Development of Internet of Things (IoT) Based by Using Blynk for Irrigation and Fertigation System

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Abstract

Urban agriculture provides innovative solutions to meet the growing demand for sustainable food production in areas with limited ground availability, particularly in densely populated urban regions. A significant challenge for urban gardeners and plant enthusiasts is maintaining plant health during prolonged absences, often resulting in dehydration and plant loss. This research introduces a smart irrigation system designed to automate plant care and enhance convenience. The system incorporates a soil moisture sensor, a liquid ultrasonic sensor, and the Blynk application for efficient monitoring and management of irrigation processes. Inventor software was used to design the system, construct circuits, and develop an intuitive application interface. The system operates autonomously, watering plants when low soil moisture is detected, while also enabling users to manually activate irrigation via a mobile application during extreme weather conditions or emergencies. Real-time data on soil moisture and water levels are transmitted to the user's mobile device through the internet, ensuring seamless remote control and monitoring. The methodology involved integrating hardware and software components, calibrating the system, and conducting performance evaluations to validate its reliability. Experimental results demonstrated the system's capability to maintain optimal plant health by addressing dehydration risks effectively. This research offers a practical, efficient, and user-friendly solution for urban gardeners, contributing to the development of innovative and sustainable urban agriculture practices. By addressing key challenges associated with plant care in restricted environments, the system could promote convenience, reliability, and improved plant vitality in modern living spaces, advancing the potential for smart urban farming solutions.

Keywords: Automation, Fertigation, Internet of Things (IoT), Irrigation, Mobile Application

1.0 Introduction

The agricultural sector has not been exempted from the rapid advancements in technology, with the application of the Internet of Things (IoT) becoming increasingly widespread and thriving. IoT-based systems play a crucial role in monitoring and maintaining optimal soil moisture levels, directly addressing challenges inherent in traditional farming practices. IoT technologies are employed in various agricultural processes, including monitoring and recording crop growth, applying treatments, cultivation, and irrigation [1]. Modern irrigation and fertigation systems, enhanced by IoT, are transforming agricultural practices by enabling farmers to remotely manage the delivery of water and nutrients to plants, thereby improving efficiency, productivity, and sustainability.

IoT-based irrigation systems automate crop watering by utilising soil sensors that measure moisture levels, temperature, and other environmental conditions. Data from these sensors is transmitted to a central, often cloud-based, platform for analysis. When soil moisture falls below a specified threshold, the system automatically activates to provide the precise amount of water needed. As described by Hamdoon and Zengin [2], IoT-enabled irrigation systems minimise water wastage by automating irrigation processes only when soil moisture is insufficient, ensuring optimal water delivery and plant growth while reducing manual labour. These systems can be monitored and controlled remotely via mobile applications or web interfaces. Similarly, fertigation systems use IoT sensors and controllers to monitor soil nutrient levels, plant health, and environmental factors, determining the timing and quantity of fertiliser application. By delivering precise amounts of nutrients at appropriate times, IoT-based systems minimise waste and promote healthier crop growth [3].

IoT technologies offer substantial potential for remotely monitoring and managing agricultural processes in real time, making them highly suitable for precision agriculture [4]. These systems provide numerous benefits, including improved water and nutrient efficiency, achieved by minimising over-watering and over-fertilisation, which conserves resources and enhances plant health. Remote monitoring and control capabilities allow farmers to manage their systems from any location via connected devices. Additionally, continuous data collection facilitates informed, data-driven decisions for optimising crop management. Improved accuracy in water and fertiliser application leads to significant cost savings by reducing operational expenses. Furthermore, IoT-enabled systems promote sustainability by mitigating environmental impacts, such as water wastage and runoff pollution, and thereby support more sustainable farming practices [5].

Research by T. Obasanya et al. [6] highlights the development of IoT-based smart irrigation and tank monitoring systems to reduce water wastage, minimise human effort, and enable remote monitoring of water levels and supply via the internet. In the context of smart irrigation, real-time data acquisition from soil, plants, and weather parameters is critical for effective irrigation scheduling. This requires continuous monitoring of factors affecting plant growth and development, alongside strategies for delivering the optimal quantity of irrigation water [7]. Sensors play an integral role in such systems, monitoring variables such as temperature, humidity, light intensity, water nutrient solution levels, pH, electrical conductivity (EC), and carbon dioxide (CO_2) concentration. These parameters are essential for planning agricultural activities and optimising resource use with minimal human intervention [8].

The focus of this project is to enhance knowledge and innovation in the application of IoT technologies for gardening. It addresses challenges faced by individuals who struggle to consistently monitor their gardens while improving essential processes, such as irrigation. Modern irrigation systems, including IoT-enhanced drip irrigation, have demonstrated significant benefits. According to Iva and Vasil [9] the concept of "smart garden" arises as a promising solution that seeks to integrate different components and technologies to ensure optimal management and maintenance of green areas in the urban environment.For example, Askaraliev et al. [10] report that such systems can reduce water consumption by up to 50% while increasing crop yields by 30%, making them particularly valuable in water-scarce regions. These advancements also address environmental and socio-economic concerns, promoting sustainable agricultural practices.

Reddy et al. [11] propose integrating cloud-based platforms to enable farmers to remotely monitor and control irrigation processes via mobile applications or web interfaces. By combining sensor data with weather forecasts and evapotranspiration rates, these systems dynamically adjust irrigation schedules, ensuring precise water usage and minimal wastage. Abdul Rasak [12] demonstrated the integration of the IoT-based Blynk platform into a fertigation system, enabling remote monitoring and control of both the fertigation process and soil conditions. These innovations underline the need to revitalise automatic irrigation and fertilisation systems with advanced features that align with contemporary requirements.

This project aligns with the broader objective of advancing smart irrigation technologies by developing a minimalist, yet effective system tailored for small-scale gardening. Leveraging IoT, this system enables users to monitor soil moisture remotely, ensuring plants receive adequate water with minimal manual intervention. This is particularly relevant for home gardeners and small-scale growers who require sophisticated yet accessible solutions. While Malaysia has advanced irrigation and fertilisation systems, these are often designed for large-scale farming and are unsuitable for individuals with limited gardening space. Consequently, a need exists for a compact and user-friendly system that caters to home gardening. By integrating soil moisture sensors, this project aims to implement an automated irrigation and fertilisation system that maintains optimal soil conditions, addressing key factors influencing plant growth and ensuring the success of small-scale gardening initiatives.

2.0 Methodology

This section presents the development of irrigation and fertigation systems using Blynk apps. The proposed system consists of hardware and software parts. The hardware part involves the modification and installation of the sensors in the hydroponic system. The software part contains the programming and development of the control system using the Blynk application as shown in Figure 1.

2.1 Selection of Components for Control System

The components selected for the development of the system are integral to its functionality and efficiency. The single-channel relay module facilitates the control of high-power devices, enabling the Arduino microcontroller (ESP8266) to automate the irrigation system based on sensor data. The ESP8266 acts as the central controller, processing real-time data from the soil moisture sensor to inform decision-making and enabling remote control via the Blynk application. The ultrasonic sensor monitors water tank levels and transmits this data to the ESP8266 for remote tracking and management. The DC power jack with a 12V adapter ensures stable and consistent operation of all system components. Collectively, these components support a reliable, automated irrigation system with efficient water usage and remote monitoring capabilities.

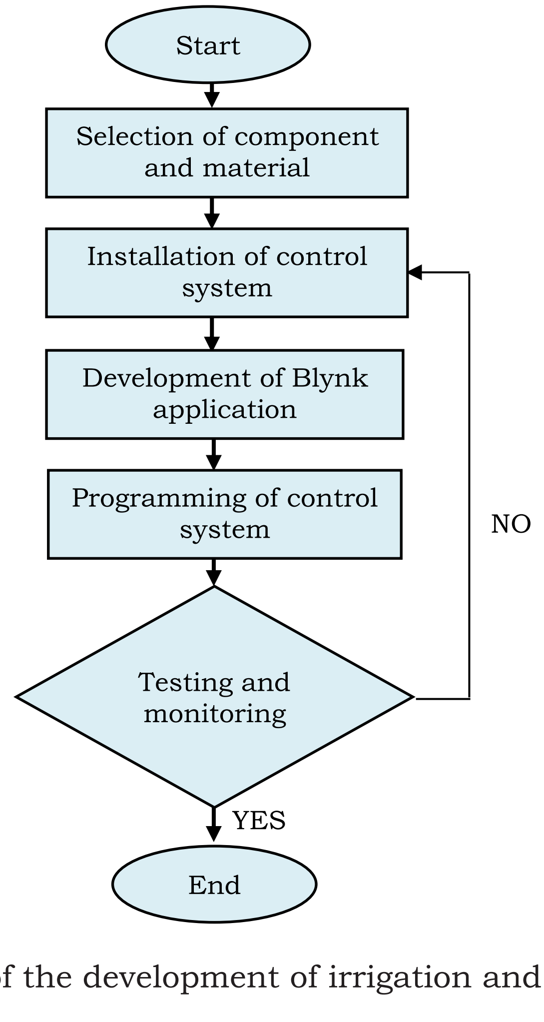

Figure 1: Flowchart of the development of irrigation and fertigation systems

2.1.1 Microcontroller ESP8266

Figure 2 shows the Microcontroller ESP8266. It is a connecting device to the WIFI network, hosting a web server, and facilitating WIFI communication between devices. The ESP8266 comes with built-in Wi-Fi capability, allowing seamless integration with the Blynk platform for real-time monitoring and control. The Node MCU is connected to the internet from the hotspot of the smart phone via WIFI connection as the Node MCU has ESP8266 circuit to connect with the internet [13]. Its cost-effectiveness and compatibility with IoT applications make it ideal for this project. According to Roshahliza and Waheb [14] it is a single-board microcontroller intended to make the application of interactive objects or environments more accessible. It is a cost-effective and open-source physical computing platform with an extensible software development environment for board programming.

Figure 2: Microcontroller ESP8266

2.1.2 Single-Channel Relay Module

The main function of a single-channel relay module is to operate as a switch, allowing low-power signals or control circuits to control higher-power circuits as shown in Figure 3. The primary function of the single-channel relay module is to actuate high-power devices, such as water pumps or solenoid valves, using the low-power output from the ESP8266 microcontroller. The relay can be controlled remotely via the Blynk app, giving users the ability to manually override automation, turn the pump on/off, or respond to real-time alerts.

Figure 3: Single-channel relay module

2.1.3 Soil Moisture Sensor

The main function of soil moisture sensors as shown in Figure 4 is to measure and report the moisture content of the soil where they are installed. It measures the electrical resistance between two metal probes inserted into the soil. As moisture increases, resistance decreases. This sensor can be utilised by embedding it in the ground, and the status of the soil's water content can be expressed as a percentage [15]. The sensor helps to monitor soil moisture levels to determine whether irrigation is necessary. It measures the volumetric content of water inside the soil and give the moisture level as output [16].

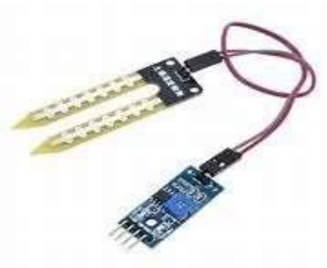

Figure 4: Resistive type of soil moisture sensor

2.1.4 Ultrasonic Sensor

Ultrasonic sensors as shown in Figure 5 are commonly used to measure the levels of liquids, usually water and nutrient solutions in storage tanks. The sensor measures the water level in the tank to prevent dry runs of the pump and ensure a consistent water supply. Ultrasonic sensor emits high-frequency sound waves, which bounce off the surface of the liquid. The sensor measures the time taken for the echo to return, calculating the distance and thus the liquid level. It works as a fail-safe mechanism to alert users via the Blynk app in case of low water levels. The reason why we use ultrasonic sensors is because it is reliable, affordable, and easy to interface with the microcontroller.

Figure 5: Ultrasonic sensor

2.2 Programming and Development of Blynk Application

In this section, the researcher has developed the system in two parts. Among them, the researcher has developed a smartphone application for users that can continuously monitor soil moisture, even when the distance between the user and the control system is significant. This monitoring can be carried out as long as the control system has an internet connection to send data to the user's smartphone application. This application can control hardware devices, display sensor data, and store data, and data visualize visualisation. Blynk can work in real-time for remote control and monitoring via the internet.

2.2.1 Development of Blynk Application

Figure 6 shows the Blynk console interface for an IoT-based irrigation and fertigation system. This system is designed to automate and optimize urban farming operations, ensuring efficient water and nutrient management through real-time monitoring and control. The key functions of items in the Blynk console are listed in Table 1.

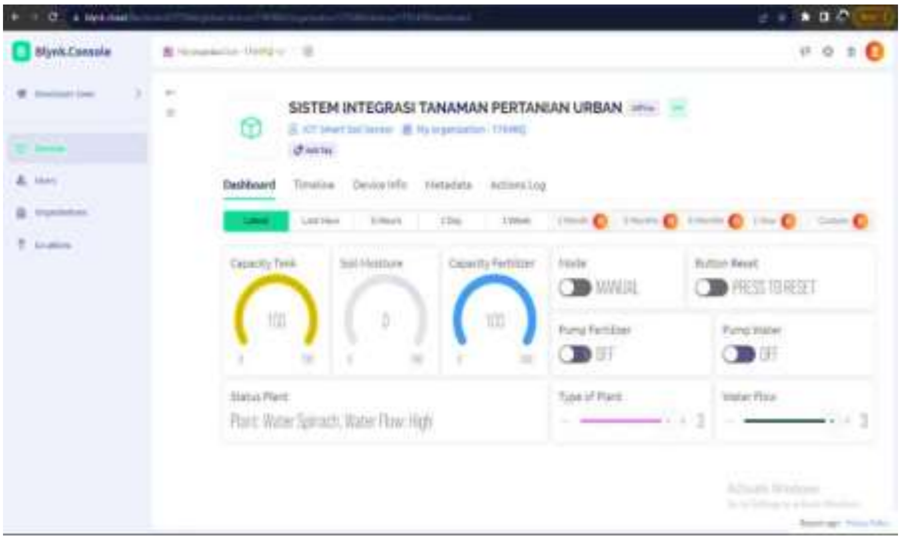

Figure 6: The Blynk console interface

Table 1: The key functions of the system

Item	Description
System Overview	The system is named "Sistem Integrasi Tanaman Pertanian Urban" (Urban Agriculture Plant Integration System). It integrates IoT components, specifically smart soil sensors for monitoring plant conditions.
Dashboard Indicators	i. Capacity Tank: Displays the current water tank capacity (100% in this case), essential for irrigation management. ii. Soil Moisture: Shows the soil's moisture level, which is crucial for irrigation timing. iii. Capacity Fertiliser: Indicates the fertiliser tank's capacity (100% in this case), ensuring adequate nutrients for the plants.
Control Panel	i. Mode Selection: Allows users to toggle between Manual and Automatic control modes. ii. Pump Fertiliser & Pump Water: On/Off switches for activating pumps to dispense water or fertiliser. iii. Button Reset: A "Press to Reset" button to restore default settings or clear any system warnings.
Plant Status and Customization	i. Status Plant: Displays information about the plant type (e.g., Water Spinach) and water flow status (High/Low). ii. Type of Plant: A slider to select or adjust the type of plant, indicating system customization based on different plant requirements. iii. Water Flow: Slider to control or monitor water flow rate.
Time Range Options	Users can view system data for different periods, from the latest to custom-defined time ranges, helping in

	long-term data analysis.
Navigation and Organization	The left-side menu allows navigation between Devices, Organizations, and Locations, making it easy to manage multiple IoT devices in different areas.

Figure 7 shows the device information where important details are included in the diagram, covering firmware configuration, board type, intellectual property (IP), and more. This dashboard is specifically designed to facilitate real-time monitoring and management of various agricultural parameters through the integration of IoT (Internet of Things) devices. These devices continuously collect and transmit data, allowing users to have a detailed and up-to-date view of essential factors such as water tank capacity, soil moisture levels, and fertiliser availability. By leveraging this data, users can make informed decisions and efficiently control critical systems, including water irrigation and fertiliser distribution. The system adapts its operations based on real-time soil conditions, ensuring that plants receive the optimal amount of water and nutrients when needed. This not only helps in reducing resource wastage but also promotes healthier plant growth by maintaining ideal growing conditions, ultimately contributing to higher agricultural productivity and more sustainable farming practices.

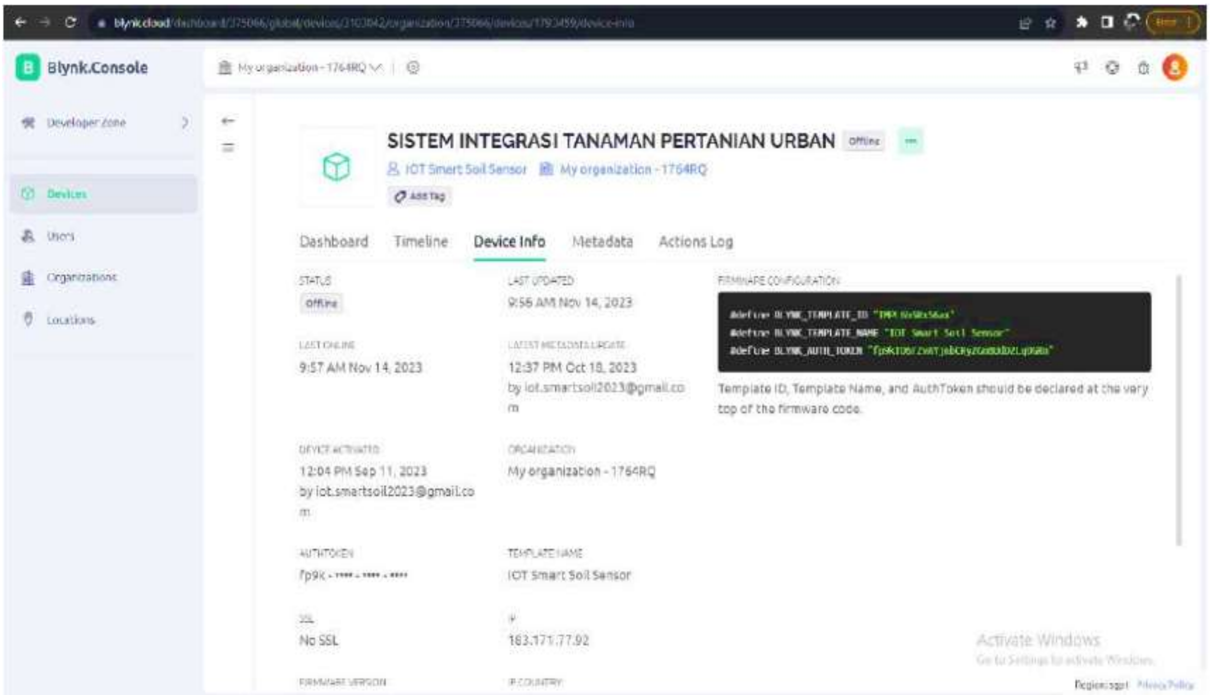

Figure 7: Device information on the dashboard

Figure 8 shows the data streams configuration page in the Blynk Console for an IoT Smart Soil Sensor system. This page allows users to configure and manage the data inputs and outputs for their IoT system, ensuring seamless communication between hardware sensors/actuators and the Blynk platform. By organizing data streams, users can effectively control irrigation, soil monitoring, and fertiliser management for optimized agricultural operations.

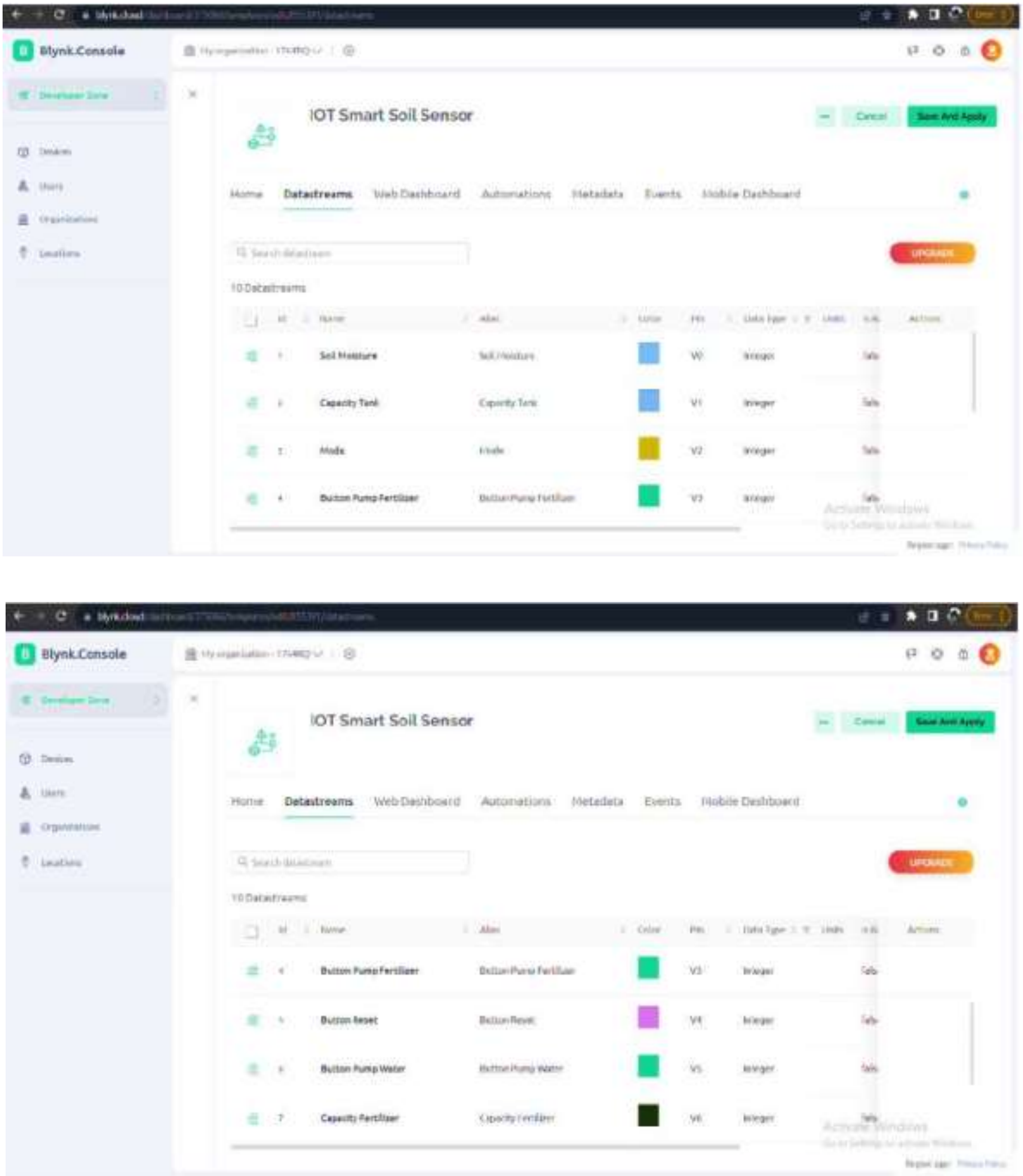

Figure 8: Device information on the dashboard

2.2.1 Coding system

This layout contains the name of the project, the author's name, the date the system was built, as well as the password and e-mail. This diagram also contains a special ID that can be found on the Blynk console, as well as the settings for the WIFI credentials and its password, which serve as an intermediary between the modem and the control system. Researchers have established limits for soil moisture sensor performance and determined the placement of the pump between the irrigation pump and the fertilization pump. Researchers have issued a warning if the trigger is below 20% of the water tank. The system has been set to manual mode. Researchers have coded three types of vegetables, including pak choi, water spinach, and spinach. Researchers have used a slider on the application in the user's mobile phone. The different flow rates for each variable are manipulated, meaning that the pump's operating time varies for each available mode. Among them are 2.0s, 4.0s, and 6.0s for each plant.

Researchers have developed an advanced coding system designed to optimize the organization of notifications within smartphone applications. The system is used to reorganize notifications on users' smartphone applications to prevent data overflow, which could lead to storage issues in the users' cloud. This system prioritizes and categorizes notifications, helping to reduce unnecessary data accumulation on users' devices. By streamlining how notifications are managed, the system minimizes the risk of excessive data storage requirements, which could otherwise overwhelm users' cloud storage. As a result, this approach not only prevents potential storage limitations but also enhances the overall user experience by reducing clutter and ensuring that only relevant notifications are delivered in an organized manner.

2.3 Installation of Control System Device

The process of installing the control system involves wiring and installation as shown in Figure 9. The first step is to create an overall sketch of the tools used in the control system using the Fritzing application. Next, the wiring process is carried out to distribute power to the pump, transfer data, connect sensors and actuators, establish networks and pathway connections, as well as addressing concerns regarding reliability and safety in the control system.

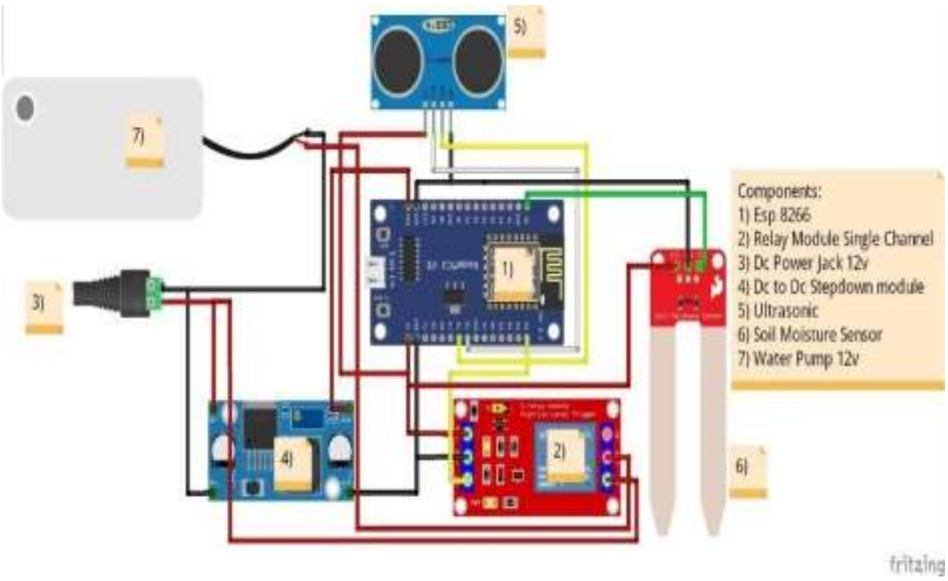

Figure 9: Circuit diagram of the IoT-based fertigation system

The diagram illustrates the connection of key components: (1) ESP8266 microcontroller for IoT integration, (2) single-channel relay module for water pump control, (3) 12V DC power jack, (4) DC-to-DC step-down module for voltage regulation, (5) ultrasonic sensor for water level measurement, (6) soil moisture sensor for monitoring soil conditions, and (7) 12V water pump for automated irrigation and fertilization. The system is designed to automate fertigation processes with real-time monitoring and control via the IoT platform.

2.4 Observation and Data Collection

The IoT system is used to monitor water levels in the irrigation system and ensure an adequate water supply for crops. Readings are taken at regular intervals which is 1 hour daily from 0900H to 1300H, to maintain consistency. The water levels and fertiliser solutions are monitored, along with the time, date, and environmental conditions. To ensure the pH of water and fertiliser solutions is within optimal ranges for plant health, a digital pH meter, buffer solutions (pH 4.0 and 7.0), and sample containers are used. The pH meter probe is then submerged into the sample, and the reading is recorded once it stabilizes. The pH value readings of the fertiliser solution were taken 5 times. To monitor soil moisture levels for efficient irrigation and prevent overwatering or underwatering, a soil moisture sensor is used. The sensor is placed at the root zone, typically 10-15 cm deep. Once the sensor stabilizes, the moisture level is recorded including time and date. The time interval for measuring the percentage of soil moisture is every 1 hour from 0700 to 1900 every day.

3.0 Results and Discussion

Based on the observations made, the researcher has obtained several findings from the development of irrigation and fertigation systems. The data was obtained from measurements of water levels and fertiliser solutions, pH values, and soil moisture content.

3.1 Water Level and Fertiliser Solution

Data from the observation of water level and fertiliser solution and its caption is shown in Table 2. The mean values (62.2% for water level and 49% for solution level) provide an average representation of the data, which is sufficient for analysis without needing excessive data points.

Table 2: Data of water level and fertiliser solution level

No	Time	Water level (%)	Solution level (%)
1	0900	62	49
2	1000	65	47
3	1100	64	51
4	1200	59	50
5	1300	61	48
Mean		62.2	49

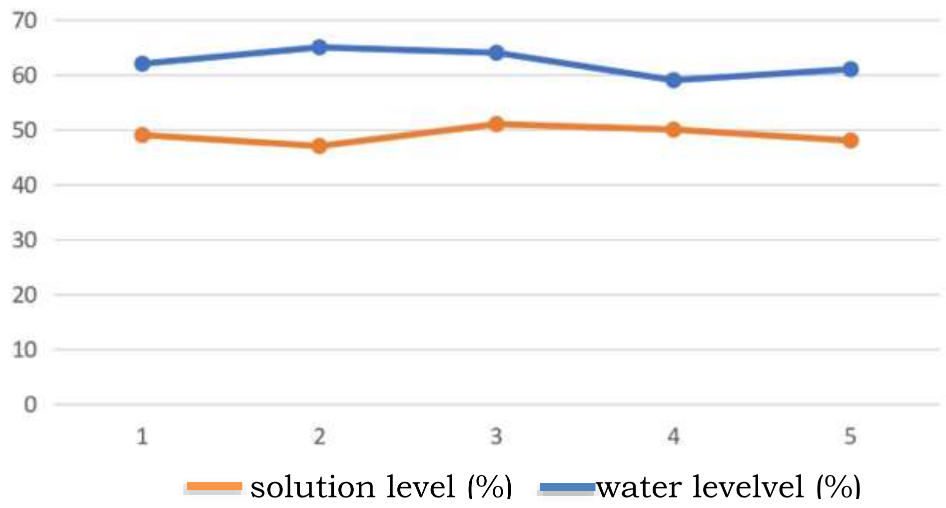

Figure 10: Water level and fertiliser solution against time

Figure 9 shows the water level trend which fluctuates throughout the day, ranging from 59% to 65%. There is not a drastic change, but it is relatively stable. While, the solution level is slightly lower than the water level, ranging from 47% to 51%. Like the water level, it remains relatively stable throughout the monitored period. This indicates that there is a consistent supply of both water and solution, possibly for irrigation or fertilisation, with slight variations based on consumption or other factors.

3.2 Fertiliser Solution pH value

Data from the observations of pH value from the fertiliser solution is shown in Table 3. In this study, five pH readings were measured to represent the overall conditions, especially since the system is relatively stable, and the pH values show consistency with little variation (except for minor deviations), indicating that five data points provide a reliable mean.

Table 3: Data of pH value from the fertiliser solution

No.	pH value
1	5.2
2	5.2
3	4.8
4	5.2
5	6.1
Mean	5.3

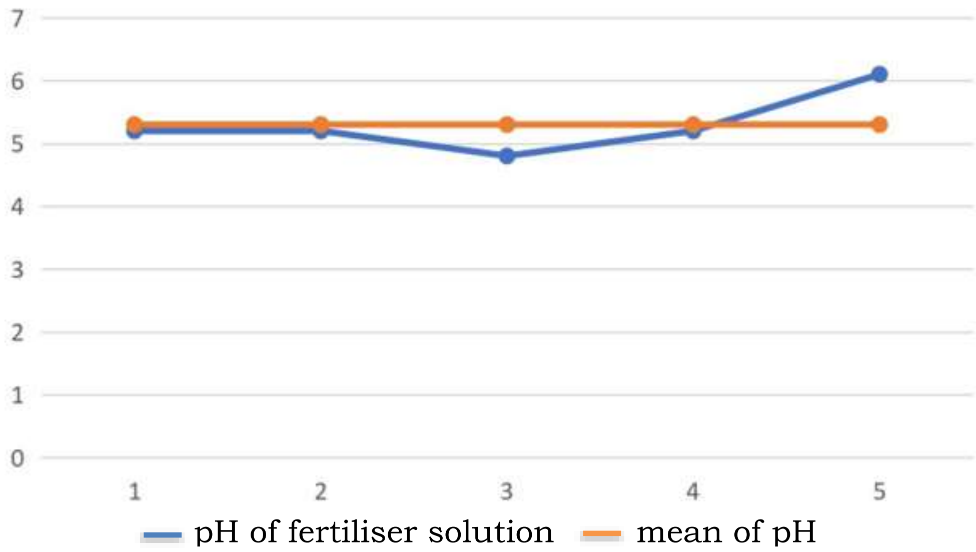

Figure 11: pH value in fertiliser solution

Through the study conducted by the researchers, the average pH reading for the fertiliser solution is 5.3, while the optimum pH value based on the investigation is between 5.5 and 6.5. This indicates that the pH reading during the testing is lower compared to the investigation carried out by the article source as shown in Figure 11.

3.3 Soil Moisture

The findings from the data analysis on the percentage of soil moisture for this crop are very important and should be given thorough attention by researchers, as water is a fundamental necessity for plants. The soil moisture level starts high in the early morning, gradually decreases around noon, and then stabilizes in the afternoon. Table 3 shows the data of soil moisture taken for a one-hour time interval. 07:00 AM to 7:00 PM aligns with typical daylight hours, which is when soil moisture is most impacted by external factors like sunlight, evaporation, and plant transpiration.

Monitoring during these hours provides insights into how environmental conditions affect soil moisture and when irrigation is most needed. This timeframe is practical for agricultural operations, as most farming activities occur during the day. It allows operators to make real-time adjustments if soil moisture levels drop below critical thresholds.

Table 3: Data on soil moisture

Time	Percentage of Soil Moisture (%)
0700	97
0800	96
0900	96
1000	90
1100	82
1200	79
1300	81
1400	80
1500	83
1600	82
1700	83
1800	81
1900	82

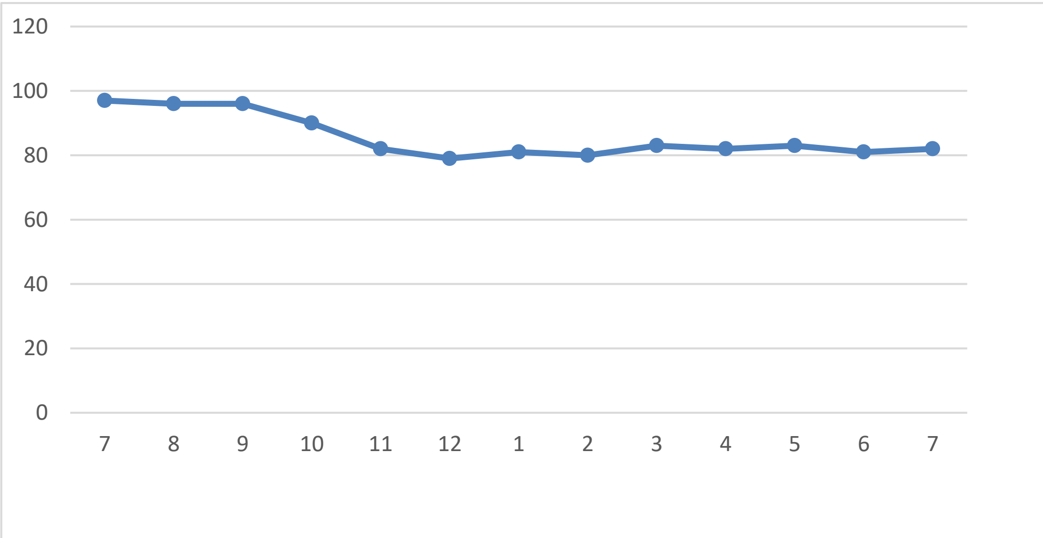

Figure 11: Soil moisture percentage over time

Results show that the highest percentage of soil moisture occurs in the morning because plants are exposed to high environmental humidity at night. However, the soil moisture decreased at noon, causing the pump to start operating because the soil moisture percentage was below 80%. Morning (07:00 - 11:00 AM): Soil moisture is high, starting at 97% and gradually decreasing to 82% by 11:00 AM. This decline suggests water absorption by the soil or plant uptake. Midday (12:00 - 14:00): The lowest moisture level was recorded at 79% around noon. Likely due to evaporation or high plant water consumption during peak sunlight hours. Afternoon (15:00 - 19:00): Soil moisture stabilizes around 82-83% with minor fluctuations, indicating that either irrigation or environmental conditions have balanced the moisture level.

During the testing, the researchers faced several difficulties in obtaining accurate data. Among the difficulties often faced by researchers is that the ultrasonic sensors on both the water and fertiliser tanks frequently experience errors, causing researchers must replace these sensors multiple times to obtain consistent readings. Therefore, researchers need to perform more precise calibrations to reduce the risk of errors in the ultrasonic components.

In addition, the researcher also faces frequent issues with the replacement components in the cooling system, where they need to replace these components regularly to obtain consistent reading values. This is because the replacement components in the reading system often malfunction. To address this issue, the researcher needs to make modifications to the wiring system and replace the faulty components. Finally, the researchers also faced challenges in calibrating soil moisture because the findings obtained from journals and articles were too basic and not focused on specific types of crops. Therefore, the researcher needs to conduct tests to obtain the desired range values for soil moisture.

4.0 Conclusion

This project sets out to design and develop a prototype for a smart agricultural fertigation system leveraging IoT technology. The system automates both irrigation and fertilisation processes, providing farmers with the capability to monitor and control key parameters such as pH levels of the fertiliser solution and liquid levels in real-time via an IoT platform. The platform facilitates remote monitoring of critical factors including pH levels, tank liquid levels, and operational status, offering ease of use and significantly enhancing operational efficiency. The prototype has successfully automated these processes, demonstrating reliable functionality in real-world conditions. Furthermore, the system shows substantial potential for conserving water and fertiliser through its precise and targeted application, which could be particularly beneficial in large-scale agricultural operations. For future research, it is recommended to integrate additional sensors, such as those for temperature, humidity, or plant health, to further optimise decision-making and automation. Additionally, incorporating renewable energy sources, such as solar power, would reduce the environmental impact of the system, aligning with sustainable agricultural practices.

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Author Contributions

Siti Salwa Samsuri: Conceptualization, Methodology, Writing-Original, Draft Preparation, Editing; **Masniza Yusof**: System, Writing-Reviewing, Editing, Validation; **Mohd Azhar Othman**: Hardware and Data Curation.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission, and declare no conflict of interest in the manuscript.

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