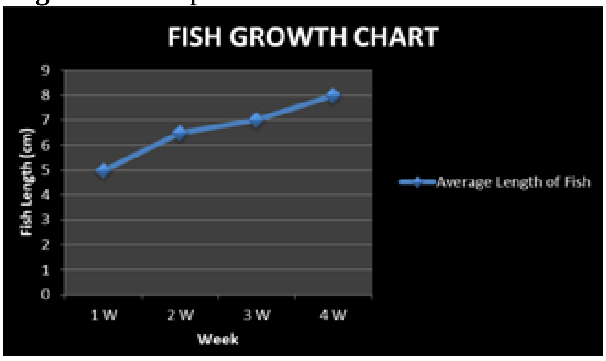


Figure 13. Lettuce Growth **Figure 14.** Tilapia Growth

Figure 15. *Smart Aquaponics System*

Figure 15. is an overview of the overall aquaponic system circuit. All components in the system design have been installed properly including fish and plants that will be cultivated in a smart aquaponic system.

4. Conclusion

Based on the results of testing and research conducted conclusions can be drawn that the level of accuracy of the sensors used is quite high with an average success rate of 99.943% for ultrasonic sensors, pH sensor of 92.353% and temperature of 97.907%. The process of sending and receiving sensor data to an Internet of Things based server runs well using a WiFi connection. Growth of plants and fish on the smart aquaponic system ranges from 25 ^{o}C to 30 ^{o}C and pond water pH between 7-7.5 with the intensity of fish feeding 3 times a day. The characteristics of the smart aquaponic system monitoring network system is not very good with the throughput index value is 1, packet loss 4 and delay with index 1. The suggestion for the next research is to make an adaptive aquaponic system where the system can be adjusted according to the type of crop and the appropriate nutrient needs.

Acknowledgement
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