DEVELOPMENT OF AN IoT-BASED SMART WATERING SYSTEM FOR CUCUMBER PLANTATIONS

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Abstract. Over the last decade, the farming industry has experienced substantial growth. Previous studies have demonstrated that smart technologies including artificial intelligence (AI) and the Internet of Things (IoT) can be applied across all agricultural processes. The implementation of an IoT system for watering cucumber plantations can streamline the growth and development of plants including aspects such as marketing, farm management and monitoring thereby enhancing the efficiency of nearly all processes. This research aims to develop an IoT-based smart watering device specifically for cucumber plants. This tool incorporates a soil moisture sensor to determine soil moisture levels and automatically control the watering process. Data from the device will be displayed on an Android-based smartphone application. Data on the tool's features, responsiveness and customization were collected through interviews. The analysis aims to assess customer satisfaction based on the prototype's requirements. Results indicate both the functional and non-functional requirements of the system. The data also serve as a benchmark to evaluate the suitability of soil moisture levels for cucumber plants. The amount of water supplied during the watering process affects soil moisture levels. The IoT-based smart watering system can automate watering by using soil moisture percentages as a benchmark. Additionally remote control of watering can be achieved via a WiFi connection between the smartphone client and the microcontroller.

Keywords: Smart plant, Smart farming, agriculture, IoT.

1 INTRODUCTION

Industrial agriculture refers to the modern, industrialized production of livestock, poultry, fish and crops [1]. This method relies on technological, economic and political innovations including advancements in agricultural machinery and farming techniques, genetic technology, methods for achieving economies of scale, the creation of new markets, patent protection for genetic information and global trade. These approaches are widely used in the farming industry today, often under the umbrella of smart farming.

This research aims to examine how information technology (IT) innovations can facilitate farmers' work. Smart Watering is an automated system that uses environmental data to optimize plant watering [2]. The Internet of Things (IoT) involves interconnected devices, mechanical and digital machines, objects, animals, or people with unique identifiers (UIDs) that can transfer data over a network without human-to-human or human-to-computer interaction [2]. This project focuses on applying IoT technology to smart watering systems. Users can maintain their crops more efficiently, benefiting the farm environment, accelerating plant growth, stabilizing the economy, and enhancing commercial crop production.

Maintaining both crop production and environmental health promotes a green environment, ensuring healthy plants. The advantages of using IoT Smart Watering include disease and weed prevention specific to each plant, water and time conservation, and improved soil structure and nutrient preservation. Hand watering, especially in the early morning and evening, can be time-consuming. IoT Smart Watering allows users to monitor watering through their mobile phones, which helps prevent root disease associated with compacted soil. Using drip or sprinkler systems produces smaller water droplets, preserving nutrients and reducing soil compaction [12].

The IoT expands our ability to gather and utilize accurate data, making tasks more efficient. The IoT Smart Watering system for cucumber plants is designed for cucumber plantations because Cucumber (Cucumis sativus L.) is an important vegetable crop in the world and the third largest vegetable crop in Malaysia in terms of planting area [3]. Cucumbers are widely available in night markets, wholesale markets, and satay stalls, and can be harvested every two months. This makes cucumber plants an ideal subject for testing the IoT Smart Watering system, given their prominence in Malaysia.

2 LITERATURE REVIEW

2.1 Internet of Things (IoT)

The term "Internet of Things" (IoT) was first coined by Kevin Ashton in 1999 in the context of supply chain management [4]. The IoT refers to a network of interconnected, sensor-equipped electronic devices that collect data, communicate with each other, and can be monitored or controlled remotely over the Internet [4]. The main goal of IoT development is to extend internet connectivity from digital devices to physical objects, enabling communication between digital devices, objects, and other systems. The data collected can be shared between people, between machines and people, or between machines, with data being stored and managed in the cloud. Looking to the future, Cisco IBSG predicts that there will be 50 billion devices connected to the Internet by 2020 [5].

Using the IoT, the smart watering system is designed to be user-friendly and efficient, automating the irrigation process and reducing the need for manual intervention [9]. By utilizing precise sensors to monitor soil moisture levels, the system ensures that plants receive the optimal amount of water, thereby conserving water and preventing over-irrigation. The integration of advanced sensors allows for accurate monitoring of soil conditions, ensuring that plants receive the right amount of water based on real-time data. Once installed, the system requires minimal maintenance, reducing overall costs associated with traditional irrigation methods. The system provides users with real-time updates and notifications about the field conditions, enabling better management and timely interventions. Currently, there is no standardized protocol for tagging and monitoring plants with sensors, which can lead to compatibility issues between different components and systems. The use of IoT devices raises significant privacy and security concerns [10]. Data about plant status and crop quantities must be encrypted to protect sensitive information from unauthorized access. The reliance on software and internet connectivity introduces potential safety risks. The system could be vulnerable to hacking, leading to misuse of personal information, alteration of system settings, or unauthorized access to account details. These risks place the burden of ensuring safety and security on the consumer.

2.2 Devices

Arduino is a small circuit board with immense potential, capable of reading inputs and outputs according to [6]. The Arduino processor, developed by the Atmel Corporation in California, powers the Arduino Uno microcontroller board, which is based on the ATmega328. It features 14 digital input/output pins, of which 6 can be used as PWM outputs, and 6 analog inputs. Additionally, it includes a 16MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino is designed to help people understand modern technology, facilitating quick task completion and easy connectivity with various components such as relays, motors, and sensors. Furthermore, this device allows these electronics to be programmed using the IDE software, which is user-friendly and compatible with platforms like Windows, Linux, and Mac.

Other devices were Raspberry Pi. It's powerful, small computer about the size of a credit card, created to inspire a new generation of learners to be creative. According to [7], the ESP8266 is a Chinese-manufactured system on a chip (SoC) microprocessor designed by Espressif Systems. It features a built-in TCP/IP protocol stack and a 2.4GHz Wi-Fi module that supports WPA/WPA2, capable of running applications independently. The ESP8266 can work with other modules to build higher-performing devices and is suitable for various applications, such as IoT devices, tiny web servers, and data collection. In this research, Arduino was selected due to its suitability for straightforward, repetitive tasks like operating a watering system or managing related components. Moreover, Arduino offers a wider range of compatible components compared to Raspberry Pi. For the obstacle detection sensor, the soil moisture sensor consists of two probes that measure the volumetric content of water. These probes allow current to pass through the soil, and the sensor measures the resulting resistance to determine moisture levels. When water is present, the sensor conducts electricity with less resistance, resulting in a higher moisture level reading. Conversely, dry soil conducts less electricity, leading to higher resistance and a lower moisture level reading.

While the rain sensor module detects rainfall and can act as a switch when rain drops fall on the board, also calculating the rain intensity. The module consists of a separate rain board and control board for convenience, a power indicator LED, and an adjustable sensitivity meter. The sensor outputs data to detect the amount of rainfall. When connected to a 5V power supply, the LED indicator turns on to inform the user of rainfall.

Meanwhile the buzzer produces sound upon contact with an object. For instance, if the product encounters rain, the buzzer will emit a sound to notify the user.

3 PROBLEM STATEMENT

The adoption of industrial agriculture practices has significantly modernized farming, incorporating advanced technology, economic strategies, and political policies to enhance production efficiency. However, traditional farming methods still face significant challenges, particularly in the areas of resource management, crop health, and environmental sustainability.

One of the major issues is the inefficient use of water resources, leading to wastage and increased labor demands. Traditional hand-watering techniques, for instance, are time-consuming and often result in over or under-watering, which can adversely affect plant health and yield. Furthermore, soil compaction and nutrient loss are common problems associated with improper irrigation practices.

In the context of cucumber cultivation, which is one of the most prominent crops in Malaysia, these issues are particularly pressing. Cucumber plants require precise watering schedules to prevent root diseases and optimize growth. Despite its popularity and economic importance, current irrigation methods in cucumber farming are not sufficiently leveraging modern technology to address these challenges.

Based on the farmers' experience, planting cucumbers involves several steps. They must start by planting the seeds manually and then transferring them to polybags. When watering their plants, farmers need to check whether the plants are still in the seed stage or have started growing, as the water requirements vary. Newly planted seeds need at least 100ml of water every two hours, while plants that have been growing for a week require at least 300ml per polybag and need to be watered at least six times a day. The water needs of the plants depend on their age [11].

Additionally, watering depends on the daily weather. During heavy rains, farms can become waterlogged, causing stagnant water in the polybags of newly planted seeds. Farmers must remove this stagnant water because excess water can prevent seeds from absorbing nutrients and performing photosynthesis, leading to their death.

In terms of supply chain management, after planting the cucumber seeds, farmers can start harvesting cucumbers after two months. They then sell the cucumbers to consumers and receive payment. The price of cucumbers is flexible and depends on the current market price, which can be around RM3 per kilogram or less, depending on the grade of the cucumber. However, farmers face challenges in sustaining their operations in the farming industry. Some farmers have more advanced technologies and better experience in planting, giving them a competitive advantage.

The emergence of the Internet of Things (IoT) offers a potential solution through smart farming technologies such as automated watering systems [9]. IoT Smart Watering systems can provide precise and efficient irrigation by monitoring environmental conditions and adjusting water delivery accordingly. This innovation promises to conserve water, save time, and improve crop health and yield.

Therefore, this research aims to explore the implementation of an IoT Smart Watering system for cucumber plantations in Malaysia. By integrating IoT technology, the project seeks to enhance water management, promote sustainable farming practices, and ultimately improve the economic viability of cucumber farming. The focus will be on how information technology can streamline agricultural operations, making farming more efficient and environmentally friendly.

4 METHODOLOGY

4.1 Environment and Data Collection

The methodology involves six phases of prototype development which are: requirement gathering and analysis, quick design, building the prototype, customer evaluation, refining the product and engineering the product. These phases are based on the System Development Life Cycle (SDLC) of the Prototype Model as Figure 1. The prototyping model is an attractive approach for complicated and large systems where no manual process or existing system can help determine the requirements [8]. The prototypes are usually incomplete systems and many details about how the user develops the system are not included in the prototype. The goal of this model is to provide a system with overall functionality.

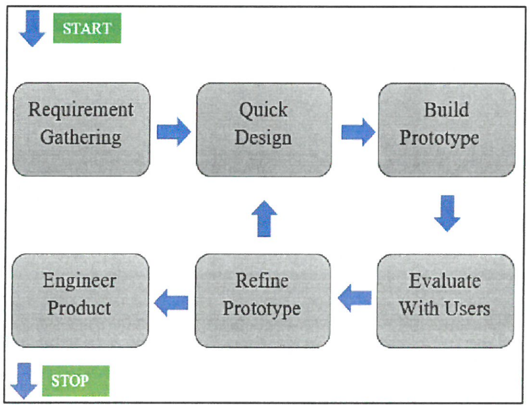

Fig. 1. Prototype Model

For the Requirement Gathering, the product analysis team identifies the basic requirements. This involves understanding the user's functional needs. Once the team fully understands the user's needs and wants, they prepare a product requirement document. However, detailed internal design and external aspects like performance and security are ignored at this stage.

In Quick Design Phase, the development team creates an initial prototype of the system. The basic requirements are reflected in the user interface. These features may not exactly match the final software but provide a similar look and feel to the final product for the customer.

Building Prototypes Phase involves taking the output from the quick design and building the prototype logically. This prototype gives a look and feel reminiscent of the final product.

After constructing the prototype, the evaluation with users phase is evaluated by the customer. The customer checks the functionality to ensure it works as expected and provides feedback to the development team. Feedback from customers and stakeholders is collected in an organized manner and used for further enhancements.

For the Refine Prototype Phase also known as the revise and enhance phase, this stage involves discussing feedback and reviews with the customer. Any problems identified are addressed, and the prototype is refined to meet customer requirements. This stage may involve negotiations with the customer regarding time, budget constraints, and the technical feasibility of the actual implementation. The cycle repeats until customer satisfaction is achieved.

5 DESIGN

Design is a stage where the product evolves from conceptual ideas into detailed plans. During the design process, various diagrams are created before product development. All requirements are translated into diagrams which include the Project Flowchart Diagram, Block Diagram, Network Architecture Diagram, Schematic Diagram and Prototype Design.

5.1 Project Flowchart Diagram

A flowchart is a visual representation of the sequence of steps and decisions required to perform a process. Each step in the sequence is noted within a diagram shape. In this flowchart diagram, the process of the IoT Smart Watering system is illustrated. It provides an overview of the system and shows the process flow, including how the soil moisture sensor operates.

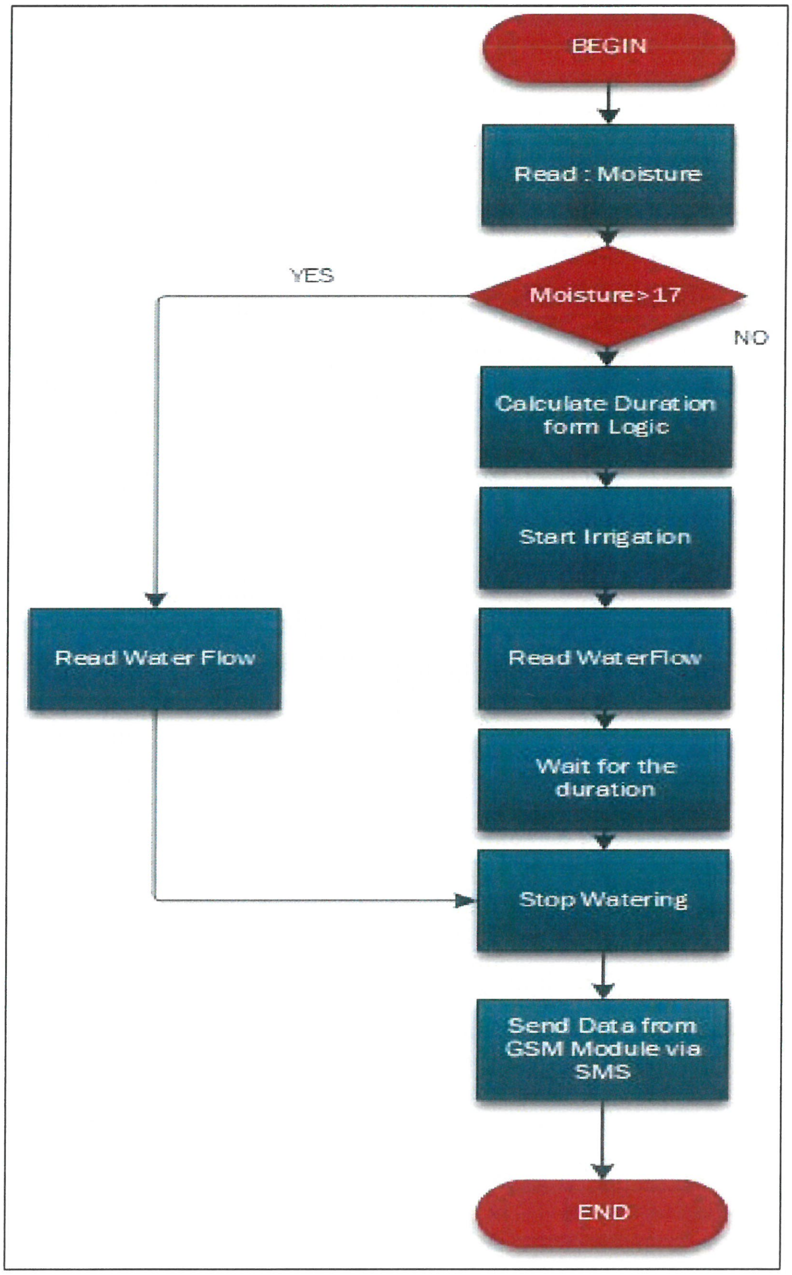

Fig. 2. Flowchart Diagram

5.2 Block Diagram

The IoT Smart Watering system with a soil sensor and rain detector follows a specific procedure to produce optimal results. This research aims to assist farmers by leveraging IoT technology to improve their irrigation practices. The soil sensor measures soil moisture levels to ensure adequate water supply. When the soil sensor detects moisture levels, it sends the information to the microcontroller for processing. The processed information then triggers the output indicators if the conditions are met, reducing the need for farmers to manually check which polybags need water.
The IoT Smart Watering system also integrates a rain sensor with the microcontroller to detect potential heavy rainfall [13]. The rain detector, installed on the Arduino board, activates when it starts to rain. When the rain sensor detects rain, the user receives notifications via SMS on their mobile phone. This allows the user to easily control the water pump, ensuring it is turned off during rainfall to prevent overwatering.
Additionally, a water pump motor is installed to manage water flow. The system uses a GSM module to send and receive signals between the product and the user via SMS. This offline network connection ensures reliable communication without relying on Wi-Fi or internet access. Only if the GSM module is used, signals will be received clearly [14]. Figure 5.2 shows the block diagram of the project.

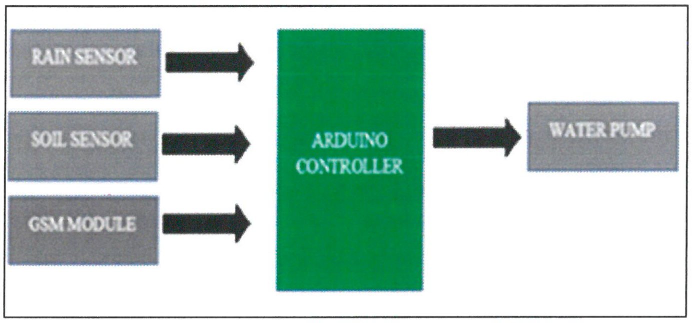

Fig. 3. Block Diagram

5.3 Network Architecture Diagram

The network architecture design for the IoT Smart Watering encompasses all the essential components required for the system's development process. The figure illustrates the network architecture design for the IoT Smart Watering. The network facilitates access to the microcontroller for sending signals to the smartphone, providing real-time updates on the product's status. Subsequently, the signal is transmitted to the smartphone via SMS, notifying the user accordingly.

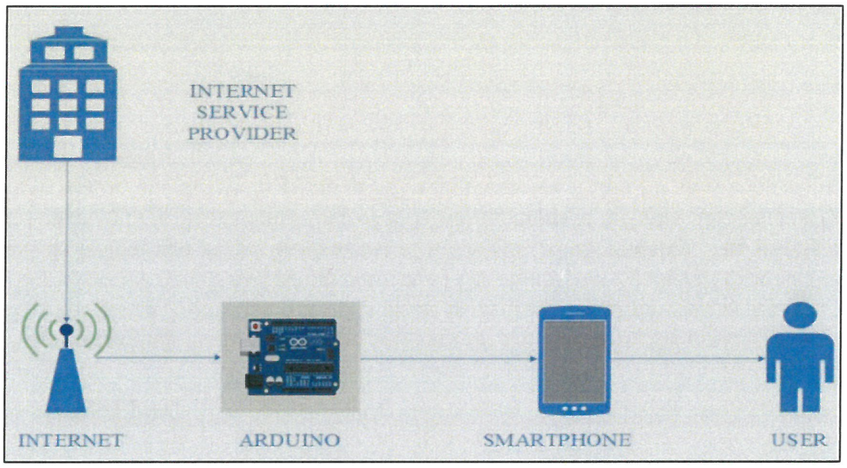

Fig. 4. Network Architecture Diagram

5.4 Schematic Diagram

This diagram illustrates the connection from the Arduino to the breadboard. The breadboard serves as a platform for connecting sensors and other devices without requiring soldering, making it convenient for users. They can directly connect components to the board without the need for soldering. Additionally, the diagram delineates the correct connection methods to ensure error-free project implementation. Schematic diagrams play a vital role in describing the high-level functioning of a system or process [15]. They simplify complex relationships between system objects by visually representing them, making the connections more evident.

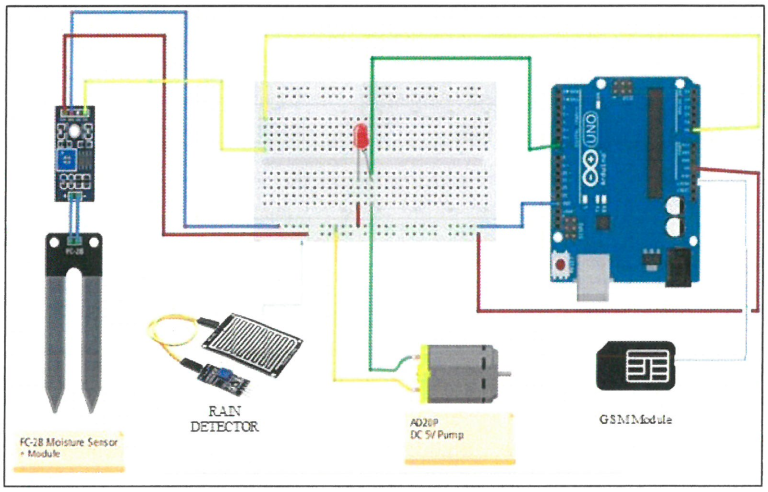

Fig. 5. Schematic Diagram

5.5 Prototype Design

This overview presents the prototype's functionality, particularly focusing on the Arduino's operational flow for plant management. The inclusion of a water pump serves as a motor to regulate water flow in and out of the system. Additionally, the prototype integrates a GSM Module, enabling user notifications via SMS. The moisture sensor installed in the plant plays a crucial role in determining soil moisture, ensuring optimal water supply. Should the soil become dry, the sensor alerts the user accordingly. Furthermore, the water level sensor is incorporated to prevent water overflow during rainfall, allowing the user to deactivate the water pump and conserve water effectively.

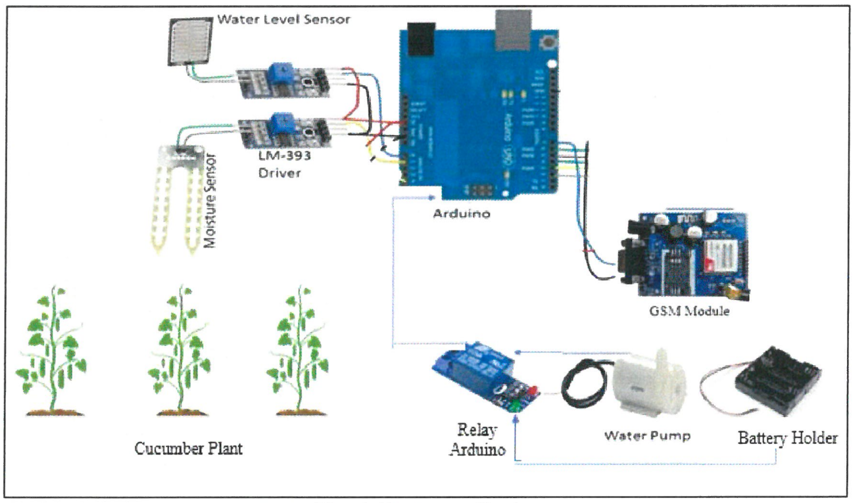

Fig. 6. Prototype Design

6 TESTING

After integrating the hardware and software for the assembly, the prototype is now ready to be tested. Information for this phase is recorded based on various aspects, including expected results and actual outcomes. The results were gathered from analysis based on testing and proper assessment of the project's functionality. The testing focuses on analyzing the response time of SMS notifications to the user, the rain detector, the soil sensor, and the water pump in different scenarios. Table 1.1 shows the steps of the testing process.

Table 1.1 Water Sensor Testing

No	***Test Step***	***Test Data***	***Expected Result***	***Actual Result***	***Status (Pass/Fail)***
1	Power up the prototype	On and Off	The prototype is power up and operate normally	The result is same as the expected result	Pass
2	Test the detection based on 1 cm water depth	If the reading of the rain sensor detect the water presence on the rain detector more than 10% , the water pump will not watering the plant and give the SMS notification to user	Water pump will not operate due to rain and will operate if there is no rain detected	Water pump will not operate due to rain and will operate if there is no rain detected	Pass
3	Test the detection based on 4 cm water depth	If the reading of the rain sensor detect the water presence on the rain detector more than 10% , the water pump will not watering the plant and give the SMS notification to user	Water pump will not operate due to rain and will operate if there is no rain detected	Water pump will not operate due to rain and will operate if there is no rain detected	Pass
4	Test the detection based on 7cm water depth	If the reading of the rain sensor detect the water presence on the rain detector more than 10% , the water pump will not watering the plant and give the SMS notification to user	Water pump will not operate due to rain and will operate if there is no rain detected	Water pump will not operate due to rain and will operate if there is no rain detected	Pass
5	Documentation	Record the result and analyse the data	Record the result and analyse the data	Record the result and analyse the data	Pass

After testing the water sensor, the user will be informed about the presence of water, and the water pump will stop watering the plant. Table 1.2 shows the soil sensor testing.

Table 2.2 Soil Sensor Testing

No	*Test Step*	*Test Data*	*Expected Result*	*Actual Result*	*Status (Pass/Fail)*
1	Power up the prototype	On and Off	The prototype is power up and operate normally	The result is same as the expected result	Pass
2	Test the soil sensor in moist plant	If the sensor detects the soil , it will read the moisture of the plant	If the moisture of the plant reading percentage is more than 30% than there will be no watering occur	If the moisture of the plant reading percentage is more than 30% than there will be no watering occur	Pass
3	Test the soil sensor in dry plant	If the sensor detects the soil , it will read the moisture of the plant	If the moisture of the plant reading percentage is below than 10% than it will give a signal to water pump to start watering the plant until it get enough amount of water	If the moisture of the plant reading percentage is below than 10% than it will give a signal to water pump to start watering the plant until it get enough amount of water	Pass
4	Test the soil sensor when the rain is occurred	If the sensor detects the soil , it will read the moisture of the plant	If the moisture of the plant is below thsn 10% suddenly rain occur therefore the automatic watering will	If the moisture of the plant is below thsn 10% suddenly rain occur therefore the automatic watering will	Pass

			pending due to rain	pending due to rain	
5	Documentation	Record the result and analyze the data.	Record the result and analyze the data.	Record the result and analyze the data.	Pass

After completing all the sensor detection tests, the user can easily operate the prototype without any issues. The user will receive alerts from the soil sensor and rain detector, ensuring proper functionality. This system also helps the user confirm that all sensors are working correctly without any problems. Table 1.3 shows the GSM module testing.

Table 3.3 GSM Module Testing

No	***Test Step***	***Test Data***	***Expected Result***	***Actual Result***	***Status (Pass/Fail)***
1	Power up the prototype	On and Off	The prototype is power up and operate normally	The result is same as the expected result	Pass
2	Obtaining the network signal	There will be blinking red LED every 3 second when the GSM Module is Ready	The red LED on GSM Module are blinking every 3 seconds	The red LED on GSM Module are blinking every 3 seconds	Pass
3	Sending SMS test	If the prototype is switch on , the user will receive a message	SMS will send to the user when the prototype is ready to be use.	SMS will send to the user when the prototype is ready to be use.	Pass
4	Documentation	Record the result and analyze the data.	Record every result and analyze the data	Record the data and analyze it	Pass

After integrating the system, the results demonstrate the effectiveness of SMS notifications sent to the user. The SMS messages are triggered each time the rain sensor or soil sensor is activated, providing real-time updates on the plant's condition. However, if the prototype is not powered up, the user will not receive any notifications. The example results are based on a forest environment, as this is where the user's cucumber field is located.

Table 4.4 SMS (Short Messaging Service) Respond Time According To Signal

Telco	*Telco Signal Bar (1-4)*	*Condition*	*Time taken for user getting message (min)*
Celcom to Unifi	4	Forest environment	2 mins
Digi to Maxis	3	Forest environment	5 mins
U Mobile to U Mobile	1	Forest environment	10 mins
Maxis to Digi	2	Forest environment	5 mins
Digi to Celcom	3	Forest environment	4 mins

SMS notifications are sent every time the rain sensor and soil sensor are activated on the plant. These messages inform the user about the plant's current condition. However, if the prototype is not powered on, the user will not receive any notifications from the plant.

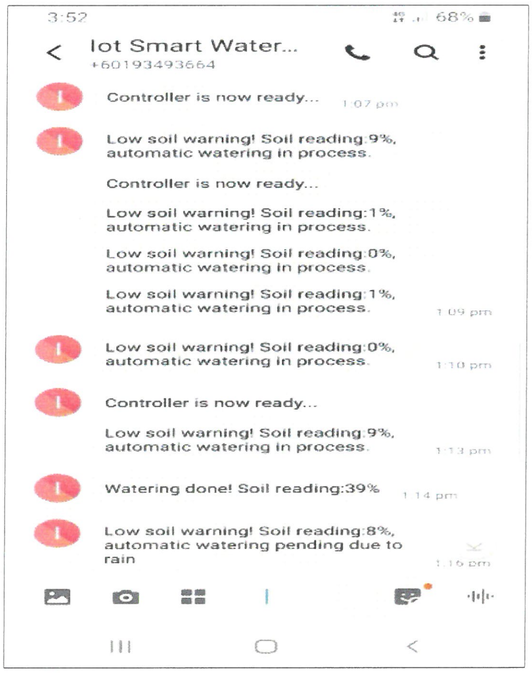

Fig. 7. SMS Notification

7 CONCLUSION

The adoption of IoT Smart Watering systems in cucumber cultivation has significant potential to modernize and enhance the efficiency of agricultural practices in Malaysia. This technology can address key challenges faced by traditional farming methods such as inefficient water usage, soil compaction and nutrient loss by providing precise and automated irrigation solutions. The scalability of such systems offers a transformative opportunity for larger agricultural applications, extending the benefits beyond cucumber farming to other crops and farming practices. The scalability of the IoT Smart Watering System can be enhanced water management by precisely monitoring and managing water delivery based on real-time environmental data such as soil moisture, weather conditions and plant growth stages. This precision can be scaled to larger farms and different crop types, ensuring optimal water use across diverse agricultural operations.

IoT Smart Watering improved crop health and yield by customized irrigation schedules. The system can be tailored to the specific needs of various crops, adjusting watering schedules to match the unique requirements of each plant species. This adaptability can enhance crop health and yield across a wide range of agricultural products. It is also can enhance labor efficiency and cost savings by automating the processes. The automated processes automate the labor-intensive task of manual watering, freeing up farmers' time for other critical activities. This automation can reduce labor costs and increase operational efficiency on larger farms. By minimizing the need for manual intervention, larger agricultural operations can manage more extensive areas with fewer workers, leading to significant cost savings.

The scalability of IoT Smart Watering systems holds great promise for revolutionizing agriculture in Malaysia and beyond. By addressing critical challenges in water management, crop health, labor efficiency, environmental sustainability and supply chain optimization these systems can significantly enhance the productivity and sustainability of agricultural operations. The adoption of such scalable technology can lead to a more efficient, competitive and sustainable agricultural sector, benefiting farmers, consumers and the environment alike.

8 FUTURE WORKS

This research can be enhanced with several features to increase its effectiveness and efficiency. The concern about the power source for the prototype should be addressed. It is recommended that future researchers use rechargeable batteries with solar technology for better mobility and durability. Implementing solar panels in the system allows the prototype to gather solar power from the sun throughout the day, improving the system's usage duration. This also helps reduce the cost of current usage at night, as the solar system can power the prototype all night. By adding a Wi-Fi module would allow the prototype to run more efficiently. Currently, the GSM module used as the network platform is limited, as it only provides notifications and stores data in message history. Using both Wi-Fi and GSM modules simultaneously would ensure continuous network connectivity, offering offline SMS notifications as a backup. Moreover, integrating a Wi-Fi module would enable the addition of a database system to store notifications in a cloud server, allowing easy access and backup of data. Adding more sensors, such as solenoid valves, can enhance the system's functionality. The solenoid valve controls the water flow in and out, which is crucial for watering cucumber plants according to their age. This addition helps regulate water flow and ensures that not all water is used at once. It is recommended that future researchers integrate the prototype functions with third-party applications or custom-built applications. This would improve data collection and storage and allow users to control the prototype's capabilities via a smartphone.

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References

1. https://www.fao.org/home/en/
2. A. Mitra, Pooja and G. Saini, "Automated Smart Irrigation System (Asis)," 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS), Greater Noida, India, 2019, pp. 327-330, doi: 10.1109/ICCCIS48478.2019.8974466. keywords: {Irrigation system;Internet of Things;soil moisture sensor;temperature sensor;crop quality;fertilizer;NPK sensor;ARIMA},
3. Sakthivel Poraya Goundar1,2, Sandhya Ramani1 , Khamsah Suryati Mohd1 , Chua Kim Aik2 , Hasan Nudin Nur Fatihah1 * EVALUATION OF NEW CUCUMBER (Cucumis sativus L.) HYBRIDS FOR AGRONOMIC CHARACTERISTICS AND BEGOMOVIRUS RESISTANCE Special Issue, 2022, 2, (30 - 37): 5th International Plant Breeding Conference 2022
4. Kramp, T., van Kranenburg, R., Lange, S. (2013). Introduction to the Internet of Things. In: Bassi, A., *et al.* Enabling Things to Talk. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-40403-0_1
5. Amina Salim Abeid; Internet of Things Issues and Challenges; International Journal of Academic Management Science Research (IJAMSR) ISSN: 2643-900X Vol. 4, Issue 5, May – 2020, Pages: 71-75
6. Ismailov, Alisher & Jo`rayev, Zafar. (2022). Study of arduino microcontroller board.
7. Soy, H. (2021). ESP8266 and ESP32 Series of SoC Microcontrollers. In S. Kocer, O. Dundar & R. Butuner (Eds .), Programmable Smart Microcontroller Cards (pp. 110 –125). ISRES Publishing.
8. Http://www.lumitex.com
9. Khaled Obaideen, Bashria A.A. Yousef, Maryam Nooman AlMallahi, Yong Chai Tan, Montaser Mahmoud, Hadi Jaber, Mohamad Ramadan,An overview of smart irrigation systems

using IoT,Energy Nexus,Volume 7,2022,100124,ISSN 2772-4271, https://doi.org/10.1016/j.nexus.2022.100124.

10. Tawalbeh L, Muheidat F, Tawalbeh M, Quwaider M. IoT Privacy and Security: Challenges and Solutions. *Applied Sciences*. 2020; 10(12):4102. https://doi.org/10.3390/app10124102
11. https://www.haifa-group.com/cucumber-fertilizer/crop-guide-growing-cucumbers
12. Lim, C., Baharudin Bin Osman, Yuhanis Yusof, & Rahmat, A. R. (2024). Integrating Iot And Mobile Applications For Efficient Plant Watering: The Iot Smart Watering System (SWS). Journal of Digital System Development, 2(1), 124–139. https://doi.org/10.32890/jdsd2024.2.1.8
13. Kurundkar, Sangeeta & Dhandar, Pranav & Lahudkar, Manoj & Chaudhari, Lalit & Kandare, Utkarsh & Boge, Rohan. (2024). IoT-Enabled Smart Irrigation System for Precision Farming using Microcontroller. 10.56155/978-81-955020-2-8-80.
14. R Ratnadewi et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 407 012160
15. Suffian, Dhiauddin & Ibrahim, Suhaimi. (2012). Adopting Six Sigma in Formulating a Defect Prediction Model for System Testing. International Journal of Digital Content Technology and its Applications. 6. 60-76. 10.4156/jdcta.vol6.issue21.8.