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Design and Construction of Control Devices for Aquaponic Monitoring Management

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Abstract

Ridwan Siskandar, and Billi Rifa Kusumah. 2019. Design and Construction of Control Devices for Aquaponic Monitoring Management. *Aquacultura Indonesiana, 20(2) : 16 -23.* The management concept of aquaponic cultivation requires good care and management. Aquaponics that are not managed properly have great potential to cause failure. Simplification of management steps, we need a system that can simplify and must minimize the risk of failure. This research creates an integrated system between hardware and software that can help manage aquaponic cultivation more simply and safely. The purpose of this research is to device construct physical data gauges for pool water quality and planting media quality, and design software for easy of monitoring systems of instrument device work and monitoring systems for users. The system has a built-in aquaponic condition monitoring feature via an installed sensor. The conditions monitored by this system are conditions of air temperature, humidity, water temperature, light intensity, level of turbidity of water, and height of fish feed at the feedlot. The system has two automation features. The first automation feature is the automation of fish feeding with a certain time lag. The second automation feature is the automation of the water heater engine. Water heater engine will be turned on or off at a certain temperature. The system also features an engine control feature in aquaponics that includes a water pump engine, an aerator engine, and a water heater engine. System monitoring, automation and control features can be accessed by users via the web. Testing of the system has indicated that the system is functioning properly in accordance with the objectives. The algorithm is correct, so the system output matches the expected output.

Keywords: Aquaponic; supervision system; automatic control; manual control; design; contruction

Introduction

Water is an important part of living systems. According to Osman et al (2018), the factors causing the decline in water quality can be relate to urbanization, industrialization and excessive exploitation of nature. For that the quantity and quality of water for living things needs to be considered. To support the UN SDG Goal 6 (Ensure access to water and sanitation for all) program, one way that can be done is to save water. The cultivation system that supports this is aquaponics.

Aquaponic can be interpreted as a system that integrates aquaculture systems with hydroponic systems. Existing water in fish aquariums will be used as a nutritious water source for plants (Goddek et al. 2015). Aishwarya et al (2018) say that 30% of the raw protein produced by fish droppings in the aquaponic system can meet almost all the nutrients that plants need. The aquaponics system is a symbiotic relationship system between plants and fish with the use of certain parameters (Mamatha and Namratha 2017). The parameters that become the benchmark are air temperature, humidity, light intensity, water temperature, and turbidity of the water. The purpose of this research is to device construct physical data gauges for pool water quality and planting media quality, and design software for easy of monitoring systems of instrument device work and monitoring systems for users. Techniques to facilitate the management and maintenance of aquaponics use integration between microcontrollers with electronic sensors such as temperature sensors, humidity sensors, water temperature sensors, light sensors, and turbidity sensors which connected to internet.

The aquaponics system will use an ESP8266 microcontroller which will be connected to several sensors that will retrieve condition data based on a certain time interval. The aquaponics system will also be connected to the servo and relay. Servo is used as an actuator in an automatic feed system while a relay is used to set the engine off or on in the aquaponic system. The machines contained in the aquaponics system include water pumping machines, aerator engines and water warmers.

Previous researchers who have examined aquaponic cultivation systems include Agustina et al. (2018), Andriani et al. (2018), Bethe et al. (2017), Bittsánszky et al. (2016), Boxman et al. (2018), Cohen et al. (2018), Estim et al. (2018), Estrada-Perez et al. (2018), Li et al. (2019), Mchunu et al. (2018), Nhan et al. (2019), Oliver et al. (2018), Palma Lampreia Dos Santos (2018), Saaid et al. (2013), Setiadi et al. (2018). These studies are limited to aquaponic systems without microcontroller integration. Researchers who combine aquaponics with microcontrollers include Karimanzira and Rauschenbach in 2019, Kumar et al. (2016), Manju et al. (2017), Murad et al. (2017), Murugesan et al. (2017), Nagayo et al (2017), Odema et al. (2018), Pasha et al. (2018). The concept of developing this research is the addition of a light intensity sensor that does not exist in the previous research implementation mentioned earlier.

Materials and Methods

The steps taken in this research are as follows: concept of tool design, design and construction of hardware and software, hardware testing and inspection of software systems.

1. Tool concept

In the scope of aquaponics, the problem that may occur is the failure of cultivation of plants and biota that are maintained. This is due to the lack of owner control and monitoring of the aquaponic system. The aquaponics surveillance system automatically requires hardware and software. Hardware includes materials for making aquaponic systems, and materials for making circuit systems.

The tool will run the logic and function when there is an electric current in the microcontroller. If there is an electric current, the microcontroller will configure the network to transmit condition data. Then the microcontroller will read the input from the DHT11 sensor, Turbidity, HCSR-04, DS18B20, and BH1750. Then the data will be sent to the database server. Then the system will check the sensor data. If the water temperature is below 25 ° C, the water heater will turn on. Meanwhile, if the water temperature is above 25 ° C, the system will carry out further checks on the temperature. If the water temperature is greater than 29 ° C, the water heater will be turn off by the system. Then the system will retrieve the current time data.

Not only with the automation system, but users can make changes to control tool settings via the web. Then the system will ensure the relay conditions are in accordance with the expected settings. When there is still an electric current flowing on the microcontroller, the process flow will repeat itself back to the process of retrieving condition data from the sensor. If there is no electric current, the process will stop.

2. *Construction design*

The aquaponic framework adapts to a general system model. It can be seen as Figure 1. The design of working tools is illustrated in the block diagram Figure 3. Pipes for hydroponic plants are given as many as four holes and have three levels. The bottom of a hydroponic plant pipe is designated as a place for raising fish.

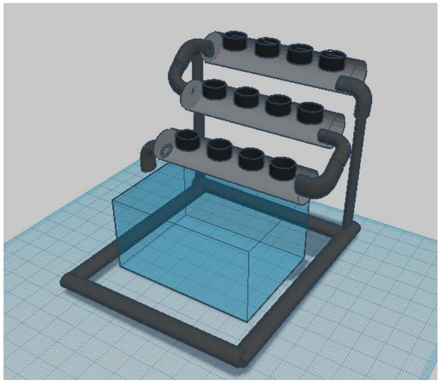

Figure 1. Aquaponic system frame model

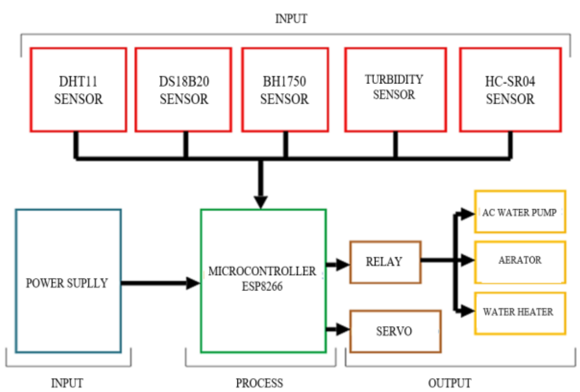

Figure 2. Electronic circuit diagram block in the aquaponic system

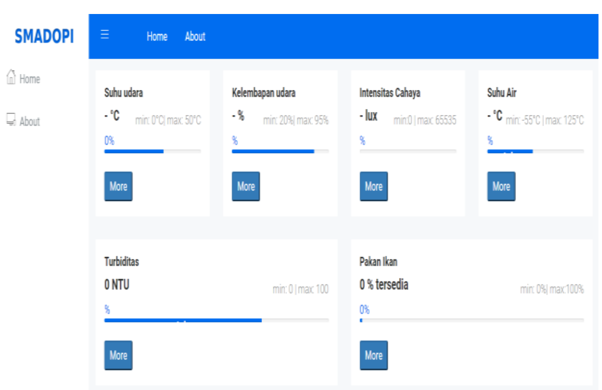

Figure 3. *Main page*

The developed electronic circuit can be seen in Figure 2. The microcontroller (NodeMCU ESP8266) functions as a program code processor and logic. Power supply as a microcontroller and sensor power source for work. Sensors are used to measure physical data. The sensors used include the DHT11 sensor as a temperature and humidity sensor, DS18B20 as a water temperature sensor, BH1750 as a light intensity sensor, turbidity as a water turbidity sensor, HC-SR04 as a distance measuring sensor. The measurement results of the data by the sensor then the microcontroller will process and order the output sensors such as ac water pump relays, aerators, and water heaters to work.

The stages of software design include the design of work algorithms and web design. The front page web design can be seen in Figure 3. The front page displays information of system conditions such as air temperature, humidity, light intensity, water temperature, turbidity and availability of fish food. The blue line indicator located below the condition information is used to display the current condition in the sensor reading range. At the bottom there is a "more" button to bring up the sensor information menu. If the button is pressed, a display will appear as shown in Figure 4. The menu is the sensor information menu containing sensor information, sensor reading chart, and the sensor complete data button to access the sensor reading history table.

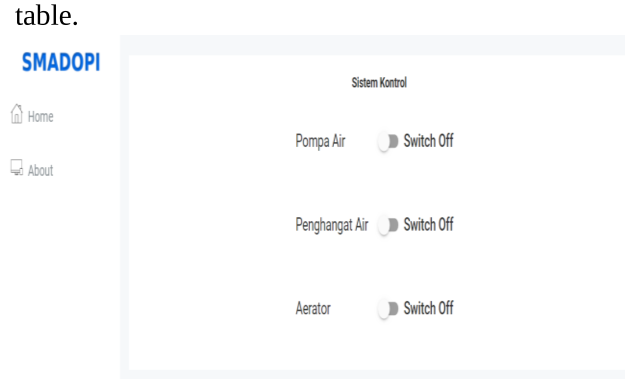

Figure 4. *Control system*

At the bottom of the front page a control system menu is displayed. The "engine" name appears in the aquaponics and the "switch" next to the machine named: "Switch Off" represents the engine's dead condition, while "Switch On" represents the engine's on condition.

3. *Systems Examination*

The test process was carried out on an aquaponic system using water spinach and carp. The test carried out is testing the tool control system manually and automatically. Manual control includes relay control of the ac pump, aerator and water heater, while the automatic control is tested for water heater. After testing the tool control system manually and automatically carried out then the monitoring system testing is then performed by comparing the value of the sensor results with the value of a standardized tool. The tools used are WQC LIPI as a gauge of water turbidity, HTC-2 as a gauge of air temperature, water temperature and water humidity, Benetech GM1010 as a measure of light intensity, Butterfly ruler as a distance meter.

Results

Contruction

The design includes hardware and software. Following are the results of the implementation of a series of tools and data viewer via the web to the aquaponics system. Implementation of the model that has been made can be seen in Figure 5.

Figure 5. Aquaponic system

The mecanic of aquaponic system is made exactly the model that was designed. Pipes for plants have three levels, and each level has as many as four holes. The bottom of the hydroponic plant pipe was placed in the fish aquarium as a place for raising fish.

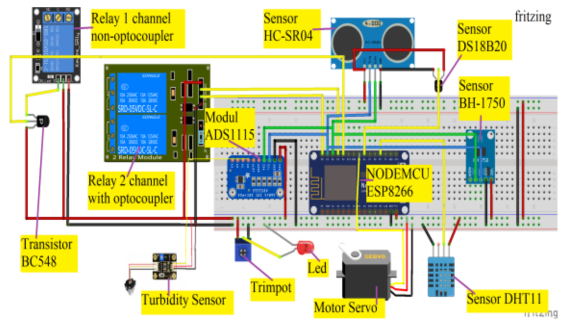

Figure 6. Electronic devices circuit

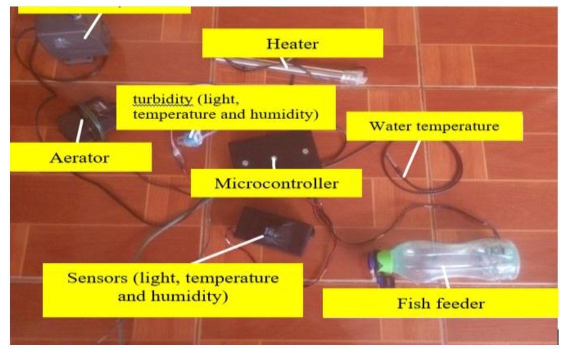

Figure 7. Casing tool series

This implementation resulted in an aquaponics system controlled by an automation control device. The sensor retrieves condition data every 20 seconds. The feed system will automatically open the valve according to the settings given by the user through the web. The relay will connect and disconnect the electricity in accordance with user orders via the web. The water heater will turn on automatically when the temperature is <25 ° C and will turn off at ≥ 29 ° C. The algorithm was based on statements from Claude E and Lichtkoppler F in 1979 which stated that warmwater fish can develop well between temperatures of 25 ° C to 32 ° C.

The main web page display is seen in Figure 8. The top part is the navigation bar that is used to navigate pages on the web. On the front page there is information on the sensor name, the value read by the sensor, information on the minimum and maximum values that can be read by the sensor, buttons to display sensor information and the scale of the value read on the sensor in units of percent (%). If the value scale shows 100%, then the condition obtained is the maximum condition that can be read by the sensor.

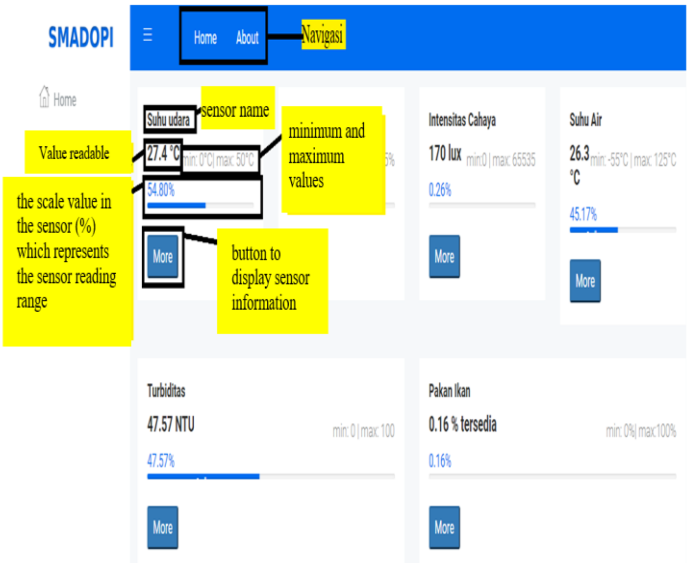

Figure 8. Front page web display

In Figure 9, the sensor information menu is displayed. On the sensor information menu there is information about the current sensor reading value. Underneath it appears the sensor data chart which contains the five most recent sensor reading history. Charts are displayed using a line chart model. The x-axis explains the time information while the y-axis explains the sensor value at that time. Below the chart there is a complete data button temperature sensor. When clicked will display complete data sensor readings. In the lower right corner there is a button to close the sensor information menu.

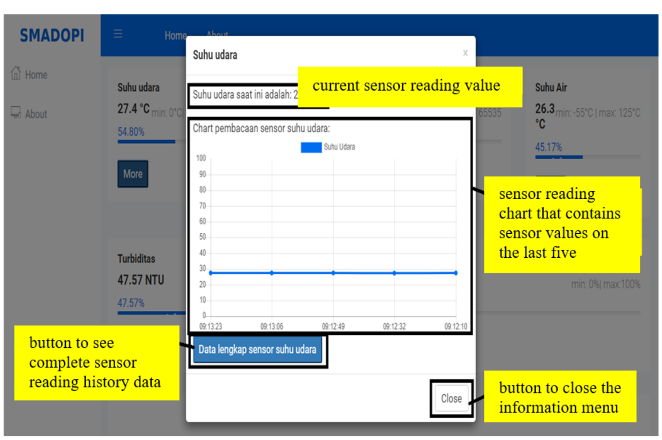

Figure 9. Sensor information menu

In Figure 10, can be seen a complete data display from a sensor reading sensor. In that view, there is a search field to filter information for specific dates, months, years or reading values. Users can adjust the amount of data on one page only through the settings dropdown placed in the upper left corner. The user can also erase the entire data by clicking on the "truncate" button for all data.

Settings to arrange many data on one pagesettings to arrange many data on one page

Figure 10. Complete sensor reading data

Discussion

Experiments were carried out in the aquaponic system with water spinach and carp. The experiments carried out were testing the tool control system manually and automatically. It includes relay control of the ac pump, aerator, and water heater, After testing the tool control system manually and automatically were carried out, than the monitoring system testing were performed by comparing the value of the sensor with the value of a standardized tool. The tools used are WQC LIPI as a gauge of water turbidity, HTC-2 as a gauge of air temperature, water temperature and water humidity, Benetech GM1010 as a measure of light intensity values, the Butterfly ruler as a distance meter. The test results can be seen in Table 1

Table 1. Test result

No	Mode	Information	Current condition	Output
1	Manual	Aerator relay is set to turn on via the web	Aerator is not on	Aerator relay is on
2	Manual	The water pump relay is set to turn on via the web	The water pump is not running	Water pump relay is on
3	Manual	Water heater relay is set off via the web	The water heater is on	Water heater relay is off
4	Automatic	-	Current temperature =21° C	The water heater is on
5	Automatic	-	Current temperature =34° C	Dead water heater

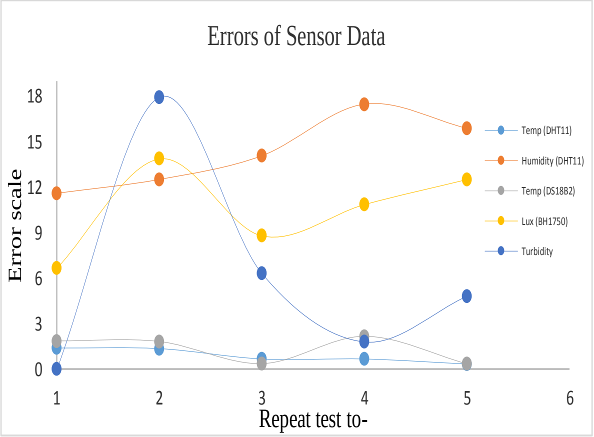

Figure 11. Data error test

Control system test results show that the system can run well. The relay will turn off and turn on according to user control. The water heater will turn off and turn on automatically under certain conditions as expected. Figure 11 shows the comparison of the sensors used with the reference sensor. Errors of less than 10 are good, bigger than 10 is not good. DHT11 sensor error test results as an air temperature sensor can be seen in Figure 11 light blue line with an average error difference of 0.87. The sensor error value is ≤ 10, it can be said that the sensor has good accuracy. DHT11 sensor test results as an air humidity sensor can be seen in Figure 11 orange line with an average error difference of 14.30. The sensor error value is> 10, it can be said that the sensor has poor accuracy. DS18B20 sensor test results can be seen in Figure 11 ash line with an average error difference of 1.30%. The sensor error value is ≤ 10, it can be said that the sensor has good accuracy. BH1750 sensor test results can be seen in Figure 11 yellow lines with an average error difference of 10.54%. The sensor error value is> 10, it can be said that the sensor has poor accuracy. Turbidity sensor test results can be seen in Figure 11 dark blue lines with an average error difference of 6.17%. The sensor error value is ≤ 10, so it can be said that the sensor has good accuracy.

Testing of the system indicates that the system is functioning properly in accordance with the objectives of the study. The system logic is correct, so the system output matches the expected output. The relay will turn on according to the settings given by the user. The water heater will turn on when the water temperature is below 25 ° C. The monitoring system has been able to run and monitoring results can be displayed on the web as it should.

In the tool developed, the error value on the DHT11 sensor as a measure of air humidity and BH1750 as a measure of light intensity is quite large. The error value of the two sensors has a value> 10. So the use of these two sensors needs to be further analyzed with sensors that have higher accuracy. In the future, additional features in this system are the export of sensor data to pdf and excel.

Conclusion

Tests of the design have indicated that the hardware and software systems are functioning properly in accordance with the objectives. The system logic is correct, so the system output matches the expected output.

The relay will turn on according to the settings given by the user. The water heater will turn on when the water temperature is below 25 ° C. The monitoring system has been able to run and monitoring results can be displayed on the web as it should.

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