Development of Automatic Plant Irrigation System using Soil Moisture Sensors for Precision Agriculture of Chili

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Development of Automatic Plant Irrigation System using Soil Moisture Sensors for Precision Agriculture of Chili

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***Abstract*— In agriculture, water management is crucial to reduce the amount of water used for irrigation. This study aims to develop an automatic plant irrigation system to be implemented in the Greenhouse of the Department of Computer Science, IPB University. The system is made of solenoid valves and soil moisture sensors whose amount is adjusted to the number of plants. This automatic plant irrigation system was created to support the development of smart and precision farming in Indonesia. Irrigation is done automatically and precisely for each plant by using a solenoid valve and a relay. The system prototype has been tested with different soil moisture values. Experiment results show that the prototype has successfully read the soil moisture value and can do the irrigation properly according to the specified functional requirements.**

Keywords—agriculture, chili, smart farming, precision farming, automatic irrigation, soil moisture.

I. INTRODUCTION

Water is a necessity of life that is very important for the lives of humans and other living things. However, pure water is one of the many limited resources that will become scarce in the near future [1, 2, 3]. Therefore, water usage shall be managed properly, as to maximizing the use of water and minimizing the wastage of water [4]. In agriculture, water management is required to save the amount of water used for irrigation.

In Indonesia, chili is an important vegetable commodity and has a high economic value [5]. Cayenne pepper is a type of chili whose fruit is used for various food purposes. It is a type of plant that requires the right amount of water to ensure its crop quality. Because of its importance, this study focuses on cayenne pepper plants (Capsicum frutescens L) which belong to the family of Solanaceae [6]. These plants are classified as annual plants or short-lived plants that grow as shrubs, with plant height reaching 1.5 meters.

The use of drip irrigation will significantly help the cultivation of chili plants. Some works using drip irrigation for agricultural plantations have been reported before, such as the use of drip irrigation for tomatoes [7], cotton [8], and bell pepper [9]. It is reported that sufficient scheduling in drip irrigation will increase productivity and save water usage [10]. Soil sensing may be a good option for irrigation scheduling as reported in [11]. In this case, several homogeneous plants can be represented by one soil sensor. This may be beneficial in terms of economic value, but may also be unable to represent multiple pots accurately due to its lack of knowledge of the many different variations of each pot.

This work focuses on the use of drip irrigation for potted chili plants by using one soil moisture sensor and one solenoid valve for each pot, so that the irrigation for each pot can run well according to the water required by each plant. The developed automatic plant irrigation system is implemented in the Greenhouse of the Computer Science Department, FMIPA, IPB University.

The work is described in this paper with the following structure. Chapter I introduces the background and contribution of this work. Chapter II emphasizes the problem statement and the corresponding system requirements. Then, Chapter III explains the system design and development according to the predetermined system requirements. Chapter IV explains the experimental testing and justification of the system in a real greenhouse environment. The overall conclusion of this work is given in Chapter V.

II. PROBLEM STATEMENT AND SYSTEM REQUIREMENTS

Conventional irrigation system may result in an excess or lack of water. It is difficult to guarantee the adequacy of plant water at all times, because farmers must repeatedly monitor their plants. Therefore, an automation system for plant irrigation is needed to control the water intake of cayenne pepper plants, the control of which is done based on the optimal soil moisture value for cayenne pepper plants. Based on the report from [12], the ideal soil moisture value for cayenne pepper plants is between 60%-80%.

The developed automatic irrigation system is expected to be able to control the water intake of chili plants based on the condition of soil moisture in each pot. The system will give water to each plant by using the concept of drip irrigation. The watering process occurs when the soil, which is used as the planting medium for the plant, has a soil moisture value of less than 60%. The designed system is expected to keep the soil moisture value between 60%-80%, following the needs of cayenne pepper plants.

To restrict the problem, the scope of this work is defined as follows:

1. The developed system is only applicable to cayenne pepper plants.
2. The developed system only utilizes one type of sensor: the soil moisture sensor, and one type of actuator: the solenoid valve.
3. The utilized microcontroller is the Arduino Mega. Due to the limitations of numbers of analog pins on Arduino Mega, the maximum number of pots that can be covered by one instrument is only 16 pots.

III. System Design and Development

The design of the automatic plant irrigation electronic components is shown in a block diagram in Fig. 1. Each instrument of the system has a microcontroller, 16 solenoid valves, 16 soil moisture sensors, and four 4-channel relays as ON / OFF switches. The instrument requires AC current to supply the 16 solenoid valves, and DC current from 12 V adaptor to supply power to the Arduino Mega 2560 microcontroller and relays. One UBEC regulator is utilized to divide the current for the microcontroller and the relays. UBEC regulator is used as a substitute for IC regulators because IC regulators can only produce a maximum current of 1 Ampere. Meanwhile, this instrument has to give sufficient current to the relays that are higher than 1 Ampere in total.

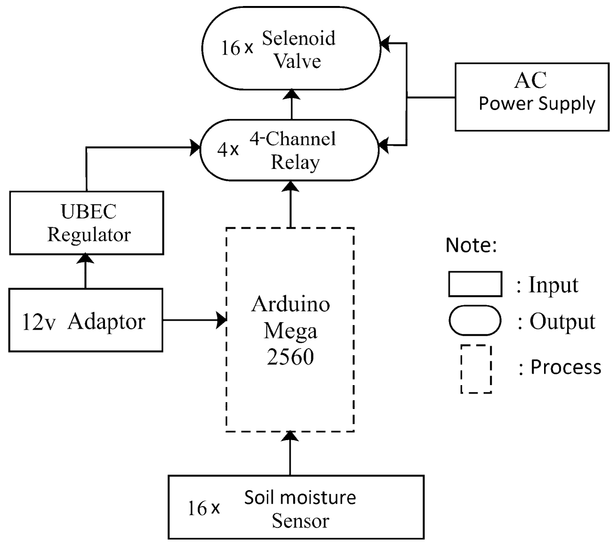


Fig. 1. Automatic plant irrigation system: block diagram of the electronic components for one instrument

The functional principle of the developed instrument is described in a flowchart as shown in Fig. 2. First, the soil moisture value is obtained from the YL-69 sensor. If the value is less than or equal to 60%, the microcontroller will order the relay to send current to the solenoid valve so that it is turned ON (watering the plant). On the other hand, when the soil moisture value is more than 60%, the microcontroller will order the relay not to send current to the solenoid valve so that it is turned OFF (not watering the plant, or stop watering the plant). The soil moisture value is read from the YL-69 sensor every 2 seconds and the system will continue this cycle infinitely as long as the microcontroller is still powered.

The frame design for the system is depicted in Fig. 3. The frame is constructed by 2 pipe sub-structures, each with a width of 36 x 90 x 100 cm. Each sub-structures has 2 levels and each level has 4 solenoid valves with an inter-distance of 10 cm. Thus, this system prototype can guarantee precision irrigation for 16 pots of cayenne pepper (chili plants).

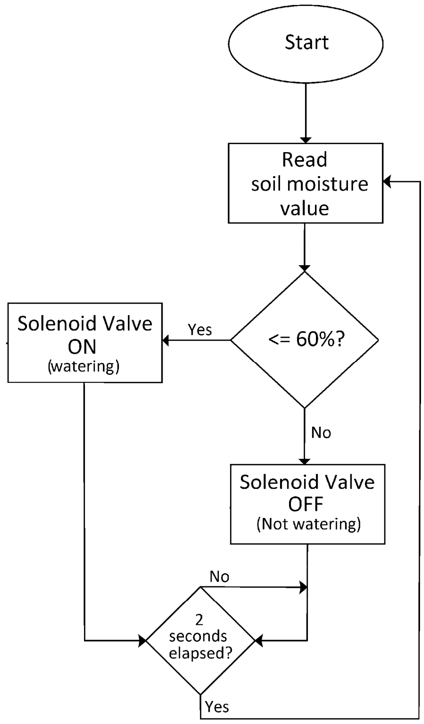
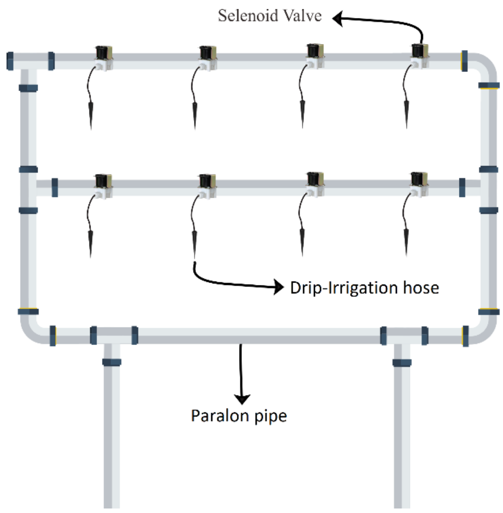


Fig. 2. Automatic plant irrigation system: functional flowchart



(a)

(b)

Fig. 3. Automatic plant irrigation system: frame design for one pipe substructure (a) and the manufactured frame that consists of 2 sub-structures (b).

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The developed automatic plant irrigation system was then tested by using chili (cayenne pepper) plants. The position of each chili pot in the manufactured frame is shown in Fig. 4, whereas the position of the soil moisture sensor in each pot is shown in Fig. 5.

Fig. 4. The real implementation of the developed automatic plant irrigation system for chili plants.

Fig. 5. Position of the soil moisture sensor in each chili pot

Experimental tests were carried out to evaluate whether the developed system can water the plant according to the determined optimal soil moisture requirements. The testing scenario is illustrated in Fig. 6. As shown in the figure, various soil moisture values were tested so that the function of the prototype system under various conditions can be observed. For testing purposes, the soil moisture sensor is placed at a constant distance of 5-10 cm from the drip irrigation hose.

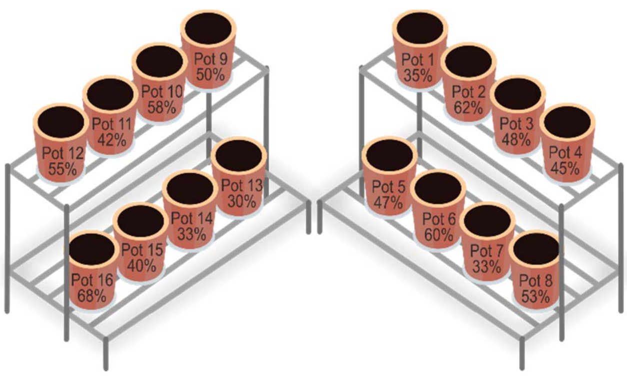


Fig. 6. Experimental testing scenario: the initial condition of soil moisture value for each potted chili plants

The test results for pots 1 and 2 are shown in Figs. 7 and 8. The horizontal axis of the graph shows the watering period in seconds. The vertical axis on the left side of the graph shows the status of the relay (1 = high, 0 = low). A high pulse of relay corresponds to the ON condition of the solenoid valve, which means that the solenoid is running water to the plant. On the contrary, low pulse means that the solenoid valve is turned OFF, or not watering the plant. The vertical axis on the right of the graph shows the soil moisture value of the plant in percentage. This value is taken from the soil moisture sensor.

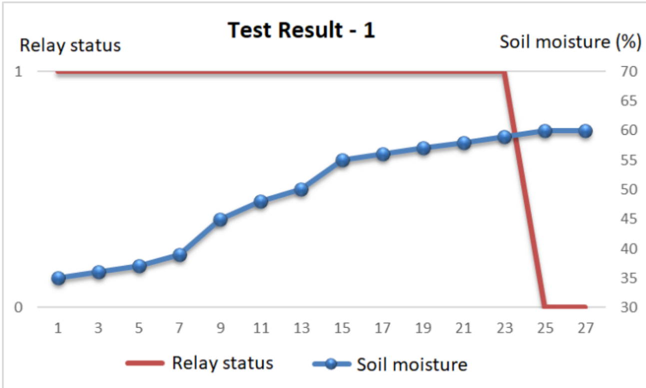


Fig. 7. Experimental testing result for chili pot 1

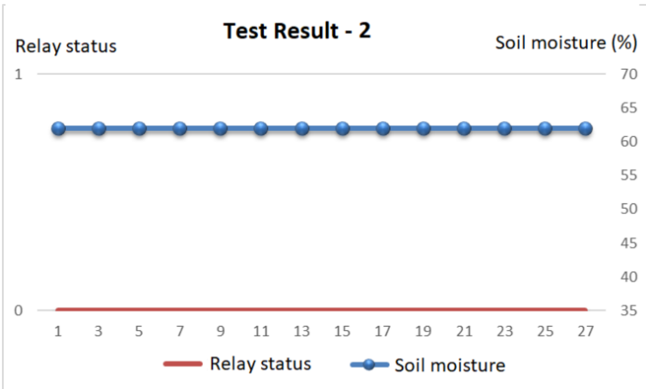


Fig. 8. Experimental testing result for chili pot 2

Fig. 7 shows that pot 1 has an initial soil moisture value of 35%. Since this value is less than 60%, the relay status becomes high and the solenoid valve runs the water to the pot for 23 seconds, until the soil moisture value is more than 60%. Fig. 8 shows that pot 2 has an initial soil moisture value of 61%. Since this value is more than 60%, the relay status becomes low and the solenoid valve does not run the water to the pot.

The test results for all pots can be seen in Table 1. In the table, the column of "initial soil moisture value" indicates the value that is read by the soil moisture sensor before the system is turned on. The "relay status" column shows the irrigation status. If the status is high, it means that the solenoid valve is watering the plant; whereas if the status is low, it means that the solenoid valve does not water the plant. The "watering period" column shows the watering time for each plant in seconds. The "final soil moisture value" column shows the value that is read by the soil moisture sensor after watering. From the 16 potted plants tested with different initial soil moisture values, it can be observed that all pots have a final soil moisture value of between 60% - 80%, except for pot number 12. The discrepancy for this pot may occur due to the fault of the soil moisture sensor during its operation. Nevertheless, the experimental results show that 91.7% of the testing scenarios is successful and in accordance with the optimal water requirements for chili plants. These results indicate that the developed automatic plant irrigation system can work well, according to the predetermined requirements.

TABLE I. OVERALL EXPERIMENTAL RESULTS

Pot No.	Initial soil moisture value (%)	Relay status	Watering period (s)	Final soil moisture value (%)
1	47	*High*	17	60
2	61	*Low*	0	60
3	48	*High*	15	60
4	33	*High*	27	60
5	40	*High*	21	60
6	65	*Low*	0	64
7	60	*Low*	0	60
8	53	*High*	13	60
9	35	*High*	25	60
10	39	*High*	23	60
11	43	*High*	19	60
12	55	*Low*	0	55
13	52	*High*	11	60
14	38	*High*	23	60
15	55	*High*	8	60
16	60	*Low*	0	61

V. CONCLUSION

This work has successfully developed an automatic cayenne pepper (chili) plant irrigation system to be implemented in the Greenhouse of the Computer Science Department, FMIPA, IPB University. Irrigation is done automatically by using a soil moisture sensor and a solenoid valve for each chili plant. This system has been tested using 16 potted chili plants that have different initial soil moisture values. Based on the experimental testing results, the soil moisture values of 15 pots (91.7% of the test subjects) have been successfully read and the irrigation for these pots has been carried out properly in accordance with the functional requirements specified for chili plants, that is, 60% - 80%.

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REFERENCES

[1] S. B. Murshed, J. J. Kaluarachchi, “Scarcity of fresh water resources in the Ganges Delta of Bangladesh,” *Water Security*, vol. 4-5, pp. 8-18, 2018. doi: 10.1016/j.wasec.2018.11.002.

[2] C. Cerro, "Developing solutions for dealing with water and food scarcity: Atmospheric water generator and urban farm tower," 2018 *Advances in Science and Engineering Technology International Conferences* (*ASET*), Abu Dhabi, pp. 1-6, 2018. doi: 10.1109/ICASET.2018.8376754.

[3] I. Mako, K. Kalcngo, G. Mmoke, G. Binini and O. Ponoola, "Remote Rural Area Water Scarcity Solution: An Innovative Green Energy Mobile DC Water Pump System," 2018 *IEEE PES/IAS PowerAfrica*, Cape Town, pp. 474-479, 2018.

[4] C. Rajurkar ; S. R. S. Prabaharan, S. Muthulakshmi, “IoT based water management,” 2017 *International Conference on Nextgen Electronic Technologies: Silicon to Software* (ICNETS2), India, 2017, doi: 10.1109/ICNETS2.2017.8067943.

[5] M. Syukur, R. Yunianti, R. Dermawan. *Sukses Panen Cabai Tiap Hari*. Bogor (ID): Penebar Swadaya, 2011.

[6] B. Cahyono, *Cabai Rawit, Teknik Budidaya & Analisis Usaha Tani*, Yogyakarta(ID): Kanisius, 2003.

[7] W. Yang-ren and Z. Zhi-wei, "Research of tomato economical irrigation schedule with drip irrigation under mulch in greenhouse," 2016 *Fifth International Conference on Agro-Geoinformatics (Agro-Geoinformatics)*, Tianjin, 2016, pp. 1-5. doi: 10.1109/Agro-Geoinformatics.2016.7577636

[8] Li Sha and He Xin-lin, "The effect of irrigtion on water consumption and yield of cotton under drip irrigation in Saline land," 2011 *International Conference on New Technology of Agricultural*, Zibo, 2011, pp. 344-348. doi: 10.1109/ICAE.2011.5943816

[9] Q. Kong, G. Li, Y. Wang and H. Huo, "Precision application of water and nitrogen for bell pepper under subsurface drip irrigation," 2010 *World Automation Congress*, Kobe, 2010, pp. 311-318.

[10] Y. Qiu and G. Meng, "The Effect of Water Saving and Production Increment by Drip Irrigation Schedules," 2013 *Third International Conference on Intelligent System Design and Engineering Applications*, Hong Kong, 2013, pp. 1437-1441. doi: 10.1109/ISDEA.2012.343

[11] A.G. El-Naggar, C.B. Hedley, D. Horne, P. Roudier, B.E. Clothier, “Soil sensing technology improves application of irrigation water,” *Agricultural Water Management*, vol. 228, 2020, doi: 10.1016/j.agwat.2019.105901.

[12] M. Syukur, *Cabai: Prospek Bisnis dan Teknologi Mancanegara*. Depok (ID): Agriflo, 2012.