DESIGN OF FERTIGATION CONTROL SYSTEM BASED ON FUZZY LOGIC ALGORITHM

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DESIGN OF FERTIGATION CONTROL SYSTEM BASED ON FUZZY LOGIC ALGORITHM

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A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "DESIGN OF FERTIGATION CONTROL SYSTEM BASED ON FUZZY LOGIC ALGORITHM is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : LAI NGIT SIEW

Date : 5 July 2021

APPROVAL

I hereby declare that I have checked this report entitled “DESIGN OF FERTIGATION CONTROL SYSTEM BASED ON FUZZY LOGIC ALGORITHM” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

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Date : 5 July 2021

DEDICATIONS

To my beloved parent, Lai Thiam Choi and Foo Yoke Yoon, your love and support are the greatest inspiration upon accomplish this project.

To my dear friends for all the motivation along this project.

To my dearest supervisors, Dr. Ainain Nur Binti Hanafi for being responsible, supportive and helpful throughout this project.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest appreciation to my main project supervisor, Dr. Ainain Nur Binti Hanafi for the useful comments, guidance and encouragement throughout this project. I would not have gone this far without her advices, motivation and support in every way. I am truly grateful she has spent her precious time in guiding me upon accomplish my final year project.

Furthermore, I would like to thank my family especially my beloved parents, Lai Thiam Choi and Foo Yoke Yoon for their love, sincere support and care they have given to me all through my study journey.

Last but not least, an honorable mention goes to my lovely friends and course mates who helped and supported me both practically and mentally along completing this project.

ABSTRACT

Fertigation control system is developed based on fuzzy logic controller that aims to perform high efficiency of water and fertiliser usage in fertigation process in agricultural field to ensure adequate moisture and nutrients are delivered to the crops. The main objective of the system is to accurately deliver the certain amounts of water and fertiliser to the chili plants. The parameter readings of agricultural including pH value and soil moisture level are measured as inputs. The outputs for the system is the water pump and the fertiliser pump. Fuzzy logic is implemented as the controller in this system to control the water and fertiliser amounts to soil in order to maintain the moisture level and pH value of soil. 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. Simulink model of the fertigation system control system is constructed to observe the output's performance. Flowchart is used to present the working principle of the control algorithm in this system. Real time implementation of this system is conducted on a chili plant where the growth of plant with Fuzzy logic controller has better growth in terms of the height of plant, the diameter of stems and the number of fruits compared to the chili plant with traditional method. In terms of water and fertiliser usages, the fertigation system with Fuzzy Logic uses less resources than the traditional method.

ABSTRAK

Sistem kawalan fertigasi ini dibangunkan berdasarkan pengawal logik kabur bagi memastikan penggunaan air dan baja secara efisien dalam proses fertigasi di bidang pertanian. Ini untuk memastikan kelembapan dan nutrien yang mencukupi dibekalkan ke tanaman. Objektif utama sistem ini adalah memberikan sejumlah air dan baja ke tanaman cili dengan tepat. Bacaan parameter yang dikenalpasti adalah nilai pH dan tahap kelembapan tanah sebagai input kepada sistem ini. Keluaran untuk sistem ini adalah pam air dan pam baja. Logik kabur dilaksanakan sebagai pengawal dalam sistem ini untuk mengendalikan jumlah air dan jumlah baja ke tanah untuk mengekalkan tahap kelembapan dan nilai pH yang sesuai untuk tanaman. Pengawal logik kabur dibuat menggunakan perisian MATLAB dan peraturan kabur yang dirancang dalam MATLAB diprogramkan ke dalam mikropengawal Arduino untuk mengendalikan jumlah air dan baja yang disalurkan ke tumbuhan. Model Simulink sistem fertigasi automatik digunakan untuk menguji prestasi output bergantung pada keahlian yang telah dibina. Carta aliran digunakan untuk membentangkan prinsip kerja algoritma kawalan dalam sistem ini. Pelaksanaan masa nyata dilakukan pada tanaman cili di mana tanaman dengan pengawal logik Fuzzy mempunyai pertumbuhan yang lebih baik dari segi ketinggian tanaman, diameter batang dan jumlah buah berbanding dengan tanaman cili yang menggunakan kaedah tradisional. Penggunaan air dan baja bagi sistem fertigasi logik kabur adalah lebih sedikit berbanding kaedah tradisional.

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	-	Artificial Intelligent
PID	-	Proportional-Integral-Derivative
pH	-	Potential of Hydrogen
IR	-	Industrial Revolution
AR	-	Agricultural Revolution
MATLAB	-	Matrix Laboratory
FYP	-	Final Year Project
VCC	-	Voltage Common Collector
GND	-	Ground
FIS	-	Fuzzy Inference System

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is the largest economic sector and it plays an important role in the economic growth of the world (Chetan Dwarkani M, et al., 2015). It has been one of the most significant sector since it provides humans with different resources such as food, medicine, fiber and energy for the current and future generations (Minwoo Ryu, et al.). However, the major problem faced in many agricultural sectors is the lack of mechanization involved in agricultural activities. Majority of farmers are the elderly and they are less educated to adopt new technology in agriculture. This will result in low production of plant and fruit yield. According to Junjin Ruan, et al. (2015), in the developed country, crucial technology of precision agriculture is the intelligent control of both irrigation and fertilisation. Therefore, design of fertigation control system in agriculture based on artificial intelligence must be emphasized in order to produce crops with minimum use of natural resources such as water and fertiliser. Besides, crops yield could be increased with less environmental effects.

Fertigation is the process of delivering fertilised water in the agricultural field. In the 11th Malaysian Plan (2016-2020), the agricultural sector has to be transformed and modernized to ensure food security, increase productivity, improve skillsets of farmers and enhancing agro-food supply chain (Ahmad, S. B. & Badril Hashim, A. B., 2019). Nowadays, artificial intelligent (AI) algorithm such as fuzzy logic and neural network have been introduced as intelligent control for fertigation system instead of using timer-based system and Proportional-Integral-Derivative (PID) based controller. The reason of using this novel is to increase growth efficiency through process automation. By using smart devices such as Arduino Mega and few other sensors to detect pH value, soil moisture level, humidity and temperature, farmers can automate various processes across the production cycle of plants, for example irrigation, fertilisation and even pest control.

1.2 Motivation

According to the Malaysian Productivity Corporation (MPC) in its 26th Productivity Report 2018, the productivity growth in Malaysia is low and the growth level was reported to be stagnant in 2017 and then went through a significant decline in 2018.

Table 1.1: Growth of Labour Productivity, 2016 - 2018

	Growth (%)		
	2016	2017	2018
Productivity	3.1	3.7	2.2

(Source: Department of Statistics, Malaysia)

Agriculture only contributed 7.3% of Malaysia 2018 Gross Domestic Product (GDP), which is the fourth largest contributor to GDP among 5 main sectors namely services, manufacturing, construction, agriculture and mining and quarrying.

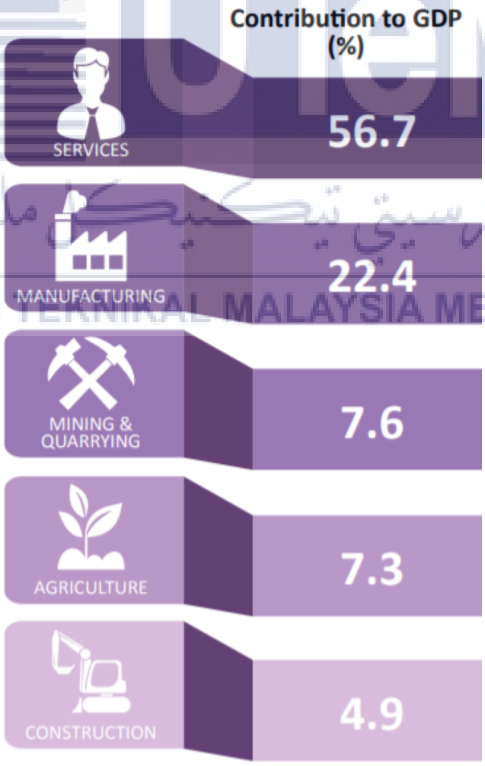

Figure 1.1: Performance of the Main Economic Sectors, 2018

(Source: Department of Statistics, Malaysia)

Hence, as one of the strategies to boost the growth capacity, equipment efficiency and reduction of underutilization of resources include water and fertiliser, the government has launched the Policy of the Industry Revolution (IR 4.0) in 2018 and Agriculture 4.0 is introduced. (Rozhan, A. D. & Mohammad, F. T., 2020). AI is one of the pillars in IR 4.0 and it can be applied in AR 4.0, which it analyzes the data from sensors and device to make decision on the amount of water and fertiliser for each plant by activating the pump and valve.

In addition, the importance to control the concentration of fertiliser and pH of soil is to avoid the growth of plant being affected and prevent environment from pollution. This happens when fertilisers are not fully utilized by the growing plants, those excessive fertilisers can be lost from the farm fields carries by the rain water into lakes and rivers. This phenomenon will result in the negative impact on downstream water quality and causes water pollution.

Over the years, the agricultural and forestry productions are increasing gradually among every country as well as in Malaysia. As the population increases, the demand for food rises as well. Department of Agriculture of Malaysia had published that the data of agricultural and forestry production from 2017 through 2019. As shown in Table 1.2, in 2017, the total number of agricultural production in Malaysia is about 30.3 million tonnes while in 2019, Malaysia has a total agricultural production of 30.6 million tonnes. This shows that the growth of production of crops is increasing in the duration of merely 3 years. In addition, Malaysia currently has high contribution to palm oil production and export in the world which is 39% and 44%, respectively (Ahmad Safwan, A. B., Zareen, Z., 2019).

Table 1.2: Agricultural and forestry production, 2017-2019

Types of Plant		Production in '('000) Mt - Tonnes		
		2017	2018	2019
Natural rubber	Estate	49.3	55.5	61.2
	Small holding	690.8	547.8	578.6
	Total	**740.1**	**603.3**	**639.8**
Crude palm oil		19919.3	19516.1	19858.4
Palm kernel		4951.0	4859.4	4892.0
Cocoa beans		1.0	0.8	1.0

Coconut oil (crude and refined)	50.5	69.1	83.4
Paddy	2570.5	2639.2	2912.2
Rice	1656.3	1700.2	1876.9
Pepper (black pepper and white pepper)	30.4	32.3	33.9
Pineapple	340.7	322.6	302.4
Tea (green leaves)	10.4	10.8	6.6
Total in production	**30270.2**	**29753.8**	**30606.6**

(Source: Department of Agriculture of Malaysia, 2017-2019)

With the raise of irrigated cropland, the demand for irrigation water will definitely increase in the same time. According to Rosegrant and Cai (2002), the total water demand for irrigation purpose will be increased by 13.6% by 2025.

As reported by Department of Agriculture of Malaysia, the planted area for main crops in Malaysia exceeded 7.8 million hectares in 2019, it shows increment of 0.2 million hectares compared to 2017. These statistics show the water demand for irrigation is also increase simultaneously as well as the requirement of fertiliser for fertilisation process.

Table 1.3: Planted area for main crops, 2017-2019

Main crops		Production in '('000 Ha) - Hectare		
		2017	2018	2019
Rubber	Estate	75.1	73.5	95.4
	Small holding	1006.6	1011.5	1107.4
	Total	**1081.7**	**1085.0**	**1202.8**
Oil Palm	Estate	4831.4	4869.4	4913.8
	Small holding	979.8	979.9	986.3
	Total	**5811.1**	**5849.3**	**5900.2**
Cocoa	Estate	0.9	0.9	0.9
	Small holding	16.6	14.8	14.8
	Total	**17.5**	**15.7**	**15.7**
Paddy		685.5	700.0	684.4
Pepper		17.1	7.2	7.3
Pineapple		12.9	13.6	12.8
Tea		2.3	2.3	1.6
Total in production		**7628.1**	**7673.1**	**7824.8**

(Source: Department of Agriculture of Malaysia, 2017-2019)

In fact, some of the problems that arise from rapid growth of agricultural and extension of irrigation area which are low efficiency of irrigation and water wastage. From the Figure 1.2 below, the efficiency of irrigation is very low, which only 65% of the water is used by the crops and other water is lost. (Chartzoulakisa, K. & Bertaki, M., 2015).

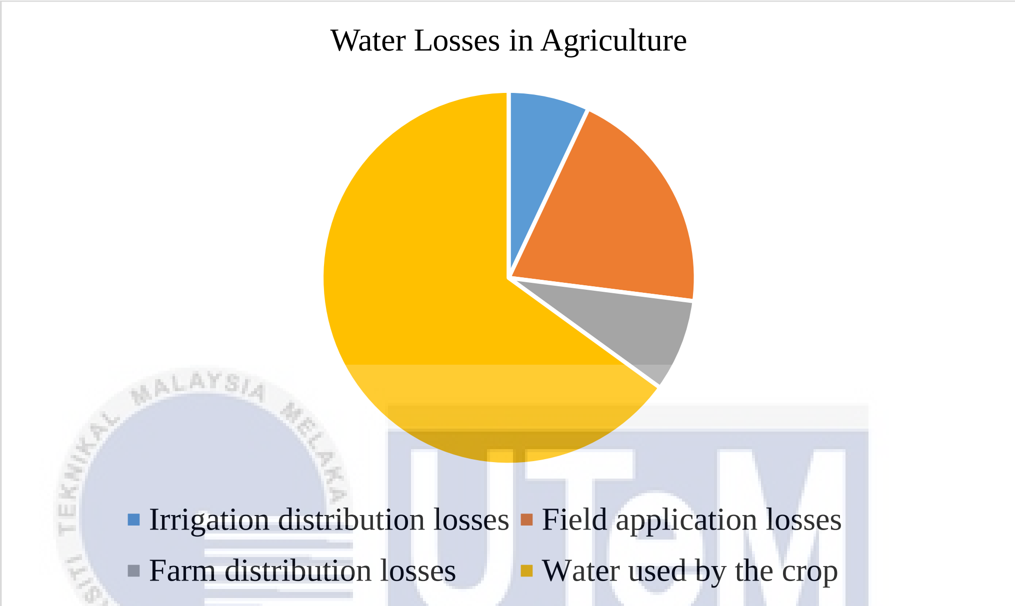

Figure 1.2: Water Losses in Agriculture

(Source: Agriculture and Agricultural Science Procedia 4 (2015) 88 – 98)

There is water wasting during watering and over-fertilisation during fertilising. Errors in irrigation scheduling causes either water is wasted or crop yield is reduced (M. H. Pham, et al., 2013). Besides, Md. Azizul Bari et al., 2015 has done the research on the water consumption patterns in Kuala Lumpur, Malaysia. There is a total of 197 households were surveyed in and the water consumption for gardening is 21.1 litres per capita day with a standard deviation of 23.1.

Emmanuel A. A. et al., 2020 have stated that the demand for freshwater is increasing due to the growth in population in addition present the effect of global warming and climate change which to threaten the clean water use and food security. In the aftermath of these threats, many farmers all over the world are demanding a very high amount of water consumption from various source in the irrigation systems. Therefore, in order to minimize the waste of supplies and improve the efficiency of water usage in fertigation agriculture, implementing a control algorithm for fertigation system by considering weather, moisture and pH of the soil in Malaysia is tremendously important since it is an effective solution to water and fertiliser wastage.

1.3 Problem Statement

The first problem statement of this study is each sensor such as analog pH sensor kit and soil moisture sensor is needed for each plant respectively, where bigger field costs higher expenses. Hence, the limitation of scope in this study is home and small-scaling farming.

Next problem is there are water wasting during watering and over-fertilisation during fertilising in the timer-based method or conventional method. To overcome this, an involvement of intelligent algorithm as fertigation control is playing a crucial role in controlling the fertigation system in order to decide the amount of water and fertiliser for each plant.

The major problem faced in many agricultural sectors is the lack of mechanization involved in agricultural activities. Majority of farmers are the elderly and they are less educated to adopt new technology in agriculture. This will result in low production of crop yield due to the traditional method is not sufficient to monitor the plants' condition.

1.4 Objectives

1. To develop an automated fertigation system using microcontroller system.
2. To design the fuzzy logic controller for the fertigation system.
3. To analyse the water and fertiliser usages by comparing traditional method with fuzzy logic controller method.

1.5 Scope

1. Focus in home and small-scale farming for chilies plant where both chilies plant are put under open shelter in this project.
2. The data collection period of plants' growth is within 30 days.
3. Arduino Mega 2560 used as microcontroller to setup the configuration of the system.
4. Fuzzy logic controller is chosen in the fertigation control system.
5. The simulation of fuzzy logic system is done using MATLAB software and Simulink.
6. Soil moisture level and pH value as the soil parameters to be measured for fertigation purpose.
7. The output components of this system are the water pump and the fertiliser pump.