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Development Prototype of IOT Based System to Monitor Agricultural Crops

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Abstract

The agricultural sector in Malaysia is experiencing a significant decline in workforce participation, with the number of individuals decreasing from 554,247 in 2020 to 496,683 in 2021. Additionally, unpredictable climate changes have become a key factor manipulating environmental conditions, ultimately posing challenges to the agricultural sector. Therefore, this project is to develop an IoT-based prototype system designed to monitor and manage agricultural crops, focusing on maintaining optimal soil moisture levels and automating the watering process through a mobile application. The methodology involves the use of an ESP32 microcontroller integrated with soil moisture, temperature, humidity, and rain sensors. Data collected by these sensors is transmitted to the Blynk application, enabling users to remotely control water pumps and fertilizer mixers. The system automates irrigation and fertilization processes based on predefined conditions, optimizing water usage and improving operational efficiency. Experimental results demonstrate the system's effectiveness in maintaining ideal soil moisture levels between 50% and 70%, particularly for chili plants, ensuring proper delivery of water and nutrients while minimizing wastage. Thus, the innovation developed demonstrates how IoT technology can play a role in helping to address farmers' challenges. This leads to more efficient and sustainable practices to ensure better crop yields and the continuity of the agricultural sector in the future.

1. Introduction

Nowadays, the economic statistical trend of the agricultural sector has shown a reduction in the number of people who specialize in the agricultural sector. The number of people who specialize in this field recorded a decrease from 554,247 people to 496,683 people from 2020 to 2021. In line with the total salary and wages decreased by RM8.4 billion in 2020 to RM8.1 billion in 2021 [1]. This project aims to focus on the development of a prototype system to detect the level of humidity on the ground using a soil moisture sensor, detect the level of humidity and temperature in the environment using a humidity/temperature sensor and a rain sensor to detect if it is raining. The sensors will then be connected to the ESP32 which is used as a microcontroller that receives input from the sensors and will send the output signal to the smartphone because the ESP32 is specially designed to support Internet-of-Things (IoT) applications. The blynk application is used to help develop Internet of Things applications. It helps to create mobile and web interface for this project. From the data display received on the smartphone, the user can control the water pump to water the plant and the fertilizer mixer to fertilize the plant. Both the water pump and the fertilizer mixer are controlled by the ESP32. The propose of this system is to measure data to improve efficiency in the agriculture sector while advancing the Malaysian agricultural business. Since the Kementerian Pertanian dan Keterjaminan Makanan (KPKM) wants to empower urban agriculture efforts to foster and attract the interest of a new generation of entrepreneurs in the agriculture and food sector [2]. In addition, the uncertain climate change is one of the factors that manipulate the environment, thus affecting the agriculture sector. Therefore, Malaysia must take steps and strategies in a short period of time to face this problem before 2023. The strategy that needs to be focused is on agriculture, farming practices and overall resilience against climate-related threats [3]. Overall, this can strengthen Malaysia's position with an agriculture system that moves along with future development.

2. Research Methodology

This section provides an inventory of all the techniques used to finish the development prototype of IoT based system to monitor agriculture crops. It is divided into three sub-sections which include overview of proposed system, hardware design and circuit design.

2.1 Overview of Proposed System

This In this section, the process from the beginning to the end of the product can be seen. Based on Fig. 1 types of procedures and plans to be done. Inside stage 1, two ESP32 being used. This is because ESP32 is a data development board with a Wi-Fi chip and can be programmed just like other Arduino boards. In addition, the main advantage of this board compared to Arduino is that it can be connected directly to the internet easily only through Wi-Fi and comes out with bridge features to control two ESP together compared to the normal ESP8266 module. The function of ESP32 in this phase is to store the data received from the humidity sensor, rain sensor and soil moisture sensor according to the predetermined program. Next, in stage 2, the received information will be sent to the cloud data stream. In this project blynk cloud is used and the results can be seen through the blynk application on a smartphone. In that application, the user can control the function or button according to the program that has been set. The system is designed to make it easy to control water pumps automatically based on conditions. When pressing Switch 1, Water Pump 1 will turn on and keep working until the soil moisture level reaches 60%. This helps to water the plants just enough without wasting water. When pressing Switch 2, the servo motor will move to perform its task and then reset back to its starting position after 10 seconds. At the same time, Water Pump 2 will turn on for 15 seconds to water the plants. This allows the system to handle two different tasks, making it more useful and flexible.

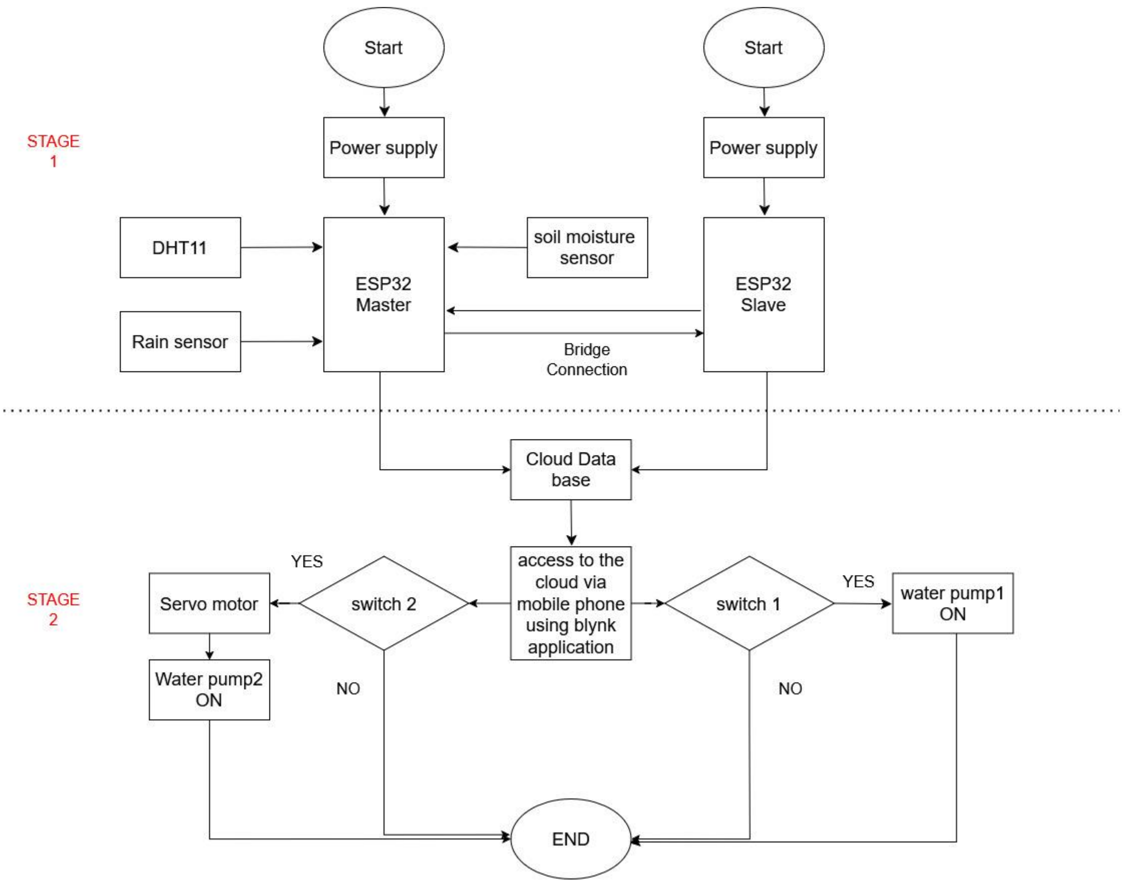
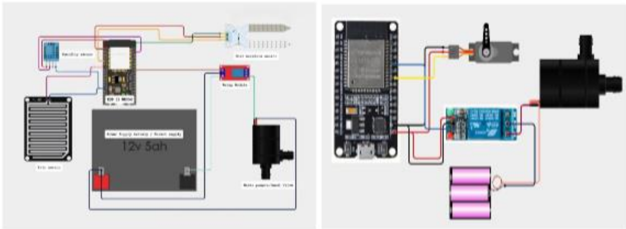


Fig. 1 *Flow Chart of the overall system*

2.2 Hardware Connection

This section explained the hardware connection setup using ESP32, divided into two parts, the master controller and the slave controller as show in Fig. 2. The master controller includes a soil moisture sensor, a DHT11 sensor to measure humidity and temperature, a rain sensor, a single-channel relay, and a water pump. The slave controller includes a servo motor, a single-channel relay, and a water pump. Both controllers use ESP32 microcontrollers to operate. To monitor or control the system, the Blynk app must be installed on a mobile phone, allowing interaction with the ESP32 for efficient system management.



(a) Master Controller (b) Slave Controller

Fig. 2 *Circuit diagram of Proposed System (a) Master Controller (b) Slave Controller*

2.3 Prototype Design

This part discusses the prototype design for monitoring agricultural crops. The drawings of this prototype hardware were created by using the Autocad2D as shown in Fig. 3. The proposed system is to monitor the plants that are planted and provide water or fertilizer to the plants remotely when needed. Three sensors are used in this system to record rain, temperature, humidity, and soil moisture. Each sensor is connected as shown in Fig. 3, with the ESP32 acting as the main controller of the system. In addition, the ESP32 is programmed to receive signals from smartphones, allowing users to control the system through a mobile application. These signals can activate either Switch 1 or Switch 2, depending on the user's choice. Switch 1 turns on Water Pump 1, which waters the plants until the soil moisture reaches the desired level. Meanwhile, switch 2 activates the mixer system for fertilizer. This process includes triggering the servo motor, which performs its task and resets after 10 seconds. At the same time, Water Pump 2 operates for 15 seconds to distribute the mixed fertilizer solution effectively.

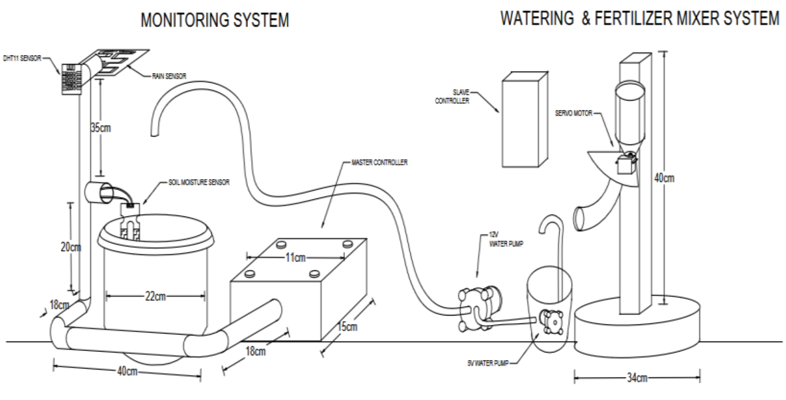


Fig. 3 *Design fof prototype of Monitor Agricultural Crops*

3. Results and Discussion

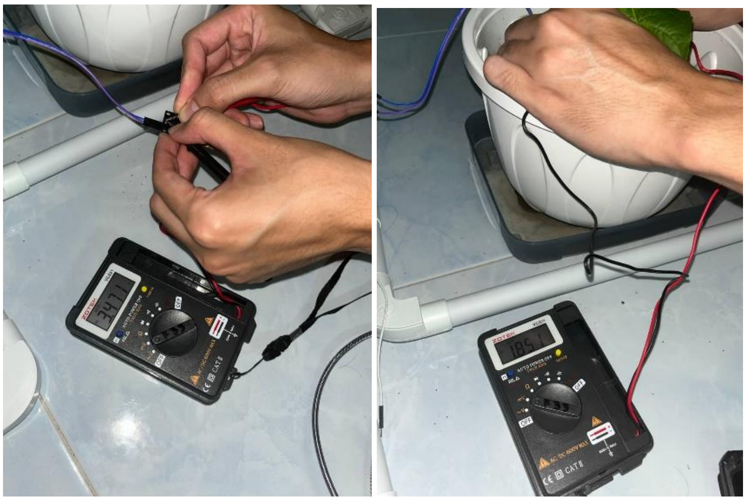
In this section, it discusses and presents the results achieved from the system created and the research that has been done. The recorded results are explained in statements, figures and diagrams so that they are easy to understand. In addition, the analysis of results is also described in this section. The data obtained is from observations and results obtained. The observations and results obtained are from the experiments carried out on the parts that are on the prototype.

3.1 Soil Moisture Sensor Calibration and ADC Voltage Mapping

The soil moisture sensor measures how much water is in the soil by checking its ability to conduct electricity. Wet soil conducts electricity better, producing a higher voltage, while dry soil conducts less, resulting in a lower voltage. The ESP32 microcontroller reads this voltage using its built-in Analog-to-Digital Converter (ADC), which changes the voltage into a digital number between 0 and 4095. This number helps to understand how wet or dry the soil is. To calculate the voltage from the digital value, the formula as in equation 1.

$$\text{Voltage (V)} = \frac{\text{ADC Value}}{4095} \times 3.3\text{V} \tag{1}$$

Then ESP32 converts this digital number into a percentage, where 0% means very dry soil and 100% means fully wet soil, making it easier to understand and use the data. According to Fig. 4, picture (a) shows the voltage reading (3.471 V) when the sensor does not detect moisture, while picture (b) shows the voltage reading (1.851 V) when the sensor detects moisture. If the voltage decreases, the system concludes that the moisture percentage has increased, and if the voltage increases, the system concludes that the moisture percentage has decreased.



(a)Before (b)After

Fig. 4 Voltage Measurement of Soil Moisture Sensor (a) Before (b) After

A comparison of ADC readings, calculated voltages, and measured voltages to assess the accuracy of the soil moisture sensor as indicated in Table 1. For the initial voltage, the ADC reading of 4095 corresponds to a calculated voltage of 3.300V, while the measured voltage is 3.471V, resulting in an error percentage of 5.18%. For the operating voltage, the ADC reading of 2177 corresponds to a calculated voltage of 1.755V, compared to a measured voltage of 1.851V, leading to an error percentage of 5.47%. To calculate the error percentage, use the formula: Note that Yn represents the voltage from the specification, and Xn represents the measured voltage.

$$\%error = \left|\frac{Yn - Xn}{Yn}\right| \times 100\% \tag{2}$$

Table 1 *Percentage of Error Soil Moisture Sensor Reading*

Types	ADC	Yn-Calculation (Yn) (V)	Xn-Measurement (V)	Error (%)
Picture A • Reading of Initial Voltage	4095	3.300	3.471	$3.3V - 3.471V = -0.171V$ $\left\lvert\frac{-0.171}{3.3}\right\rvert \times 100 = \mathbf{5.18\%}$
Picture B • Reading of operating sensor voltage	2177	1.755	1.851	$1.755V - 1.851V = -0.096V$ $\left\lvert\frac{-0.096}{1.755}\right\rvert \times 100 = \mathbf{5.47\%}$

3.2 Blynk Application Interface

The Blynk interface is designed to help users easily monitor and control soil and environmental conditions as referring to Fig. 5. It includes alerts that let users know when the soil needs watering or if it is raining, helping to save water by preventing unnecessary watering during rain. A real-time graph shows data from all connected sensors, including humidity, temperature, soil moisture, and rain, so users can track changes over time. The interface also displays the current soil moisture percentage, rain percentage, humidity percentage, and temperature in Celsius, giving users instant updates. Additionally, there are two control switches, one to turn the water pump on or off based on the soil moisture, and another to control the fertilizer mixer, allowing the user to turn it on or off when needed. This setup gives users full control and a clear view of the system, offering both automatic monitoring and manual control to keep the soil in the best condition for plant growth. The interface is easy to use, making it suitable for both experienced and new users.

Fig. 5 *Blynk App Interface*

3.3 Comparison of Temperature and Soil Humidity

This test evaluates soil moisture, temperature, humidity, and rain levels within a controlled indoor environment, emphasizing the importance of maintaining sufficient soil moisture for optimal plant growth, especially under higher temperatures. The test is divided into three phases. This systematic approach ensures optimal soil conditions, promoting healthy plant growth and efficient water use.

During Phase One (Morning), data collected from 6:00 AM to 11:00 AM shows the water pump activating at 6:00 AM due to soil moisture levels falling below the optimal range, with an average soil moisture of 66.90% recorded as presented in Table 2.

Table 2 *Soil Moisture in The Morning*

Time (Hours)	Humidity (%)	Temperature (°C)	Soil Moisture (%)	Rain	Water pump
6.00am	82	29	55	NO	ON
6.30am	80	29	69	NO	OFF
7.00am	81	29	69	NO	OFF
7.30am	81	29	69	NO	OFF
8.00am	78	29.2	69	NO	OFF
8.30am	75	29.9	69	NO	OFF
9.00am	74	30.3	68	NO	OFF
9.30am	74	31.1	67	NO	OFF
10.00am	67	31.5	67	NO	OFF
10.30am	59	33.1	67	NO	OFF
11.00am	69	32.2	67	NO	OFF
Average Soil Moisture			**66.90**		

Next, Phase Two (Noon), the data gathered from 12:00 PM to 5:00 PM as presented in Table 3. In this situation the water pump activates at 5:00 PM when the soil moisture sensor detects 58%, resulting in an average soil moisture of 63.45%.

Table 3 *Soil Moisture in The Noon*

Time (Hours)	Humidity (%)	Temperature (°C)	Soil Moisture (%)	Rain	Water pump
12.00pm	70	32.4	67	NO	OFF
12.30pm	70	32.4	67	NO	OFF
1.00pm	70	32.2	67	NO	OFF
1.30pm	71	32.3	67	NO	OFF
2.00pm	70	32.9	65	NO	OFF
2.30pm	69	32.3	63	NO	OFF
3.00pm	69	31.9	62	NO	OFF
3.30pm	69	32.1	62	NO	OFF
4.00pm	71	31.6	60	NO	OFF
4.30pm	72	31.2	60	NO	OFF
5.00pm	75	31.2	58	NO	ON
Average Soil Moisture			**63.45**		

Additionally, Phase Three (Night), during the 6:00 PM to 11:00 PM, the data indicates that the water pump remains inactive as the soil moisture percentage stays within the desired range, with an average of 65.72% recorded as presented in Table 4.

Table 4 *Soil Moisture in The Night*

Time (Hours)	Humidity (%)	Temperature (°C)	Soil Moisture (%)	Rain	Water pump
6.00pm	75	31.2	67	NO	OFF
6.30pm	75	30.7	67	NO	OFF
7.00pm	75	30.5	67	NO	OFF
7.30pm	76	30.5	67	NO	OFF
8.00pm	75	30.4	66	NO	OFF
8.30pm	76	30.2	66	NO	OFF
9.00pm	76	30.1	65	NO	OFF
9.30pm	76	30.1	65	NO	OFF
10.00pm	76	30	65	NO	OFF
10.30pm	76	29.9	64	NO	OFF
11.00pm	76	30.2	64	NO	OFF
Average Soil Moisture			**65.72**		

The soil moisture testing showed that the system has able to maintain optimal moisture levels for the plants. Instead of watering at fixed times, water is supplied based on the soil condition to ensure the plants get the right amount of moisture when needed. For chili plants, the ideal soil moisture is between 50% and 70%. Temperature plays a big role in this process, as hot weather can cause the soil to dry out quickly. Maintaining proper soil moisture is crucial for healthy plant growth, as both overly dry and overly wet soil can harm the plants. Specifically, the growth of red chili plants depends heavily on maintaining the right balance of soil moisture and temperature.

4. Conclusion

The IoT-based agricultural crop monitoring and management system provides an efficient and sustainable alternative to modern farming. Technology makes sure that plants get exactly the right amount of water and nutrients they need for healthy growth by automating crucial procedures like fertilization and irrigation. Real-time data is provided through sensors that monitor soil moisture, environmental conditions, and rainfall, enabling accurate adjustments to be made. The integration of the Blynk app allows for seamless monitoring and control, enhancing convenience and accessibility. This system not only maintains ideal moisture levels but also reduces water and fertilizer waste, contributing to healthier plant growth and consistent yields. With its ability to minimize resource consumption while promoting eco-friendly practices, the system serves as a practical innovation for achieving sustainable agriculture.

To further enhance the IoT-based system's efficiency and adaptability, several advancements can be implemented. First, the use of smart sensors, including nutrient analysers and pH sensors, would offer a more thorough comprehension of soil health and enable accurate interventions suited to the unique requirements of different crops. Furthermore, by analysing gathered data, predicting environmental trends like weather patterns and crop requirements, and providing proactive suggestions for improved resource management, the integration of artificial intelligence and machine learning algorithms may enhance decision-making. Adding solar panels to power the system is another crucial upgrade that ensures sustainability and energy efficiency, especially in remote areas with poor or limited access to electricity. Next the fertilizer mixer can also be significantly improved by allowing it to automatically modify the water to fertilizer ratio in accordance with the unique nutrient needs of various crops. The system would be easier to handle, require less manual labor, and run smoothly if the fertilizer container had an autonomous refill mechanism and users received real time alerts when the tank needed to be refilled. These enhancements seek to increase the system effectiveness, usability, and versatility for a variety of future of agricultural.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the paper's publication.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohamad Adli Bin Mohd Abbas, Ain Binti Nazari;* ***data collection:*** *Mohamad Adli Bin Mohd Abbas;* ***analysis and interpretation of results:*** *Mohamad Adli Bin Mohd Abbas, Ain Binti Nazari****; draft manuscript preparation:*** *Mohamad Adli Bin Mohd Abbas, Ain Binti Nazari. All authors reviewed the results and approved the final version of the manuscript.*

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