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Precision Crop Management for Indoor Farming

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***Abstract*—This paper offers a method to manage crops for indoor farming which is focused on providing the crops a precise amount of water, ambient temperature and humidity. The proposed method utilizes six soil moisture sensors that are placed in the soil around the crops, and the source of water is mounted above the plants. The water pump was repeatedly tested at different configurations to determine the optimum flow rate and pressure of the water supply. The saturation point of the soil under investigation was also identified to precisely control the amount of water supplied to the plants. The advantage of this crop management system is that it could be remotely monitored using IoT (Internet of Things). The outcome of this work shows optimistic possibility of managing indoor farming in precise conditions to yield optimum production of crops.**

Keywords—Precision crop management; Indoor farming

I. INTRODUCTION

Due to the ongoing threat of global warming, agriculture activities in many countries are severely affected, including Malaysia. According to the report by the Technology Executive Committee of United Nations, 75% of world's population is engaged in agriculture sector and thus vulnerable to the climatic impact. Therefore to ensure better adaptation to the global warming, technologies in agriculture should be implemented at various scales [1].

Apart from that, the world population is increasing by year. It is estimated that by 2030, the population will be 8.5 billion, and will increase to 9.7 billion people by 2050[2]. The rapid population growth creates greater demand for food produce and resources, and thus better management of crops is highly desirable to avoid broken chain in food supply.

The demand of supplying the crops is always constant throughout the year because food is important for human to live. However certain hindrance could affect the supply of the crops, such as changing of climate, the growth of crops is not stable and constant. Thus, the productivity is inconsistent which lead to the fluctuating of prices on crops. Hence, to protect the farm, some farmers decided to make it indoor to increase the safety of the farm. However, by making an indoor farming by itself does not give solution to the growth of the crops. Even though they have good watering system that can always supply the water and nutrients, but they cannot face the problem regarding the growth.

A new agriculture method, called as precision farming has been developed and introduced in certain developing countries. Precision farming is the practice that uses technology to gain precise information of a crop, soil, and weather conditions. Thus, by using precision farming methods, higher quality products could be yield and decrease the percentages of bad crops [3]. Among common methods for precision farming are indoor vertical farming, greenhouse farming, satellite imaging and sensors technology.

Indoor vertical farming uses no soil as the medium for the crops to grow and require less human workers to manage the farm because the system only focuses on supplying enough water and nutrient directly to the roots. However it limits the number of type of crops that can be planted [4][5].

Satellite imaging, also known as remote sensing is the process of scanning the earth by satellite or high flying- aircraft to obtain information about it. In the case of precision farming, remote sensing is used to detect the conditions of the crops and the soils. The data collected through this method then can be used to properly manage the crop [6], to assess the crop yield [7] as well as irrigation system [8]. This technique, although very promising, is costly to be implemented.

Greenhouse farming is one of the viable options for farmers to achieve the target of precision farming. For Malaysia that experiences hot and humid climate, greenhouse farming is suitable to be used as it can maintain certain temperature required for selective plants to grow. By implementing greenhouse technology, light distributions, disease and pest protection, wind and rain protection, controlled microclimate and maximum production could be achieved [9][10]. The limitation of greenhouse technology is lack of pollination as crops in the greenhouse are isolated from insects [11].

Another option for precision farming is utilizing of sensor networks. By the help of sensors, control centre can collect and process data and information regarding the crops field that will lead the farmers to reach best decision in planting, fertilizing and harvesting crops [12]. Sakthipriya demonstrated that if the soil moisture level detected below its setup value, water will be sprayed at the particular area and data for the soil pH value will be reported to the farmer through electronic communication system [13].

This paper replicates the capability of works reported in [13] with a more economical approach. Extensive experiments were conducted to determine the saturation point of the soil under investigation, and six moisture sensors were utilised to detect amount of water in the soil and provide feedback to water pump system to precisely control the amount of water supply to the soil of the crops. This paper also demonstrates how the conditions of the soils were remotely monitored via the applications of Internet of Things (IoT).

II. METHODOLOGY

In this design only three parameters will be considered which are soil moisture, temperature, and relative humidity because these three factors could be related towards the water content in the soil and by having soil moisture sensor as indicator, we could counter the problem of the soil drying.

A. Soil Moisture Indicators

Soil moisture is the capability to hold the water in between the soil particles by action of surface tension that attracts the water. The availability of soil moisture to support the crops is also crucial that relies on the soil type. The water holding capacity is dependent on the soil type because the smaller the particles of the soil, the more the soil will be able to hold onto water through surface tension [14].

Water content can be levelled into four points, firstly is water is excess that contains 55% of soil moisture. Second point is Field capacity, where the range of soil moisture is in between 45% to 55%. Third point is called Management Allowable Depletion, where the soil moisture is in between 5% to 45%. Last point is known as Permanent Wilting Point, in which the soil moisture is below 5% [14][15].

B. Software Configuration

The conceptual design on the precision crop management for indoor farming is inspired from the method sensor networks and greenhouse system. Fig. 1 shows the flowchart of the entire system.

In this system, initially the Raspberry Pi will be turned on and it will initialize the sensors in the system. Then, the process of taking a reading for temperature, humidity and soil moisture will be in simultaneous. However, the process of reading the soil moisture requires the movement of the motor to move down towards the soil and insert the soil moisture sensor into the crop soil.

Additionally, after reading the soil moisture, Raspberry Pi will check whether it necessary to water the crops. If the soil moisture is found to be high, it will not do anything and if the soil moisture is found to be low, the water pump will on for duration of five seconds and stop afterwards.

C. Hardware Configuration

For monitoring three crucial parameters of indoor farming, soil moisture sensor with module FC-28 is used to read the soil moisture, DHT22 sensor is commonly used for temperature and humidity, these two parameters are crucial for indoor farming because overheating and high humidity is not recommended for indoor farming. For control system, Raspberry Pi 3 model B is used as microcontroller to read and

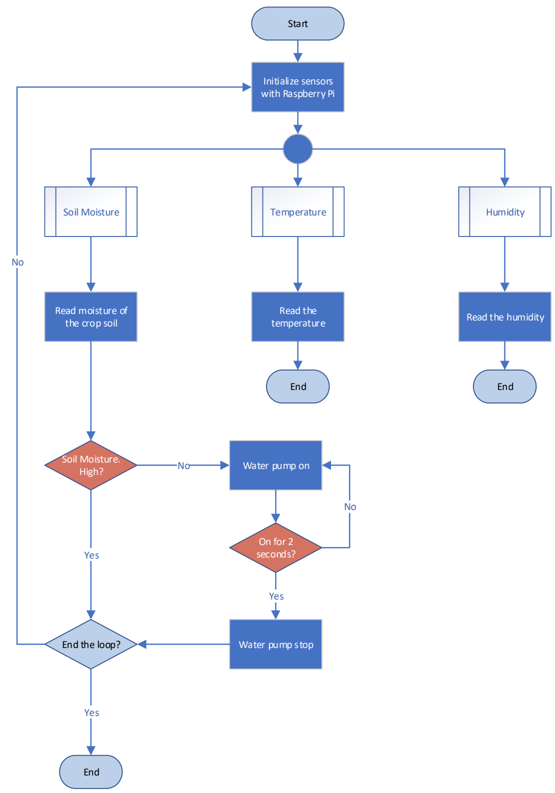


Fig. 1. Flowchart of the system

to display the data. Moreover, it has WLAN built-in that enable the microcontroller to connect with Wi-Fi.

Fig. 2 shows that the experiment setup. The experiment setup consists of a frame like an arc to support water supply in the middle to avoid from having random value of head loss at random level during irrigation.

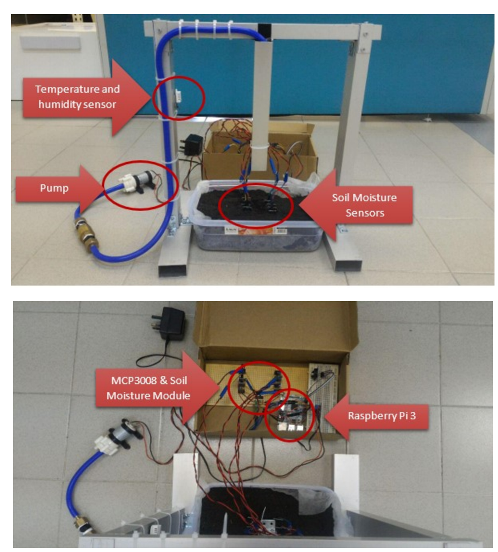


Fig. 2. Hardware configuration of the prototype from sie view (top) and top view (bottom)

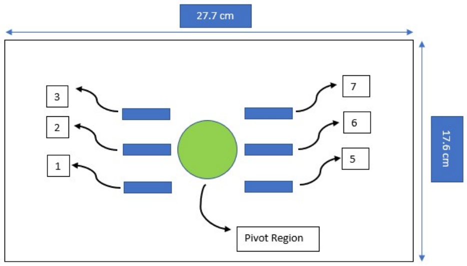


Fig. 3. Position of pivot and soil moisture sensors

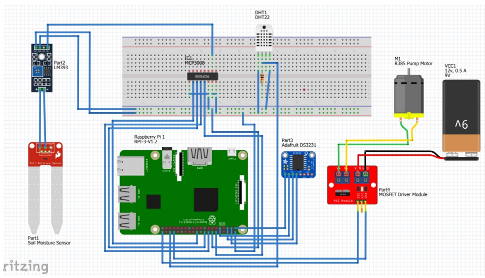


Fig. 4. System connectivity for one soil moisture sensor

There are six soil moisture sensors placed around the pivot area (at the middle) as shown in Fig. 3, and water tube is mounted at the middle of the frame.

Fig. 4 shows the connectivity of the system with a single soil moisture that will be used as an indicator at the most crucial position the crops.

III. Results And Discussions

Prior to collecting data, all soil moisture sensors were calibrated. This calibration is important to show the lowest (dry) and the highest (damp) reading of the soil moisture. The result shows that the lowest soil moisture is at 12% and the highest soil moisture is at 69%. Fig. 5 shows the result from the calibration.

Based on the experimental results made to precisely control the amount of water needed by crops, it shows that by using 2 seconds of irrigation, the amount of water obtained has been measured, which is 36ml for 6000 mW. This is when the water tube experiences the least turbulence flow.

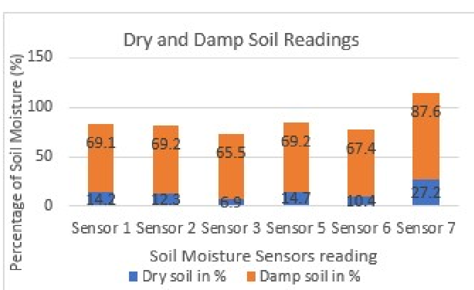


Fig. 5. Calibration output of soil moisture sensors

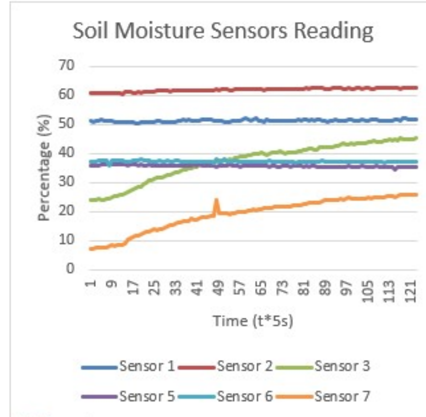
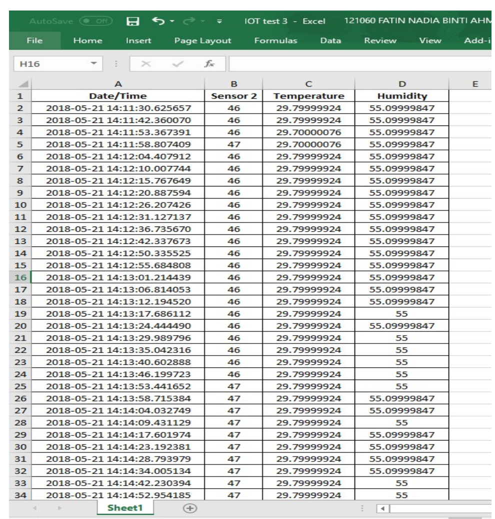


Fig. 6. Soil moisture reading (%)

However, the sensor 2 in Fig. 6 detects that soil moisture is above 60% which is excessive water content according to theory. The soil moisture reading of Sensor 2 is slightly above 55% but the reading for soil at saturated is around 69%. Two seconds of irrigation does give enough amount of water to be restored in the soil which will give the optimum condition for crops to live. In conclusion, only 36 ml is sufficient in this experiment with 340 mm of thickness of the soil.

For monitoring purpose, the data that has been read will be saved inside an excel file until the program is stop from running. This method is to enable the user to have the raw data into a file without concerning about losing a single data. For example, in Fig. 7, the data of soil moisture for Sensor 2, temperature and relative humidity are stored in excel including the time taken.

For IOT monitoring purpose, the MQTT Broker is used as medium between Raspberry Pi 3 and interface for user through application named MQTT Dash. The address used in this project is an open source named iot.eclipse.org. For this work,



	A	B	C	D
1	Date/Time	Sensor 2	Temperature	Humidity
2	2018-05-21 14:11:30.625657	46	29.79999924	55.09999847
3	2018-05-21 14:11:42.360070	46	29.79999924	55.09999847
4	2018-05-21 14:11:53.367391	46	29.70000076	55.09999847
5	2018-05-21 14:11:58.807409	47	29.70000076	55.09999847
6	2018-05-21 14:12:04.407912	46	29.79999924	55.09999847
7	2018-05-21 14:12:10.007744	46	29.79999924	55.09999847
8	2018-05-21 14:12:15.767649	46	29.79999924	55.09999847
9	2018-05-21 14:12:20.887594	46	29.79999924	55.09999847
10	2018-05-21 14:12:26.207426	46	29.79999924	55.09999847
11	2018-05-21 14:12:31.127137	46	29.79999924	55.09999847
12	2018-05-21 14:12:36.735670	46	29.79999924	55.09999847
13	2018-05-21 14:12:42.337673	46	29.79999924	55.09999847
14	2018-05-21 14:12:50.335525	46	29.79999924	55.09999847
15	2018-05-21 14:12:55.684808	46	29.79999924	55.09999847
16	2018-05-21 14:13:01.214439	46	29.79999924	55.09999847
17	2018-05-21 14:13:06.814053	46	29.79999924	55.09999847
18	2018-05-21 14:13:12.194520	46	29.79999924	55.09999847
19	2018-05-21 14:13:17.686112	46	29.79999924	55
20	2018-05-21 14:13:24.444490	46	29.79999924	55.09999847
21	2018-05-21 14:13:29.989796	46	29.79999924	55
22	2018-05-21 14:13:35.042316	46	29.79999924	55
23	2018-05-21 14:13:40.602888	46	29.79999924	55
24	2018-05-21 14:13:46.199723	46	29.79999924	55
25	2018-05-21 14:13:53.441652	47	29.79999924	55
26	2018-05-21 14:13:58.715384	47	29.79999924	55.09999847
27	2018-05-21 14:14:04.032749	47	29.79999924	55.09999847
28	2018-05-21 14:14:09.431129	47	29.79999924	55
29	2018-05-21 14:14:17.601974	47	29.79999924	55.09999847
30	2018-05-21 14:14:23.192381	47	29.79999924	55.09999847
31	2018-05-21 14:14:28.793979	47	29.79999924	55.09999847
32	2018-05-21 14:14:34.005134	47	29.79999924	55.09999847
33	2018-05-21 14:14:42.230394	47	29.79999924	55
34	2018-05-21 14:14:52.954185	47	29.79999924	55

Fig. 7. Sample data taken from Soil Moisture Sensor 2

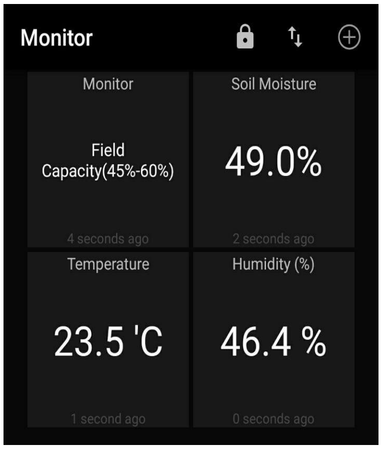


Fig. 8. Example MQTT Dash Output for Field Capacity

Raspberry Pi 3 will publish message to soil_moisture/sensor value, Monitor/soil_moisture, temperature/value, and humidity/value of soil moisture sensor value, soil moisture condition, temperature, and humidity respectively.

However, MQTT Broker requires a high-speed internet connection to receive the latest update of the data which can be obtained within split seconds. In this experiment we experienced some lagging and delay which the error for the experiment can be that either comes from the internet speed or the execution of the coding is taking a longer time before it could be publish the result. Despite of errors that we went through, the MQTT Dash is able to receive the data that we wanted to be displayed as shown in Fig. 8.

IV. Conclusions

This project has achieved all the objectives successfully. The first objective is to monitor the soil moisture sensor, temperature and relative humidity effectively in the python shell and the data is stored in the excel. Secondly, this project managed to analyze which amount of water is suitable to reach the field capability (45-60%), with two seconds of irrigation with power supply of 6000 mW for the pump. The last objective also is achieved very well by graphically shown in MQTT Dash. The output from this research work provides optimistic possibility of precision farming to be implemented in hot and humid weather, with close monitoring using the IoT.

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References

[1] United Nations Framework Convention on Climate Change. Technology Excecutive Committee, "Technologies for Adaptation in the Agriculture Sector," 2014.

[2] United Nations Department of Economic and Social Affairs, "World population projected to reach 9.7 billion by 2050," New York, 2015.

[3] "Precision Crop Management," *CEMA - European Agricultural Machinery*, 2018. [Online]. Available: http://www.cema-agri.org/page/3-precision-crop-management.

[4] "The Pros and Cons of Indoor Vertical Farming," *World Agriculture*, 2018. .

[5] B. G. Bareja, "The Arguments in Favor of Vertical Farms," *CropsReview.com*, 2018. [Online]. Available: https://www.cropsreview.com/vertical-farms.html.

[6] K. Sheffield and E. Morse-McNabb, "Using satellite imagery to asses trends in soil and crop productivity across landscapes," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 25, no. 012013, pp. 1–10, 2015.

[7] S. D. Khirade and A. B. Patil, "Plant Disease Detection Using Image Processing," in *2015 International Conference on Computing Communication Control and Automation*, 2015, pp. 768–771.

[8] W. Zhang, Z. Zhang, and Z. Huang, "Auto-Extraction Method of Farmland Irrigation and Drainage System Based on Domestic High-Resolution Satellite Images," in *Fifth International Conference on Agro-Geoinformatics (Agro-Geoinformatics)*, 2016, pp. 1–6.

[9] B. Cemek, Y. Demir, S. Uzun, and Vedat Ceyhan, "The effects of different greenhouse covering materials on energy requirement, growth and yield of aubergine," *Energy*, vol. 31, no. 12, pp. 1780–1788, 2006.

[10] "Fan and Pad Evaporative Cooling Systems," *The Center for Agriculture, Food and the Environment*. [Online]. Available: https://ag.umass.edu/greenhouse-floriculture/fact-sheets/fan-pad-evaporative-cooling-systems. [Accessed: 13-Sep-2018].

[11] M. Malinowski, "Pros and Cons of Greenhouse Growing," *MidAtlantic Farm Credit*, 2014. .

[12] S. Whalley, "Smart sensors: the key to precision agricultural production," *Electronic Products*, 2016. [Online]. Available: https://www.electronicproducts.com/Sensors_and_Transducers/Sensors/Smart_sensors_the_key_to_precision_agricultural_production.aspx.

[13] N. Sakthipriya, "An effective method for crop monitoring using wireless sensor network," *Middle - East J. Sci. Res.*, vol. 20, no. 9, pp. 1127–1132, 2014.

[14] L. Pitts, "Monitoring Soil Moisture for Optimal Crop Growth," *Observant TM*, 2016. [Online]. Available: https://observant.zendesk.com/hc/en-us/articles/208067926-Monitoring-Soil-Moisture-for-Optimal-Crop-Growth.

[15] "Soil Moisture Classification," *University of New South Wales*, 2007. [Online]. Available: http://www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_water-soil_moisture_classification.html.

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