Design of Fertigation Control System based on Fuzzy Logic Algorithm

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ABSTRACT: Over the years, agricultural production is increasing gradually in Malaysia. However, the major problem faced in many agricultural sectors is the lack of mechanization involved which results in low production of crop yield due to the traditional method is not sufficient to monitor the plants' condition. This fertigation control system is developed based on a fuzzy logic controller that aims to accurately deliver certain amounts of water and fertilizer to the chili plants. The inputs to the system are pH value and soil moisture level, and the outputs are the water and fertiliser pumps. The fuzzy logic controller is built on MATLAB software and the fuzzy rules designed in MATLAB are programmed in the Arduino microcontroller to regulate the amount of water and fertiliser for the plant. Real-time implementation of this system is conducted on a chili plant where the growth of the plant with fuzzy logic controller has better growth in terms of the height of the plant, the diameter of stems, and the number of fruits compared to the chili plant with a traditional method. In terms of water and fertiliser usages, the fertigation system with fuzzy logic uses less water and fertiliser.

Keywords: *Fertigation control system; Fuzzy logic algorithm; chili plant*

1. INTRODUCTION

Agriculture is the largest economic sector and it plays an important role in the economic growth of the world [1]. It provides humans with different resources such as food, medicine, fiber, and energy for the current and future generations [2]. Fertigation is the process of delivering water and fertilizer in the agricultural field. Due to water wasting during watering and over-fertilisation during fertilising in the traditional method, the production of crop yield is low. Besides, those excessive fertilisers are carried by the rainwater into lakes and rivers. This phenomenon will result in a negative impact on downstream water quality and causes water pollution. To produce crops with minimum use of natural resources, advancement in fertigation system involved a fuzzy logic controller to determine the accurate amount of water and fertiliser for a plant.

2. TARGET SPECTRUM

This project aims to design the fuzzy logic controller for the automatic fertigation system to control the irrigation and fertilisation of chili plants. Next, to conduct a real-time implementation of the experiment to analyze the water and fertilizer usages between fuzzy logic controller method and traditional method. This project focus in home and small-scale farming for chilies plant where both chilies plant are put under open shelter. The two chili plants used are 16-weeks old. Arduino Mega 2560 is used as a microcontroller to set up the configuration of the system. Soil moisture level and pH value as the soil parameters to be measured while the output components of this system are the water pump and the fertilizer pump. The pumps were triggered based on the designed fuzzy rules. The simulation of the fuzzy logic system is done using MATLAB software and SIMULINK.

3. METHODOLOGY

The fuzzy logic algoritm was designed in MATLAB software. Tables (1-2) show the fuzzy if-then rules designed for the inputs, pH value and soil moisture with water pump output and fertilizer pump output.

Table 1 Input pH and soil moisture with water pump output

Soil moisture (%) \ pH	Acidic (1-5)	Neutral (5.01-9)	Alkaline (9.01-14)
Low (0-35)	On 6s	On 6s	On 6s
Medium (35.1-70)	On 3s	Off	On 3s
High (70.1-100)	Off	Off	Off

The water pump time was in "On 6s" when the soil moisture is 0-35% (low) for all pH values of soil. When the pH value of soil was acid and soil moisture is in the range of 35.1% to 70%, the water pump was "On 3s". If the input of soil moisture is high (70.1% to 100%), the output water pump time will be "Off" for all pH values. When the soil is alkaline for a medium moist of soil, the water pump is "On 3s". Moreover, if the input of pH value is 5.01 until 9 and soil moisture is medium (35.1-70%), the output watering amount is "Off". The fertiliser pump time is "On 3s" when the pH value of soil is acidic (pH 1-5) and soil moisture is in range of low and medium (0-70%). Other than that, the fertilizer pump is "Off".

Table 2 Input pH and soil moisture with fertilizer pump output

Soil moisture (%) \ pH	Acidic (1-5)	Neutral (5.01-9)	Alkaline (9.01-14)
Low (0-35)	On 3s	Off	Off
Medium (35.1-70)	On 3s	Off	Off
High (70.1-100)	Off	Off	Off

4. RESULT AND DISCUSSIONS

The Simulink model for the fuzzy logic controller was built as shown in Figure 1.

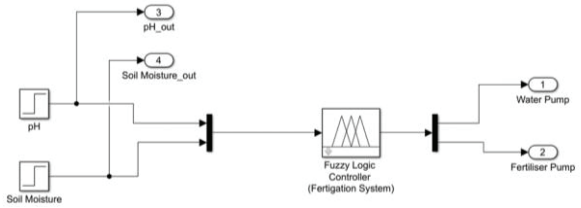

Figure 1 Simulink diagram of fuzzy logic controller

Simulation using MATLAB software was used to test the output's performance according to the membership that has been constructed. As an example, a pH value of 4.01 and a soil moisture of 27.7 are inserted into the system to observe the resulted output.

Figure 2 Example of input-output of fuzzy algorithm

Figure 2 proves the result was accurate simulated as the fuzzy logic system constructed in Tables 1-2.

The data collection period is 30 days. The growth of plants and water and fertilizer usages are recorded every 3 days. Plant A is manual fertigation, the watering time is at 9.00 a.m. and 5.00 p.m. with 200 ml every time, and it is fertilized every 2 weeks with 100 ml fertilizer. The fertigation of plant B is implemented by the automatic system. The fertigation frequency is twice a day and same fertigation time as Plant A. 500 ml of water and 500 ml of fertiliser are filled in two different containers with label of measurement of 1000 ml. Then, the water and fertiliser usage after the fertigation are recorded.

Table 3 Data collection of both chili plants

Data collection	Height of plants (cm)		Average diameter of stems (cm)		Number of fruits	
Date	A	B	A	B	A	B
20/5/2021	34.5	37	1.875	2	4	5
23/5/2021	36.3	39.7	1.9	2.05	7	8
26/5/2021	38.8	43.6	1.95	2.075	9	11
29/5/2021	43	48.5	2	2.15	11	13
1/6/2021	45.6	51	2.025	2.225	14	15
4/6/2021	48	55	2.15	2.25	16	18
7/6/2021	48.4	55.3	2.375	2.725	20	23
10/6/2021	48.7	55.8	2.75	3.2	25	24
13/6/2021	48.9	56.6	3.325	3.55	28	27
16/6/2021	49.4	57.6	3.5	3.825	29	31
18/6/2021	50.6	58.3	3.625	3.875	29	34

Based on Table 3, the plant B has better growth compare to the plant A. Plant B which is managed by fuzzy logic controller is 5.2cm higher, 0.125 cm larger in diameter and has extra 4 chilies than Plant A.

Table 4 Total water and fertilizer usage

Total usage (ml)	Plant A	Plant B
Water usage	4400	3600
Fertilizer usage	300	200

The percentages of water and fertiliser saving for fertigation using fuzzy logic, calculated based on Table 4, are 18.2% and 33.3%, respectively.

5. CONCLUSION

The objectives in this project were successfully achieved. The setup of plant's automatic fertigation system is proposed. The fuzzy rules were designed in MATLAB are programmed in the Arduino. From the results, it shows that the plant B with fuzzy logic controller gives better results in terms of water and fertilizer usages and plant's growth compared to plant A.

ACKNOWLEDGEMENT

Authors are grateful to Universiti Teknikal Malaysia Melaka for this research.

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