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Research paper

Implementation IoT in System Monitoring Hydroponic Plant Water Circulation and Control

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Abstract

Hydroponics is the cultivation of plants by utilizing water without using soil by emphasizing the fulfillment of nutritional needs for plants. Deep Flow Technic (DFT) is a type of hydroponics that implements a continuous flow of nutrients and there is a pool of half of the diameter of the pipe that inundates the roots of the plant. A common obstacle experienced by DFT is the lack of maintenance of plant growth elements such as water circulation, light intensity, temperature, humidity and pH of the water which causes these plants not to grow optimally. Then it is necessary to monitor and control the circulation of water on DFT-based IoT hydroponics to anticipate changes in plant growth elements. Data on plant growth elements are acquired by sensors integrated with Raspberry Pi. In the monitoring process using the website will display data on plant growth elements in the form of pH, temperature, humidity and water level in the hydroponic reservoir. Temperature and humidity are used as water circulation control parameters that are processed using the Fuzzy Sugeno Method. From the results of the tests that have been carried out, the system can monitor plant growth elements displayed on the website in real time and control water circulation automatically. The system applied in the hydroponics of mustard greens also produces significant growth in leaf number and plant height.

Keywords: *Hydroponics, IoT, Fuzzy Sugeno.*

1. Introduction

Hydroponics is the cultivation of plants by utilizing water without using soil by emphasizing the fulfillment of nutritional needs for plants. Hydroponics is more efficient in areas that have limited green space. This makes hydroponics an urban agricultural solution. Both on an industrial scale and home scale for self consumption.

One type of hydroponics is Deep Flow Technic is a type of hydroponics that implements a continuous flow of nutrients and there is a pool of half of the diameter of the pipe that inundates the roots of the plant. The DFT system aims to make the absorption of nutrients from plants more optimal. Special attention needs to be given to the growing elements of hydroponic plants in order to produce good and healthy plants. Hydroponic plant growth elements in the form of water circulation, light intensity, temperature, humidity and pH of water. Often the hydroponic activists fail during the plant growth process, due to lack of maintenance of plant growth elements that cause the plant to wither, to change the color of the plant leaves to yellow, to death. With so many plant growing elements, to make it easier to know the condition of the plant, it is necessary to monitor these elements regularly.

The development of communication technology is now increasing rapidly with the advent of the term Internet of Thing (IoT). IoT allows all objects to communicate with each other via the internet. The IoT concept can be applied to both conventional agriculture (soil media) and hydroponic agriculture [6]. In this final project will design and build a system based on the needs of hydroponic plants. The system is designed to control the circulation of DFT hydroponic systems and monitor the growth of hydroponic plants such as ph, temperature, humidity and high water in hydroponic reservoirs using sensors related to the growth elements of hydroponic plants.

2. Literature Review

A. DFT

The Hydroponic System Deep Flow Technique is a method of cultivating hydroponic plants by placing plant roots in deep water layers [1]. The working principle of the DFT hydroponic system is to circulate the plant nutrient solution continuously for 24 hours. This hydroponic technique is categorized as a closed hydroponic system.

Generally, the application of this hydroponic technique is used in the cultivation of leaf and fruit vegetable plants. In the pipe system DFT technique, the flow of nutrients with a depth of 2-3 cm flows on a PVC pipe with a diameter of 10 cm and the plant is placed in a plastic pot, so the plant will receive the flowing nutrients.

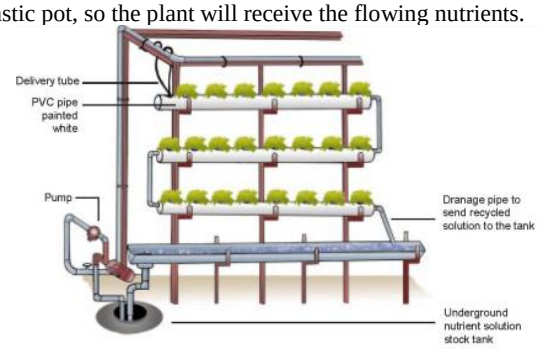


Figure 1. Illustration of Zig Zag DFT System

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B. Sugeno Fuzzy

Method is a fuzzy inference method for rules that are represented in the form IF - THEN, where the output (consequently) of the system is not a fuzzy set, but a constant or linear equation. This method was introduced by Takagi-Sugeno Kang in 1985. The Sugeno model uses the Singleton membership function, which is a membership function that has a degree of membership 1 in a single crisp value and 0 in another crisp value. For Order 0 with the formula:

IF (x1 is A1) ° (x2 is A2) ° ... ° (xn is An)

THEN z = k, (1)

with AI is a fuzzy set to i as an antecedent (reason), ° is a fuzzy operator (AND or OR) and k is a strict constant as a consequence (conclusion). Whereas the Order 1 formula is:

IF (x1 is A1) ° (x2 is A2) ° ... ° (xn is An)

THEN z = p1 * x1 +. . . + pn * xn + q, (2)

with AI is a fuzzy set to i as an antecedent, ° is a fuzzy operator (AND or OR), pi is a constant to i and q is also a consequent constant [8]. In Sugeno method, fuzzification, fuzzy operation, and the implications are the same as the Mamdani method. The difference is only in aggregation and defuzzification. If on the Mamdani method under curve, Then on method Sugeno aggregation under curve. Then on method Sugeno aggregation form Singleton-singleton. In the Sugeno zero-order case model, the output of each rule fuzzy is a constant and all membership functions consequently passing by single nail.

3. Research Methodology

In building a monitoring system and automation of hydroponic water circulation controllers, using the fuzzy Sugeno method for automation of the water circulation controller. This method is applied to help conclude that water circulation will be done by turning on the pump or not circulating water by turning off the pump in hydroponics based on temperature and humidity parameters.

A. Data Retrieval Methods

At the data collection stage used in this study is to do a literature study where this method is done by studying the literature obtained from the collection of documents, references, books, sources from the internet, and other sources. This stage studies the concepts and materials needed in the design and implementation of a system that has a connection with this research

B. Development Method

1.1 General Picture

The initial process carried out by the system is that the sensor is placed on the hydroponics to detect sensor data values that are in accordance with the parameters needed for mustard plants in hydroponics. After obtaining data from sensors such as temperature, humidity, pH and water level, the reservoir will be stored in the database and displayed on the website as the output of the monitoring process. Then the sensor data that has been obtained will be processed to determine the process of controlling hydroponic water circulation. In this control process, the data used is the temperature and humidity that will be processed using the Sugeno fuzzy method in determining the right time to drain hydroponic water.

1.2 Block Diagrams

Water circulation control and monitoring systems are designed using temperature and humidity DHT11 sensors, SEN0161 pH sensors and HC-SR04 proximity sensors. Data obtained from the sensor is stored in the MySQL database contained in raspberry pi which is then accessed by the website via the webserver contained in raspberry pi to display the data and processed by fuzzy to determine the ignition of the water pump in hydroponics. The use of a relay functions as a switch to control the water pump in the on or off condition based on the output of fuzzy. The following Figure 2 below is a system block diagram.

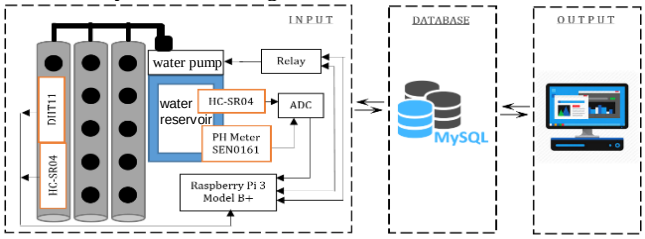


Figure 2. Block Diagram

1.3 Design Tool

For the application of hydroponic design using a pipe that is assembled to form DFT hydroponics with an area of 1 x 0.75 x 0.75 in units of meters, equipped with a water pump and a water reservoir under the pipe.
The design of the hydroponic circuit is found in the figure below:

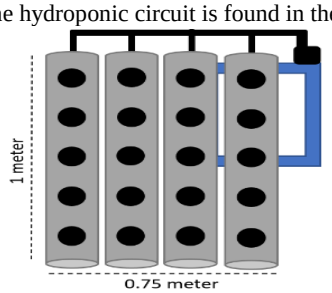


Figure 3. Hydroponic circuitry appears above

Then the planning tool consisting of several sensors includes DHT11, HC-SR04, SEN0161 and MPC3008 ADC which are connected to raspberry pi using a jumper cable. Here is Figure 4. below is a schematic of a sensor circuit.

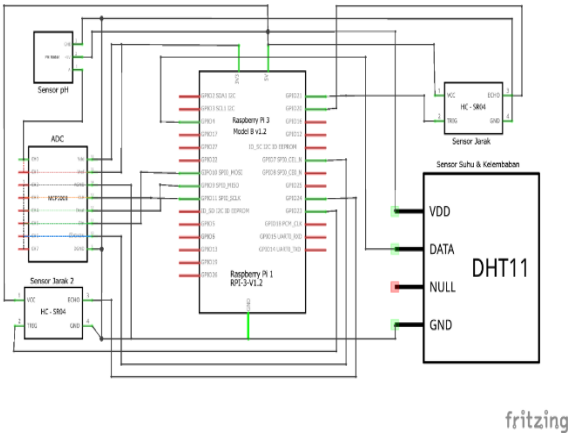


Figure 4. Schematic of sensor circuits

1.4 Analysis of Software and Hardware

In working on this system the author requires software and hardware specifications to support the work of the system.

a. Software specifications.
   - Windows 7/8/10 Operating System

- Raspbian
- puTTY
- IP Scanner

a. Hardware specifications.
- Raspberry Pi 3
- Analog to Digital Converter (MCP3008)
- pH Meter Sensor (SEN0161)
- Temperature and Humidity Sensor (DHT11)
- Ultrasonic Distance Sensor (HC-SR04)
- 1 channel Relay 5V
- Jumper Cable
- 1k Resistor
- PCB matrix
- USB Adapter
- Aquarium Pump 220V

1.5 Designing System

Design the system using fuzzy method requires several processes so that the formation of a decision on the output of the system in accordance with fuzzy calculations.

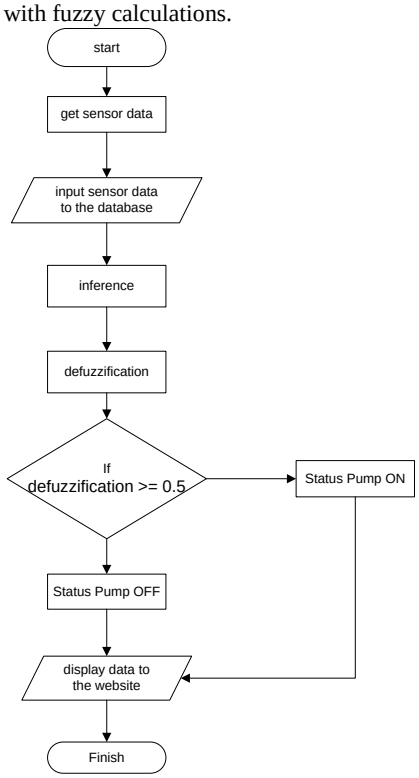


Figure 5. Flow Chart Fuzzy Systems

Figure 6 and Figure 7 are a set of variables input temperature and humidity in which there are 5 conditions, for input temperature conditions have a range that is Cold [0, 0, 18, 21], Somewhat Cold [18, 21, 24], Normal [21, 24, 27], somewhat hot [24, 27, 30], and heat [27, 30, 40, 41]. As for the range of conditions the input moisture is Dry [0, 0, 15, 25], rather dry [20, 30, 40], moderate [35, 50, 65], rather wet [60, 70, 80], and wet [75, 85, 90, 100].

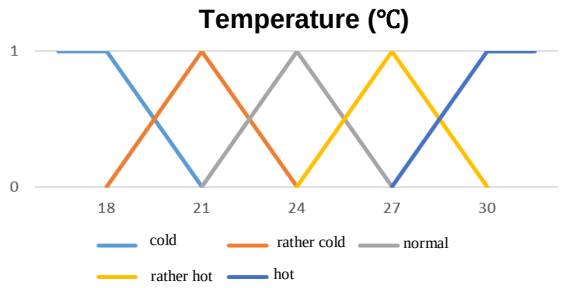


Figure 6. Membership Temperature

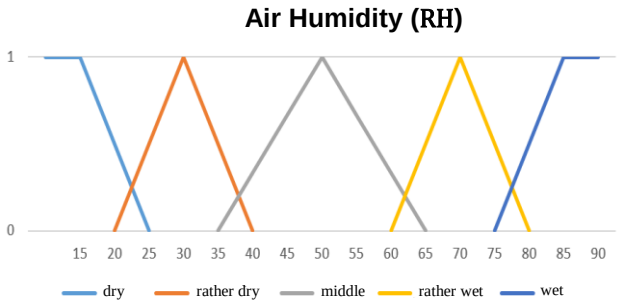


Figure 7. Membership Humidity

The second stage is the implication of using the min function, takes the value α-predicate in the form of a minimum value of each rule. In the Sugeno fuzzy logic method, aggregation is only singleton. In this study the value singleton states the status of the pump actuator, namely Pump ON or Pump OFF which is represented by values 0 and 1.

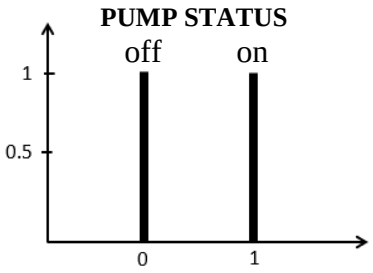


Figure 8. Singleton Pump Status

The last stage is defuzzification. Defuzzification take input in the form of α-predicate value and z each rule. Defuzzification done by calculating the center of singleton value, which is the sum of the multiplication between the membership value and the value singleton then divided by the total membership value. The defuzzification results will determine the status of the pump actuator. Aquatic status consists of ON or OFF. Because in this system is a system real time, the calculation of defuzzification is done for every last data entered in the fuzzy rule. So the formula used becomes:

$$Z^* = \frac{\mu_c(\bar{z}).\bar{z}}{\mu_c(\bar{z})} \; Z^* = \frac{\mu_c(\bar{z}).\bar{z}}{\mu_c(\bar{z})} \qquad (3)$$

4. Implementation

A. Interface Implementation

Website is the user interface used in this hydroponic water circulation monitoring and control system. On the website page, in accordance with the existing interface planning, it will display data on temperature, humidity, pH, reservoir water level and existing

pump status.

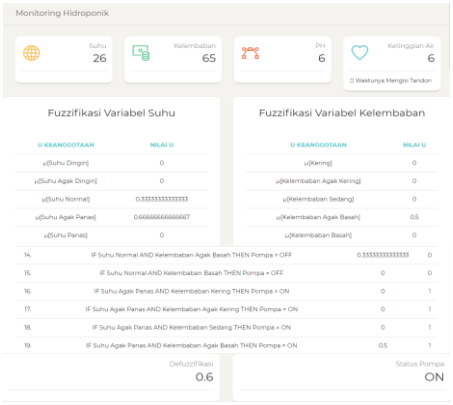


Figure 11. Sensor Series

B. Hardware Implementation

In the implementation phase, especially hardware installation, DFT hydroponics manufacturing process and microcontroller circuit are used. The hydroponic circuit is made from 2.5-inch pipe as a place to put mustard plants. Then it is equipped with a water container and a 220V water pump to channel nutrient water from the container into the pipe.



Figure 10. DFT Hydroponics

Circuit The entire hardware circuit is in a box consisting of raspberry pi to control the entire system, mcp3008 serves to convert from analog data to digital, the relay functions to switch on or off, the temperature and humidity sensor DHT11 functions to detect temperature and air humidity, pH sensor and ultrasonic proximity sensor used to detect water levels in the pipe and on the reservoir.

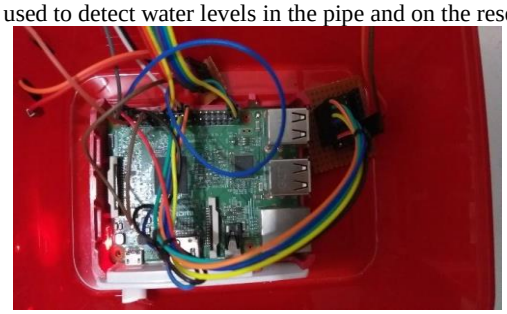


Figure 11. Sensor Series

C. Testing and Analysis

Testing of the water circulation control system is automatically carried out by comparing the growth results of mustard plants that use hydroponic water control manually and automatically. The following in tables 5.6 and 5.7 is a trial of planting hydroponic mustard manually or without using a water circulation control system and by using a water circulation control system or automatically using mustard plants aged 18 days after seedling.

Table 1. Growth of Mustard Without Water Circulation Control System.

No	18 Days		21 Days		25 Days		30 Days	
	D	T	D	T	D	T	D	T
1	11	18	13	20	15	22	18	24
2	10	14	11	18	13	20	15	22
3	10	17	12	19	13	20	15	22
4	10	15	11	17	12	19	14	21
5	10	16	12	18	13	20	15	22
6	11	16	12	17	14	20	16	23
7	10	14	12	16	13	19	16	22
8	10	17	11	18	14	20	16	23
9	12	15	13	19	15	21	17	22
10	12	18	14	20	16	22	18	25
11	10	15	11	17	13	18	15	20
12	9	16	11	18	13	21	14	24
13	9	14	11	16	12	18	14	20
14	10	17	12	19	14	20	16	22
R	**10.3**	**15.8**	**11.8**	**18**	**13.5**	**20**	**15.6**	**22.2**

Table 2. Growth of Mustard Using Water Circulation Control Systems.

No	18 Days		21 Days		25 Days		30 Days	
	D	T	D	T	D	T	D	T
1	11	16	14	19	16	22	18	24
2	11	17	14	20	15	23	17	24
3	10	15	12	19	14	22	17	23
4	10	17	14	22	16	24	18	25
5	11	16	13	19	14	22	16	24
6	11	17	14	21	16	23	18	25
7	11	15	14	19	15	23	18	24
8	10	17	12	19	14	22	16	24
9	9	16	13	19	15	21	17	23
10	10	17	13	20	15	23	19	25
11	9	15	13	18	15	21	18	23
12	10	17	13	20	14	23	16	24
13	11	16	13	19	14	22	16	24
14	10	15	13	18	14	21	16	23
R	**10.3**	**16**	**13.2**	**19.5**	**14.7**	**22.3**	**17.1**	**23.9**

Description:
D = Number of Leaf
T = Plant Height
R = Average

Table 3. Comparison of System Testing Results

Age	of Average Height of Mustard Plants		Average Number of Mustard Leaves	
	Manual	Automatic	Manual	Automatic
18 Days	15.8	16	10.3	10.3
21 Days	18	19.5	11.8	13.2
25 Day	20	22.3	13.5	14.7
27 Days	22.2	23.9	15.6	17.1Out

Analysis of trial results is obtained from after conducting a trial by comparing the growth results of hydroponic mustard plants using a tool from the water circulation control system and without using ala t of the water circulation control system. In the process of testing the temperature and humidity sensors placed in the area of the hydroponic pipe can detect the temperature and humidity in accordance with the predetermined. The results of the sensor data can control the circulation of water using a pump in hydroponics in accordance with a system that has been previously designed. Based on the data of plant growth from the results of existing tests, there are differences in the results of growth of mustard plants that are quite significant in the form of height and number of leaves that grow.

5. Conclusions

Based on the research that has been done by the author regarding monitoring and controlling the circulation of water in hydroponics mustard greens using raspberry pi, it can be concluded that:

- This study has succeeded in making a system used for monitoring and controlling hydroponic water circulation automati-

cally with fuzzy Sugeno through the website interface.
- This system is very suitable and runs well in Hydroponic Deep Flow Technic (DFT), because water circulation can run more effectively when certain conditions.

Based on the comparison of the results of observations on the growth of mustard plants in two conditions resulted in a significant difference in the results of high growth and number of leaves.

Acknowledgement

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