IMPLEMENTATION OF FUZZY LOGIC METHODS IN NUTRIENT CONTROL IN HYDROPONIC PLANTS

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ABSTRACT

Hydroponics is a farming technique using water media that contains nutrients that plants need to grow and develop, therefore we must be careful in maintaining the nutrient content that is usually stored in a reservoir. This is the main problem if we cannot maintain optimal nutritional conditions in the reservoir, plants that lack nutrients will affect their growth, otherwise, plants with excess nutrients will quickly rot and turn yellow. Therefore, we need a tool that can control the levels of hydroponic nutrients in the reservoir. We need a tool that can control the hydroponic nutrient reservoir based on a microcontroller in which fuzzy logic is embedded. Fuzzy logic itself consists of many rules that can regulate the output of the output pump which consists of a nutrition pump and a water pump, the output is in the form of a delay value which will be used to turn the relay on and off. As we know hydroponic farming requires patience and accuracy in managing the nutrient reservoir, with this tool we no longer need to worry about nutrition for plants because everything is fully controlled by a microcontroller, for further it is hoped that this tool that already contains fuzzy logic can work continuously to control nutrient levels in the reservoir.

Keywords: hydroponics, fuzzy, nutrition, reservoir, Arduino Uno

BACKGROUND

Hydroponics is a farming technique using water media that contains nutrients that plants need to grow and develop, therefore we must be careful in maintaining the nutrient content that is usually stored in a reservoir. This is the main problem if we cannot maintain optimal nutritional conditions in the reservoir, plants that lack nutrients will affect their growth, otherwise, plants with excess nutrients will quickly rot and turn yellow. Therefore, we need a tool that can control the levels of hydroponic nutrients in the reservoir.

We need a tool that can control the hydroponic nutrient reservoir based on a microcontroller in which fuzzy logic is embedded. Fuzzy logic itself consists of many rules that can regulate the output of the output pump which consists of a nutrition pump and a water pump, the output is in the form of a delay value which will be used to turn the relay on and off.

As we know hydroponic farming requires patience and accuracy in managing the nutrient reservoir, with this tool we no longer need to worry about nutrition for plants because everything is fully controlled by a microcontroller, for further it is hoped that this tool that already contains fuzzy logic can work continuously to control nutrient levels in the reservoir.

LITERATURE STUDY

This chapter describes the theories used as a reference in research. These theories are taken from various literature sources, journals, and the internet. Sotyohadi, and Wahyu Surya Dewa, and I Komang Somawirata [1] have stated Hydroponics is one of the agricultural methods that are often applied by modern farmers today. This method has a lot of advantages. Namely, it can be cultivated in a limited space and only requires growth media in the form of water with nutrients. However, one aspect that needs to be considered in hydroponics is plant nutrition. To improve the quality and growth of hydroponics plat, the nutrient content of PH and TDS should be in around PH 5.5 - 6.5 and TDS around 1050 - 1200 ppm. My research will focus on optimizing the volume of nutrients in the reservoir tank, where the volume of nutrients in the reservoir will not run out and its height will be maintained thanks to ultrasonic sensors that will monitor the level of nutrients in the nutrient tank. This will also be the difference between my research and existing research, where research that has not monitored the volume of nutrients from the nutrition tub, if the sensor reads the nutrient level is still within the appropriate range, the sensor will not work even though the nutrients are in the tank and almost runs out.

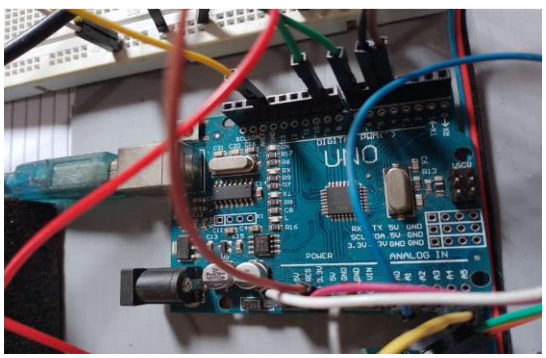

Figure 1. Arduino Uno

As a microcontroller, Arduino Uno will execute all program code that contains fuzzy Sugeno logic including fuzzification, rule base, and defuzzification. Arduino will also process the twelve pre-programmed rules and the last stage is defuzzification to find out the final value which will be used as a pump delay. Arduino will also control the relay used to activate or deactivate the nutrition pump and water pump based on the result of the defuzzification value. Arduino Uno itself can accept voltages ranging from 6-20 volts and issue a maximum voltage of 5 volts which is enough to activate 2 output pumps, besides that Arduino Uno has 16 pins that are used to regulate the input and output of the system.

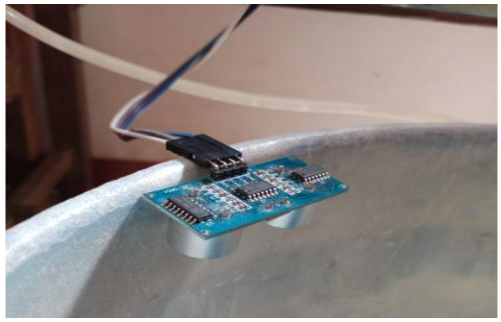

Figure 2. Ultrasonic sensor

Ultrasonic sensors are used to detect the water level in a hydroponic reservoir, this sensor uses reflected ultrasonic waves that are reflected in the object, namely water, and then the reflected waves are captured to further provide data to the microcontroller.

Figure 3. Relay

Relays are used to turn on or turn off the electric current that drives the nutrient pump and water pump. This study uses a single channel relay to facilitate the arrangement of the relay circuit, it also has a voltage of 5V relay to match the input voltage on the microcontroller.

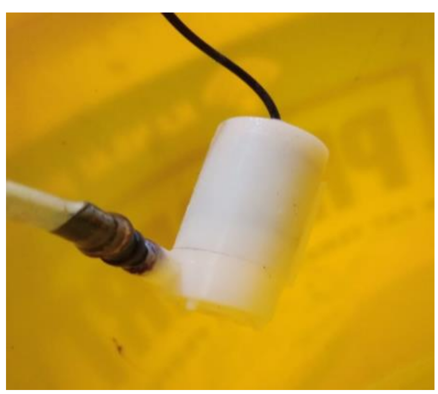

Figure 4. Mini water pump

The pump is used to suck the nutrient solution and water which will then be mixed automatically in the nutrient reservoir. The pump used has a voltage of 6 volts which is compatible with the Arduino Uno microcontroller.

FUZZY ALGORITHM

The algorithm used in this project is fuzzy with the Sugeno method, there are 3 main stages in the fuzzy algorithm, namely f*uzzification*, r*ule base*, and *defuzzification.* In *Picture 6* it is explained that the ultrasonic sensor and TDS sensor will enter the fuzzification process to determine the membership value of each input, then enter the rule base that has been formed so that the system runs properly and the last stage is defuzzification to find out the final value, this final value used as a delay on the relay then the relay works to turn off or turn on the pump according to the delay value that has been obtained.

Membership Water level variable

Variable water level consists of 3 sets including full, adequate, low. In full water conditions, a parameter range of less than 15 is given. Then insufficient water conditions, a range of 10 to 20 is given. Then in low water conditions, a range greater than 20 is given.

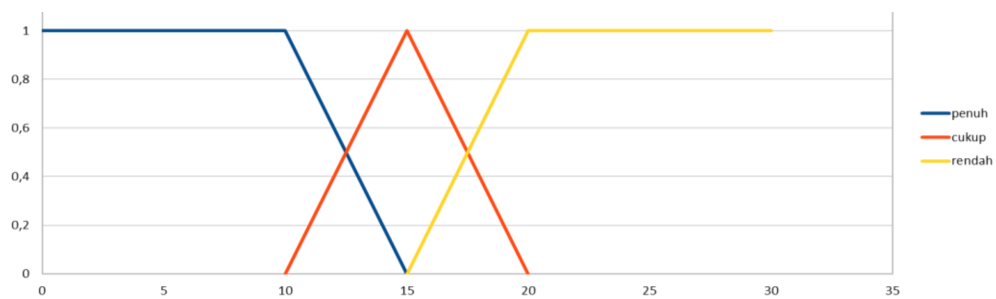

Figure 5. Fuzzyfication membership water level

$$penuh = \begin{cases} 1, x < 10 \\ \dfrac{15 - x}{15 - 10}, 10 \leq x \leq 15 \\ 0, x \geq 15 \end{cases}$$

$$cukup = \begin{cases} 0, x \leq 10 \\ \dfrac{x - 10}{15 - 10}. 10 \leq x \leq 15 \\ \dfrac{20 - x}{20 - 15}, 15 \leq x \leq 20 \\ 0, x \geq 20 \end{cases}$$

$$rendah = \begin{cases} 0, x \leq 15 \\ \dfrac{x-15}{20-15}, 15 \leq x \leq 20 \\ 1, x \geq 20 \end{cases}$$

Membership Nutrient Variable

The nutrition variable consists of 4 sets of which are very poor, lacking, normal, high. In conditions of very poor nutrition, a parameter range of less than 750 is given. Then in conditions of poor nutrition, a parameter range of 500 to 1050 is given. Then in conditions of normal nutrition, a parameter range of 750 to 1600 is given. Then in a state of high nutrition, a parameter range greater than 1600 is given.

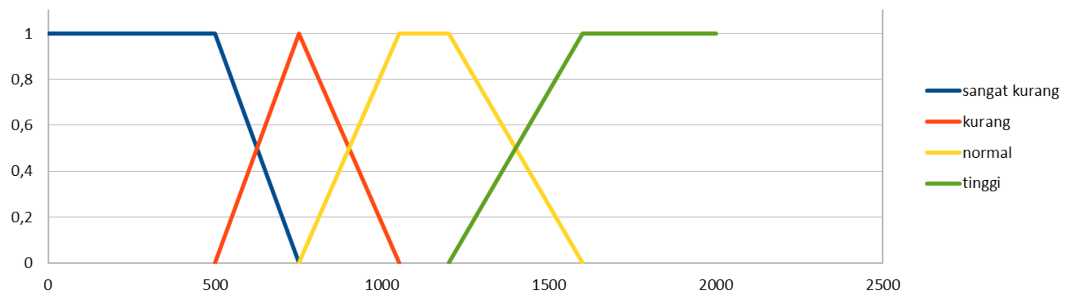

Figure 6. Fuzzyfication membership nutrition value

$$\text{sangat kurang} = \begin{cases} 1, x \leq 500 \\ \frac{750-x}{750-500}, 500 \leq x \leq 750 \\ 0, x \geq 750 \end{cases}$$

$$\text{kurang} = \begin{cases} 0, x \leq 500 \\ \frac{x-500}{750-500}, 500 \leq x \leq 750 \\ \frac{1050-x}{1050-750}, 750 \leq x \leq 1050 \\ 0, x \leq 750 \end{cases}$$

$$\text{normal} = \begin{cases} \frac{x-750}{1050-750}, 750 \le x \le 1050 \\ 1, 1050 \le x \le 1200 \\ \frac{1600-x}{1600-1200}, 1200 \le x \le 1500 \end{cases}$$

$$\text{tinggi} = \begin{cases} 0, x \le 1200 \\ \frac{x-1200}{1600-1200}, 1200 \le x \le 1600 \\ 1, x \ge 1600 \end{cases}$$

Membership Water Pump Duration

The duration of the water pump is divided into three, namely silent 0 seconds, fast 10 seconds, and long 20 seconds. The water pump will turn on when the water condition in the nutrient reservoir is low.

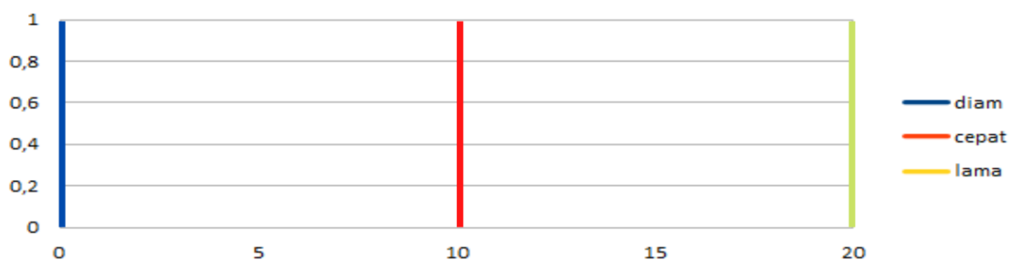

Figure 7. Fuzzyfication membership water pump duration

Membership Nutrient Pump Duration

The duration of the nutrient pump is divided into four, namely silent 0 seconds, fast 5 seconds, medium 10 seconds, long 15 seconds. The nutrient pump will turn on when the nutrients are at very low and low levels.

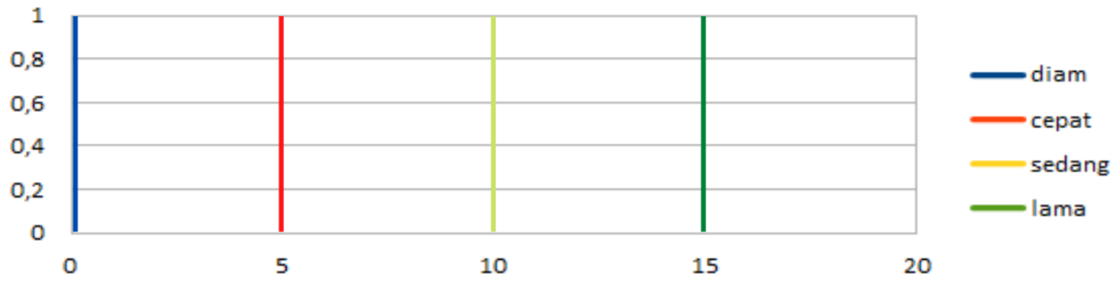

Figure 8. Fuzzyfication membership nutrition duration

Rule

Water / Nutrient	Sangat Kurang	Kurang	Normal	Tinggi
Penuh	Diam / cepat	Diam / diam	Diam / diam	Cepat / diam
Cukup	Cepat / lama	Cepat / sedang	Cepat / diam	Cepat / diam
Rendah	Lama / lama	Lama / sedang	Lama / diam	Lama / diam

At the rule base stage, the minimum value of the two rule parameters is searched for example in the first rule containing silence and long, the silent parameter contains a value of 0.8 and the old parameter contains a value of 0.2 then the value that will fill the first rule is 0.2. Through two sensor inputs and two outputs, 12 rules are formed which include :

1. If the water is *penuh* and the nutrients are *sangat kurang* then the water pump is *diam* and the nutrient pump is *cepat*.
2. If the water is *cukup* and the nutrients are *sangat kurang* then the water pump is *cepat* and the nutrition pump is *lama*.
3. If the water is *rendah* and the nutrients are *sangat kurang* then the water pump is *lama* and the nutrient pump is *lama*.
4. If the water is *penuh* and the nutrients are *kurang*, then the water pump is *diam* and the nutrient pump is *diam.*
5. If the water is *cukup* and the nutrients are *kurang* then the water pump is *cepat* and the nutrient pump is *sedang*.
6. If the water is *rendah* and the nutrients are *kurang* then the water pump is *lama* and the nutrient pump is *sedang*.

7. If the water is *penuh* and the nutrition is *normal* then the water pump is *diam* and the nutrient pump is *diam.*
8. If the water is *cukup* and the nutrition is *normal* then the water pump is *cepat* and the nutrient pump is *diam.*
9. If the water is *rendah* and the nutrition is *normal* then the water pump is *lama* and the nutrient pump is *diam.*
10. If the water is *penuh* and the nutrient is *tinggi* then the water pump is *cepat* and the nutrient pump is *diam.*
11. If the water is *cukup* and the nutrient is *tinggi* then the water pump is *cepat* and the nutrient pump is *diam.*
12. If water is *rendah* and nutrients are *tinggi* then the water pump is *lama* and the nutrient pump is *diam.*

DEFUZZIFICATION

The last stage is defuzzification, which is changing the output fuzzy set into crisp output. The method in this calculation is the Sugeno or Weight Average (WA). Defuzzification is carried out twice, namely first to determine the value of defuzzification in nutrients and then to determine the value of defuzzification in water. This defuzzification value will be used as a delay to start the pump. The formula for defuzzification of the Sugeno model is as follows.

$$output = \frac{(a1*z1)+(a2*z2)+(a3*z3)+\ldots\ldots(an*zn)}{a1+a2+a3\ldots\ldots an}$$

a_n = Rule value to ...n

z_n = Output value to ...n

RESULT AND TESTING

At this stage, testing is carried out with the initial nutrient conditions of 777.88 ppm and the height of the water is 19.33 cm. The microcontroller will work according to the fuzzy logic that has been implemented into it. To determine the pump delay is done with the following logic

- Output Nutrient pump:

if (hasil_defu >= 0.00 && hasil_defu < 5.00) = Pompa off

if (hasil_defu >= 5.00 && hasil_defu < 10.00) = Pompa cepat

if (hasil_defu >= 10.00 && hasil_defu < 15.00) = Pompa sedang

if (hasil_defu >= 15.00) = Pompa lama

- Output Water pump:

if (hasil_defu_air >= 0.00 && hasil_defu_air <10) = Pompa off

if (hasil_defu_air >= 10.00 && hasil_defu_air <20.00) = Pompa cepat

if (hasil_defu_air >= 20.00) = Pompa Lama

From Table 2 it can be seen that the movement of nutrients and water level to the optimal condition is where the value of defuzzification of water and nutrients is off. based on data from where the initial condition is the nutrition of 777.88 ppm and the height of the nutrient reservoir is 19.23 cm it takes 7 minutes 18 seconds to reach the optimal condition in the table with code *. In other words, the designed tool can work according to the ordered program to mix nutrients with water properly.

Tabel 1. Tabel Testing

Time	Nutrient	Water Level	Nutrient Pump	Water Pump
20:13:25	777.88 ppm	19.33 cm	8.43	17.85
20:14:52	793.26 ppm	18.59 cm	7.29	16.14
20:15:10	805.76 ppm	18.28 cm	6.87	15.74
20:15:34	818.45 ppm	18.04 cm	6.87	15.34
20:15:48	818.45 ppm	17.75 cm	6.67	15.08
20:16:11	824.86 ppm	17.56 cm	6.31	14.71
20:16:37	837.82 ppm	17.27 cm	6.97	14.92
20:17:00	815.26 ppm	17.44 cm	7.18	13.43
20:17:22	808.92 ppm	16.41 cm	6.97	14.25
20:18:44	815.26 ppm	16.00 cm	6.72	12.48
20:18:55	831.31 ppm	15.82 cm	6.94	11.89
20:19:10	828.08 ppm	15.58 cm	7.15	9.86*

Time	Nutrient	Water Level	Nutrient Pump	Water Pump
20:19:51	841.09 ppm	15.33 cm	6.99	10.40
20:20:10	837.82 ppm	15.10 cm	6.69	9.67*
20:20:33	847.66 ppm	14.91 cm	7.12	9.24*
20:20:35	963.83 ppm	14.73 cm	3.08*	9.01*
20:20:38	1159.05 ppm	14.30 cm	0.00*	8.59*
20:20:39	1205.00 ppm	14.67 cm	0.00*	8.49*
20:20:40	1195.99 ppm	14.24 cm	0.00*	9.36*
20:20:41	1205.00 ppm	14.67 cm	0.00*	9.39*
20:20:42	1214.06 ppm	14.67 cm	0.00*	9.41*
20:20:43	1223.18 ppm	14.67 cm	0.00*	9.41*

Furthermore, testing is carried out on a nutrient condition of 122.10 PPM (very low) and a water level of 14.30 cm (full), this test will prove that the nutrient pump will still turn off even though the nutrients in the reservoir are not optimal. This is done so that the water in the reservoir is not full and overflows everywhere which causes wastage of nutrients. The data can be seen in the following table

Tabel 2. Tabel Testing

Time	Nutrient	Water Level	Nutrient Pump	Water Pump
15:37:10	122.10 ppm	14.30 cm	13.32	8.32*
15:37:27	122.10 ppm	14.16 cm	12.64	7.64*
15:37:43	199.52 ppm	13.82 cm	11.93	6.93*
15:37:58	280.68 ppm	13.46 cm	12.03	7.03*
15:38:13	331.97 ppm	13.52 cm	12.17	7.17*
15:38:29	393.94 ppm	13.58 cm	12.61	7.61*
15:38:44	446.10 ppm	13.80 cm	10.98	5.98*
15:38:59	478.19 ppm	12.99 cm	8.44	3.75*
15:39:21	557.52 ppm	11.85 cm	7.82	4.60*
15:39:32	568.81 ppm	12.19 cm	5.92	2.96*
15:39:41	592.03 ppm	11.05 cm	6.06	3.34*
15:39:50	608.80 ppm	11.25 cm	5.41	2.89*
15:39:59	623.53 ppm	11.02 cm	4.19*	1.91*

In table 3, it can be concluded that the nutrient pump will continue to stop if the water in the reservoir is full in the table with code *, in the data the nutrient pump stops at a value of 633.53 PPM or the nutrients are in the less category, this is because the distance of the water in the nutrient reservoir is full or close. Which is less than 10 cm from the ultrasonic sensor.

CONCLUSION

The following conclusion can be derived from the Implementation of Fuzzy Logic Methods in nutrient Control in Hydroponic Plants is.

1. TDS sensor can detect the ppm value in nutrient water quite accurately and the ultrasonic sensor can detect the water level in the reservoir very well.
2. Fuzzy logic can be implemented on a micro-controller with several stages such as determining the membership of each input which will then enter the Fuzzyfication process, then the Rulebase stage or the stage of comparing the two inputs to take the minimum value, and the final stage is the Defuzzyfication of the Sugeno model to take the final value. which is used as a delay to set the pump.
3. From the data in the testing table, it can be concluded that the system can run continuously as expected. The tool is made using a pump through a relay by controlling nutrients to the optimal point (777.33 ppm to 1050 ppm) with a time of 7 minutes 16 seconds and the water level (19.23 cm to 15 cm) with a time of 3 minutes 14 seconds. The two pumps will also stop when the water condition in the reservoir is full, to prevent water from overflowing everywhere.

Suggestions for further research are to add a WiFi module so that the device can be controlled remotely with real-time data and can be implemented into mobile applications and the last one uses a better TDS sensor to get more accurate data.

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