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Optimal Plant Management System via Automated Watering and Fertilization

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Abstract. Different type of plants needs different amount of fertilization and water. The high or low amount of water or fertilization daily can damage the plant's roots leading to unhealthy crops. In this paper, a Smart Plant Management System to control the plant's watering and fertilization based on their optimal growth conditions ranging from temperature to soil moisture presented. A conditional based algorithm deployed into the controller to determine the optimal condition for the plant based on schedule, temperature, humidity and soil condition. The controller will relay information to two pumps for necessary water and fertilization. The system comprises of Bluetooth connectivity to allow user to provide input through phone application based on type of plants alongside optimal temperature, humidity and soil moisture for the plant to grow. The system also capable to monitor the plant life, status, and management history. The selected plant selected for this study is green mustard (Brassica Parachinensis) or called choy sum locally. The performance of the Smart Plant Management system under several conditions to determine their performance in maintaining the plants optimal condition is tested.

INTRODUCTION

A number of research is around to develop solution to conserve the plant management systems for urban setting. For example, Sreeram Sadavisam et al. developed a watering system for the plant using IoT. The project used an application of an intelligent system by using Net Gadgeteer to monitor the plant. It provided proper irrigation by receiving information from the temperature and moisture sensors and light conditions of surrounding plants. The project used Machine based curation and User-based curation to control the system where machine based curation integrated with active weather forecasting systems that propagated in the cloud server. In User-based curation, the user could use the Android device to manually operated the system [1]. Meanwhile, S. A. H. Z. Abidin et al. developed an automated fertigation system using a web-based monitoring system using Arduino for both irrigation and fertigation. The sensors used were flow sensors and EC (electricity conductivity) sensors. Farmers could choose the ratio of fertilizer mixed if the scheduled ratio unbalance. Farmers did not need to be on-site for manual operation [2]. O. M. E. Ahmed et al. developed an automated fertigation system using IoT with Arduino as the microcontroller. The project used a pH electrode to detect soil acidity and the soil pH regulated by the system. When the soil was too acidic, the system would add an alkaline solution, if the soil too alkaline the system would add an acidic solution to maintain an optimal pH. The data of moisture, pH, EC of soil, process status were displayed in the cloud [3]. S. Aparajitha et al. implemented Bluetooth and Arduino in an irrigation system. An android and moisture sensor could control the motor. The readings were displayed in Bluetooth [4]. Additionally, R. Dagar et al. use a soil pH sensor, water volume sensor, soil moisture sensor, air temperature sensor and motion detector sensor with the

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application of Wi-Fi IoT in their study. The project was developed for irrigation inside the polyhouse [5]. C. J. T. Dinio et al. develop the scheduling system for the management of water and fertilizer with a flow management system using Arduino and Real-Time Clock DS321. The irrigation and fertilization controller in real-time on daily basis. IoT and sensors were not used in the system [6]. D. Dumic et al. developed a plant watering system that has medical purposes by using Arduino and soil moisture sensor. The medical system implemented for plants to have the ability to remove air pollutants and reduce the concentration of toxic pollutants in the air that could lead to respiratory diseases. Therefore, the system was developed to maintain plants hydrated without any human effort [7]. C. Joseph et al. developed an automated fertigation system using a soil moisture sensor, Wi-fi, Blynk application, and Arduino. The project allowed the user to change the scheduled ratio for NPK fertilizer, time to water and fertilize the plants, and the duration to water the plants via Blynk mobile application. The application of moisture sensors the same as other projects [8]. N. Kaewmard et al. developed an irrigation system with wireless data sensor collection using a smartphone. The project used an underground water irrigation system. Four sensors used were soil moisture sensor, air temperature sensor, humidity sensor, and underground water level sensor. Other than using a wireless sensor network for data collection, the system was equipped with Wi-Fi and controlled by mobile applications [9]. The plant environment such as temperature could be monitored and controlled through the intelligent system for a greenhouse. Arsheen Mir et al. developed a model of an industrial system on a small scale, which performs sequential operations using relays. The system shuts down automatically once it detects high water or temperature levels, which are hazardous for industrial operation. This model was implemented using an Arduino microcontroller. The status of the system was displayed using devices like the Liquid Crystal Display (LCD), buzzer, etc. The sensor data was derived and stored in a Data Acquisition System (DAS), these data could then be used for control and monitoring purposes [10]. M. H. Saleh et al. developed a Global System Mobile (GSM) based control home air-conditioner for home automation system to reduce electricity wastage. GSM module was used for receiving Short Message Service (SMS) from the user's mobile phone that automatically enable the user to switch ON and OFF the home air-conditioner. The system controls the air-conditioner based on the temperature reading through the sensor. Every period, temperature sensor sends the reading to Micro Controller Unit (MCU) through ZigBee. Based on temperature's value, the MCU sends ON or OFF signal to switch. Additionally, the system allows the user to operate the air conditioner remotely through SMS [11]. From this concept, the plant environment such as temperature and soil moisture can be monitored, and pump could be controlled by the intelligent system for a greenhouse

METHODOLOGY

The environment and weather are the main problem that needs to be investigated in this study. This section discusses the design and development of the smart plant management system. Several Tests were carried out to evaluate the system performance. The system comprises of three primary components such as measurement, controlling and monitoring. The system will measure data such as temperature, humidity and soil moisture through their respective sensors in real-time. Optimal plant conditions have been predefined in the controller. The sensors will transmit data to the controller that will determine the current plant condition. The controller will proceed with watering or fertilizing if necessary, based on comparison between real-time plant condition status with the predefined optimal condition. Fig. 1 below is the block diagram of the smart plant management system. The systems are divided into three major components such as input, process, and output. The input consists temperature, humidity and capacitive soil moisture sensor. Additionally, real-time clock (RTC) DS3231 was used for time, and date recordings. The actuators in this system are two pumps for water and liquid fertilizer. As the moisture sensors detected enough moisture in the soil, both pumps would stop pumping water to the plant. The moisture sensor in this project also would overwrite the RTC's function during rainy days and when the plant already received enough water at the scheduled time. This would minimize water usage and overwatering the plant. Bluetooth module was used to connect with user interface via mobile app. The user will provide water and fertilizing schedule and send the controller using a bluetooth connection.

Fig. 2 and Fig. 3 shows a 3D plan layout for the system. It includes the position of every component such as water tank, liquid fertilizer tank, pumps, rubber tube, controller housing, plant pot, soil moisture sensor, temperature sensor and humidity sensor. Fig. 2 shows the design and concept in this system.

Fig. 2 also shows the controller watering and monitoring compartment content of the controller unit. The overall system was supported by a 5 Volt supply with is 0.5 Amp rechargeable battery packs. The system can operate for at least a couple of days before requiring charging. In real operation, the system is estimated to run for three to four months through battery saving mode. Microcontroller house was designed to be placed away from the plant and the water tank, and to prevent from water damage.

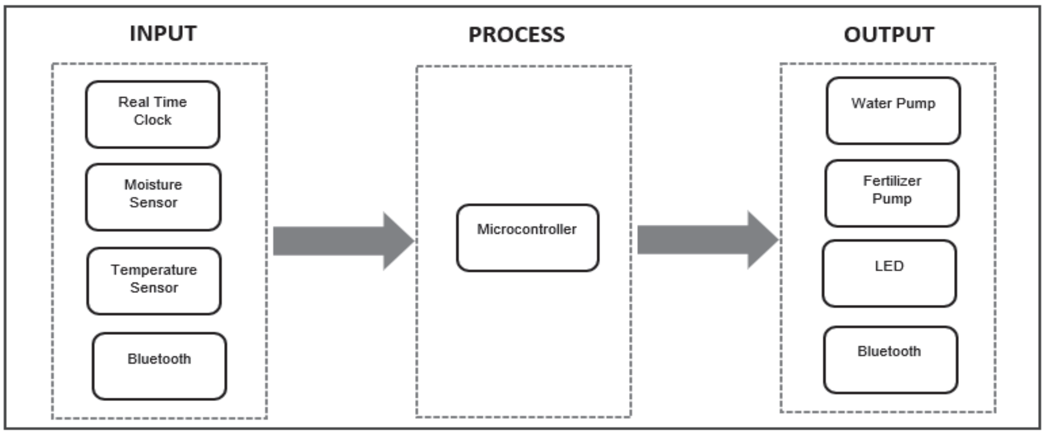

FIGURE 1. Smart plant management system Block Diagram.

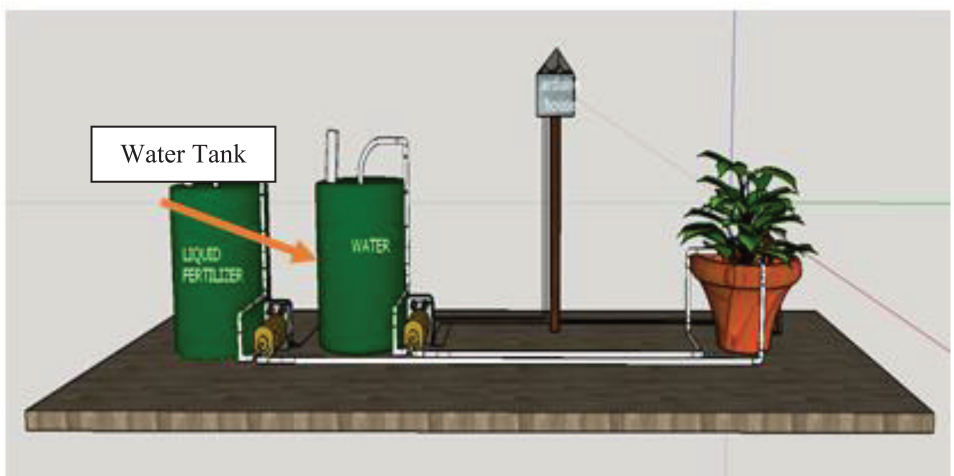

FIGURE 2. Front view "Smart Plant".

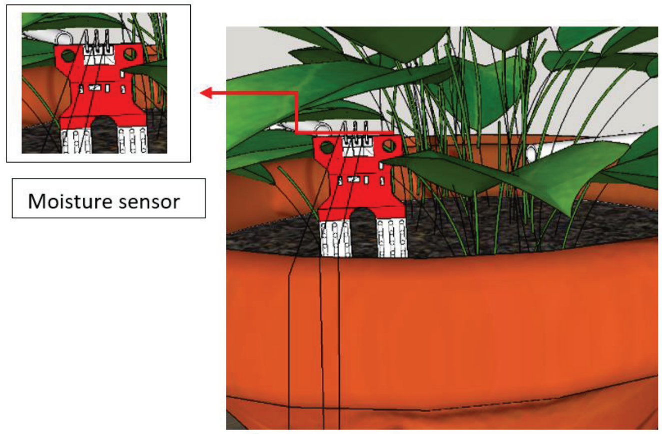

FIGURE 3. Moisture sensor placement in "Smart Plant".

In order to measure soil moisture sensor sensitivity during the Test, a simple calculation was conducted. The calculation involved interval's = air value – water value / 3. The value of "3" is the moderate dry calculation for this testing [12]. The next calculation shows the range of moisture value (soil), during the data in decline or expending to the data expected environment of green farm as in Equation (1).

$$Intervals = \frac{AirValue - WaterValue}{3} \tag{1}$$

where very wet value ranges from 390 until 473. The next calculation shows the range of moisture value (soil), during wet value and dry value. Estimated value under the range of the green technology specification. The wet value follows similar equation as in Eq. (1). The number of wet value and dry value come from non-stationary initial voluntary plant grows or process of watering the plants. The wet value ranges from 473 until 556.67. Meanwhile, the dry value ranges from 556.67 until 640. Fig. 4 shows the controller and temperature and humidity sensor system for monitoring temperature and humidity. The Arduino was selected for this study because it is user-friendly and low-cost compared to another controller that is complex and expensive. This controller has 8 input/output port that capable for additional sensors. The goal of capacitive soil moisture sensor measurement is to monitor the soil condition in three situations morning, afternoon and night. The system will be monitored by the computer system and integrated with the water supply system. Fig. 5 shows the design of the moisture sensor for soil condition measurement. The moisture sensor was connected to pin A0, ground, and 5V.

1	Arduino	Pin 1 digital	Temperature /humidity

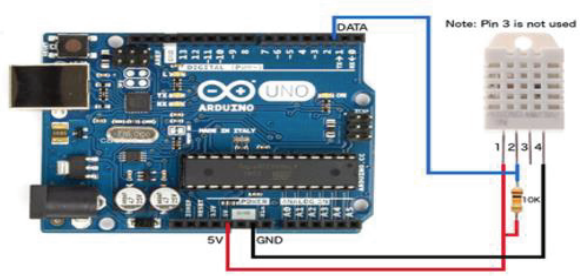

FIGURE 4. Temperature and humidity sensor [4].

1	Arduino	Pin 1 digital	Temperature /humidity

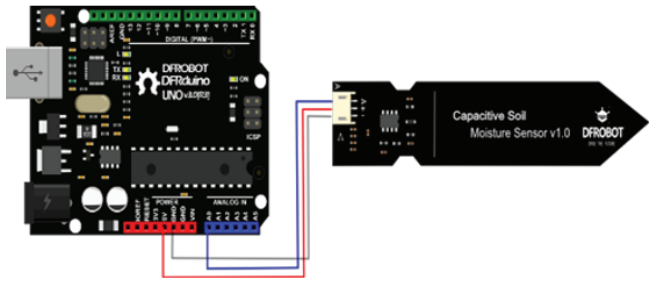

FIGURE 5. Moisture sensor circuit [5].

Fig. 6 and Fig. 7 shows the actual connection and placement of the sensor in the plant pot. The watering system installed by using flexible PVC pipe 5mm to 7mm diameter of each watering wiring.

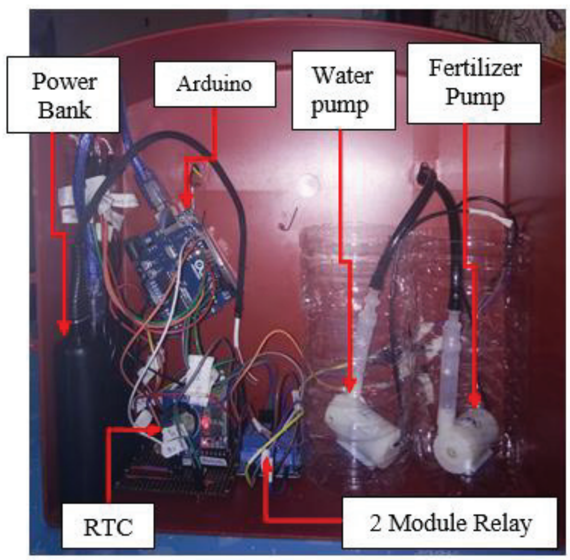

FIGURE 6. Overview of the watering system inside the controller box.

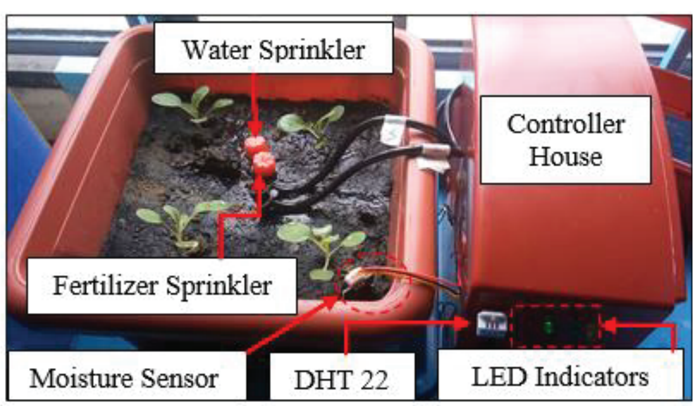

FIGURE 7. Watering system and sensor placement

RESULT AND DISCUSSION

Three tests were conducted to evaluate the system performance. Test 1 was on watering the plants in the morning. The water pump turned ON when RTC, soil moisture sensor, and temperature sensor meet the set conditions. First, RTC's time was at 8:00:00. Second, the soil moisture sensors read the value above 400 or equal. Third, the temperature sensor exceeded or equal to 10°C. As these three conditions were true, the water pump turned ON. The pump operated for one minute, which was 8:00 am until 8:01 am. After one minute, the water pump turned OFF when the RTC, soil moisture sensor and temperature sensor meet the setting conditions. The soil moisture sensor values below or equal 450 and the temperature sensor exceeded or equal to 10°C. Test 2 was on watering the plants in the evening. The water pump turned ON when RTC, soil moisture sensor, and temperature sensor meet the set conditions. First, RTC's time was set at 18:00:00. Second, the soil moisture sensors read the value above 400 or equal and the temperature sensor exceeded or equal to 10°C. As these three conditions were true, the water pump turned ON. The pump operated for one minute, which from 6:00 pm until 6:01 pm. After one minute, the water pump turned OFF as the RTC, soil moisture sensor and temperature sensor meet the setting conditions which below or equal 450 and exceeded or equal to 10°C respectively. Test 3 was conducted for fertilizing the plants in the evening once a week. There were several characteristics to be considered for the fertilizer pump to run. First, RTC's day of the week was set for Tuesday. Second, RTC's time set for 18:30:00. Third, soil moisture sensors read the value above or equal to 400 and the temperature sensor above or equal to 10°C. As these conditions were true, the water pump turned ON. The pump operated for one minute, which was from 6:30 pm until 6:31 pm. After one minute, the fertilizer pump turned OFF as the RTC, soil moisture sensor and temperature sensor meet the setting conditions. Test 1 (watering plant in the morning) and test 2 (watering plant in the evening) was for daily plant maintenance while Test 3 (fertilizing plant in the evening) was for weekly plant management. In this test, the day chosen was Tuesday evening only. Based on all the variables in the set conditions, this project was suitable for the tropical climate such as Malaysia. Both watering and fertilizing process was set to one minute because of the capacitive soil moisture sensor used in the project. From the output displayed in the serial monitor, the soil moisture values were varied as shown in Fig. 8. Many attempts were conducted throughout the tests to find the optimal duration to water the plants that could be synchronized with the capacitive soil moisture sensor. The soil moisture sensor took around 30 seconds to read the value decreased until ≤450 during the watering process. As a result, one minute was adequate to water the plant, as all the sensor reading and RTC's reading meet with the setting for pump operation. Fig. 9 shows the temperature, humidity, and soil moisture value during Test 2 waterings in the Evening. As the humidity of the soil increases, the value of the output decreases; conversely, when the humidity decreases, the output value becomes higher. Therefore, for this capacitive soil moisture sensor, the higher the reading, the drier the soil, where lower shows wet soil. The capacitive soil moisture value's chosen was 400 and 450 was because the type of soil selected for this study is Serbajadi Gardening High-Quality Black Soil [13]. After conducting all the tests, the ≥400 value considered as the most suitable soil condition to be watered and the ≤450 soil moisture value was the optimal soil wetness to stop watering the plant. Although, the value was in Very Wet Value, the result proved that the plant grew healthy after two weeks. The reason was this type of soil need to be watered generously for best result. Fig. 10 shows the reading of temperature, humidity, and soil moisture value during Test 3 Fertilizing in The Evening.

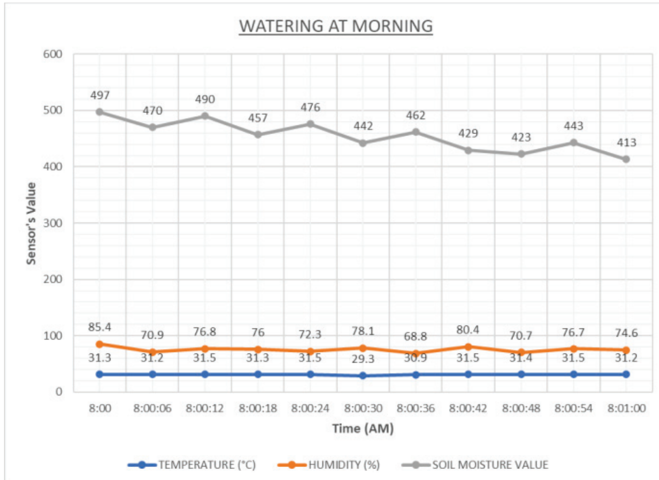

FIGURE 8. Temperature, humidity, and soil moisture value in test 1.

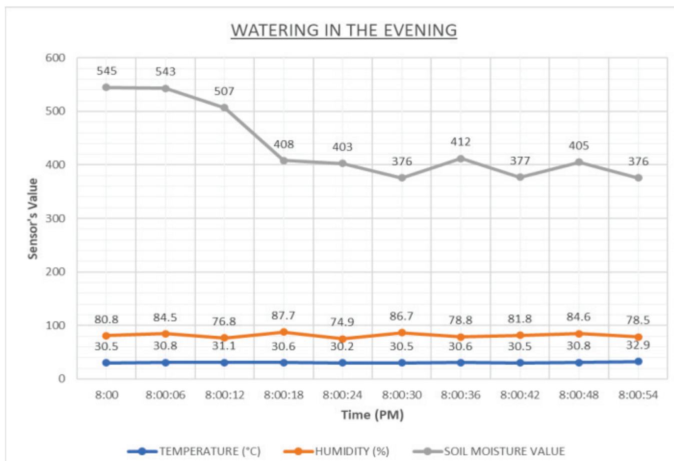

FIGURE 9. Temperature, humidity, and soil moisture value during test 2.

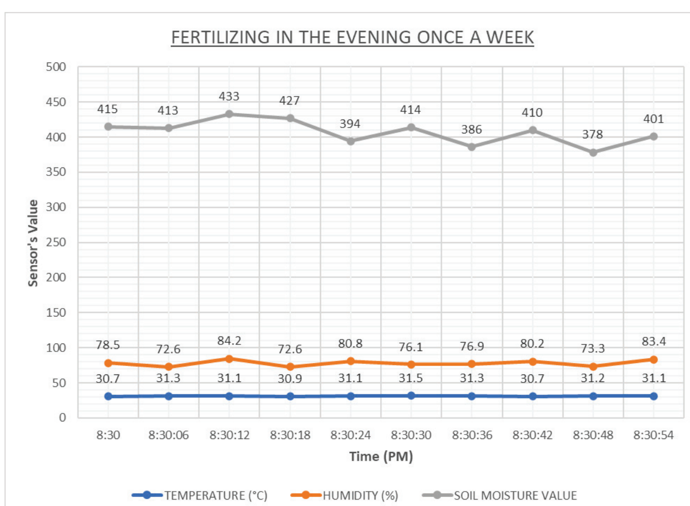

FIGURE 10. Temperature, humidity, and soil moisture value during test 3.

CONCLUSION

A smart plant management system capable to water and fertilize, plant automatically based on temperature, humidity and soil moisture is presented in this work. User also capable to schedule for automatic watering and fertilization through a mobile app. that automate the process of plant watering and fertilization, while using mitigating water usage. This work also able to increase plant lifetime through optimal growth conditions.

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