DEVELOPMENT OF AN IOT-BASED AUTOMATIC FERTIGATION SYSTEM USING ESP32

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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ABSTRACT

The integration of Internet of Things (IoT) technology in agriculture offers significant potential to enhance the efficiency and effectiveness of farming practices. This report presents the development and implementation of an IoT-based automatic fertigation system utilizing the ESP32 microcontroller. The system is designed to optimize the delivery of water and nutrients to crops through precise control and monitoring mechanisms. The key elements of the project are include soil moisture, temperature and humidity sensors that provide the real-time data to the ESP32 microcontroller. This microcontroller will process the data and also manage the distribution of water and fertilizer. The data that has been collected will be sent to a cloud-based platform for the purpose of storage, analysis and remote monitoring, this system allows farmers to make informed decisions and manage their fertigation process remotely. In addition, this project can also control liquid fertilizer by using the switch on the application to activate the water pump to flow the fertilizer to the plants. This project has worked successfully and has been tested by comparing the temperature and humidity with a standard device. By using an automatic system method for watering it can help plants growth quickly. This project shows that the system that has been used can contribute significantly to optimizing agricultural resources and increasing crop productivity.

ABSTRAK

Penyepaduan teknologi Internet Perkara (IoT) dalam pertanian menawarkan potensi besar untuk meningkatkan kecekapan dan keberkesanan amalan pertanian. Kertas kerja ini membentangkan pembangunan dan pelaksanaan sistem fertigasi automatik berasaskan IoT menggunakan mikropengawal ESP32. Sistem ini direka bentuk untuk mengoptimumkan penghantaran air dan nutrien kepada tanaman melalui mekanisme kawalan dan pemantauan yang tepat. Elemen utama projek adalah termasuk penderia kelembapan tanah, suhu dan kelembapan yang menyediakan data masa nyata kepada mikropengawal ESP32. Pengawal mikro ini akan memproses data dan juga menguruskan pengagihan air dan baja. Data yang telah dikumpul akan dihantar ke platform berasaskan awan untuk tujuan penyimpanan, analisis dan pemantauan jarak jauh, sistem ini membolehkan petani membuat keputusan termaklum dan menguruskan proses fertigasi mereka dari jauh. Selain itu, projek ini juga boleh mengawal baja cecair dengan menggunakan suis pada aplikasi untuk mengaktifkan pam air untuk mengalirkan baja ke tanaman. Projek ini telah berjaya dan telah diuji dengan membandingkan suhu dan kelembapan dengan peranti standard. Dengan menggunakan kaedah sistem automatik untuk menyiram ia dapat membantu pertumbuhan tumbuhan dengan cepat. Projek ini menunjukkan bahawa sistem yang telah digunakan dapat menyumbang secara signifikan untuk mengoptimumkan sumber pertanian dan meningkatkan produktiviti tanaman.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **TITLE** **PAGE**

LIST OF FIGURES

LIST OF ABBREVIATIONS

V	-	Voltage
I	-	Current
°C	-	Celcius
%	-	Percentage
P	-	Power
A	-	Ampere
W	-	Watt
s	-	Second

CHAPTER 1

INTRODUCTION

1.1 Background

Optimizing the use of resources like water and fertilizers is essential in contemporary agriculture to maximize crop output and reduce environmental effect. An extremely effective method of supplying precise amounts of fertilizers straight to the root zone is through fertilization, which is the process of supplying nutrients to plants using irrigation systems. Modern Internet of Things (IoT) technology offers opportunities to improve traditional fertigation systems, making them more intelligent, automated, and controllable remotely. This integration enables enhanced resource management, automatic nutrient level adjustment, and real-time monitoring of soil conditions. The ESP32 microcontroller is an ideal choice for developing Internet of Things applications due to its affordability, integrated Wi-Fi and Bluetooth functionalities, and versatility. Its capability to manage data and connect multiple sensors and actuators makes it particularly suitable for creating an automated fertigation system.

1.2 Addressing development of an IoT-based automatic fertigation system using ESP32

This project utilizes an ESP32 microcontroller to develop an Internet of Things-based automatic fertigation system. The ESP32 is crucial for gathering sensor data, controlling actuators, and facilitating communication with other devices. It is recognized for its low power usage and built-in WiFi features.

Our aim is to create a dependable, scalable, and cost-effective solution to enhance the fertigation process in agriculture by leveraging the capabilities of the ESP32 and IoT technology.

1.3 Problem statement

Traditional fertigation systems frequently struggle to promptly adapt to shifting plant requirements and environmental conditions. Manual adjustments can be time-consuming and susceptible to human error, leading to resource wastage and suboptimal crop yields. Furthermore, the absence of remote monitoring and control capabilities in existing solutions limits system accessibility and scalability.

The challenge lies in developing an automated fertigation system that offers remote access and control for farmers or agronomists. This system must intelligently monitor soil conditions, determine nutrient needs, and adjust irrigation accordingly.

1.4 Project objective

The main goal of this project is to use the ESP32 microcontroller to design, implement and evaluate an Internet of Things based automatic fertigation system. The objectives are:

- To automate the irrigation and fertilization process by monitoring soil moisture, temperature and humidity environmental conditions in real-time.
- To optimize water and fertilizer usage by delivering the right amount at the right time based on crop needs.
- To provide a user interface for farmers to monitor and control the system remotely using a mobile application.

1.5 Scope of project

The scope of this project are as follows:

1. Selecting and integrating suitable sensors to monitor plant health and soil conditions.
2. Developing firmware for the ESP32 microcontroller to enable it to gather sensor data and oversee the irrigation system.

3. Implementing basic IoT functionalities for remote monitoring and control via online or mobile applications.
4. Conducting controlled tests to verify the system's operation and performance.
5. Documenting software code, hardware schematics, design and implementation details, and testing procedures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The incorporation of Internet of Things (IoT) technology in agriculture has transformed traditional farming practices by enhancing efficiency, minimizing resource use, and boosting crop yields. Automated fertigation systems, which leverage IoT for irrigation and fertilization, have garnered considerable interest. This literature review analyzes various approaches and techniques for developing IoT-based automatic fertigation systems, comparing their benefits and drawbacks, and emphasizing the societal and global impacts of these technological advancements.

2.2 Related Project Research

2.2.1 Real-Time Monitoring of Soil Conditions Using IoT Technology

The use of IoT technology for real-time soil condition monitoring has transformed modern agriculture, offering farmers unprecedented insights into field health and optimizing resource utilization. Critical parameters such as temperature, nutrient content, pH, and moisture levels are continuously tracked and wirelessly transmitted to a central hub via IoT sensors placed in the soil. This hub serves as a link, relaying the data to a cloud-based system accessible from any internet-connected device. Here, the incoming data is processed by sophisticated analytics and machine learning algorithms to provide real-time insights into environmental conditions and soil health. By using this data to set up warnings for crucial thresholds like low moisture or extremely high temperatures, farmers may use it to make proactive decisions [1].

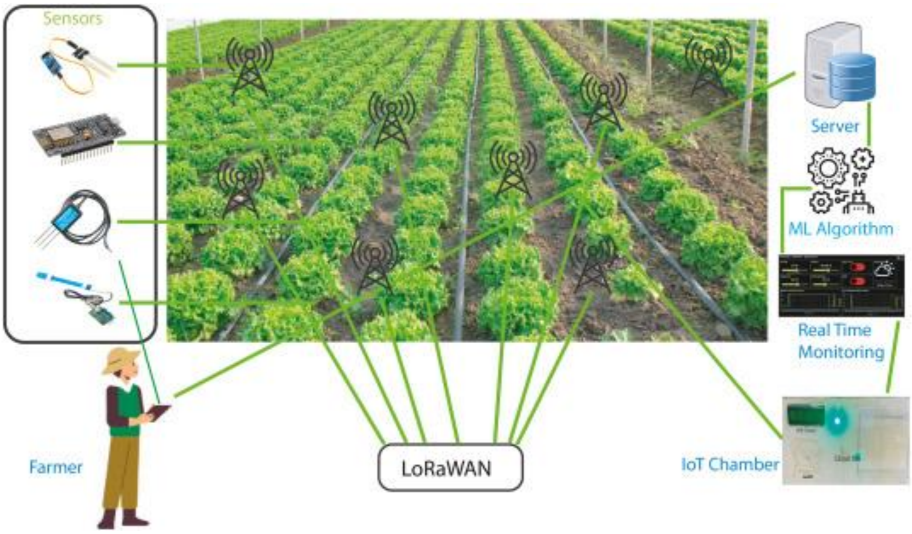


Figure 2.1: Enabled IoT System for monitoring soil nutrients and crop recommendations[2]

2.2.2 Precision Nutrient Management in Agriculture

Precision nutrient management in agriculture is a critical aspect of modern farming practices, aiming to optimize crop productivity while minimizing environmental impact and resource wastage [3]. This approach includes utilizing progressed innovations such as soil sensors, rambles, and information analytics to tailor supplement applications to the particular needs of crops and the conditions of the soil. By precisely coordinating supplement supply with edit request, agriculturists can move forward supplement utilize productivity, diminish the chance of supplement runoff and filtering, and eventually improve both the financial and natural maintainability of agrarian operations. This concept is progressively vital in advanced farming because it looks for to meet the developing worldwide request for nourishment whereas relieving the negative impacts of ordinary cultivating hones on the environment.

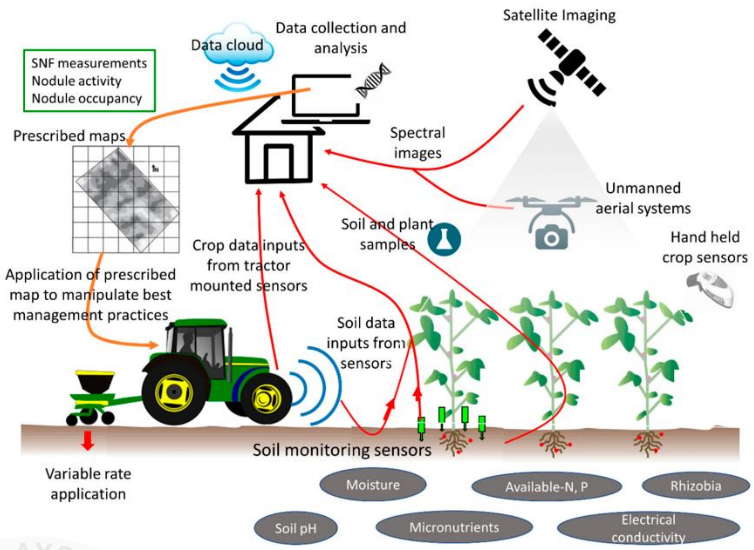


Figure 2.2: Precision Agriculture[4]

2.2.3 An IOT based Irrigation System in Floriculture

Modern agricultural technology that maximizes water distribution for flowers and decorative plants is called an irrigation system for floriculture that is based on the Internet of Things. It combines data analytics, actuators, and Internet of Things sensors to automate watering based on current environmental data. While some sensors assess temperature and light intensity, soil moisture sensors keep an eye on moisture levels. Based on the system's analysis of this data, actuators are activated to deliver water directly to the plant roots. Moreover, IoT-based technology can be utilized to establish a fertilizer application infrastructure, ensuring optimal plant growth through precise and controlled fertilizer application. This holistic approach ensures that not only water distribution but also nutrient application is finely tuned to the specific needs of the plants, maximizing yields while minimizing environmental impact [5]. Farmers can access information and modify irrigation schedules via remote monitoring and control. Over time, data analysis enhances plant fertility and water efficiency. This technology is anticipated to offer substantial benefits for floriculture, such as higher yields and greater sustainability.

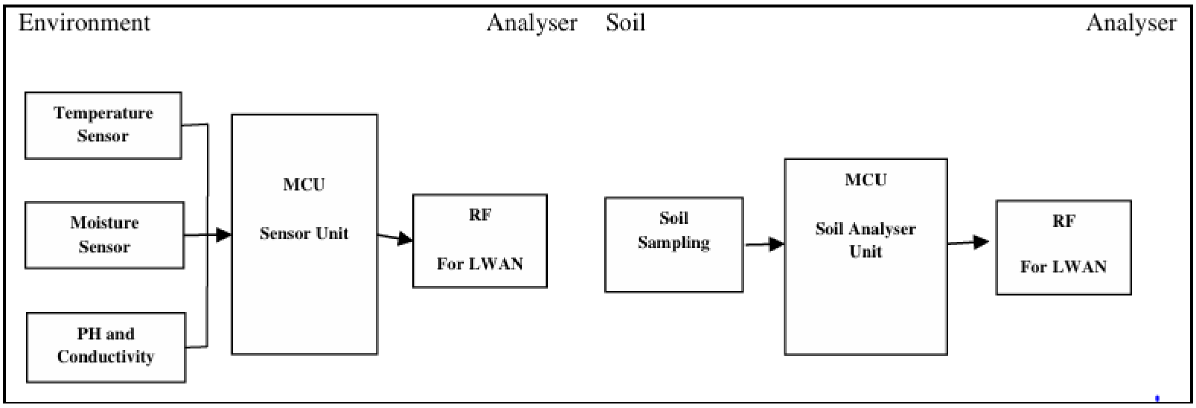


Figure 2.3: Block Diagram of the Basic Analyser Unit[6]

2.2.4 IoT-based Smart Irrigation System Using ESP32

This project demonstrates the use of ESP32 to create a smart irrigation system which can monitor soil moisture levels and automate the plant watering process. The system uses various sensors to gather real-time data, which is then processed to decide the optimal watering schedule, thereby conserving water and ensuring healthy plant growth [7]. The system's main hardware components are a microcontroller, moisture sensor, temperature sensor, air humidity sensor, water flow sensor, solenoid valve, relay, and a step-down transformer [8]. The ESP32 microcontroller, selected for its adaptability and robust features, is at the heart of the system. It efficiently manages multiple sensors and actuators, making it ideal for IoT applications. Its built-in Wi-Fi and Bluetooth capabilities ensure seamless data transmission and remote control. A soil moisture sensor measures the volumetric water content in the soil, and by placing these sensors at different depths and locations, the system can accurately assess soil moisture levels throughout the area.

The temperature and humidity sensor is a precise component for detecting environmental conditions in the plant area. This sensor collects additional data on temperature and humidity, which aids in making informed irrigation decisions, as these factors influence soil moisture levels and plant water requirements. Next, the ESP32 reads the humidity sensor values and notifies the user when the humidity is too high or too low [9]. Water pumps and valves are employed in this project and managed by the ESP32 microcontroller, which regulates water flow across various sections of the field. This setup enables precise control over the timing and volume of water delivery, effectively reducing wastage. Additionally, the project includes a remote monitoring system accessible via a mobile application. Users can monitor real-time system status, adjust parameters, access historical data, and receive alerts for abnormal conditions detected by the system.

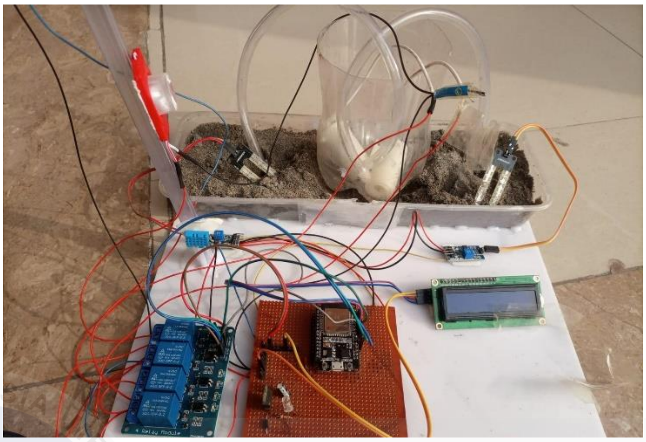


Figure 2.4: Smart Irrigation System Using ESP32[10]

2.2.5 Automatic Fertigation System

In automated fertigation system projects, a variety of innovative approaches have emerged to address the management challenges of modern agriculture. One such strategy involves the proposal of remote control systems utilizing GSM-SMS technology, specifically tailored for greenhouse management [11]. These systems facilitate the monitoring of crucial environmental parameters such as temperature and humidity, while also enabling remote control over watering equipment via SMS. Another promising avenue is the development of irrigation systems based on GSM Bluetooth technology [12]. The system enhances water management efficiency by providing remote control capabilities for on-board irrigation systems. Numerous researchers have investigated microcontroller-based architectures for designing intelligent irrigation systems. This system prioritizes low power consumption and integrates sensors to automate tree watering based on local environmental conditions, offering substantial potential to transform resource-efficient agriculture.

Moreover, the advent of IoT-based solutions has ushered in a new era of intelligent irrigation technology. These solutions leverage sensors to autonomously monitor and regulate irrigation operations, effectively reducing human intervention and maximizing water efficiency in agriculture. Additionally, wireless sensor networks (WSNs) have emerged as crucial tools for monitoring agricultural environments. These networks enable remote sensing of critical factors such as soil moisture, temperature, and humidity, thereby significantly enhancing crop management and optimizing resource utilization across agricultural settings. Together, these insights highlight diverse strategies being explored to tackle contemporary agricultural challenges, encompassing remote control systems, innovative irrigation technologies, IoT-based solutions, and wireless sensor networks.

2.2.6 IoT-Enabled Smart Drip Irrigation System Using ESP32

IoT technologies are transforming agriculture by automating irrigation processes, conserving water, and enhancing crop yields. Research indicates that IoT systems significantly improve resource management and productivity in farming through real-time monitoring and control capabilities. Utilizing IoT technology, intelligent irrigation systems have the potential to lower water usage by 30% while also ensuring the ideal levels of soil moisture, enhancing plant growth and yield [13].

The ESP32 microcontroller, known for its affordable price and built-in Wi-Fi/Bluetooth capabilities, effectively handle multiple sensors and actuators, making it ideal for smart irrigation systems [14]. Capacitive soil moisture sensors are highly favored for extended applications due to their ability to provide essential data for precise irrigation management. Relay modules use this soil moisture data to control water pumps, thereby enhancing the efficiency of irrigation systems.

Practical cases demonstrate the benefits of IoT-driven smart irrigation, such as improved water conservation and higher crop yields observed in India, alongside enhanced grape quality and reduced water usage in Spain. Despite these advantages, challenges like sensor accuracy, connectivity, and power management remain [15]. Future studies need to concentrate on enhancing these components to fully leverage the capabilities of IoT-powered smart irrigation systems in farming.

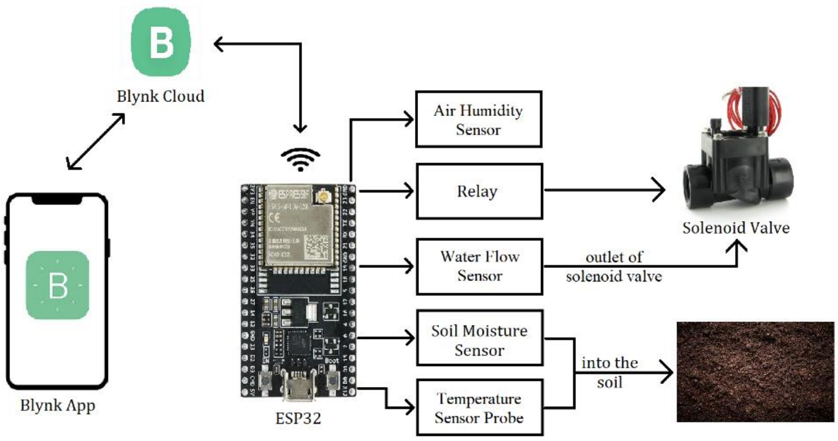


Figure 2.5: Overview of the IoT-enabled smart drip irrigation system[16]

2.2.7 IoT-Based Automated Irrigation System with Weather Prediction

Combining IoT technology with weather prediction models in automated irrigation systems represents a significant advancement in agriculture. This project combines weather prediction models with an IoT-based irrigation system to optimize water usage. The ESP32 microcontroller is used for collecting weather data and adjusting irrigation schedules accordingly [17]. IoT-based systems utilize sensors to continuously monitor soil moisture and environmental conditions, providing precise real-time data essential for efficient water management. These systems benefit from integrating weather prediction models to adjust irrigation schedules based on anticipated weather conditions. Machine learning algorithms further enhance prediction accuracy, ensuring water is applied only as needed.

Research indicates these systems significantly conserve water, reduce labor costs, and enhance crop yields. However, challenges such as the necessity for accurate weather forecasts, dependable sensors, and stable internet connectivity must be overcome. Future studies should focus on advancing predictive models, integrating these systems with other smart farming technologies, and ensuring scalability and accessibility for farmers worldwide. This fusion of IoT and weather forecasting not only optimizes resource utilization but also promotes sustainable agricultural practices.

2.2.8 Development of an IoT-Based Soil Moisture Monitoring System for Agricultural Applications

The integration of IoT technologies in agriculture has significantly advanced soil moisture monitoring systems, addressing the limitations of traditional methods. This research focuses on soil moisture monitoring using IoT technologies. The ESP32 is employed to collect real-time soil moisture data and automate irrigation processes based on the data collected [18]. These IoT-driven systems utilize microcontrollers such as the ESP32, known for its cost-effectiveness, energy efficiency, and built-in connectivity features, to gather real-time soil moisture data from sensors. This data is subsequently transmitted to cloud servers via various communication protocols like Wi-Fi, LoRa, or Zigbee, depending on the connectivity infrastructure in place. Cloud platforms offer scalable storage and robust analytics capabilities, enabling comprehensive data analysis and visualization through intuitive applications.

Automated irrigation systems, responsive to real-time data, optimize water usage, thereby improving crop yields and minimizing wastage. Case studies demonstrate significant enhancements in water efficiency and productivity, despite challenges related to sensor calibration, connectivity issues, and initial setup expenses. Future advancements integrating AI, machine learning, and blockchain technologies hold promise for further enhancing the efficiency and accessibility of these systems, fostering sustainable and productive precision agriculture practices.

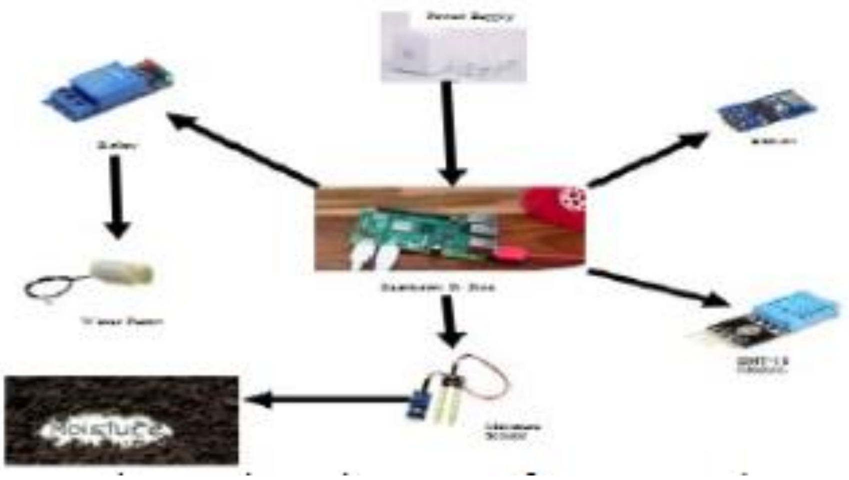


Figure 2.6: Schematic Layout of Proposed System[19]

2.2.9 Enhancing Crop Growth Efficiency through IoT-enabled Smart Farming System

The agricultural sector faces significant challenges in meeting the increasing demand for food production while ensuring sustainability and efficient resource use. To address these challenges, there has been a growing emphasis on integrating Internet of Things (IoT) technology into agricultural practices as a viable solution. This research focuses on developing and implementing an IoT-based smart farming system to enhance crop growth effectiveness. The proposed system utilizes IoT sensors and devices to continuously monitor and collect real-time data on environmental conditions, soil moisture levels, and crop health. This data is then analyzed using advanced analytics techniques to derive valuable insights and make informed decisions regarding irrigation, fertilization, and pest management.

By utilizing IoT technology, farmers can optimize their resource utilization, reduce waste, and maximize crop productivity [20]. The objective of this study is to explore the advantages and difficulties linked to adopting the IoT-powered intelligent agriculture system. This paper delves into the latest Internet of Things (IoT) technology to monitor weather and soil conditions for optimal crop growth. The purpose of the system was to track temperature, humidity, and soil moisture with the help of Node MCU and multiple connected sensors. Moreover, a Wi-Fi connection is employed to transmit an alert via SMS to the farmer's mobile phone regarding the environmental condition of the field. The outcomes will support the creation of plans and recommendations for the extensive implementation of IoT-powered smart agriculture methods, ultimately resulting in sustainable and effective crop cultivation to address the needs of an increasing population.

2.2.10 Wireless Smart Greenhouse Management System Based on Multi-sensor of IoT

The merging of science and technology in farming enhances crop production in a beneficial way. The smart greenhouse management system is the most typical form. Therefore, this project was created for a wireless smart greenhouse management system based on IoT multi-sensor [21]. The system offers both automatic and manual control options, and users access the APP on their mobile devices to observe the current data regarding the growth of crops in the greenhouse (such as air temperature, humidity, soil moisture, and light intensity)

[22]. They can also manage devices like fans, roller blinds, and water-saving irrigation systems in the greenhouse, as well as regulate the temperature within a range of ±2°C, humidity within ±5%RH, and light intensity within ±20%. During a set of functional tests, the smart greenhouse management system demonstrates satisfactory functionality and offers a viable practical answer for advancing smart agriculture.

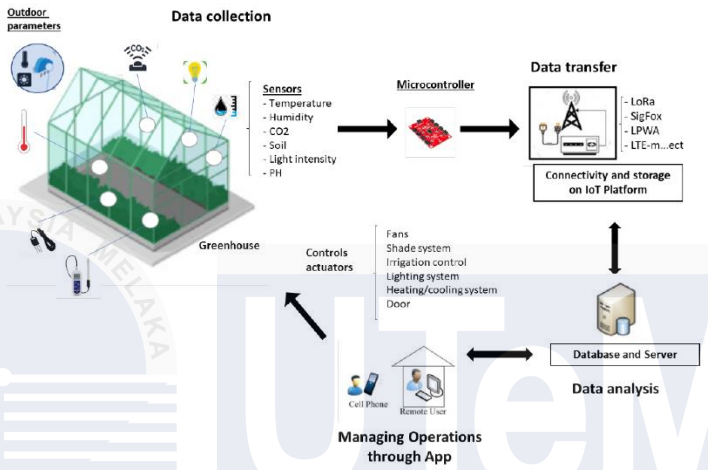


Figure 2.7: Smart Greenhouse[23]

2.2.11 Automatic Fertilized Vertical Irrigation Control and Management System

The system is designed to enhance water and nutrient distribution in vertical farming by using sensor technology and automation for precise control. It includes sensors for moisture, nutrients, light, temperature, and humidity to continuously monitor plant needs and environmental conditions. Drip irrigation lines, pumps, and valves transport water and nutrient solutions to plant roots, all controlled by a central microcontroller or PLC [24]. Nutrient mixers and injection pumps maintain precise fertilizer concentrations. The system includes a user interface for monitoring and adjustments, often accessible remotely. This automated method ensures even distribution of water and fertilizers, reduces waste, fosters uniform plant growth, and lowers labor expenses. As a result, it enhances the efficiency, scalability, and sustainability of vertical farming practices. Additionally, this automatic fertilized vertical irrigation management and control system improves soil vitamins and porosity, resulting in increased plant growth and reduced time and cost in agriculture [25].

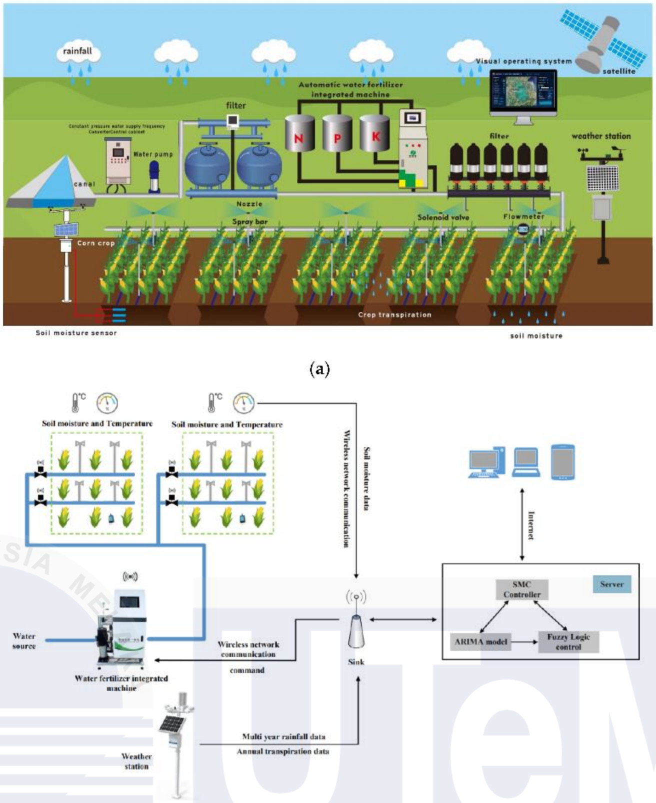


Figure 2.8: Irrigation Control System[26]

2.2.12 Automated Greenhouse Monitoring using Control Systems

Utilizing control systems for automated greenhouse monitoring is a technology-based method aimed at enhancing the growing conditions in a greenhouse [27]. The system uses various sensors to constantly monitor important environmental factors like temperature, humidity, light levels, CO2 concentration, and soil moisture [28]. Data collected from these sensors is transmitted to a central control unit, typically a microcontroller or PLC, which analyzes the information and adjusts actuators automatically to maintain optimal conditions for plant growth.

Temperature, humidity, light, CO2, and soil moisture sensors are integral components of this system. Equipment such as ventilation systems, heaters, coolers, grow lights, irrigation systems, and CO2 generators adjust greenhouse conditions based on commands from the control unit. For instance, if temperatures exceed the ideal range, the cooling system activates, or if soil moisture levels drop, the irrigation system provides water.

The system includes a user interface accessible mobile apps or computers, enabling growers to monitor conditions remotely and make necessary adjustments. This automated approach ensures consistent and reliable greenhouse management, leading to enhanced plant development, increased yield, and more efficient resource utilization. It reduces labor and operational costs, accommodating various greenhouse sizes and types. Furthermore, the system records data for analysis, empowering farmers to refine strategies and improve overall efficiency.

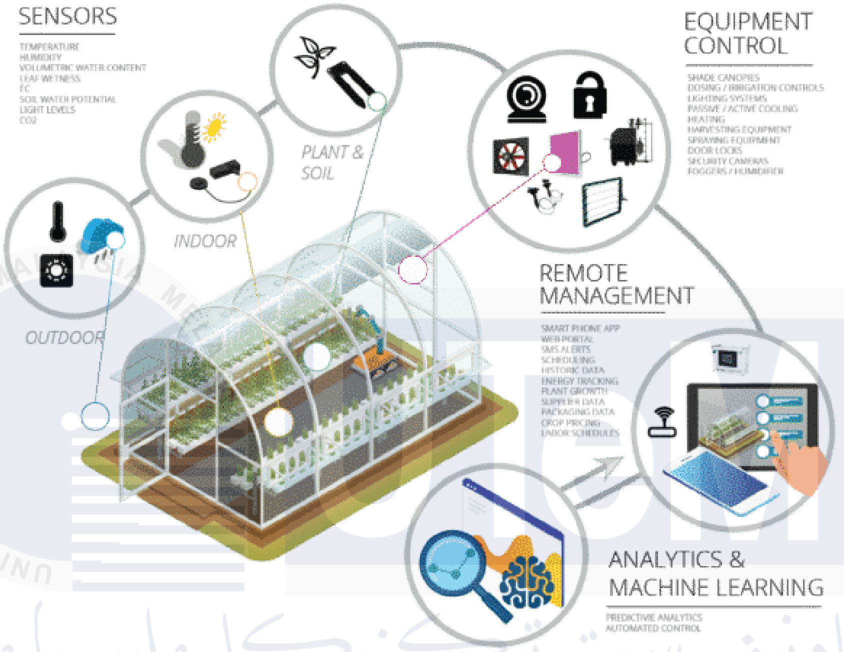


Figure 2.9: Automated Greenhouse Monitoring[29]

2.3 Comparison Each Chapter

Table 2.1: Comparison Each Chapter

No	Title	Purpose	Method/Technique	Advantages	Disadvantages
1	Real-Time Monitoring of Soil Conditions Using IoT Technology	Provide real-time soil condition data for better resource allocation and proactive decision-making.	Deployment of IoT sensors to monitor temperature, nutrient content, pH, and moisture. Data sent to a central hub and processed using analytics and machine learning.	Provides real-time insights, proactive decision-making, improved resource allocation.	Requires continuous internet connectivity, high initial setup costs, potential data privacy concerns.

2	Precision Nutrient Management in Agriculture	Optimize nutrient application to crops while minimizing environmental impact and resource wastage.	Use of soil sensors, drones, and data analytics to tailor nutrient applications to specific crop needs.	Optimizes nutrient use efficiency, reduces environmental impact, enhances sustainability.	High cost of advanced technology, need for technical expertise, potential data accuracy issues.
3	An IoT-Based Irrigation System in Floriculture	Automate watering of flowers and decorative plants based on real-time environmental data.	Combines IoT sensors, data analytics, and actuators to automate watering based on current environmental data.	Increases water efficiency, improves crop health, enables remote monitoring and control.	Initial setup costs, requires reliable sensor calibration, potential connectivity issues.
4	IoT-Based Smart Irrigation System Using ESP32	Monitor soil moisture levels and automate the watering process for efficient plant growth.	Utilizes ESP32 microcontroller, soil moisture sensors, temperature and humidity sensors, and actuators to automate irrigation.	Conserves water, ensures healthy plant growth, allows remote monitoring and control via mobile app.	Dependence on internet connectivity, initial setup costs, need for regular maintenance and sensor calibration.
5	Automatic Fertigation System	To address challenges in modern agricultural management, particularly in greenhouse management.	Utilizes remote control systems with GSM-SMS technology for greenhouse monitoring and control.	Facilitates remote monitoring and control of crucial environmental parameters, enhancing efficiency.	Requires GSM-SMS technology and reliable cellular network coverage, potential limitations in scalability and complexity.

6	IoT-Enabled Smart Drip Irrigation System	To automate irrigation, conserve water, and improve crop production using IoT technology.	Utilizes the ESP32 microcontroller, capacitive soil moisture sensors, relay modules, and real-time data transmission for smart irrigation.	Lower water usage by 30%, ensures ideal soil moisture levels for plant growth and yield improvement.	Challenges include sensor accuracy, connectivity issues, and power management.
7	IoT-Based Automated Irrigation System with Weather Prediction	Optimize water usage in irrigation by combining IoT technology with weather prediction models.	Combines IoT sensors with weather prediction models and machine learning algorithms to adjust irrigation schedules based on real-time data and anticipated weather conditions.	Conserves water, reduces labor costs, increases crop yields, adapts to anticipated weather conditions.	Requires accurate weather forecasts, reliable sensors, stable internet connectivity, higher complexity.
8	Development of an IoT-Based Soil Moisture Monitoring System for Agricultural Applications	Enhance soil moisture monitoring and automate irrigation to improve water use efficiency.	Uses ESP32 microcontroller and soil moisture sensors to collect real-time data, automate irrigation via cloud platforms.	Optimizes water use, enhances crop yields, allows detailed data analysis and visualization.	Initial setup and maintenance costs, potential connectivity issues, sensor calibration required.
9	Enhancing Crop Growth Efficiency through IoT-enabled Smart Farming System	To improve crop growth effectiveness by integrating IoT technology into farming practices.	Utilizes IoT sensors and devices for real-time monitoring of environmental conditions, soil moisture levels, and crop health.	Optimizes resource utilization, reduces waste, and maximizes crop productivity through data-	Challenges may include initial setup costs, technical complexities, and data security concerns.

				driven decision-making.	
10	Wireless Smart Greenhouse Management System Based on Multi-sensor of IoT	To create a wireless smart greenhouse management system based on IoT multi-sensor for efficient crop monitoring and control.	Incorporates automatic and manual control options via a mobile app for observing and managing greenhouse conditions.	Offers real-time data monitoring of critical parameters like air temperature, humidity, soil moisture, and light intensity, enabling precise control and optimization of greenhouse conditions.	Potential challenges may include technical complexities in system integration and calibration.
11	Automatic Fertilized Vertical Irrigation Control and Management System	To enhance water and nutrient distribution in vertical farming through sensor technology and automation.	Utilizes sensors for continuous monitoring of plant needs and environmental conditions, automated drip irrigation systems, and central control units for regulation.	Promotes uniform watering and fertilization, minimizes wastage, reduces labor costs, and improves efficiency and sustainability in vertical farming.	Challenges may include initial setup costs, technical complexities, and maintenance requirements.
12	Automated Greenhouse Monitoring using Control Systems	To automate greenhouse monitoring for optimal plant growth conditions, resource	Utilizes various sensors for continuous monitoring of environmental factors, microcontrollers or	Ensures steady and dependable management of greenhouse conditions, resulting in improved plant	Challenges may include initial setup costs, technical complexities, and potential system malfunctions.

		efficiency, and production improvement.	PLCs for data analysis, and actuators for automatic adjustments.	development, increased production, and efficient resource utilization.	

2.4 Summary

IoT technology has significantly enhanced agriculture by improving efficiency and sustainability. Various projects illustrate IoT applications that benefit farming practices. For instance, one project utilizes IoT sensors to continuously monitor soil conditions such as temperature, nutrients, pH, and moisture. This data empowers farmers to make informed decisions, optimizing resource utilization and enhancing field health. However, this system requires constant internet connectivity and involves high initial setup costs. Another project focuses on precision nutrient management, employing soil sensors and data analytics to precisely apply nutrients where needed. This approach improves nutrient efficiency, reduces environmental impact, and promotes sustainability, yet it demands significant investment and technical expertise.

In floriculture, an IoT-based irrigation system automates watering based on real-time data, thereby improving water efficiency and crop health while enabling remote monitoring. Nevertheless, this system requires accurate sensor calibration and entails substantial setup expenses. Similarly, a smart irrigation system utilizing the ESP32 microcontroller monitors soil moisture levels and automates watering, conserving water and ensuring robust plant growth. This system offers remote control via a mobile app but depends on internet connectivity and necessitates regular maintenance.

Another innovative project integrates IoT with weather prediction models and machine learning to adjust irrigation schedules based on real-time and forecasted weather data. This approach conserves water, reduces labor costs, and enhances crop yields, contingent upon reliable weather forecasts and stable connectivity. An IoT-based soil moisture monitoring system uses the ESP32 microcontroller and sensors to collect real-time data for automating irrigation via cloud platforms. This approach enhances water efficiency and crop yields but requires upfront setup and maintenance costs, and may face connectivity issues.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, discusses the approach used in creating the ESP32 microcontroller-driven automatic fertigation system for IoT. The main goal of the system is to automate the irrigation and fertilization procedures using real-time data from various sensors. This chapter discusses the system design, hardware and software requirements, and operational procedures, offering a thorough insight into the system's progress and capabilities. Between the hardware implementation is to use the hardware ESP32 as the center of the project and also use a sensor DHT11 and soil moisture as an essential hardware tool in this project. In addition, among the software implementations that I have used is proteus because I use it to draw the circuit and also use the arduino software to make the coding and enter the coding into the ESP32.

3.2 Block Diagram

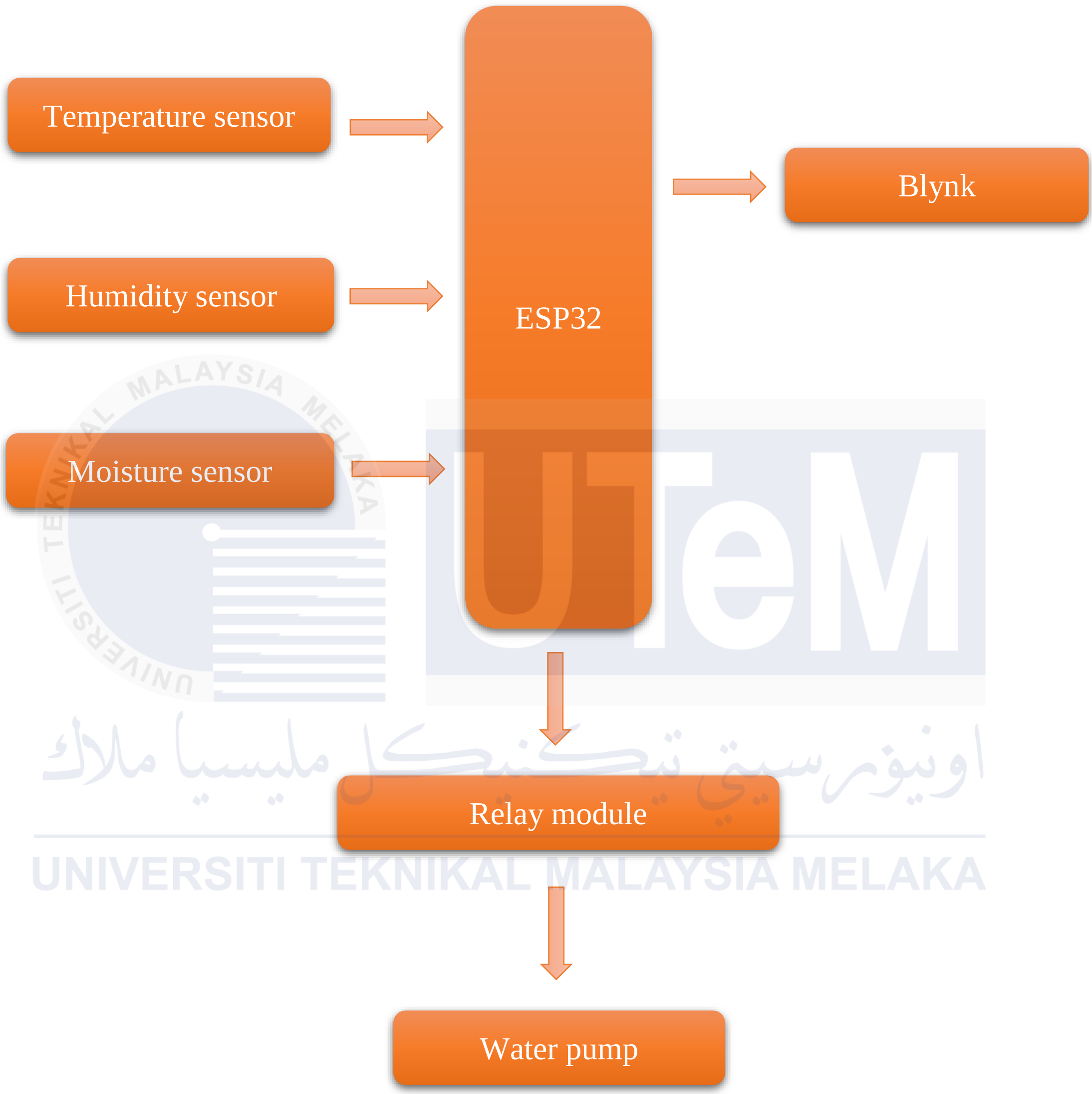


Figure 3.1: Block Diagram Project

3.3 Flowchart for Project

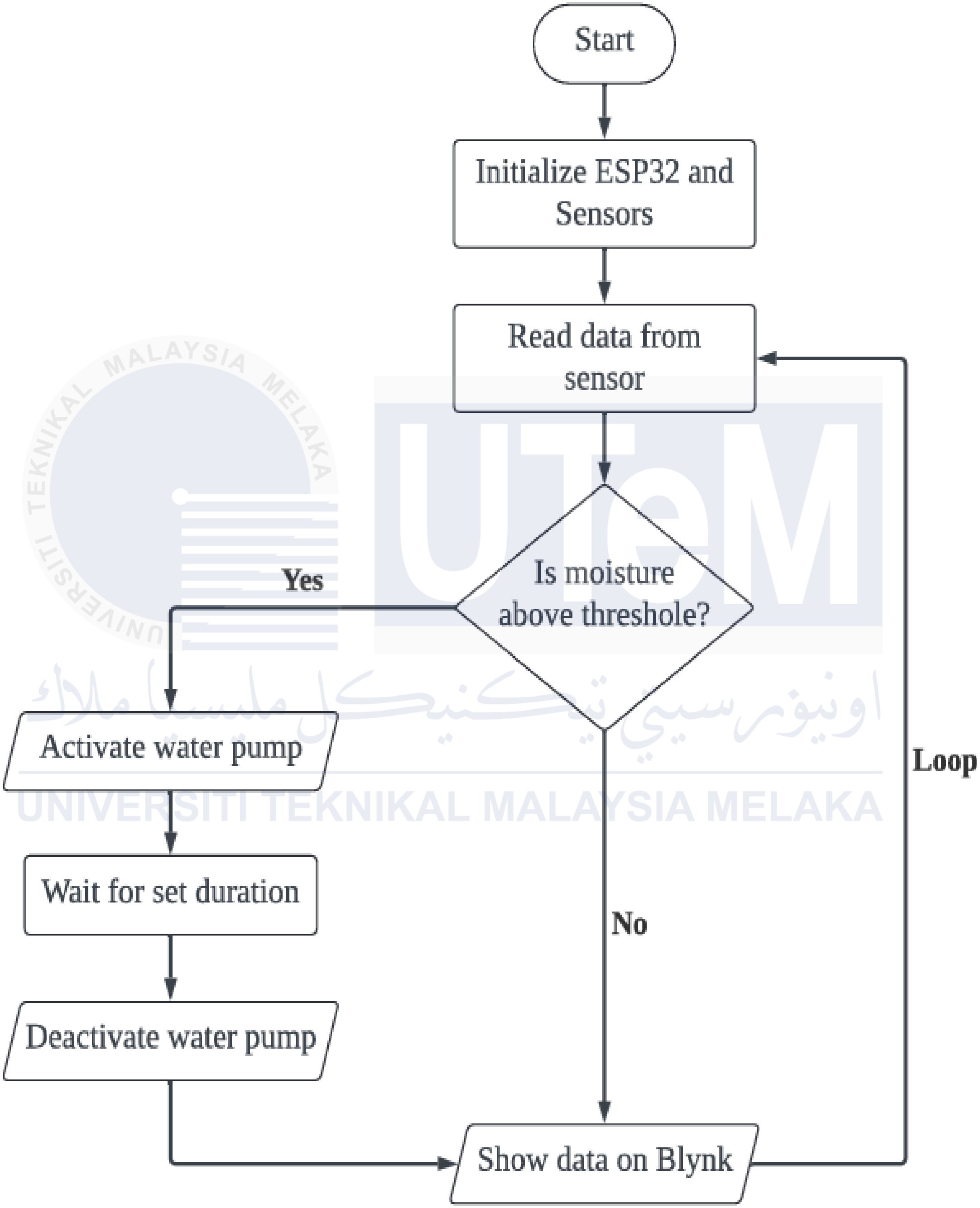


Figure 3.2: Flowchart Project

3.4 Hardware and Software specifications

Hardware and software are use in this project:

3.4.1 ESP32

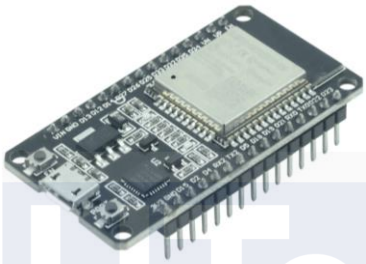


Figure 3.3: ESP 32[30]

The ESP32 is a highly powerful microcontroller widely used in IoT applications due to its robust features and performance. It boasts a integrated 2.4 GHz Wi-Fi, and Bluetooth, including Bluetooth Low Energy, making it adept at wireless communication. With up to 36 GPIO pins, it supports a variety of interfaces such as digital input/output, Analog to Digital Converter (ADC), Digital to Analog Converter (DAC), Pulse Width Modulation (PWM), Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I2C), and Universal Asynchronous Receiver/Transmitter (UART). ESP32 is highly-integrated with in-built antenna switches, power amplifier, low-noise receive amplifier, filters, and power management modules. Its low power consumption and multiple power-saving modes make it ideal for battery-powered devices. This microcontroller is supported by popular development environments including Arduino IDE, Espressif's own ESP-IDF, PlatformIO, and MicroPython.

3.4.2 DHT11

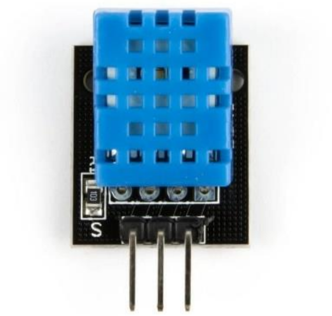


Figure 3.4: DHT11[31]

DHT11 is an inexpensive digital sensor designed to detect temperature and humidity. This sensor can easily connect to various microcontrollers like ESP32, Raspberry Pi, Arduino and others to instantly measure humidity and temperature. The DHT11 sensor for measuring humidity and temperature can be found as both a standalone sensor or a module. The pull-up resistor and a power-on LED are what distinguish this sensor from the module. DHT11 functions as a sensor for measuring relative humidity. A capacitive humidity sensor are utilized by this sensor to gauge the ambient air.

3.4.3 Moisture sensor

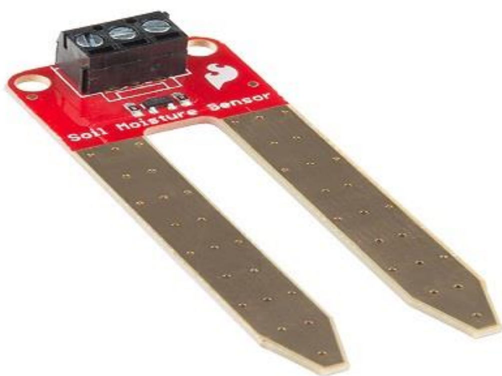


Figure 3.5: Moisture sensor[32]

The soil moisture sensor is a type of sensor that measures the water content in the soil. In order to determine the straight gravimetric dimension of soil moisture, the soil must be eliminated, dried, and weighed as samples. These sensors do not directly measure the volumetric water content; instead, they rely on other soil properties such as dielectric constant, electrical resistance, neutron interaction, and moisture content replacement. The correlation between soil moisture and the measured property may need to be modified and could vary depending on environmental factors such as temperature, soil type, or electrical conductivity. The moisture content of soil can affect the microwave radiation that is reflected, especially in applications within agriculture and hydrology remote sensing.

3.4.4 Relay module

Figure 3.6: Relay Modul[33]

The single-channel relay module board is utilized for controlling high voltage and current loads such as solenoid valves, motors, AC loads, and lamps. This module is primarily created to communicate with various microcontrollers such as PIC, Arduino, and others.

3.4.5 Water pump

Figure 3.7: Water Pump[34]

A water pump is essential to ensure effective distribution of water and nutrients to plants. The pump ensures a stable flow of water with the necessary pressure to cover all areas of the irrigation system, guaranteeing uniform distribution of the nutrient solution. It combines fertilizer with water to form a consistent nutrient mix, preventing clogging and ensuring each plant gets the nutrients it needs. Furthermore, by combining pumps with automatic controls, sensors and timers, water and nutrient delivery can be optimized according to plant and soil specific needs, increasing efficiency and minimizing resource wastage.

3.4.6 Bill of Material (BOM)

Table 3.2: Bill Of Material

NO	ITEM ID	DESCRIPTION	QUANTITY	COST/ITEM	COST
1	Nodemcu ESP32	ESP32 series of modules are powerful WiFi + Bluetooth/Bluetooth LE	1	RM24.50	RM24.50
2	DHT11 sensor	The DHT11 is a commonly used Temperature and humidity sensor	1	RM4.80	RM4.80
3	Soil moisture sensor	The Soil Moisture Sensor uses capacitance to measure the water content	1	RM4.50	RM4.50
4	Water pump	To move, compress, or transfer water	2	RM6.50	RM13.00
5	2 Channel Relay module	Permits a small amount of electrical current to control high current loads	1	RM5.90	RM5.90

6	Jumper wire	Used to interconnect the components of a breadboard or other prototype	1	RM4.60	RM4.60
7	Mini water pipe	Transfer water flow to other part	1	RM11.00	RM11.00
8	Expansion board	To easy used for ESP32	1	RM8.90	RM8.90
9	Battery	Supply power to activate pump	1	Rm6.00	Rm6.00
10	Battery snap connector	Connector for battery supply power	1	Rm1.00	Rm1.00
11	PVC Electrical box	Weatherproof PVC box for placing component items	1	Rm16.47	Rm16.47
12	Bioactive	1 litre organic liquid fertilizer	1	Rm15	Rm15
13	Planter box	Long rectangular plastic flower planter box	1	Rm3.30	Rm3.30
14	Pipe	For make water tanks and liquid fertilizers	1	Rm8.00	Rm8.00
15	Pipe cover	To close the pipe so that the water does not come out	4	Rm4.50	Rm18.00
16	Power supply adapter plug	To ON the esp32 microcontroller	1	Rm12.90	Rm12.90
				Total cost	RM157.87

3.4.7 Arduino IDE

Figure 3.8: Software Arduino IDE

The Arduino IDE is a crucial tool for creating projects with ESP32 boards. Its easy-to-use interface, wide library support, included examples, and ability to work on multiple platforms make it a flexible environment for both education and career growth in embedded systems and electronics.

3.4.8 Blynk App

Figure 3.9: Blynk App

Blynk is a IoT platform that makes it easier to develop, deploy, and manage connected devices. It includes a mobile application, a cloud server, and comprehensive libraries, forming a environment where individuals can construct personalized dashboards by utilizing a drag-and-drop interface on the application to manage and supervise their devices instantly. The platform is compatible with various microcontrollers and single-board computers, allowing smooth communication between the app and devices through Wi-Fi, Ethernet, or cellular networks. Blynk guarantees secure and efficient IoT project management by offering real-time data exchange, automation, and notifications.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter starts with the first phase of creating an IoT-based automatic fertigation system using ESP32 and also focuses on the implementation of an automatic fertigation system. The main goal for this projeck is to improve the setup of automated systems using IoT technology such as the Blynk application also integrating sensors to monitor humidity, temperature and soil moisture. This project is not like the traditional method because this automatic fertigation system can facilitate monitoring through the Blynk application. The project and system also aims to empower farmers and stakeholders by providing real-time monitoring of environmental conditions and can also ensure compatibility with fertigation requirements. For the initial testing of this project, simulation and hardware testing can provide a comprehensive overview of system performance, identify potential challenges and suggest improvements. This chapter also lays the foundation for evaluating the effectiveness of proposed solutions in optimizing agricultural practices through comprehensive analysis.

4.2 Result

4.2.1 Hardware

Figure 4.1: Complete hardware

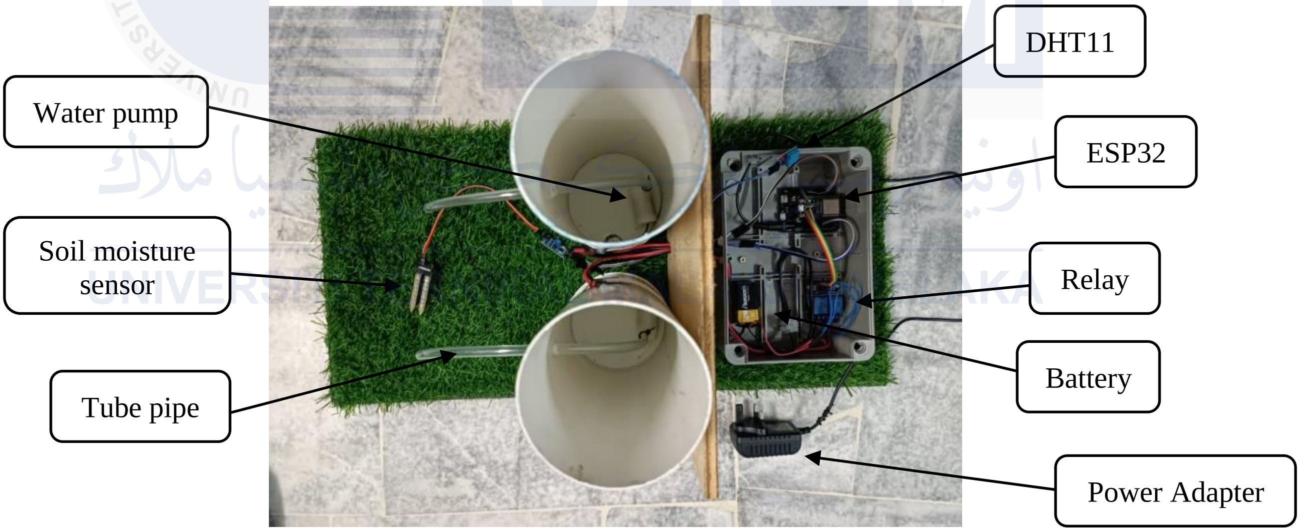


Figure 4.2: Hardware configuration

For this project, there are several components and items needed to complete this project. Among the most important components is the microcontroller which is ESP32 and is the heart of this project. Based on figure 4.2, for this project circuit, firstly connect the ESP32 with the soil moisture sensor on the GPIO pin, like the pin that has been used, which is VCC and GND from the soil moisture sensor, connect to the Vin and GND pins of the esp32. For AO from soil sensor connect to pin GPIO34. Secondly, connect two channel relays to ESP32 using jumper wire, for Vcc and GND on two channel relays connect to pin 3.3v and GND on ESP32. For two channel relay, relay 1 connect to pump1 and relay 2 connect to pump2 and also to turn on pump1 and pump2 there must be a power supply like the one used for this project 9V battery.

The connection for the battery must be positive battery connected to NO relay and negative battery connected to negative pump and then, positive pump connected to COM relay. Next, this project also has a DHT11 sensor to detect the temperature and humidity of the plant environment and the connection method is the GPIO5 pin from the ESP32 connected to the DHT11 sensor pin. Finally, to turn on the circuit of this project there must be a power supply and connect it to the ESP32 so that it can turn on all the components in this circuit and all these connections are important to make this project work well.

4.2.2 Software

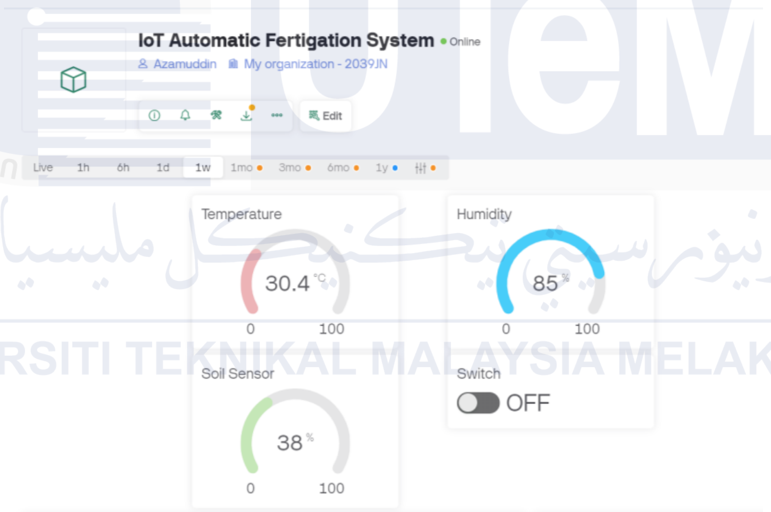


Figure 4.3: Blynk Interface for Automatic Fertigation System

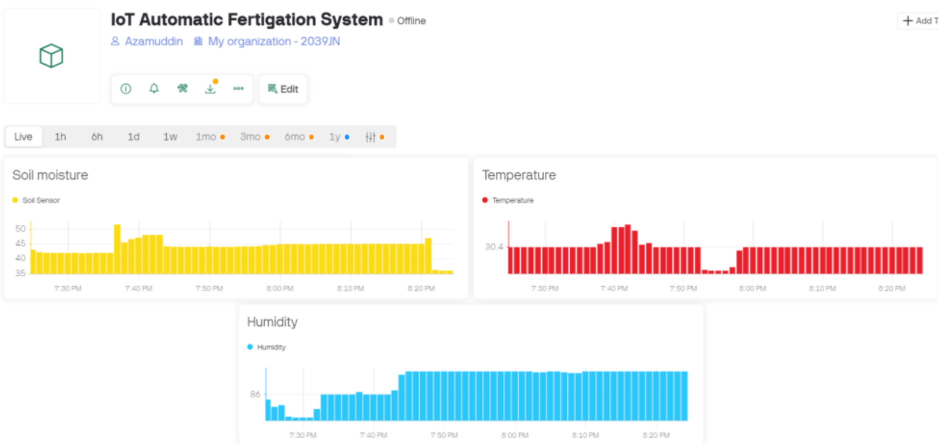


Figure 4.4: Blynk Data Interface for Automatic Fertigation System

This blynk platform is designed to build and manage Internet of Things (IoT) solutions, blynk also makes it easy for users to create custom dashboards and it's also easy to monitor and control various connected devices and sensors. This application also supports real-time data visualization and remote-control function and can make it ideal for managing IoT projects. This project is an IoT based automatic fertigation system showing that this dashboard is used to control and automate the fertigation system, which combines fertilization and irrigation using IoT technology. This project uses sensors to send data in order to monitor environmental conditions and use blynk to control the delivery of water and nutrients to plants.

Sensor readings displayed on the dashboard provide important data to manage the fertigation process. Based on figure 4.3, at the blynk interface there are three sensors and one switch to monitor. First of all, for the soil sensor it shows a reading of 38% soil moisture, it can be said that the soil is still wet because it is less than or equal to 60% can be considered still wet. For the Temperature it reads 30.4°C, it shows an excellent environmental temperature for plants. Next, for humidity at 85% it shows the air humidity is high and this means that the air contains 85% of the maximum amount of water vapor that can be captured by the air at a certain temperature and it can be said that very humid air can feel sticky. Next, the switch at blynk interface is to control the pump2 so that it can deliver liquid fertilizer to the plants. Finally, figure 4.4 shows a graph of real-time data sent from soil moisture, temperature and humidity sensors to blynk application.

4.3 Data analysis

4.3.1 Monitoring data analysis

Table 4.1: Monitoring data at morning

Time stamp	**Temperature**	**Humidity**	**Soil moisture**
9.41 am	27.8 ℃	89.5 %	43.81 %
9.51 am	28.2 ℃	90.1 %	41.11 %
10.01 am	28.4 ℃	88.3 %	40.04 %
10.11 am	28.7 ℃	87.1 %	38.64 %
10.21 am	28.9 ℃	86.1 %	27.68 %
10.31 am	29.2 ℃	84.3 %	35.82 %
10.35 am	29.4 ℃	86 %	35.27 %

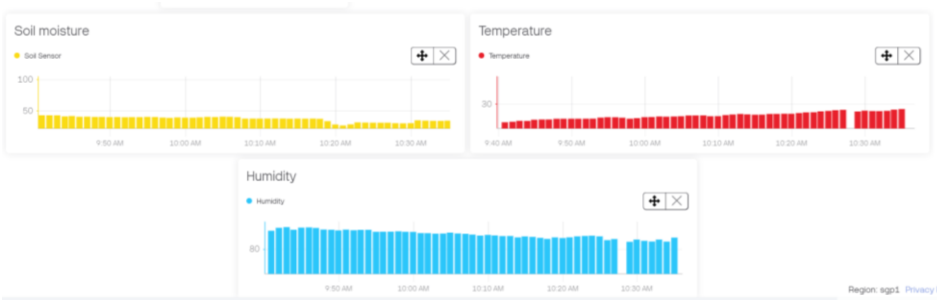


Figure 4.5: Morning Data

Monitoring data that has been collected in the morning as shown in table 4.1, this table shows the trend of changes in temperature, humidity and soil moisture over time. For the temperature there was an increase from 27.8℃ at 9.41 am to 29.4 at 10.35 am and it shows an increase in temperature or warming slowly in the morning. At the same time, humidity showed a slight decrease from 89.5% at 9.41 am to 84.3% at 10.31 am. Next, for soil moisture it also showed a decrease starting at 43.81% at 9.41 am down to 35.27% at 10.35 am and at 10.21 am showing a slight decrease at 27.68%. For figure 4.5 it shows the increase and decrease of data in the morning from 9.41 am to 10.35 am.

Table 4.2: Monitoring data at afternoon

Time stamp	**Temperature**	**Humidity**	**Soil moisture**
12.00 pm	30.7 ℃	78.2 %	40.96 %
12.10 pm	30.7 ℃	77 %	40 %
12.20 pm	31.1 ℃	77 %	39.82 %
12.30 pm	31 ℃	76.5 %	39 %
12.40 pm	31.2 ℃	76.3 %	38.93 %
12.50 pm	31.1 ℃	75.9 %	38 %
1.00 pm	31.2 ℃	75.3 %	37.89 %

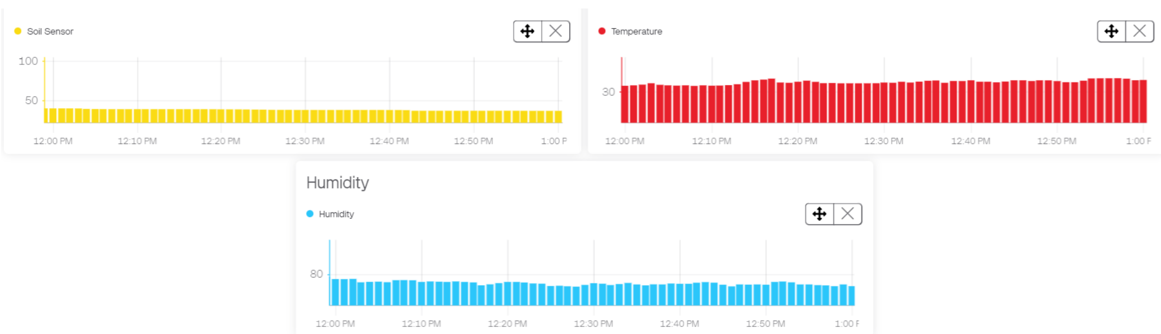


Figure 4.6: Afternoon Data

Based on table 4.2, it shows data for temperature, humidity and soil moisture taken at 12.00pm to 1.00pm. For the temperature data at noon shows 30.7℃ at 12.00pm to 31.2℃ at 1.00pm and this shows an increase of 0.5℃ from 12.00pm to 1.00pm. The humidity data showed a decrease from 78% to 75.3% at noon and the soil moisture level also showed a decrease from 40.96% to 37.89%. For figure 4.6, it is a graph for temperature, humidity and soil moisture that stores data and can also show real-time data on blynk.

Table 4.3: Monitoring data at evening

Time stamp	Temperature	Humidity	Soil moisture
5.00 pm	32.4 ℃	72.4 %	34 %
5.10 pm	32.2 ℃	71.5 %	34 %
5.20 pm	32.4 ℃	71.8 %	34 %
5.30 pm	32.1 ℃	74 %	32.93 %
5.40 pm	32.2 ℃	73 %	32 %
5.50 pm	32 ℃	72.6 %	32 %
6.00 pm	32 ℃	73.8 %	31.8 %

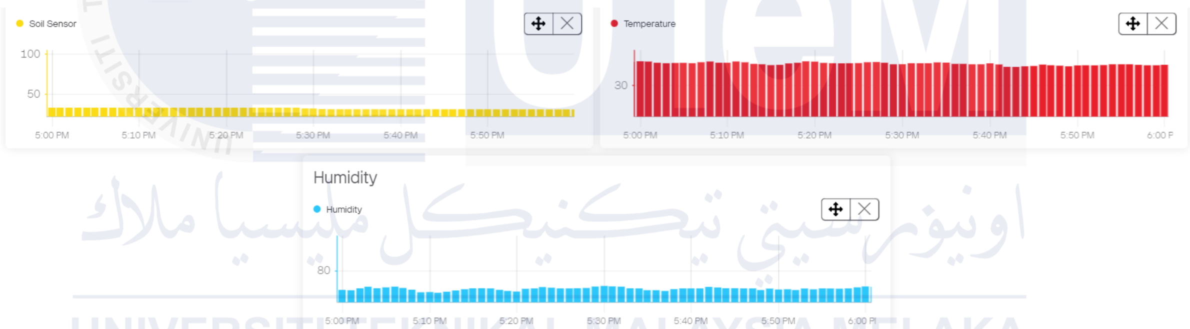


Figure 4.7: Evening Data

The evening monitoring data in table 4.3 shows a stable environmental condition from 5.00pm to 6.00pm. The temperature and soil moisture data shows a decrease in the evening where the temperature reading at 5.00pm is 32.4℃ to 32℃ at 6.00pm and the soil moisture reading at 5.00pm is 34% to 31.8% at 6.00pm. This shows the occurrence of a normal decrease in data for the evening and for the humidity there is a drop and rise at 5.00pm to 6.00pm. It can also be seen in figure 4.7 which is a graph of data taken from 5.00pm to 6.00pm and it shows stable and good for plants.

Table 4.4: Monitoring data at night

Time stamp	Temperature	Humidity	Soil moisture
8.30 pm	28.3 °C	92 %	30.96 %
8.40 pm	28.1 °C	92.8 %	30.93 %
8.50 pm	27.9 °C	92.2 %	30.89 %
9.00 pm	27.9 °C	92.7 %	31 %
9.10 pm	27.8 °C	93 %	30.86 %
9.20 pm	27.8 °C	93 %	30.64 %
9.30 pm	27.7 °C	93 %	30.44 %
9.40 pm	27.7 °C	93 %	30.25 %
9.50 pm	27.5 °C	94 %	30.11 %
10.00pm	27.4 °C	93.7 %	30.11 %

Table 4.4 Nighttime monitoring data showing temporal variations in temperature, humidity, and soil moisture. Measurements are from 8:30 to 10:00 PM with 10-minute intervals. The temperature gradually decreased from 28.3°C at 8:30 PM to 27.4°C at 10:00 PM due to the natural cooling effect of night conditions. The humidity remained high, within the range of 92% to 94%. It is seen to increase a little as the temperature goes down, which would mean that it becomes more saturated. Soil moisture gradually went down from 30.96% at 8:30 PM to 30.11% at 10:00 PM, indicating very negligible evaporation and perhaps some absorption by plants or soil itself. Overall, the data indicate stable nighttime conditions with predictable trends, providing useful insights for optimizing irrigation and environmental monitoring systems.

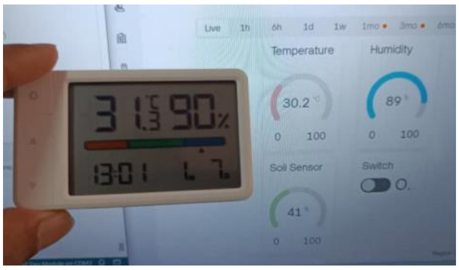
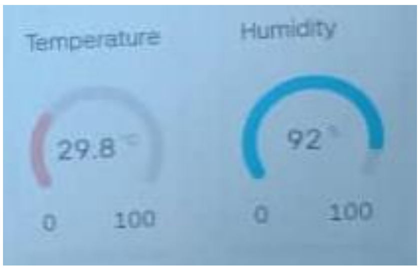
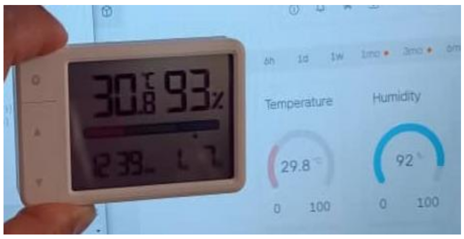
Figure 4.8: Monitoring data for 13 hours

Figure 4.8 shows data for soil moisture, temperature and humidity taken within 13 hours and stored in blynk. Based on the soil moisture graph it shows high in the morning to midday and starting at 1.00pm it decreases slowly until 10.00pm. For the temperature graph, it shows an increase from morning until 6.00 pm and starts to decrease from 6.00 pm until 10.00 pm. Finally, the humidity graph shows that the conditions in the morning are high and then drop slowly until the evening because usually from noon to evening there is a decrease in humidity due to the hot weather. In the afternoon, the humidity starts to rise again at 6:00pm until 10:00pm because the conditions at that time show that the temperature is decreasing and the humidity will increase.

4.3.2 Comparison of the temperature and humidity with standard device

The DHT11 are sensor that can detected temperature and humidity. Based on table 4.5, comparison between temperature DHT11 and temperature standard device are for DHT11 sensor detected temperature 30.3℃-30.5℃ and for industrial-grade devices temperature is 32.2℃-34.8℃. That mean to know the accuracy between temperature DHT11 and industrial-grade device it must calculate based on Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

Table 4.5: Comparison with standard device

DHT11 Sensor output	**Thermometer**
	
	

Statistical Metrics:

Table 4.6: Comparison data temperature

No.	Sensor Reading (°C)	Thermometer Reading (°C)	Difference (°C)
1	30.2	31.3	1.1
2	29.8	30.8	1.0

$$\text{MAE} = \frac{\sum_{i=1}^{n} |y_i - \hat{y}_i|}{n} \tag{4.1}$$

Mean Absolute Error (MAE):

$$MAE = \frac{1.1+1.0}{2} = \frac{2.1}{2} = 1.05\ °C$$

$$\text{Mean Thermometer} = \frac{31.3 + 30.8}{2} = \frac{62.1}{2} = 31.05\ °C$$

Accuracy Percentage:

$$Accuracy = 100 - (\frac{\text{Mean Absolute Error (MAE)}}{\text{Mean Thermometer}} \times 100) \tag{4.2}$$

$$Accuracy = 100 - (\frac{1.05}{31.05} \times 100)$$

$$Accuracy = 100 - 3.382 = 96.62\%$$

The calculation of sensor temperature readings against standard devices provided is to measure accuracy. Based on equation 4.1, the calculation of MAE is 1.05°C, which shows a moderate deviation from the standard device. This means that lower MAE indicates better accuracy. The accuracy percentage evaluates that how close the sensor reading compare to thermometer reading.

Table 4.7: Comparison data Humidity

No.	Sensor Reading (%)	Thermometer Reading (%)	Difference (%)
1	89	90	1
2	92	93	1

Average Difference Calculation**:**

$$\text{Average Difference} = \frac{\text{Sum of Differences}}{\text{Number of Readings}} \tag{4.3}$$

$$\text{Average Difference} = \frac{1+1}{2} = \frac{2}{2} = 1\%$$

Thermometer Readings Mean:

$$\text{Average Difference} = \frac{90+93}{2} = \frac{183}{2} = 91.5\%$$

Accuracy Percentage:

$$Accuracy = 100 - (\frac{\text{Average Difference}}{\text{Mean Thermometer}} \times 100) \quad (4.4)$$

$$Accuracy = 100 - (\frac{1}{91.5} \times 100)$$

$$Accuracy = 100 - 1.093 = 98.91\%$$

The calculation of sensor humidity readings against standard devices provided is to measure accuracy. Based on equation 4.3 the calculation of average difference is 1%, which shows a moderate deviation from the standard device. This means that lower average difference indicates better accuracy. The equation 4.4 shows the accuracy percentage evaluates that how close the sensor reading compare to thermometer reading. The accuracy of humidity is 98.91%.

4.3.3 Power consumption

Power of the water pump

In this project the DC water pump draws current around 0.205 A and the voltage of water pump is 6.2V. To calculate the power comsumption must have the value of pump voltage and pump current.

$$P = V \times I \quad (4.5)$$

Pump Voltage: 6.2 V

Pump Current Draw: 0.205 A

Power Consumption: P = V x I

= 6.2V x 0.205A = 1.27W

Based on calculation the result power of the water pump is 1.27W that used when running the water pump.

4.3.4 Water pump response and control

The test based on manual activation of the pump2 through Blynk at table 4.9, when control the pump using switch at blynk, the pump2 response 2 second after switch ON and also response 2 second deactivate when switch OFF. For pump1 based on table 4.8, when sensor detected wet based on threshold that have set, the activation of pump1 response 2 second and when sensor detected dry also response 2 second to activate pump1.

Table 4.8: Pump1 response

Automatic pump1	Detect dry	Detect wet
Response Time	2 second	2 second

Table 4.9: Pump2 response

Control Pump2	Switch ON	Switch OFF
Response Time	2 second	2 second

4.3.5 Data transmission efficiency

In this project, the total number of data transmission attempts that have been made is 6. Out of the total number of these attempts, 5 times have been successful and the calculation results in a success rate of about 83.33%. and 1 of them unsuccessful attempt because slow internet connectivity, highlighting the potential impact of network instability on data transmission reliability. This analysis also underscores the importance of stable internet connections to ensuring consistent and accurate communication between the ESP32 device and the blynk platform. However, with this small obstacle, the system shows a very high level of reliability, as it successfully transmits data to monitor key environmental parameters such as temperature, humidity and soil moisture. Below the calculation of success Rate:

Success Rate=5/6 x 100 = 83.33%

Data Transmission Latency:

Timestamp on ESP32 = 28863 – 26702

= 2161ms = 2.1s

Timestamp on Blynk = 7:00:37 – 7:00:35

= 2s

Latency = Timestamp on ESP32 - Timestamp on Blynk

= 2.1s – 2s = 0.1s

The latency for data transmission is 0.1s.

4.3.6 Plant growth

This project helps plants grow quickly because it uses an automatic system for watering methods by detecting soil moisture. There are several time periods for the growth of vegetable crops that have been measured based on the height of the tree. The starting time for this plant is to start from seed and measure the growth of the seedlings every week to see the difference in height. Based on table 4.10, it shows the difference in height of the plants for 4 weeks.

Table 4.10: Plants growth

Time	1 week	2 week
Height (cm)	 8 cm	 10.5 cm

Time	3 week	4 week
Height (cm)	 13 cm	 15 cm

Table 4.11: Plants without a system

Time	4 week
Height (cm)	 9 cm

4.4 Summary

This chapter describes a thorough analysis of monitoring data, comparison between temperature, humidity with Standard Devices, Power Consumption, Water Pump Response and Control, Data Transmission and also Plant growth. For the analysis of environmental parameters such as humidity, temperature and soil moisture are monitored at different times of the day such as morning, noon, evening and even night. This observation found that the temperature ranged from 27.4°C to 32.4°C and the humidity conditions varied between 71.5% to 94%. While for soil moisture, the graph shows a slight increase in the afternoon and a gradual decrease until night. This IoT-based automated fertigation system demonstrates energy efficiency with a DC water pump that consumes 1.27W and a consistent 2-second response time for activation and deactivation. The system can also achieve a data transmission success rate of 83.33% out of 6 attempts with a minimum latency of 0.1 seconds and it can ensure reliable real-time monitoring. In addition, the growth measurement for the plants every week for 1 month showed a stable increase in height and reached 15 cm by the fourth week, this also shows the effectiveness of the system in promoting healthy growth. Overall for this analysis, it efficiently monitors environmental conditions, manages resources and improves plant growth while reducing manual effort.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the use of an IoT-based automatic fertigation system using ESP32 as a microcontroller shows a very significant level of progress in this agricultural practice. This initiative can also integrate multiple sensors to monitor plant environmental parameters such as humidity, temperature and soil moisture. A custom interface for the ESP32 enables effective data collection and processing of sensor data to identify and assess plant needs and manage irrigation operations. IoT communication technology has played a very important role in integrating systems that enable remote monitoring and control of the system, this system also offers farmers a very simple and effective method to supervise the irrigation process.

In addition, with integrated real-time soil moisture, temperature, and humidity monitoring, the system automatically provides optimal crop growth conditions as far as irrigation and fertilizer application are concerned. This would improve not only efficiency but also reduce manual labor in facilitating such purposes, allowing farmers to attend to other important chores in agriculture. The project is designed to optimize the use of water and fertilizer by applying the actual amount required, guided by real-time environmental data, to avoid wastage and promote efficient farming practices. Next, a mobile application integrated into the system allows farmers to monitor and control the system remotely with ease for better convenience and decision-making. Finally, this agricultural system has been tested and can confirm that it works successfully and also the efficiency of this robust system is reliable and it can outline the potential to increase agricultural productivity and resource use. Based on the proposed objectives, this project has achieved all three objectives effectively and successfully.

5.2 Potential for Commercialization

The reason this project is a good commercialization opportunity is that it adheres to major criteria such as optimization of resources and automation of the fertigation process. Thus, by easing these processes, the project offers greater efficiency while reducing manual work, making the project very interesting in the context of modern agriculture. On another perspective, the system will be user-friendly for farmers because they can monitor crop condition status remotely and this greatly improves convenience and accessibility.

The target market of this project includes small and medium-scale farmers who would be benefited by the cost-effective and efficient solution for fertigation. It is also suitable for agricultural entrepreneurs looking to adopt innovative technologies that enhance productivity. Research and educational institutions can use this system to further studies in smart agriculture and train future professionals in the field.

5.3 Future Works

For future improvements of the development of an IoT-based automatic fertigation system using ESP32 could be enhanced as follows:

1. Adding a soil pH sensor to this project to detect soil pH so that liquid fertilizer can be sent automatically.
2. Carry out monitoring of long-term performance in order to assess the reliability and durability of the system over a long period of time and under various operating conditions.
3. Test more so that the success and accuracy of this system is high and increase the scalability of the system to ensure that it can be adapted and used in larger fields of agriculture and more complex setups.
4. Accurately estimate and identify ways to reduce the overall cost of the system to make it more affordable for small and medium farms.

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APPENDICES

Appendix A Gantt chart for BDP1

Project Activity	W1	W2	W3	W4	W5	W6	Sem Break	W7	W8	W9	W10	W11	W12	W13	W14
First meeting PSM1 with supervisor	■														
Finding a title for BDP 1	■	■					S								
Briefing PSM1 by JK PSM		■					E								
Title submission			■												
Research Components			■				M								
Research a journal				■			E								
Research for Chapter 1 introduction				■											
Writing a problem statement, scope, objective				■			S								
Bill Of Material					■		T								
Schematic Diagram						■									
Literature review						■	E	■							
Do the comparison literature review							R	■							
Methodology									■	■					
Block diagram and Flowchart									■	■					
Testing circuit							B				■	■	■		
Expected result							R				■	■	■		
Writing Chapter 4 and 5													■		
Submit Logbook							E						■		
Submission for Turnitin check							A							■	
Submission of report														■	
Presentation PSM1							K								■

Appendix B Gantt chart FOR BDP2

Project Activity	W1	W2	W3	W4	W5	W6	Sem Break	W7	W8	W9	W10	W11	W12	W13	W14
Buy components	■	■	■	■											
First meeting PSM2 with supervisor				■			SEMESTER BREAK								
Test component and connection circuit				■	■	■									
Create Blynk at website and application					■	■									
Test the relay						■									
Test water pump						■									
Submit Logbook						■									
Test connection esp32, relay and water pump						■		■	■						
Design the project fertigation system								■	■						
Test connection soil moisture sensor								■	■						
Modify coding								■	■						
Set up software tools										■					
Assemble all the hardware components										■					
Test power consumption										■	■				
Verify sensor and pump function.											■				
Compile technical documentation, schematics and code											■				
Submit logbook											■				
Result											■	■	■		
Presentation PSM2														■	
Submission of poster														■	
Submission of report														■	■

Appendix C Coding project

```
#define BLYNK_TEMPLATE_ID "TMPL6RtHRLnv2"
#define BLYNK_TEMPLATE_NAME "IoT Automatic Fertigation System"
#define BLYNK_AUTH_TOKEN "qvwgg9_z-LrB6FONMQ6aCuZrO0tUoJXH"

#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
#include <DHT.h>

#define DHTPIN 5
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

#define MOISTURE_SENSOR_PIN 34
#define RELAY1_PIN 2
#define RELAY2_PIN 4

int moistureLevel;
int moistureThreshold = 2500;
int moisturePercentage;

char ssid[] = "aze";
char pass[] = "123456789";

#define BLYNK_VPIN_TEMP 1
#define BLYNK_VPIN_HUMIDITY 2
#define BLYNK_VPIN_MOISTURE 3
#define BLYNK_VPIN_PUMP2 4

BlynkTimer timer;

void setup() {
  Serial.begin(115200);

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  dht.begin();

  pinMode(RELAY1_PIN, OUTPUT);
  pinMode(RELAY2_PIN, OUTPUT);
```

```

  digitalWrite(RELAY1_PIN, LOW);
  digitalWrite(RELAY2_PIN, HIGH);
}

void loop() {
  Blynk.run();

  unsigned long timestamp = millis();

  moistureLevel = analogRead(MOISTURE_SENSOR_PIN);

  moisturePercentage = map(moistureLevel, 0, 4095, 0, 100);
  moisturePercentage = constrain(moisturePercentage, 0, 100);

  float humidity = dht.readHumidity();
  float temperature = dht.readTemperature();

  Serial.print("Timestamp: ");
  Serial.print(timestamp);  // Display timestamp in milliseconds
  Serial.print(" | Moisture: ");
  Serial.print(moistureLevel);
  Serial.print(" (");
  Serial.print(moisturePercentage);
  Serial.print("%)");
  Serial.print(" | Humidity: ");
  Serial.print(humidity);
  Serial.print(" | Temperature: ");
  Serial.println(temperature);

  Blynk.virtualWrite(BLYNK_VPIN_TEMP, temperature);
  Blynk.virtualWrite(BLYNK_VPIN_HUMIDITY, humidity);
  Blynk.virtualWrite(BLYNK_VPIN_MOISTURE, moisturePercentage);

  if (moistureLevel > moistureThreshold) {
    digitalWrite(RELAY1_PIN, LOW);
    Serial.println("Pump1 ON - Soil is Dry");
  }

```

```
  else {
    digitalWrite(RELAY1_PIN, HIGH);
    Serial.println("Pump1 OFF - Soil is Wet");
  }

  delay(2000);
}


BLYNK_WRITE(BLYNK_VPIN_PUMP2) {
  int pinValue = param.asInt();

  if (pinValue == 1) {
    digitalWrite(RELAY2_PIN, LOW);
    Serial.println("Pump2 ON");
    Blynk.virtualWrite(BLYNK_VPIN_PUMP2, 1);
  }
  else {
    digitalWrite(RELAY2_PIN, HIGH);
    Serial.println("Pump2 OFF");
    Blynk.virtualWrite(BLYNK_VPIN_PUMP2, 0);
  }
}
```