Faculty of Electrical Technology and Engineering

DEVELOPMENT OF IOT IN APPLICATION OF PLANT MANAGEMENT SYSTEM

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

2023

DEVELOPMENT OF IOT IN APPLICATION OF PLANT MANAGEMENT SYSTEM

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development of IoT in Application of Plant Management System

Sesi Pengajian: Disember 2023/2024

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DEDICATION

I dedicate this project to my parents, who instilled in me the values of perseverance and hard work. Their unwavering support and belief in my abilities has been my pillar of strength throughout this academic endeavour.

I also dedicate this to my friends, with whom I have a companionship that helps to make difficult times tolerable and achievement even more pleasurable. Your advice and support are much appreciated.

In memory of the late nights, the rigorous research, and the many challenges faced, I dedicate this project to the pursuit of knowledge, growth, and the pursuit of excellence.

Thank you to everyone who played a role, big or small, in making this trip memorable and transformative.

ABSTRACT

A plant management system is very important for every farmer nowadays, especially with the current technology that can be offered around the world. Plant management systems are very important for every farmer today, especially with the current technology that can be offered around the world. This is also caused by incorrect watering and fertilizing and can result in the plant being damaged, not flowering and not growing well. The main purpose of this project is to monitor plant management consisting of fertilizing and watering plants or gardens in the house automatically with the help of the Internet of Things (IoT) that connects hardware to smartphones using the Thingspeak and Telegram Bot application. Sensor measurements of pH, moisture, humidity, temperature, nitrogen, phosphorus, and potassium (NPK) have been used to check the irrigation and fertilization systems. This system makes the proper use of a Capacitive Soil Moisture Sensor, a Soil Multi-Parameter Sensor, and DHT22 sensor to help monitor and keep records of plant growth changes. With all the data collected from the sensors, it will be processed by the microcontroller which is the ESP32 and sent to the cloud server via Wi-Fi. Since the system is integrated with the IoT platform, it allows users to monitor plant management remotely from the user interface by accessing specific Internet Protocol (IP) addresses on mobile electronic devices such as smartphones, laptops, and others. The results of the development system can facilitate users or small-scale farmers at home to monitor through just the application. Furthermore, the development of this system can promote overall optimal plant growth, and this IoT-based system can enhance benefits by providing real-time monitoring and control capabilities through the integration and connectivity of sensors.

ABSTRAK

Sistem pengurusan tumbuhan amat penting bagi setiap petani pada masa kini terutama terhadap teknologi semasa yang boleh ditawarkan di seluruh dunia. Sistem pengurusan tumbuhan amat penting bagi setiap petani pada masa kini, lebih-lebih lagi dengan teknologi semasa yang boleh ditawarkan di seluruh dunia. Ini juga disebabkan oleh penyiraman dan pembajaan yang salah dan boleh mengakibatkan tumbuhan itu rosak, tidak berbunga dan tidak bertumbuh dengan baik. Tujuan utama projek ini adalah untuk memantau pengurusan tumbuhan yang terdiri daripada pembajaan dan menyiram tanaman atau kebun dalam rumah secara automatik dengan bantuan 'Internet of Things*' (IoT) yang menghubungkan perkakasan kepada telefon pintar dengan menggunakan aplikasi* 'Thingspeak*'dan 'Telegram Bot'. Ukuran sensor pH, lembapan, kelembapan, suhu, nitrogen, fosforus dan kalium (NPK) akan digunakan untuk memeriksa sistem pengairan dan pembajaan. Sistem ini menggunakan* 'Capacitive Soil Moisture Sensor'*,* 'Soil Multi-Parameter Sensor*', dan DHT22 untuk membantu memantau dan menyimpan rekod perubahan pertumbuhan tumbuhan. Dengan semua data yang dikumpul daripada penderia, ia akan diproses oleh mikropengawal iaitu ESP32 dan dihantar ke* 'Cloud*' melalui Wi-Fi. Memandangkan sistem itu disepadukan dengan platform IoT, ia membolehkan pengguna memantau pengurusan tumbuhan dari jauh dari antara muka pengguna dengan mengakses alamat Protokol Internet (IP) tertentu pada peranti elektronik mudah alih seperti telefon pintar, komputer riba dan lain-lain. Hasil pengembangan sistem ini dapat memudahkan pengguna atau petani skala kecil di rumah untuk memantau hanya melalui aplikasi. Selain itu, pengembangan sistem ini dapat meningkatkan pertumbuhan tanaman secara optimal secara keseluruhan, dan sistem berasaskan IoT ini dapat meningkatkan manfaat dengan menyediakan kemampuan pemantauan dan pengendalian waktu nyata melalui integrasi dan konektivitas sensor.*

ACKNOWLEDGEMENTS

Bismillahirrahmanirrahim. In the name of Allah S.W.T the Most Gracious, the Most Merciful, and to our prophet Muhammad S.A.W. Alhamdulillah, I am so grateful that finally I have finished all my final year project progress after all the struggle of completing this project. First and foremost, I would like to express my heartfelt appreciation to my supervisor, Dr. Syed Najib Bin Syed Salim, for his invaluable guidance, wisdom, support, and unwavering patience while helping me complete this project. I am very grateful to him for always asking for updates on my projects and spending some of his time despite his busy schedule and other work to do. I would not have been able to complete my project on time without his support.

I am also grateful to Universiti Teknikal Malaysia Melaka (UTeM) and my father for their generous financial support, which enabled me to complete this project successfully. Special thanks to my colleagues, Maizatul Amirah, Muhammad Syahmi, and Muhamad Haziq, for their insightful contributions and ideas.

I would like to express my deepest gratitude to my beloved father for his endless support, as well as for his great help in developing the prototype for this project. I am also thankful to my family members for their constant love and prayers throughout my academic journey. I extend my appreciation to Muhammad Ezzat Haziq, Ameer Shah and Nik Aiman Amirul for their motivation, understanding, and support, helping me overcome challenges and stay focused during the project's completion. Additionally, I want to recognize the faculty members for their guidance and significant role in shaping my academic development.

In conclusion, I extend my thanks to all my colleagues, classmates, faculty members, and others who may not be mentioned here for their cooperation and assistance.

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CHAPTER 1

INTRODUCTION

1.1 Background

Plant Management Systems (PMS) have been in use for many years to help manage various aspects of manufacturing plants. These systems have traditionally relied on manual data collection and analysis, which was time-consuming and prone to errors [1]. It also refers to a set of processes, tools, and techniques used to manage plants, whether it be in an indoor or outdoor environment. PMS aim to maximize plant health and growth while using the least amount of resources, including fertilizer, water, and energy. To provide the best-growing conditions for plants, plant management systems often require monitoring environmental factors such as temperature, humidity, soil moisture, and nutrient levels, and making necessary adjustments [2].

The amount of fertilizer and water required varies depending on the type of plant. A plant's roots may be damaged by too much or too little water or fertilizer each day, resulting in unhealthy crops [3]. To overcome this problem, a monitoring device is installed, defined as a system that monitors and warns when there is a defect in the growth or suitable environment. This system is created with the help of the Internet of Things (IoT).

Various research studies are exploring the use of IoT in PMS. Among them is using an IoT system for monitoring and control of hydroponic salad cultivation. The system uses various sensors to collect data on the plant's temperature, humidity and pH level, which is then used to automate the plant management process [4]. Therefore, the IoT system improves the efficiency of plant management and produces a higher yield of lettuce compared to traditional manual management methods.

According to the Malaysian Department of Agriculture, chili is an important crop in Malaysia and is one of the main producers and exporters of chili in the world, with a total production of 163,555 tons in 2020 [5]. The ideal conditions for growing chili are between 20 and 30 degrees Celsius, 1500 to 2000 millimeters of rainfall each month, and a pH of 5.5 to 6.8 on mineral soil, peat, or Bris Soil (with a proper irrigation system) [6]. In the context of chili plant cultivation in Malaysia, the use of IoT applications is being explored in several studies. Among the studies that have been found is smart IoT water sprinkle and monitoring system for chili plants. The system can detect soil moisture levels and adjust irrigation accordingly, resulting in improved water use efficiency and yield [7].

With the use of IoT applications in the plant management system, it shows great potential in increasing the productivity and efficiency of planting chili plants in Malaysia. Farmers can also monitor the growth of their crops in real-time and adjust the supply of water and nutrients according to the plant's needs, achieving better yields.

1.2 Problem Statement

Most of the plant management system, whether indoor or outdoor, is watered and fertilized manually every day. Besides, incorrect watering and fertilizing may result in plants perishing, not flowering or not thriving. To maintain the fertilization and watering for any plant is difficult without knowing the right temperature, humidity and pH needed for the plant. It needs to be careful in the measurement of the fertilizer and water so that there is no overwatering fertilization or else it will damage the plant. The other problem is there are limited resources, and the existing resources are too expensive for the farmer, especially when most of the farmers come from rural areas. Not only that, but it also needs more manpower to be managed manually and can only be used for several plants. There are about 3 sensors that are used for this project based on fertigation and irrigation, which are temperature and humidity sensor, pH and NPK sensor, and moisture sensor. Where the information from all sensors is transferred to the cloud and the apps on the smartphone. A suitable technique that is used is by using IoT in the plant management system to monitor and control remotely.

1.3 Addressing Global Warming Through the Plant Management System Project

Global warming is a major environmental issue that is having significant impacts on the planet. The development of an IoT application for a plant management system is a practical method for combating global warming. By utilizing the Internet of Things (IoT) capabilities and integrating them with plant management strategies, it is possible to improve the efficacy of agricultural practices, conserve resources, and lessen the effects of climate change.

Pollutants and global warming may be intentionally damaging ecosystems. Understanding the cycles of soil moisture, temperature, and nutrients can help solve each of these problems. Precision agricultural methods can then be used to design a management system that satisfies the needs of the flora while preventing unnecessary losses to the cycles. according to research precision agricultural structures have the potential to increase yields and improve fertilizer use efficiency.

1.4 Project Objective

The objectives for the Development of IoT in Application of Plant Management System are:

a) To develop a fertigation system and irrigation system by using drip irrigation.

b) To design and assemble an IoT-based system that can help the farmer to monitor and control the crop field efficiently.

c) To analyze and evaluate the impact of the IoT-based plant management system on plant growth and health, as well as its potential benefits for farmers and other users in terms of increased yields.

1.5 Scope of Project

The scope of this project are as follows:

a) Use sensors to collect real-time data on plant health which is temperature, humidity, and pH of chili plants.

b) Only focus on the chili plants.

c) Focus on small-scale plants which is the detailed size for this project is 70cm x 53cm x 82cm.

d) IoT applications are used to remotely monitor and control plants using mobile apps. This can provide real-time access to plant health data, as well as the ability to adjust environmental conditions and receive alerts for issues such as low water levels.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Plant management is a crucial aspect of modern agriculture. Crop cultivation performance depends on a number of variables, including the optimum quantity of water, fertilizer, and favorable environmental conditions. In conventional plant management, farmers have to rely on manual methods to maintain these conditions, which is time-consuming and labor-intensive. The Internet of Things (IoT) has completely changed how to manage plant systems. IoT offers the chance to automate plant management processes, lower labor costs, and improve plant health. This literature review aims to analyze the current state of research in the development of IoT applications in plant management systems.

2.2 Plant Management Systems

To meet the seemingly opposing needs of global population development and the need for environmental quality and sustainability, plant management systems must be both outstanding in their productivity and unaffected by natural ecosystems. There will be significant pressure for food production on marginal and environmentally sensitive land if total plant productivity declines or even plateaus [8].

A plant management system refers to a set of methods, collection of producers, and equipment used to keep track of, manage, and improve many aspects of plant growth, health, and productivity. In order to maximize the use of resources like water, nutrients, and sunlight while minimizing the dentrimental effects of pests, diseases, and environmental conditions, plans and methods must be put into place. This system also includes a variety of tasks, such as soil management, crop rotation, pest and disease control, irrigation, fertilization, and environmental monitoring [9].

The main objectives of a plant management system are to maximize crop yields, enhance overall agricultural output, and promote sustainable and effective practices. With advancements in technology, plant management systems are increasingly incorporating automation, data analytics, and IoT technologies to enable real-time monitoring, remote control, and data-driven decision-making for more precise and efficient plant management [10].

2.2.1 History of chilli plant

The chilli plant is known as Capsicum Frutescens which is cultivated extensively in warm areas where the climate is favorable. The soil has to be damp and watered regularly, especially when the plant is under long hours of sunlight which will dry it up quickly. The range pH scale of the chilli plant is from 5.8 – 7.2 where it is the most important aspect of this range is nutrient availability. All nutrients are available within a certain pH range. A pH range of 5.8 – 7.2 indicates that the majority of the nutrients required by capsicum for optimal growth are freely available to the plant. Growing capsicum in soil that is outside of this range (either more acidic which is below 5.8 or more alkaline which is above 7.2) indicates that some nutrients will be unavailable to the plant, resulting in a dissatisfied plant. It can also lead to an increase in nutritional availability, which is undesirable. The chilli plants also need humidity around 80% and smooth air circulation [8].

On a commercial scale, around 14,560 hectares of chilli were farmed in Malaysia each year in major producing areas such as Johor, Perak, and Kelantan. As shown in the Figure 2.1, chilli can grow in temperatures ranging from 20 to 30 degrees Celcius with monthly rainfall ranging from 1,500 to 2,000 millimetres, and it can grow in pH ranges ranging from 5.5 to 6.8 on mineral soil, peat, or Bris Soil (with sufficient irrigation). Depending on the harvesting season and market demands, the product is either red or green chilli. According to research, Malaysians consume 33,000 tonnes of fresh chilli each year, whereas local production is roughly 23,000 tonnes [6].

Growth Stage	Days
Seedling and transplanting	0–30
Vegetative	31–62
Flowering	57–92
Fruiting	88–120

Figure 2.1 Chili growth stages [11]

In recent years, automatic plant growth monitoring has drawn a lot of interest. Numerous opportunities have developed as a result of the need in this area, particularly for automatic classification using deep learning techniques. One of the crops with a high monetary value is chili, and crop productivity depends on the automatic detection of chili plant growth stages. Based on Figure 2.1, this study tracks the growth of chili plants with as many as 2,320 photos of Capsicum annum ‘Bird’s Eye’ plants that make up the dataset used. From seedling through harvesting phases, all growth stages were depicted. However, because of the lack of publicly accessible datasets on the many stages of chili plant growth, the study of automatic chili plant growth stage categorization using deep learning algorithms has not received much attention [11].

2.3 Fertigation system for chili plant

Fertigation is a farming method that increases crop output by carefully distributing water and fertilizers. The harmful effects of fertilizer seeping into the roots, soil, and groundwater are also avoided through this application. Food crops can be grown on barren ground or in metropolitan areas when applied in a soilless system using substrates and media like rock wool, perlite, vermiculite, or peat. By preventing illnesses that are spread by soil and increasing the number of growing cycles without the need to replenish nutrients and soil conditioning, the removal of soil also boosts yield. Additionally, fertigation using a rain-shelter system enables crop production in regions where severe rainfall, sunlight, or wind prevents the traditional cultivation of the necessary food crop [12]. It is also the process of providing plant nutrients and water in order to produce a higher-yielding crop. Farmers may dramatically optimize their water and nutrient use by using an automated fertigation system [13].

One project that can able modern life is the intelligent irrigation system for fertigation systems, which can address issues like inconsistent crop yield and the exorbitant cost of fertilizers and pesticides. The study from Hariz M is to research the fertigation system used in Malaysian agriculture and create a working prototype of an intelligent fertigation irrigation system. For agricultural crops based on small-scale green vegetable planting, irrigation method are used. A solenoid valve is used to regulate water flow in the irrigation system, and the irrigation system will be operated in accordance with a number of schedules. Prroteus software has been used to create a simulation based on the Arduino Uno microcontroller [14].

An essential part of agricultural output, particularly in fertigation-based farms, is the control of pest insects. The pest control system is still inadequate in Malaysian fertigation farms, despite its advantages in the management of irrigation and fertilization systems. Pest insects specifically cause harm to, weaken, or destroy nearly all agricultural plants. Insects continue to harm stored or processed goods even after harvest. Therefore, the study from Kassim A aims to design and develop an autonomous pesticide sprayer for the chili fertigation system and to implement a flexible sprayer arm to spray the pesticide under the crop’s leaves respectively which is the development of an unmanned pesticide sprayer can be mobilized autonomously. The flexible sprayer boom also can be flexible controlled in the greenhouse and outdoor environments such as open-space farms [15].

In addition, The goal of B. Aisham’s project is to create a fertigation system that can combine several types of fertilizer as well as mix fertilizer concentration and pH levels utilizing an Arduino system and PID controller. The primary tank contains the electrical conductivity and pH sensor, which has begun to provide feedback. The controller will fix the system when it notices an error. The experiment in this study was run under numerous settings of PID parameters. Different PID parameters will produce various outcomes and settling time. The research findings demonstrate that the system is capable of controlling and responding to changes in salinity and pH levels [16], [17].

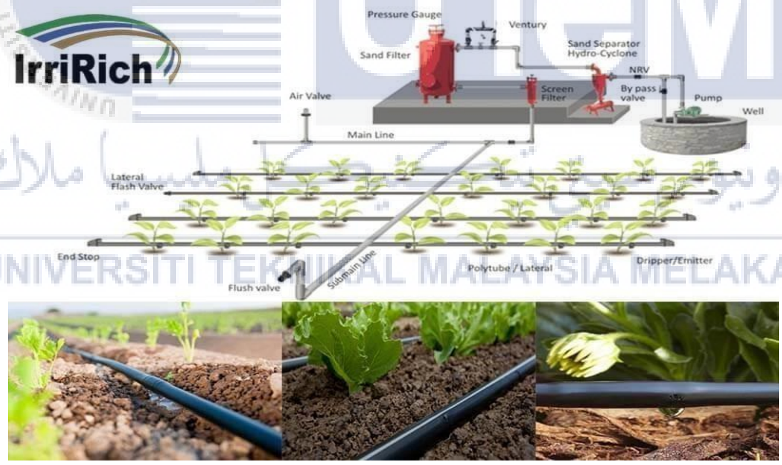

Figure 2.2 Fertigation (way of direct feed to crops) [15]

2.3.1 Hydroponic System

In hydroponics as a figure 2.3 shown, plants are grown without soil using a water-based fertilizer solution. The growing medium used in this method can include aggregate substrates like vermiculite, coconut coir, or perlite. Small farmers, amateurs, and business enterprises all use hydroponic production systems [18]. The way that hydroponic systems function is by giving users precise control over environmental factors like temperature and pH balance while also maximizing fertilizer and water exposure. The basic principle of hydroponics is to provide plants with exactly what they require at the precise moment they want it. When a plant is cultivated hydroponically, nutrient solutions that are specifically formulated for the plant are administered. It is possible to monitor and modify pH levels. Plant growth is accelerated in an environment that is highly customized and controlled. Numerous danger factors are decreased by managing the plant's surroundings. Seedlings mature significantly more quickly when the mechanical resistance of the soil is removed. Hydroponics produces significantly healthier and higher-quality fruits and vegetables by doing away with pesticides and the plants are free to develop quickly and vigorously in the absence of barriers [19].

Figure 2.3 Hydroponic System [18]

The goal of this research [20], was to develop a method that would assist farmers or owners of hydroponic farming systems in maintaining or setting up a hydroponic farming system utilizing readily available, reasonably priced hardware. This system is designed for use with hydroponics, NFT, and agricultural management systems using microcomputers, Raspberry Pi 2 Model B, and web technologies due to the dynamic interface. Furthermore, according to a study by [21], hydroponic chili plants are a sort of vegetable that is popular and has a lot of advantages. The automatic smart control technology by using UV lamps is a tool that is created so that hydroponic chili cultivators can produce the best harvests possible. There are various sensors such as EC sensors, pH sensors, RTC sensors, and ultraviolet lights that are used. Based on the results of the possible advantages for partners or chili farmers shows that this technology can maximize the efficiency of harvest time from manual hydroponic culture, which was initially 90 days to 70-80 days.

2.3.2 Aquaponic System

Aquaponics is the combination of hydroponics, which is the growth of plants without soil, and aquaculture which is the raising of fish and other aquatic creatures. The figure 2.4 shows these two are combined in aquaponics, where plants are fed the waste products of aquatic creatures. Vegetables purify the water that is returned to the fish in exchange. Microbes, together with fish and their waste, are crucial to the sustenance of plants. The fish excrement and sediments are transformed into materials the plants may use to thrive by these helpful bacteria, which congregate in the gaps between the plant’s roots. Aquaculture and gardening work together flawlessly as a result [22].

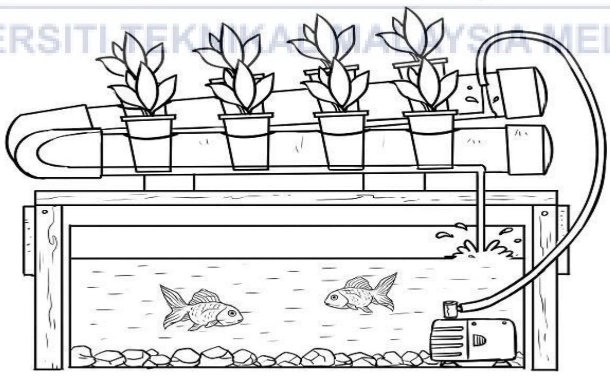

Figure 2.4 Aquaponic systems [22]

It’s important to enhance the production of red chili (Capsicum annum L), a type of horticulture with great economic and nutritional value. With the help of modern agricultural technology, many farmers are now growing crops in systems like aquaponics that do not require soil, particularly for vegetables. The purpose of this study [23] is to identify the best planting medium for the growth and yield of three kinds of red chili. The first component in this study employed four growing media (Cocopeat, husk charcoal, tanks, and a mixture of all four), and the second factor used three red chili types (Kirana, Pasemah, and Terano). It is used a factorial Randomised Complete Block Design (RCBD) with three repetitions. Plant height, number of leaves, number of branches, number of fruits, and weight of fruits are among the parameters measured.

2.3.3 Aeroponic System

The technique of aeroponics involves growing plants in an atmosphere of air or mist without the use of any substrate. In other words, the plant roots are suspended in the air and occasionally misted or sprayed with nutrient solution or nutritional aeorosol. Aeroponic systems use nutrients and water more effectively than NFT or DWC systems. The primary benefit of aeroponics is that roots are exposed to air, therefore an oxygen shortage is never an issue. Its drawbacks include high upfront building costs, high system maintenance costs, and a high level of technical expertise needed [24].

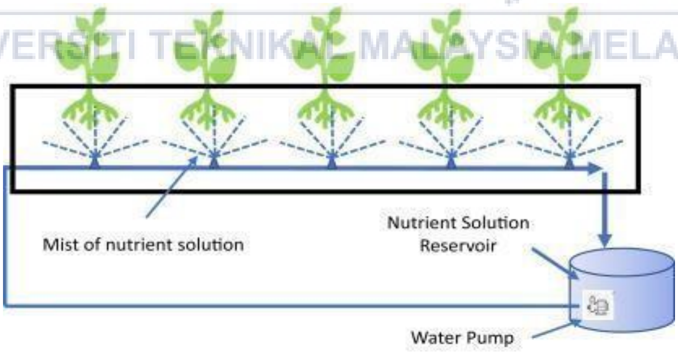

Figure 2.5 Aeroponic System [24].

2.4 Manual Method

A manual method of plant management refers to conventional methods and procedures that rely on physical labor and human intervention for the observation and management of many elements of plant development and health. Without the use of automated or technological methods, it will involve manual observation, data collection, and decision-making processes. Based on general knowledge of plant water needs, the timing and quantity of water implemented are chosen. Similarly, manual methods include soil testing, which involves the manual collection of soil samples that are then sent to a lab for nutrient content and pH level measurement [25].

Figure 2.6 Manual Irrigation Method

The maintenance of planting schedules, crop rotations, pest and disease occurrences, and other relevant data by farmers or gardeners manually using notebooks or spreadsheets is another component of record-keeping. Although manual methods have been around for a while, they can be time-consuming, labor-intensive, and prone to human mistakes [26].

2.5 Automated Method

Automated methods of plant management systems involve the use of automation and technology-driven systems to monitor and control various aspects of plant growth and health. To simplify plant management tasks, this method integrates sensors, data collection tools, and automated procedures. Based on established routines or real-time sensor data, these systems automatically water plants for ensuring efficient water use and ideal soil moisture levels. These automated techniques provide accurate and prompt responses, also lowering the need for manual labor and can increase plant health and resource efficiency.

Irrigated farming is a dependable method of food production, especially in the current condition of weather change caused by global warming as a result of industrial activity. With more and more areas being used for irrigation, it is more important to manage water resources efficiently. The microcontroller unit, which function as the system's "brain" for coordinating control of the various modules, is the system's primary controller. It synchronizes and runs the watering system and uses the GSM module to inform the user of the state of the field and watering section [27].

According to research from [28], an automated irrigation system operates by constantly monitoring the soil moisture content and wirelessly actuating the pipeline valves to open when the moisture level goes below the required minimum for the cultivated crop, causing the land to be irrigated. Researchers from [29] also present a smart irrigation system that combines an Arduino water management system with a nutrient sensor. One of the most popular and useful automatic systems, this sensor-based automatic irrigation system was created and put into service.

2.6 Automated IoT Method

Utilizing Internet of Things (IoT) technologies to monitor and regulate various elements of plant growth and health is part of an automated IoT plant management system. It creates a complete and intelligent plant management system by combining the power of sensors, networking, and data analytics [30].

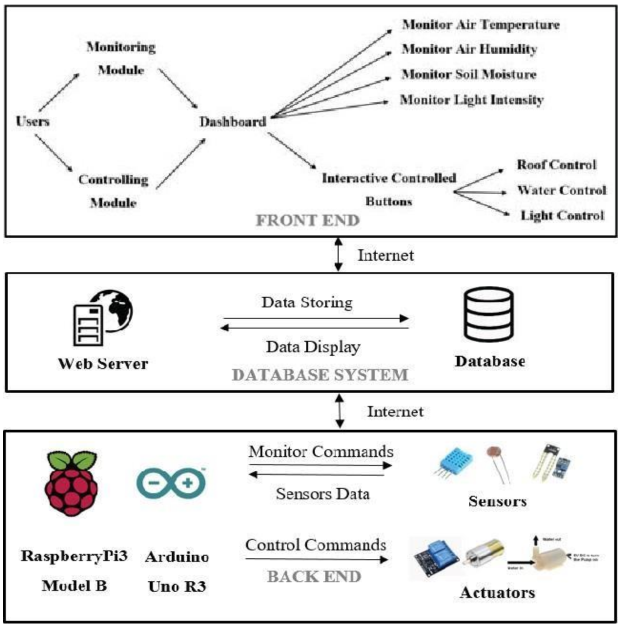

Figure 2.7 An IoT Controlled System for Plant Growth [30]

To improve irrigation techniques and avoid overwatering or water stress, the IoT system can also incorporate weather data and predictive analytics. Additionally, by utilizing IoT-enabled fertigation systems that precisely manage the amount and timing of nutrient application based on plant demands, the system can automate the delivery of nutrients and fertilizers. The automated plant management systems utilizes IoT technology to increase efficiency, accuracy, and resource utilization while lowering labor costs and supporting sustainable agriculture practices [31]. The next part will go into more detail about this method's application and the tools that researchers used.

2.7 Microcontroller Devices

A microcontroller is an integrated circuit (IC) device that controls other components of an electronic system, often through memory, peripherals, and a microprocessor unit (MPU). These gadgets are designed for embedded applications that need both computing power and quick, accurate communication with electronic, digital, or analog parts [32]. As a Figure 2.6 show, a microcontroller is a small, inexpensive computer on a chip that is made to carry out a certain set of functions. It is utilized in many different applications, including automating systems, sensing and monitoring equipment, and controlling machinery. The microcontroller can communicate with the outside world via the I/O ports. It is capable of carrying out the instructions recorded in its memory and completing the tasks for which it was created. Read-only memory (ROM) and random access memory (RAM) are the two types of memory that microcontrollers commonly feature. Temporary data that the microcontroller needs to access quickly is stored in RAM. Peripherals are extra parts that are integrated into microcontrollers to carry out specific functions [33].

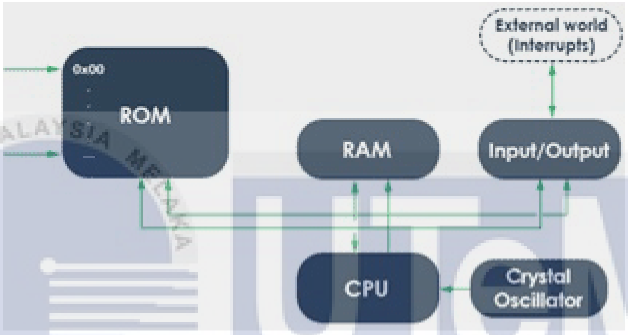

Figure 2.8 Microcontroller Working Principle Source [33]

2.7.1 Arduino Uno

A microcontroller board designated as the Arduino Uno like shown in Figure 2.7 is based on the Atmega328. It contains a 16MHz crystal oscillator, 6 analog inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It comes with everything needed to support the microcontroller which is just plug in a USB cable, an AC-to-DC adapter, or a battery to power it. The FTDI USB-to-serial driver chip is not used by the Uno, which is how it differentiates from all earlier boards. Instead, it has an Atmega8U2 that has been configured to act as a USB-to-serial converter [34].

Arduino has been used extensively in agricultural processes, including crop monitoring, irrigation control, area monitoring, water quality measurement, and insect monitoring. Additionally the information can be saved in a database and used the next planting season [35]. The system suggested by Hammami [36] uses Arduino Uno and DHT11 sensors to collect humidity and temperature data and sends it to ThinkSpeak web service that can be accessed using the Application Programmable Interface (API) via an internet connection provided by the Mobile Wi-Fi Router. A study from Alel et.al [37] is to reduce the amount of human labor required, the irrigation gate's autonomous opening and closing system is managed by an Android system and Arduino Uno boards. This system uses an Atmega328 microcontroller as the main controller, a flow metre sensor for airflow calculation, a water level sensor for air level calculation, a Bluetooh HC-05 module to connect tools to Android which is Android as an interface between users and devices also as the monitoring tool, and DC motors to raise and lower the air door.

Figure 2.9 Arduino Uno [34]

2.7.2 Arduino Nano

As Figure 2.8 shown, the Arduino Nano's microcontroller is a Atmega328P and it is the smallest and most traditional breadboard-friendly board from Arduino. The Arduino Nano has a Mini-B USB connector and pin headers that make it simple to link it to a breadboard [38]. The system monitoring irrigation designed by Hapsari et al [39] has used a water level sensor, pump, Arduino Nano, and Xbee Pro S2C for each monitoring node. To solve problems with the monitoring system, a system called a wireless sensor network is deployed. As a consequence, the user can receive all the performance parameters in a suitable way and they can all be adjusted to the actual situation in the farm field.

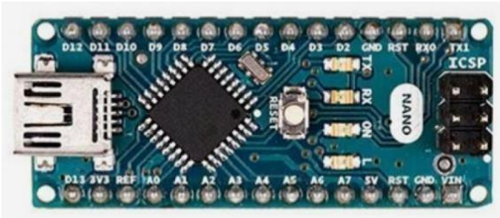

Figure 2.10 Arduino Nano [38]

2.7.3 Arduino Mega

The Arduino Mega 2560 is a board offered by the Arduino platform that stands out from other boards by having a huge number of pins and a potent controller. However, one must be familiar with the board specifications as well as its pinout for the specific Arduino board in order to use this board efficiently. The controller used in the board like shown as Figure 2.9 is Atmega2560 which has provides a flash memory of 256kB and clock speed of 16MHz [40]. This research paper describes the design and implementation of a low-cost fuzzy logic system for monitoring and remote control of a greenhouse. For the control system, an Arduino Mega board was programmed with a Fuzzy algorithm to monitor and carry out control actions for environmental temperature, soil moisture, relative humidity, and lighting [41].

Figure 2.11 Arduino Mega [40]

2.8 Design of intelligent control system for plant growth

Automated systems for plant care have been developed including automatic watering, light provision, and fertilization where plants can be cared for fully automatically and can be viewed from a mobile application [42]. An automatic irrigation system using IoT has been developed where it works to check the amount of soil moisture. The system uses a Node MCU programmed with code that turns relay switches on and off based on moisture content thresholds. The moisture content value will be transferred to the phone user where the user will monitoring the motor in his phone. A relay switch is used to turn on the moisture automatically depending on the moisture content of the soil. With the implementation of this technology, the right amount of water is delivered to the farm and can reduce difficulties caused by over-irrigation [43]. Therefore, there is a study from Abdalla S who has developed an IoT-based plant growth monitoring and management system for indoor farming. The system will transmit and display information such as temperature and humidity in a mobile application that can be viewed remotely by users. It also includes a useful GUI for users to schedule fertilizing, lighting or watering the system [42].

2.9 Internet of Things (IoT)

The Internet of Things (IoT) is a developing research area of technical, technological, socioeconomic effect. A wide range of networked products, frameworks, sensors, and actuators that benefit from web technology advancements and connections that enable new services that were not before possible are included in this breakthrough [44]. An Internet of Things node is a piece of hardware with sensors that broadcasts sensed data to users or any other devices via the internet. The structure of the IoT network is shown in Figure 2.10. This architecture includes numerous IoT sensors for measuring things like temperature, humidity, pressure, and more. These data are sensed and then sent to a cloud server via an IoT gateway. Users can also access these data via mobile apps and other platforms [45].

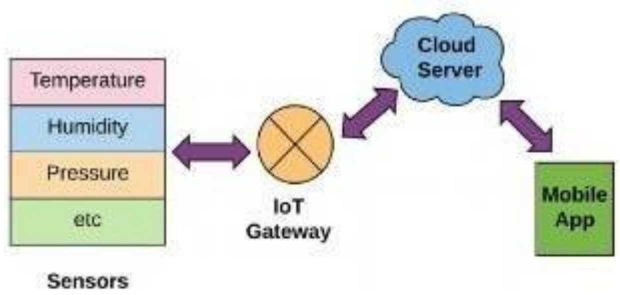

Figure 2.12 IoT network architecture [45]

2.9.1 The Importance of IoT

IoT is increasing in being used number of application areas today, and researchers and developers are increasingly emphasising the value of IoT data quality. Applications and organisations have diverse needs for data and different standards for data quality in various circumstances [46]. According to Said Mohamed et al. [47] research, the project focuses on innovative methods for smart farming. IoT connects sensor devices to carry out a variety of fundamental functions, making it one of the main components of smart systems. With data transmission speeds of up to 20 Gbps and the ability to connect a lot devices per square kilometre, this work highlights the importance of employing a 5G mobile network for creating smart systems.

2.9.2 IoT Software and Platforms

As the primary support structure for the quick creation of scalable and effective IoT applications, IoT software platforms are evolving. These platforms provide comprehensive services, such as connectivity between smart things and cloud infrastructures, flexible storage, programming frameworks, and data analytics to produce insightful information for innovative commercial use cases [38].

2.9.2.1 Thingspeak

A platform offering a variety of services specifically designed for developing IoT applications is called ThingSpeak. It gives the ability to collect data in real-time, analyse the data in charts, and build plugins and applications for interacting with online services, social networks, and other APIs [49]. To ensure that the greenhouse’s environment meets the needs of the chili plants growing, the greenhouse’s climate is monitored and controlled. The sensor is connected to the Arduino Uno so that it can give commands to the actuator and then it will connected to the ESP-01 WiFi Module to send the sensor reading data to the ThingSpeak database for monitoring [50].

2.9.2.2 Blynk

Blynk IoT stores, displays, and visualizes sensor data while enabling remote control of the hardware. With the help of personalized widgets, users of the software can design interfaces for their projects. The IoT software features offered by Blynk include device management, sensor data visualization, equipment remote control, and more. Software and web solutions are provided by Blynk IoT for a variety of small, medium-sized, and large organizations. It premits programmers and engineers to design user interfaces for controlling and monitoring their projects via smart gadgets like smartphones, and tablets [51]. The paper from Nainunis [52] is to develop an Internet of Things (IoT)-based irrigation and monitoring system for chili plants. In this project, the IoT is implemented using Wi-Fi nodes as a connection medium. The data for soil moisture and pH levels are sent to the user through the

Blynk application and control the water pump. As a result, irrigation automated and crop status can be monitored via a remote IoT platform. It was successfully used to address the issues that farmers were having.

2.10 Cloud-based plant management systems using IoT technology.

The combination of the IoT and cloud computing offers the potential to maximize their application. Because IoT systems are largely made up of interconnected widely dispersed and limited devices, they can take advantage of virtually limitless cloud entity resources, such as storage and computation capabilities, to store and process their sensed data. IoT has the potential to improve cloud computing by widening its scope to encompass real-world applications. To put this notion into practice and create an interaction layer between IoT and cloud computing, a cloud software platform is necessary, which accomodates a wide range of network communication protocols as well as security and data management concerns. This thing aware of IoT cloud services like Blynk, Thingspeak, Google Cloud Platform, Exosite IoT Platform, and Ayla IoT Platform[53].

Furthermore, the use of IoT in agriculture is becoming increasingly popular due to its potential to optimize resource utilization and increase productivity. This study from J.Yang has proposed a cloud-based IoT framework that provides a platform for integrating various sensors and devices used in agriculture, allowing farmers to monitor and control their farms remotely. The framework enables data collection and analysis, allowing farmers to make informed decisions and improve their agricultural practices. By using cloud technology, the framework can handle large amounts of data, which is essential for the efficient management of modern farms. The implementation of the proposed framework in agriculture can lead to significant benefits, including increased crop yields, reduced resource consumption, and improved profitability[54].

2.11 Comparison of Previous Studies

Table 2.1 shows previous studies that have different ideas for implementing related projects. There are several article references searched to know better about the use of manually, partial automated, and automatic methods with IoT in plant management systems.

Table 2.1 Comparison Previous Studies

Article Reference	Microcontroller	Implementation	Software	Finding
[25],[26]	X	Human	X	Cost-effective, minimal maintenance
[3],[13],[14],[15],[27],[28],[29],[37],[39],[41]	/	Partial-Automated	X	Improve their water and nutrient use
[7],[52],[53]	/	Controller with IoT	Blynk	Achieve reliability and feasibility in the monitor process, maintain long-term smart farming, save time, easier for farmers, easy to monitor and control

[49],[50],[54]	/	Controller with IoT	Thinkpeak	Increasing the overall productivity, save time, make it easier for farmers
[1],[42],[47]	/	Controller with IoT	GUI	Easy to monitor and collect data

2.12 Summary

The literature review on the development of IoT in the application of plant management systems provides an overview of the existing research and knowledge in this field. The project focuses on the utilization of Internet of Things (IoT) technology to enhance plant management practices. The review begins by highlighting the increasing importance of IoT in various industries, including agriculture and plant management. It emphasizes the potential benefits of integrating IoT devices and sensors with plant management systems, such as improved efficiency, reduced costs, and enhanced decision-making capabilities.

Overall, the literature review provides a comprehensive understanding of the current state of research and development in the field of IoT for plant management systems. It establishes a foundation for the proposed project, highlighting the opportunities, technologies, and challenges associated with leveraging IoT in the context of plant management. From all research, the method that has been chosen is by using the automated IoT method to improve the existing system for plant management system.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The use of IoT plant management systems aims to transform the agricultural industry by utilizing advanced technologies to optimize plant growth, resource utilization, and environmental sustainability. This methodology aims to improve plant management practices, increase agricultural output, and minimize the effects of climate change by integrating sensors, connection, data analytics, and automation. The project’s goal is to develop an Internet of Things-based system that allows for real-time monitoring, data-driven decision-making, and remote control of plant management activities.

3.2 Selecting and Evaluating Tools for a Sustainable Development

It is critical to carefully pick and evaluate the tools and technologies that are being used to collect and analyze data when developing and implementing a PMS project with a focus on sustainability. This includes a variety of methodological concerns, such as checking the accuracy and reliability of sensors, evaluating the compatibility of various tools and software, and taking into consideration the project's environmental impact. Furthermore, it is critical to address the project's social and economic implications, such as ensuring that the data is accessible and intelligible to a wide range of stakeholders and weighing the costs and benefits of various tool options.

3.3 Project Implementation Flowchart

Project flowcharts are used to visually represent and explain the system's flow. The flowchart accomplishes its goal in the most basic way by defining the project's working criteria. Using flowcharts, the processes of the project have to be laid out as a diagram that depicted the system from the beginning to the finish.

It describes the steps that must be followed and the decisions that must be made when a project is being implemented. The flowchart facilitates comprehension of the linkages, dependencies, and workflow among various project components.

The essential elements of a project implementation flowchart encompass the clarification of project objectives, development of a comprehensive project plan, distribution of resources, ongoing progress monitoring, execution of quality assurance assessments, and concluding the project upon successful achievement. Functioning as a visual aid, the flowchart plays a pivotal role in harmonizing project objectives and streamlining the implementation process for improved efficiency and organization.

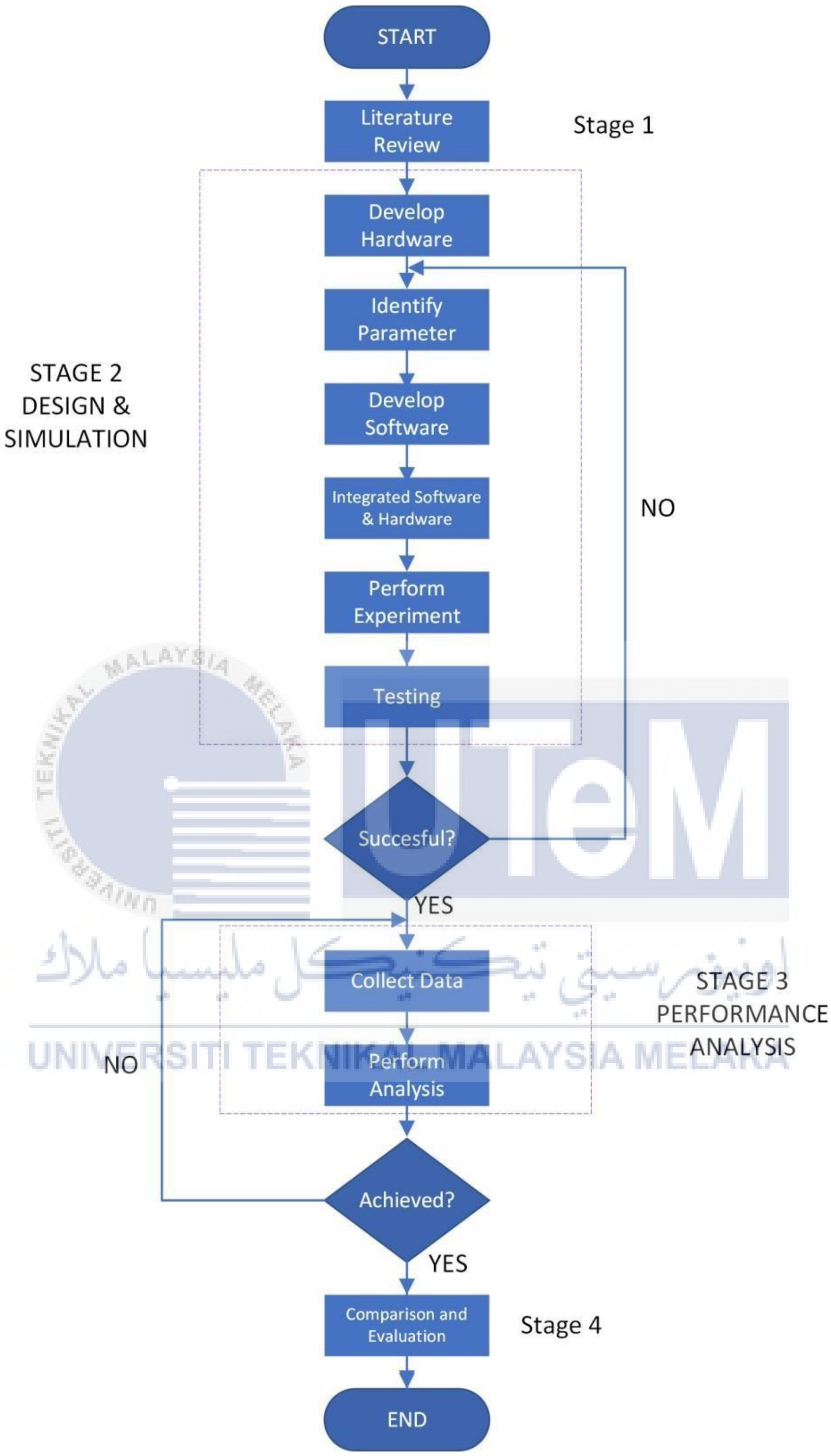

Figure 3.1 Research and Development Process Flow

3.3.1 Stage 1: Literature Survey

By referring to Figure 3.1 above demonstrates the project's implementation, which began with the selection of a few titles that complemented the supplied concept. With that, the project can begin with an introduction that includes all of its key definitions, including its title, background, objectives, problem statement, scope, methodology, preliminary results. The system is introduced in this chapter, which also provides all the essential details required for this project.

Look up some current project-related publications that are relevant to the work being done and add to the concept of this project. Compare The Development of IoT applications in Plant Management Systems (DIoTPMS) to other researchers' projects. This chapter also compares systems proposed by other researchers. At least three separate systems are contrasted with one another which is compared in terms of cost, the technology used, and the importance behind their design. Many references are made from various articles, with a total of 54 articles and journals collected. Among the referenced journals and articles are within the range of years from 2018 to 2022.

3.3.2 Stage 2: Design and Simulation

During the second stage, which is the design and simulation phase, methods of monitoring and controlling the plant management system are being identified and proposed. This stage involves ensuring the suitability of this method for implementation in the plant environment. The proposed method involves observing soil moisture conditions, temperature, humidity, and fertilization management for chili plants. An essential aspect is implementing an automatic irrigation and fertilization system based on the fertility of the chili plant.

The method used generates data from each sensor. Data from all sensors is stored and analyzed in the cloud using ThingSpeak. With this, users can access data that contributes to insight into the long-term health of plants. In addition, to perform remote monitoring and control, Telegram Bots are used for users to receive real-time updates on ground conditions. Users can also control watering and fertilizing systems through intuitive Telegram commands

In addition, users control the watering and fertilizing system through intuitive Telegram commands. Telegram instructions are designed to be intuitive to ensure that users can interact easily and can easily control the plant management system remotely. Both the water and fertilizer pumps have an emergency stop feature to allow the operation to be stopped in the event of any issues. Before doing the physical exercise, the entire plant management system is simulated in a virtual environment. This approach allows for thorough testing and refinement, ensuring system functionality and reliability.

3.3.3 Stage 3: Performance Analysis

For the first step in this phase involves the systematic collection of data where this data can be gathered through the testing, real-word observations, or any other predefined methods. The accuracy and relevance of the collected data are paramount, as the subsequent analysis heavily relies on the quality of the input. The collection process may involve continuous monitoring of the parameters identified in Stage 2, ensuring a comprehensive dataset that reflects the system's performance under various conditions. Analysis is performed when the amount of the data is collected. This involves applying predefined algorithms, statistical methods, or other analytical tools to extract derive significant insights and conclusions from the data. The analysis aims to answer specific research questions and trends within the dataset. The results of the analysis provide valuable information that contributes to a deeper understanding of the system's behavior and performance. If the results of the analysis are not achieved, then the process needs to be repeated to collect the data until a satisfactory analysis result is obtained.

3.3.4 Stage 4: Comparison

After the successful analysis, the comparison for the analysis is being made. Evaluation criteria include performance, efficiency, cost-effectiveness or other relevant metrics. This stage aims to draw conclusions about the effectiveness of the developed system and guide further improvements or iterations.

This flowchart illustrates a structured approach to research and development, ensuring that each stage is systematically completed before progressing to the next. The iterative nature of certain stages allows for refinement and improvement based on feedback and results obtained throughout the process.

3.4 Development of IoT in the Plant Managements general process flow

Figure 3.2 shows the process of the project, which starts by initiating the program. Once the program begins, it establishes a link between the controller and the network, where all of the sensors' parameters are set and read before verifying the process that uses the water pump and the fertilizer pump. The system examines the output data to determine whether or not the plant is in an ideal state. If the plant's condition does not reach the optimal level, the microcontroller sends a signal to the water pump and fertilizer pump to supply water and fertilizer until the plant's condition meets the optimal level. Simultaneously, all gathered data is transferred to the Cloud. It is then transmitted to the user interface.

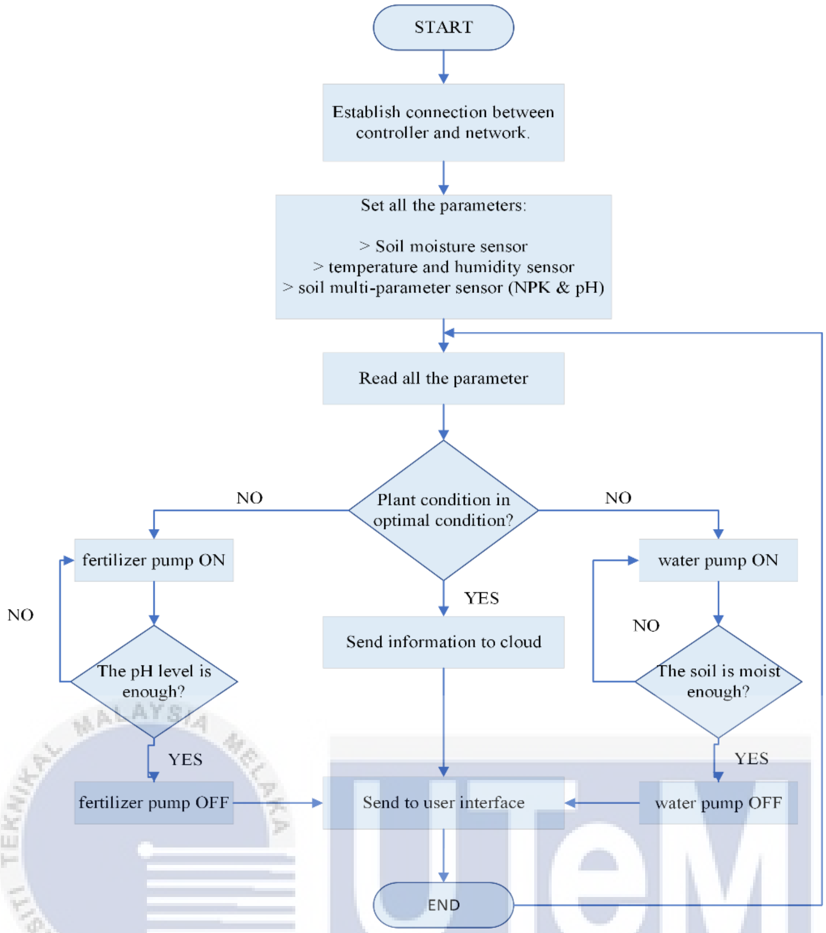

Figure 3.2 Development of IoT in Plant Management general process flow

3.5 System Block Diagram

A system block diagram helps with the project's concept. It almost resembles a flowchart but with a more straightforward presentation. Block diagrams commonly represent the intake, process, and output of design projects while also simplifying the parts and resources that were utilized.

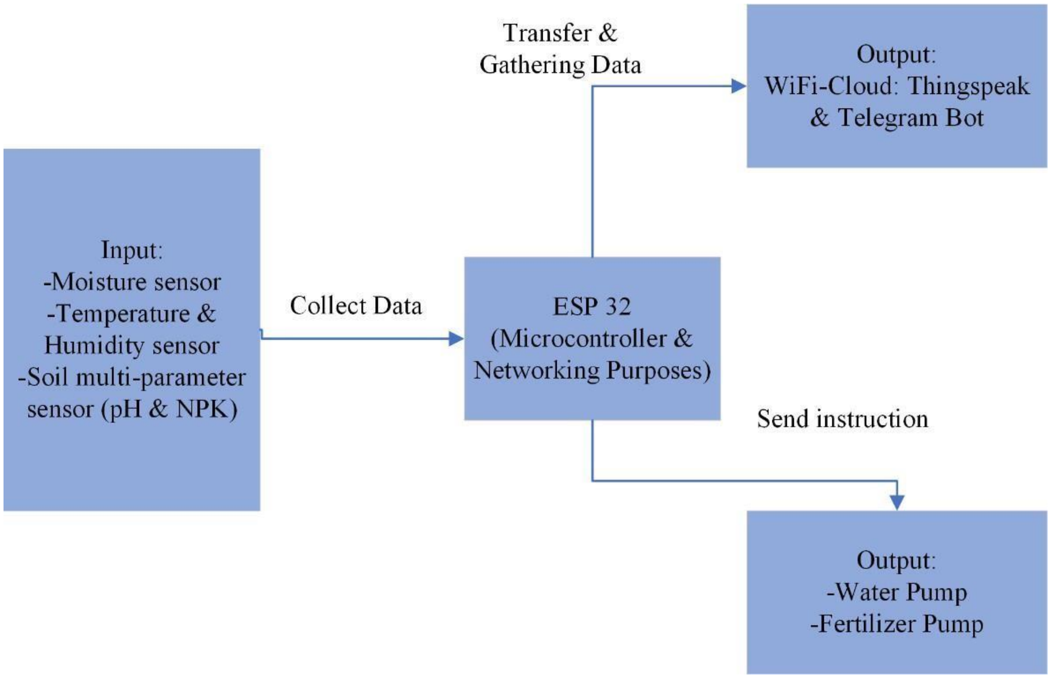

Figure 3.3 System Block Diagram

Figure 3.3 shows the system block diagram that contains the entire explanation of the project concept from input to output. The microcontroller ESP32, which is the major component of this project, regulates the input and output data throughout all of the other components. It collects and transports data, as well as gathers and provides commands. For the input, there are soil moisture sensors, temperature and humidity sensors, and a soil multi-parameter sensor (pH & NPK). Each of these components has its own functions, such as a soil multi-parameter sensor that is used for the planting system while the ESP32 is used for networking and data collection for the cloud. All sensor data is uploaded to the cloud from the ESP32, which then transfers the data to the output, which is the cloud. The data is saved there and can be accessed from the cloud through apps on the phone, laptop, or tablet. For another output, the data causes the component to function according to the selected program. The command for the water pump and fertilizer pump is to flow the water and fertilizer through the water pump to the plant when the plant needs it.

3.6 Experimental Setup

The apparatus of the plant management system, as shown in Figure 3.4 is a setup to conduct experiments to test the functionally of the system. The system consists of:

1. ESP32
2. Analog Capacitive Soil Moisture Sensor
3. DHT22 Temperature and Humidity Sensor
4. Soil Multi-parameter sensor
5. MAX485 to RS-485 Interface Module
6. Micro Submersible Water Pump DC 3V-5V
7. 2 Channels 5V Relay Module

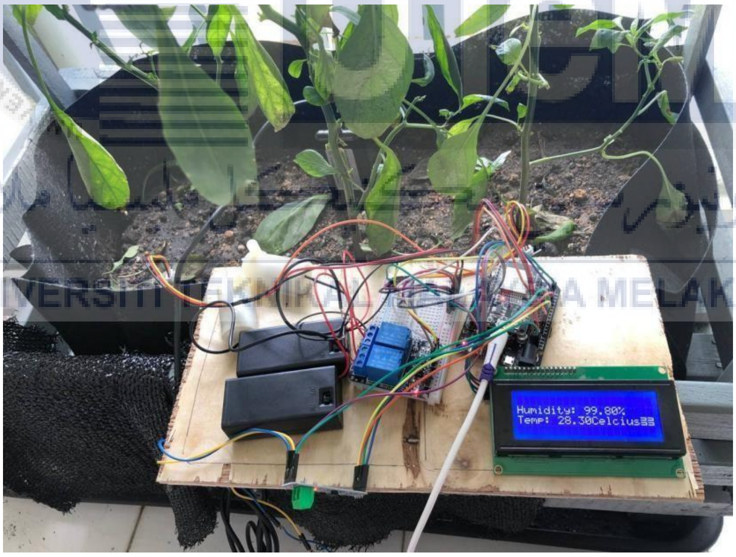

Figure 3.4 Plant Management System Experimental Setup

Figure 3.5 shows parts of the irrigation and fertilizing systems. Each system uses a submersible pump, but for the irrigation system, the pump is active when the soil moisture sensor senses that the soil on the plant is dry. In contrast, for the fertilization system, the pump is active when the pH value on the plant is lower than the neutral value. Both of these systems also use adjustable misting nozzles to coordinate the watering area on the plants.

Figure 3.5 Irrigation and Fertilization System Pump Setup

A capacitive soil moisture sensor is placed on the ground near the chili plants, like in Figure 3.6, so that it reads the moisture value accurately. Similarly, with sensors of various soil parameters, they need to be placed close to the plants so that the pH, nitrogen, phosphorus, and potassium values on the plants can be read according to the proper standards.

Figure 3.6 Soil Moisture and Soil Multi-Parameter Sensor Setup

As shown in Figure 3.7, the sensor for humidity and temperature is placed close to the plant because the sensor detects only the temperature and humidity in its environment. It is quite useful for plants because the temperature required for plants is around 20°C to 29°C and humidity above 50%.

Figure 3.7 Temperature And Humidity Sensor Setup

3.7 Hardware

Hardware components are critical elements that involve the physical components of a project. This includes microcontrollers, sensors, actuators and any other electronic devices that form the backbone of the system. The selection of hardware holds significance as it directly impacts the project's functionality, efficiency, and overall success. It is crucial to prioritize component compatibility and seamless integration, considering factors such as power consumption, communication protocols, and form factors.

3.7.1 ESP 32

This is the main component that is used for this project where it is a versatile microcontroller with integrated Wi-Fi and Bluetooth capabilities that plays an important role in the development of IoT applications for plant management systems. Monitoring and control in the context of the plant management is critical, using this ESP32 as shown in Figure 3.8, can facilitate seamless connectivity between sensors, actuators, and central systems. This ESP32 can also collect real-time data for various sensors such as temperature, humidity, soil moisture, and other metrics related to this plant management system. Furthermore, it also has robust wireless communication enabling it to transmit data to cloud platforms and enable centralized monitoring and analysis such as Thingspeak and Telegram Bot. This microcontroller's compatibility with various IoT protocols and frameworks facilities integration with existing plant management systems, fostering a more interconnected and intelligent approach to plant monitoring and control.

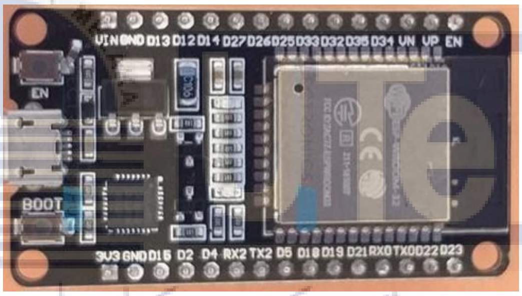

Figure 3.8 ESP 32

3.7.2 Analog Capacitive Soil Moisture Sensor

The Capacitive Soil Moisture Sensor Module as shown in Figure 3.9 measures variations in capacitance to assess soil moisture content. This is used in an automatic plant watering system or to signal some kind of warning when a plant needs to be watered. Soil moisture is measured using a variety of methods, including gravimetric, electromagnetic, hygrometric, and many more that employ a capacitive method that takes advantage of the dielectric properties of water in the soil. This sensor also has an onboard voltage regulator, giving it a working voltage range of 3.3 to 5.5 V, making it compatible with low-voltage MCUs.

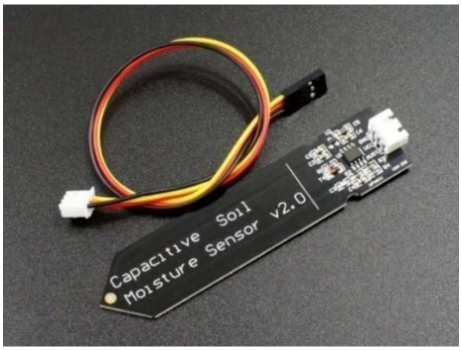

Figure 3.9 Analog Capacitive Soil Moisture Sensor

3.7.3 DHT 22 Temperature and Humidity Sensor

Figure 3.10 shows a calibrated digital signal from the DHT22 Temperature and Humidity Sensor. It is a basic sensor containing temperature and humidity sensors that is modest in size but has a long transmission distance of around 20 meters. This sensor measures the ambient temperature and air with a capacitive humidity sensor and a thermistor, then outputs a digital signal on the data port with no analogue pins required. This sensor is used in this project to measure the ambient humidity and temperature to ensure that the plant is kept at the proper temperature and humidity.

Figure 3.10 DHT22 Temperature and Humidity Sensor

3.7.4 Soil Multi-Parameter Sensor

Figure 3.11 shows a soil multi-parameter sensor that can detect up to seven parameters in one sensor. However, for this experiment, this sensor is only employed to measure soil NPK and pH. This sensor can detect the levels of nitrogen, phosphorous, potassium, and pH in the soil. It aids in determining the fertility of the soil, allowing for an in-depth analysis of the soil's state. The sensor can be buried in the soil for an extended period of time. It has a high-quality probe with rust resistance, electrolytic resistance, and salt & alkali corrosion resistance to assure the probe part's long-term functioning. As a result, it can be used in every soil type. A chemical reagent is not required in the sensor. Because of its excellent measurement accuracy, quick reaction time, and interchangeability, it may be used with any microcontroller. The sensor cannot be utilized directly with the microcontroller because it has a Modbus Communication interface. As a result, a Modbus Module, such as an RS485/MAX485 module, is required to connect the sensor to the microcontroller. The sensor is powered by 9-24V and uses relatively little power. When it comes to precision, the sensor is accurate to within 2%. The resolution of nitrogen, phosphorus, potassium, and pH measurements is up to 1 mg/kg (mg/l).

Figure 3.11 Soil Multi-Parameter Sensor

3.7.5 MAX485 to RS-485 Interface Module

The MAX485 TTL to RS485 Converter Module shown in Figure 3.12 transforms a TTL signal to an RS485 signal for long-distance, high-data-rate error-prone differential communication and uses differential signaling for noise immunity. In a linear, multi-drop design, multiple receivers can be linked to such a network. These features make such networks effective in industrial settings and other comparable applications.

This converter allows sending and receiving data from Arduino/microcontroller via the RS485 network. The RS485 interface, like the Serial TTL and RS232 interfaces, allows to transporting data between microcontrollers and devices, but with additional functionality, RS485 is an industry-standard data transport protocol that offers various benefits.

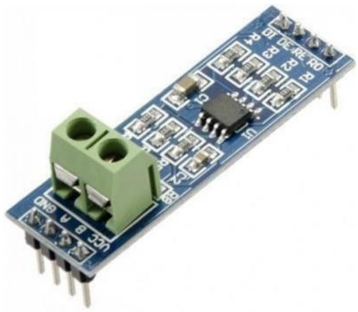

Figure 3.12 MAX485 to RS-485 Interface Module

3.7.6 2 Channels 5V Relay Module

From figure 3.13, this 2-channel 5V relay module is an electronic component used for controlling high-voltage devices or circuits with a low-voltage microcontroller or digital signal. In this context, automation and control are important in the development of IoT applications for plant management systems where this relay module serves as an important interface between digital signals from IoT devices, such as microcontrollers or sensor nodes, and physical devices in the plant. It also allows remote control of electrical devices such as pumps used for watering and fertilizing plants for automation processes based on real-time data collected from sensors. The integration of a 5V 2-channel relay module in an IoT setup for plant management system not only improves operational efficiency but also contributes to resource optimization by enabling data-driven intelligent control over critical components in the plant environment.

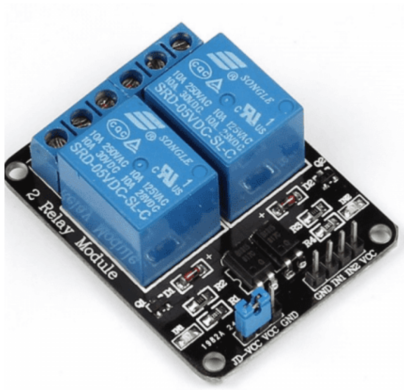

Figure 3.13 2 Channels 5V Relay Module

3.7.7 Micro Submersible Water Pump DC 3V-5V

The function of the watering and fertilizing pump system as shown in Figure 3.14, monitors the soil environment when the system requires it. The computer system monitors the system and links it with the water supply. The watering and monitoring plan is based on the current weather conditions, which are rainy, hot, and humid. The motor pump operates from 3V to 12V. The watering motor pump's capacity and capability are 8 hours each day. The electrical system controls the operation. The water pump uses a water suction method to drain and release water through its inlet and outlet.

Figure 3.14 Micro Submersible Water Pump DC 3V-5V

3.8 Software

The software used typically involves various essential tools and applications for project development, analysis, and implementation. In the context of this project, the software includes ThingSpeak and Telegram bot. Additionally, specialized software related to the project's domain, such as data analysis tools, simulation software, or design applications, can also be used. The selection of software is critical as it directly influences the success and efficiency of the project. A well-chosen set of tools enhances productivity, streamlines development, and facilitates the achievement of project objectives.

3.8.1 Arduino IDE

By referring Figure 3.15 below, Arduino IDE (Integrated Development Environment) is an open-source software tool used for programming and uploading code to Arduino microcontroller boards. It provides a user-friendly interface for writing, editing, and compiling code that runs on Arduino hardware. Arduino IDE supports the Arduino programming language based on a simplified version of C and C++. It is compatible with a wide range of Arduino boards, including the popular Arduino Uno, Arduino Nano, Arduino Mega, and more.

Figure 3.15 Arduino IDE

3.8.2 Proteus 8 Software

Without needing to begin assembling the physical components, Proteus software as shown in the Figure 3.16, is a simulator that makes it easier to see the actual or anticipated effects of a project. Any errors that occur with the circuit connection will be displayed by Proteus. Using this software can save time, energy, and money by not starting to connect the hardware.

Figure 3.16 Proteus 8 Software

3.8.3 ThingSpeak IoT

Thingspeak is an Internet of Things (IoT) platform, as shown in Figure 3.17, that empowers individuals and organizations to effortlessly collect, analyze, and visualize data from sensors or devices in real-time. Developed by Mathworks, Thingspeak provides a user-friendly interface to create IoT applications and enables the seamless integration of diverse sensors and actuators. With its cloud-based architecture, users can easily store and retrieve data, as well as implement data processing algorithms. In Figure 3.18, the graph represents real-time data recorded for soil moisture sensors. From this data, analysis can be derived regarding the moisture levels of the soil and can indicate the times when the plants are watered. For Figure 3.19, it shows the data from the Thingspeak apps in the mobile phone.

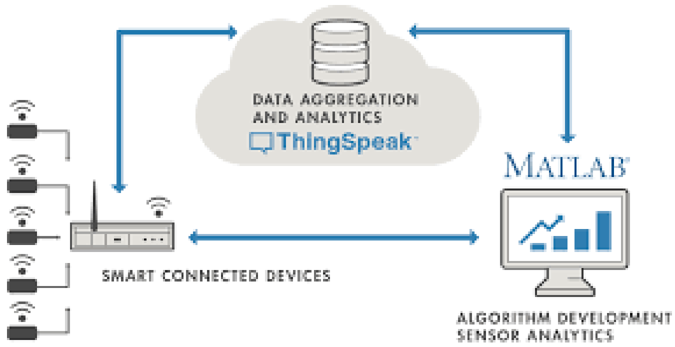

Figure 3.17 Thingspeak Framework

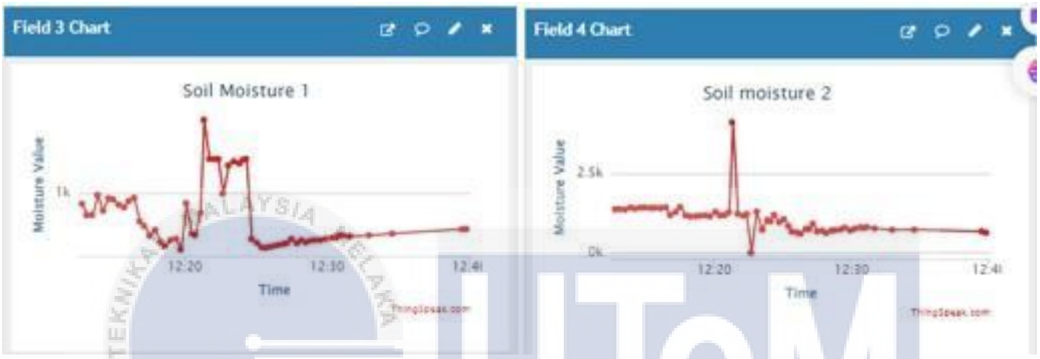

Figure 3.18 PC Base Graph Data From ThingSpeak

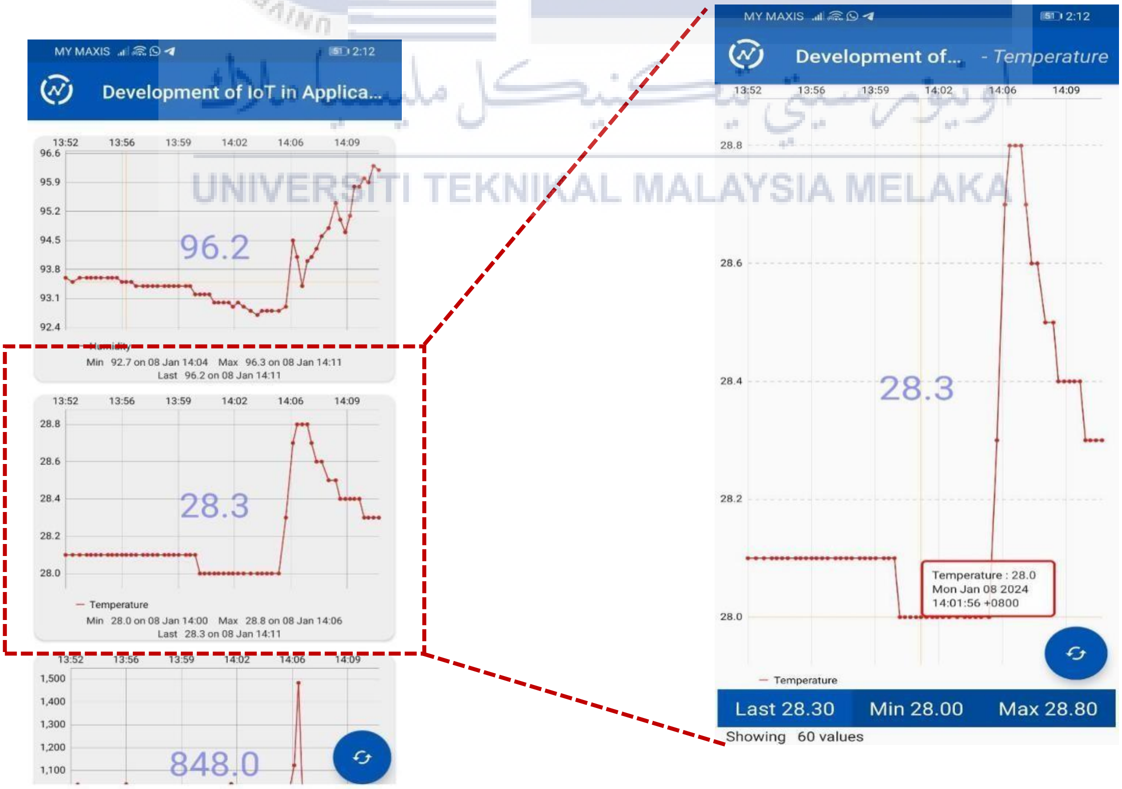

Figure 3.19 Thingspeak Apps From Mobile Phone

3.8.4 Telegram Bot Platform

The Telegram Bot Platform, as shown in the Figure 3.20, is a versatile and powerful tool that enables the creation of interactive and automated bots within the Telegram messaging application. Developed by Telegram, this platform provides a user-friendly environment for bot development, allowing individuals and businesses to enhance their communication and engagement with Telegram users. With a comprehensive set of APIs and features, the Telegram Bot Platform facilitates the creation of intelligent and dynamic bots capable of responding to user queries, delivering customized content, and even executing specific commands. The platform’s robustness is further exemplified by its support for multimedia content, inline queries, and real-time updates. Whether used for information dissemination, customer support, or entertainment, the Telegram Bot Platform offers a seamless and efficient means to integrate automated services into the Telegram ecosystem, contributing to a richer and more interactive user experience.

Figure 3.20 Telegram Bot Platform

3.9 Sensors Calibration

Calibration involves adjusting and setting up a sensor's output to align with the genuine or accurate values of the measured quantity. Sensors, which identify physical attributes like temperature, pressure, humidity, light, or other environmental conditions, may demonstrate deviations or inaccuracies in their readings, either due to the passage of time or manufacturing tolerances. The process of calibration is employed to rectify these variations, ensuring precision and dependability in measurements.

3.9.1 Capacitive Soil Moisture Sensor Calibration

Because of the sensor's precision, the Capacitive Soil Moisture Sensor needs to be calibrated. When the sensor is in dry soil, it needs to be compared to the sensor’s analog reading, and when the sensor is in moist soil, it needs to be compared to the sensor’s analog reading. Then, it can also determine the maximum and minimum analog values that can be transferred to percentage values between 0 to 100% according to the software. The wiring and coding for the capacitive soil moisture sensor can be referred in the Figure 3.21.

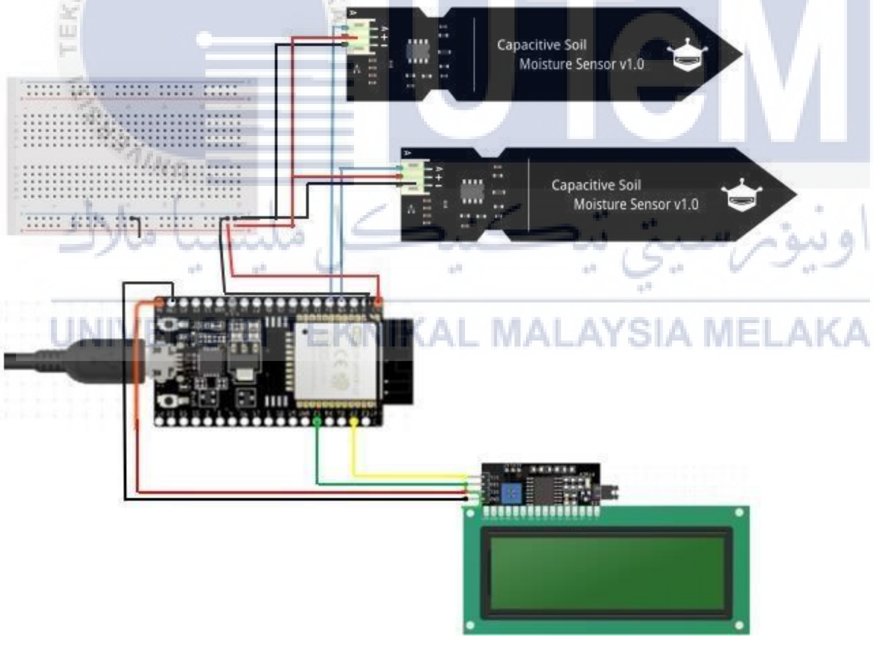

Figure 3.21 Soil Moisture sensor connection with ESP32

Referring to Figure 3.22, it shows that the value of the capacitive moisture sensor, when the value is above 2000, indicates that the soil moisture is in a moist condition. If the value decrease and falls below 2000, the condition of soil moisture is dry. and it needs to be watered. The coding for this soil moisture circuit can be referred to in Figure 3.23.

```
WiFi connected
The soil moisture is DRY => activate pump (2559),(2961)
Humidity: 94.10%  Temperature: 29.20°C
Channel update successful.
The soil moisture is DRY => activate pump (2908),(2682)

Channel update successful.
The soil moisture is WET=> deactivate the pump (1691),(1670)
Humidity: 91.30%  Temperature: 29.70°C
```

Figure 3.22 Result of Soil Moisture in serial monitor

```
int value = analogRead(35);  // read the analog value from soil moisture sensor
int value2 = analogRead(34);

if (value, value2 >= 2000) {
  Serial.print("The soil moisture is DRY => activate pump");
  digitalWrite(25, HIGH);
} else if (value, value2 <= 2000) {
  Serial.print("The soil moisture is WET=> deactivate the pump");
  digitalWrite(25, LOW);
}
Serial.print(" (");
Serial.print(value);
Serial.print("),(");
Serial.print(value2);
Serial.println(")");
delay(1000);
```

Figure 3.23 Soil Moisture Sensor code

3.9.2 Temperature and Humidity Sensor Calibration

A well-liked sensor that senses both temperature and humidity is the DHT22. It is used in conjunction with the ESP32, a powerful microcontroller that has Bluetooth and Wi-Fi built in, to develop a range of Internet of Things (IoT) projects that include tracking and reporting temperature and humidity data. This sensor is very straightforward where there is no need to be calibrated at all. The DHT22 is also less sensitive to being distorted by electrical noise over greater distances due to its digital nature. Figure 3.24 shows the connection of temperature and humidity with ESP32.

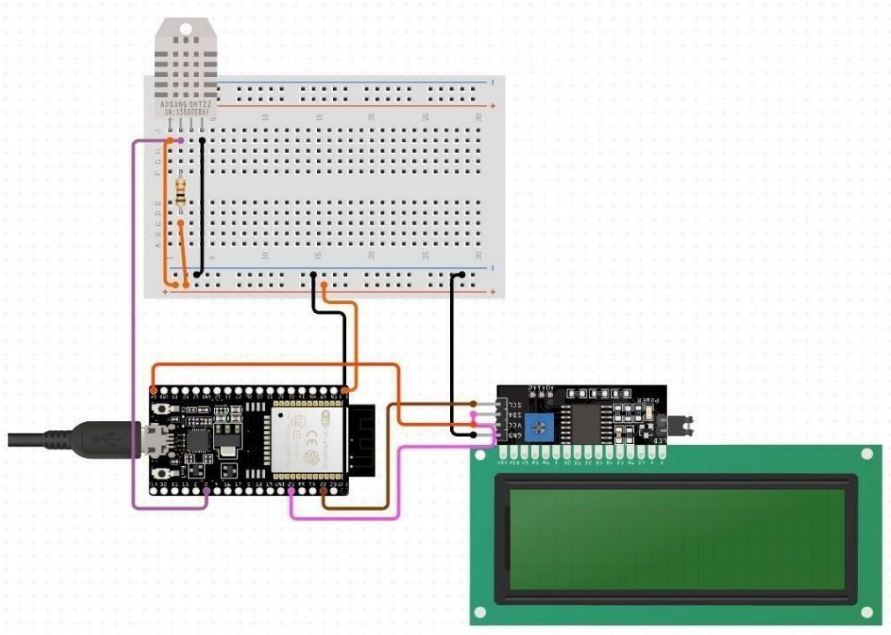

Figure 3.24 DHT22 sensor connection with ESP32

The coding for this calibration is shown in Figure 3.25. This code appears as part of a program that reads data from a DHT sensor to measure humidity (h) and temperature (t). The code utilizes the ‘isnan’ function to verify whether the humidity or temperature readings obtained from the DHT sensor are Nan (Not a Number), which can create a situation where the sensor fails to produce valid data. If either value is NaN, the program prints an error message to the serial monitor and displays a corresponding message on an LCD screen, indicating a failure in reading from the DHT sensor. In the state where the sensor produces valid data, the program proceeds to print the humidity and temperature values to the serial monitor and furnish details on the prevailing environmental conditions. This conditional check serves the purpose of managing scenarios where the sensor might malfunction or provide unreliable data, ensuring that the program refrains from utilizing inaccurate sensor readings.

```
float h = dht.readHumidity();
float t = dht.readTemperature();  // Read temperature as Celsius (the default)

// Check if any reads failed and exit early (to try again).
if (isnan(h) || isnan(t)) {
  Serial.println(F("Failed to read from DHT sensor!"));
  lcd.setCursor(0, 0);
  lcd.print("DHT reading failed");
  lcd.clear();
  return;
}

Serial.print(F("Humidity: "));
Serial.print(h);
Serial.print(F("%  Temperature: "));
Serial.print(t);
Serial.println(F("°C "));
```

Figure 3.25 Humidity and Temperature code

After running the code, the output appears in the serial monitor as Figure 3.26 shows. The result of this sensor is based on the current situation, with the humidity around 94% and the temperature ranging from 29°C to 30°C.

```
WiFi connected
Humidity: 94.10%  Temperature: 29.20°C
Channel update successful.
Humidity: 91.30%  Temperature: 29.70°C
```

Figure 3.26 Result of humidity and temperature in serial monitor

3.9.3 Soil Multi-Parameter Sensor Calibration

The Soil Multi-Parameter Sensor is different from other sensors in that it can be connected directly to a microcontroller. Modbus is the unique communication protocol used by this sensor. A Modbus device can be programmed to change the value of one of its registers, and that change will subsequently be written to the coil and holding registers. Additionally, it has the ability to read an input and output port, such as reading data from Discrete and Coil ports, and providing the device instructions on what values to broadcast back from its Holding and Coil registers. A Modbus command contains the Modbus address of the device for which it is intended (1 to 247). A Modbus address is also known as an inquiry frame. Even if others devices get the command, only the designated device will respond and act on it.

One can compute the pH and NPK value based on the response that is provided. The pH and NPK values are in the 4th bit (beginning with the 0th bit). For illustration, the pH value is 0047H in hexadecimal, however when converted to decimal, the number becomes 72, and the pH value is 7.1pH. Likewise, for the remaining three parameters:

0047 H(hexadecimal) = 71 Decimal => pH = 7.1pH

0020 H(hexadecimal) = 32 (Decimal) => Nitrogen = 32mg/kg

0025 H(hexadecimal) = 37 (Decimal) => Phosphorous = 37mg/kg

0030 H(hexadecimal) = 48 (Decimal) => Potassium = 48mg/kg

The connection of this Soil Multi-Parameter Sensor with ESP32 is as shown in Figure 3.27 below where this sensor also needs to connect with the RS-485 Interface Module because it is essential for efficient data communication and integration into a broader monitoring system.

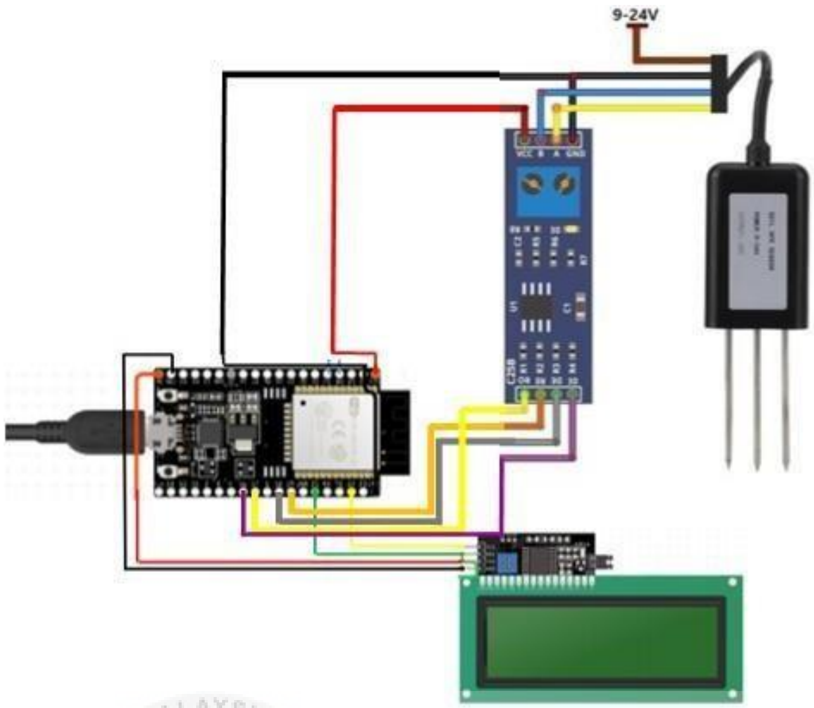

Figure 3.27 Soil Multi-Parameter Sensor connection with ESP32

Based on the Figure 3.28, the result of Soil-Multi Parameter which is pH, nitrogen, phosphorus, and potassium is shown.

```
Nitrogen: 37 mg/kg
Phosphorous: 255 mg/kg
Potassium: 255 mg/kg
Soil pH: 14.0
```

Figure 3.28 Result of NPK sensor in serial monitor

3.10 Circuit Design

Figure 3.29 represents the circuit design for the entire sensor and system for this project, showing only the installation of the components used. As can be seen, the ESP32 is an essential microcontroller for this system because it collects all the data from the sensors and transfers the data into the cloud.

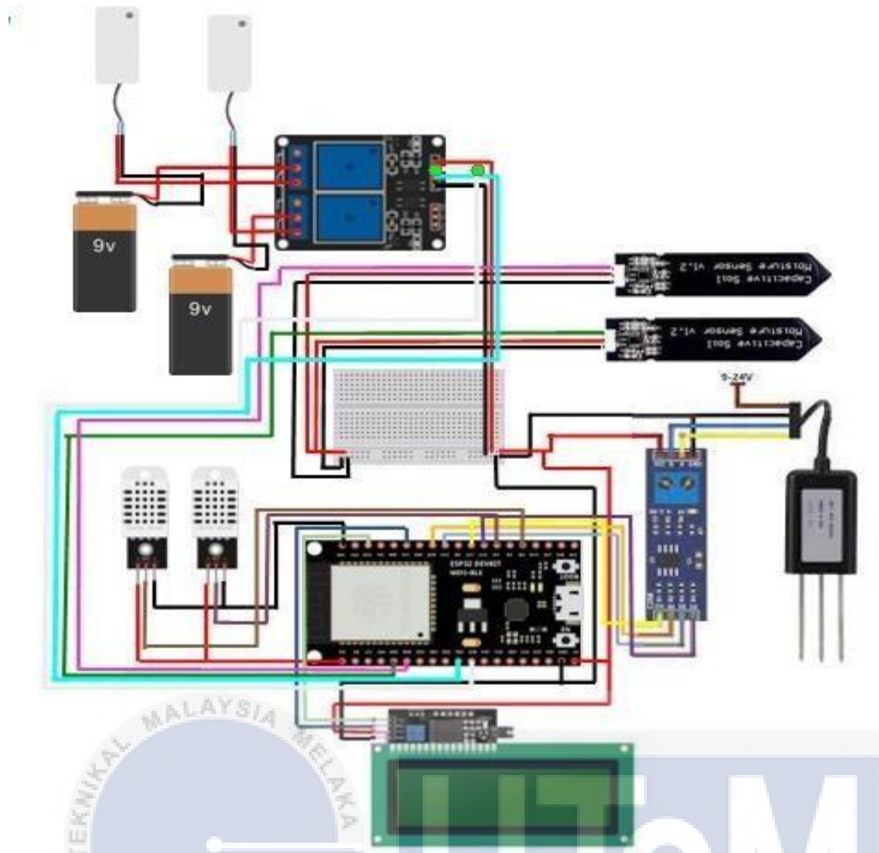

Figure 3.29 Design Circuit Plant Management System

3.11 Summary

In this chapter presents a proposed methodology for creating innovative plant management system approaches. Each component’s procedures and materials are all been specified. The ESP32 is the main device that takes data from the input and sends data to the output according to the block diagram, which also shows the other components and functions for the input and output. The results and performance analysis elaborate in the following chapter.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this section elaborates on the outcomes derived from evaluating the functionality of the planting system. The system has undergone thorough testing, and the achieved results align with the project’s objectives. These outcomes are founded on comprehensive criteria employed to assess soil conditions conducive for healthy plant growth, including nitrogen, phosphorus, potassium, pH, temperature, humidity, and moisture. The results are systematically organized and presented graphically, depicting a cohesive system where simultaneous test for the specified parameters are conducted. The system ensures the generation of real-time data, enabling users to continuously monitor the present values of these parameters through the user interface.

4.2 Hardware Prototype

Figure 4.1 illustrates that this prototype incorporates a variety of sensors to gather data on important parameters like temperature, humidity, and soil moisture. Where these sensors can be deployed in the soil, on plants, or within the plant environment to capture real-time data. The dimension of this initial prototype is 84cm x 37.5cm x 59cm.

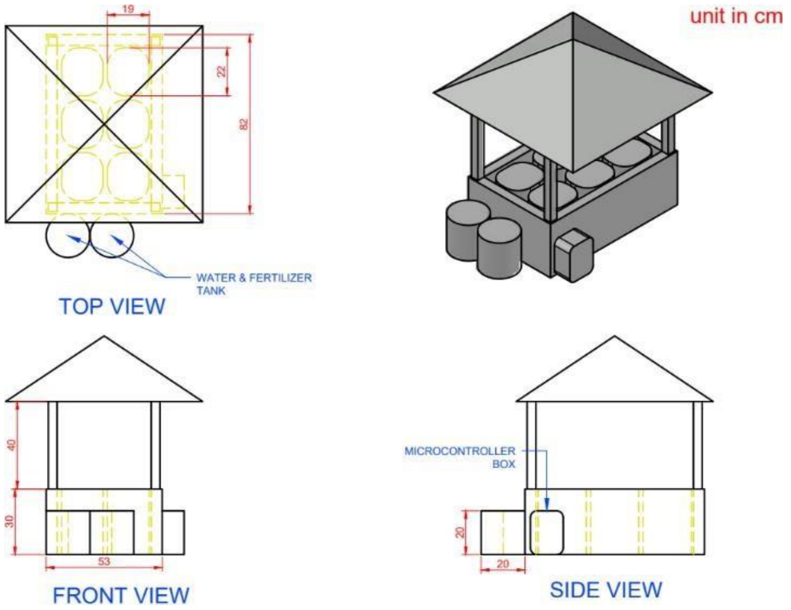

Figure 4.1 Development of IoT in PMS Prototype Design

4.3 Results

In this section, the aim is to conduct observations and analyze the data to achieve the project objectives. The findings presented here elaborate on the potential and development of the plants. Referring to the explanation for the overall observations below, it indicates the data obtained for each sensor.

4.3.1 Humidity (DHT22 Sensor) Results

Figure 4.2 shows the data graph for the humidity recorded in the Thingspeak application where it ranges between 99% and 100%. The humidity level of chili plants plays a major role in their overall health and productivity. Appropriate moisture levels are critical at every stage of growth, affecting processes such as germination, seedling growth, flowering, and fruiting.

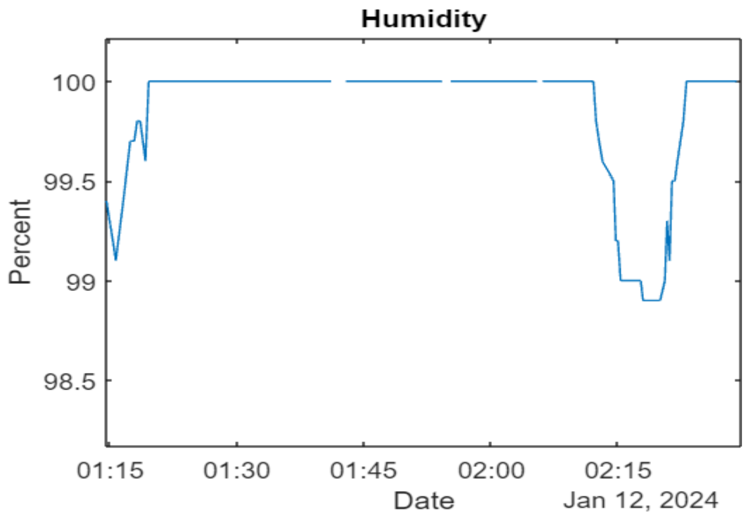

Figure 4.2 Graph for Humidity (DHT22 Sensor) Results

4.3.2 Temperature (DHT22 Sensor) Results

Based on Figure 4.3, The temperature readings obtained from the DHT22 sensor are explained in a graph extracted from Thingspeak. This graph provides a visual representation of the recorded temperature data over a specific period. Analyzing this data offers insights into temperature fluctuations, trends, and patterns observed during the monitoring period. These results contribute to a comprehensive understanding of the environmental conditions affecting the monitored area, which is crucial for assessing the impact on plant growth and well-being. A detailed analysis of the Temperature (DHT22 Sensor) results is presented in the next section.

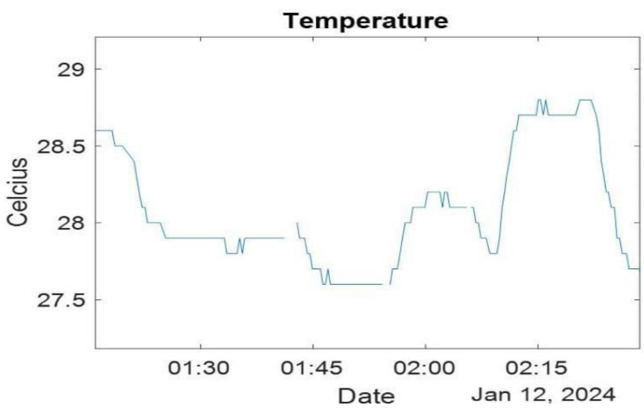

Figure 4.3 Graph for Temperature (DHT22 Sensor) Results

4.3.3 Soil Moisture Sensor Results

Soil moisture is crucial for the optimal growth and development of chili plants. Sufficient soil moisture is critical at various stages of the chili plant's life cycle, from germination to fruiting. Inadequate moisture has a negative impact on germination rates, seedling development, and the overall health of the plant. The results obtained from the soil moisture sensor, as depicted in Figures 4.4 and 4.5, provide valuable insights into the soil moisture levels over a specific period. These graphs also illustrate the fluctuations and trends in soil moisture, offering a visual representation of the conditions experienced by the plants. The outcomes obtained from the soil moisture sensor act as a measurable foundation to evaluate how well the plant management system maintains the ideal soil conditions for the growth of plants.

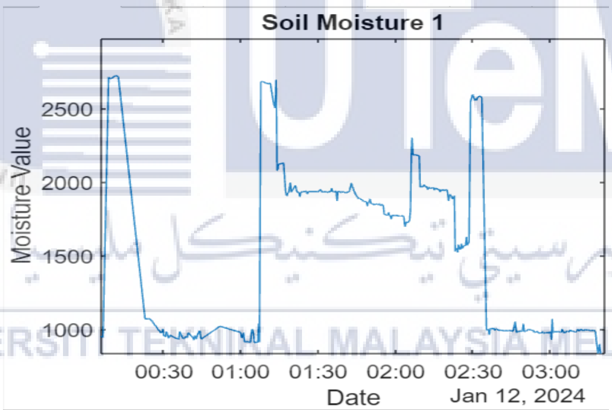

Figure 4.4 Graph for Soil Moisture 1 Result

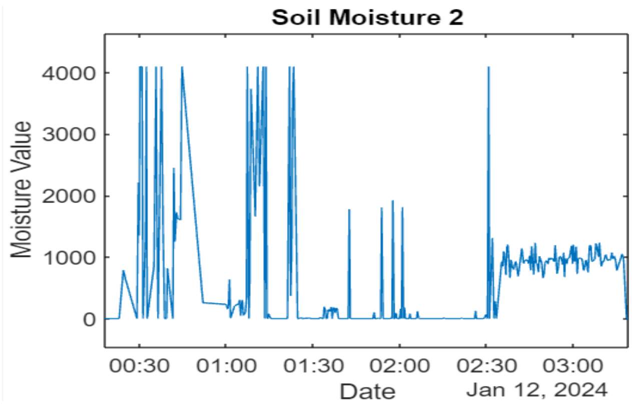

Figure 4.5 Graph for Soil Moisture 2 Result

4.3.4 Nitrogen (Soil-multi Parameter Sensor) Results

The results of the nitrogen levels as determined by the Soil-Multi Parameter Sensor are shown in Figure 4.6. The graph provide insight into changes and patterns in the amount of nitrogen in the soil over the given time frame. By providing a thorough understanding of the nitrogen dynamics, the analysis of these data aims to help in determine the fertility of the soil and how it affects plant growth.

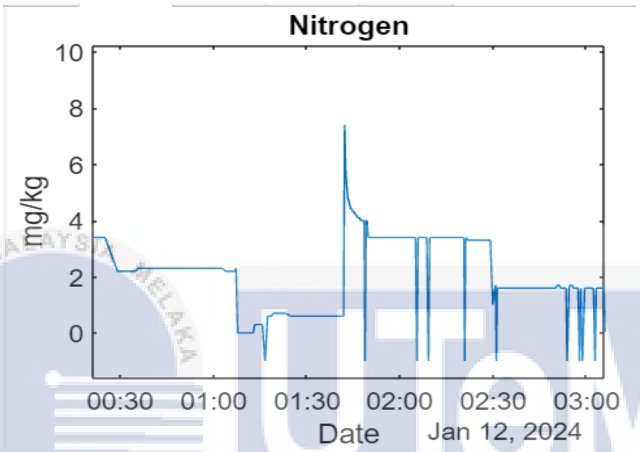

Figure 4.6 Graph for Nitrogen Results

4.3.5 Phosphorus (Soil-multi Parameter Sensor) Results

Figure 4.7 presents the results of phosphorus levels as senses by the Soil Multi-Parameter Sensor and visualized in Thingspeak through a Matlab graph. Changes in phosphorus concentration over a specific time period are depicted in the graph. A thorough examination of the phosphorus data provides crucial information about the soil nutrient status and how it influences plant growth and development.

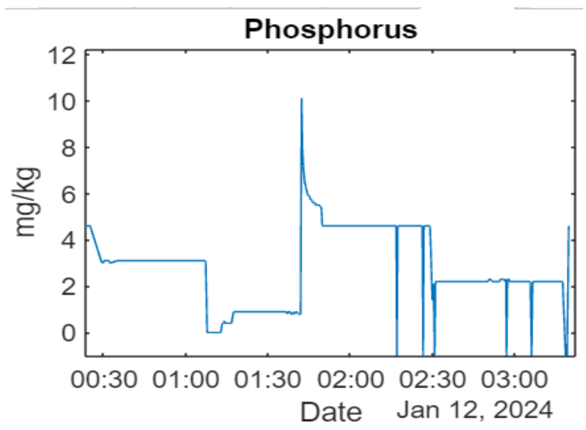

Figure 4.7 Graph for Phosphorus Results

4.3.6 Potassium (Soil-multi Parameter Sensor) Results

Figure 4.9 shows the results for potassium levels obtained from the Soil Parameter Sensor, and the data is visualized through graphs obtained from Thingspeak to Matlab. Analyzing these results provides insight into variations and trends in potassium levels, contributing valuable information to the overall understanding of soil conditions and their impact on plant growth.

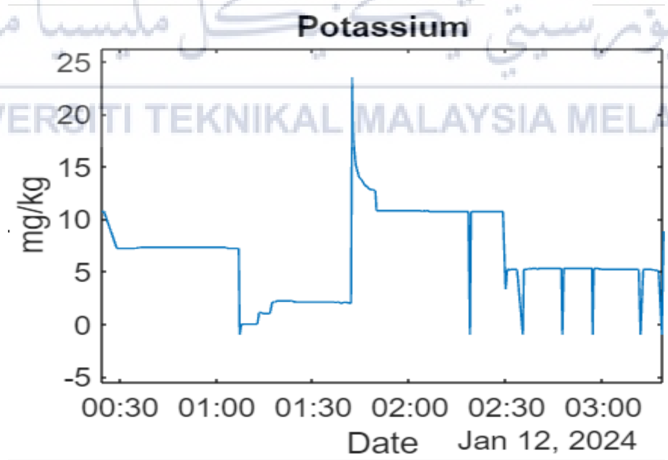

Figure 4.8 Graph for Potassium Result

4.3.7 pH (Soil-multi Parameter Sensor) Results

In this section, the results of pH measurements using the Soil-Multi Parameter Sensor are being presented, as illustrated in the graph. The pH level plays an important role in indicating the acidity or alkalinity of the soil and affects the overall health and availability of nutrients for plants. Graphs visually represent variations in pH values over a period of time by providing insight into soil conditions and their potential impact on plant growth.

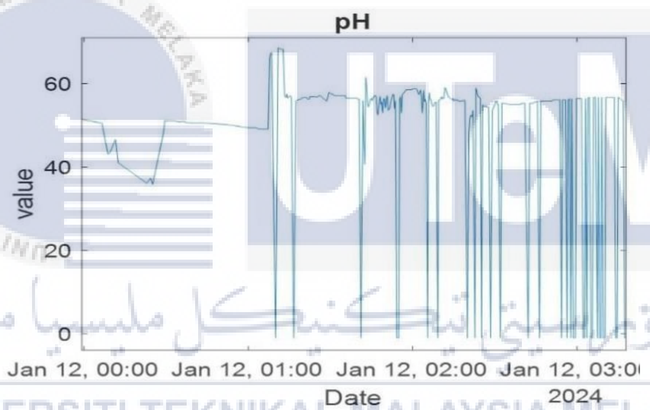

Figure 4.9 Graph for pH Result

4.4 Analysis

In this section elaborate on the analysis that can be conducted based on all the findings obtained from the sensors used in the development of this plant management system. Each collected data is real-time in nature and is visualized in graphs. The visualization of these graphs can tracks patterns of change and relationships between factors at each stage of plant growth. Through this, an understanding of the plant's conditions can be derived, enabling the formulation of plans for appropriate actions to enhance the effectiveness of this plant management system

4.4.1 Humidity Analysis

The humidity of the chili plant is very important to pay attention to because if the humidity of the plant is too high or too low, it causes the chili plant to be in trouble. The optimum humidity for chili plants that grow vegetatively is in the range of 50% to 70%. Meanwhile, chili plants that have flowered and fruited need humidity in the range of 40% to 60%. So, on the data graph that is focused in Figure 4.10, the percentage value decreases from 100% to 99%. Although the percentage value decreases, it is still in a state of high humidity due to weather factors at that time.

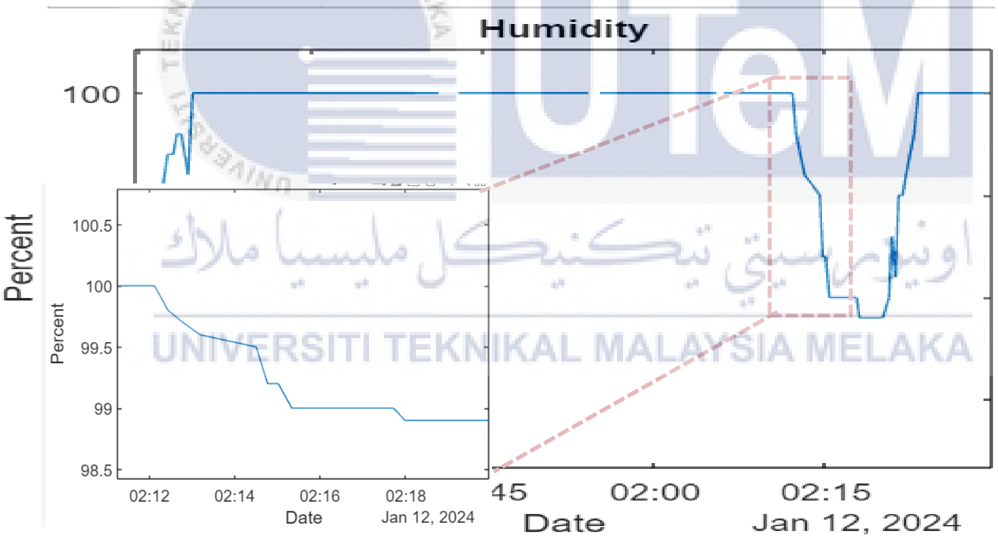

Figure 4.10 Graph data for humidity

4.4.2 Temperature Analysis

Usually, the temperature for chili plants to flourish is at a warm temperature, and the optimum temperature range for this chili plant is 21°C to 32°C for its growth and development. To promote the growth of many leaves and strong stems, chili plants need a temperature in the range of 21°C to 27°C. And for chili plants that flower and bear fruit, they need a temperature range of 24°C to 29°C. Thus, although chili plants can tolerate slightly cooler or warmer temperatures for short periods of time, extreme increases and decreases in temperature should also be avoided. Exposure to temperatures below 10°C or above 35°C can have a negative effect on the growth of chili plants as well as the growth of flowers and fruits. Figure 4.11 shows the analysis that has been recorded at the same time, where the temperature level of chili plants at that time is the optimal level, which is in the range of 27.8°C to 28.4%. And the focused graph data shows better temperature conditions in the recorded temperature range.

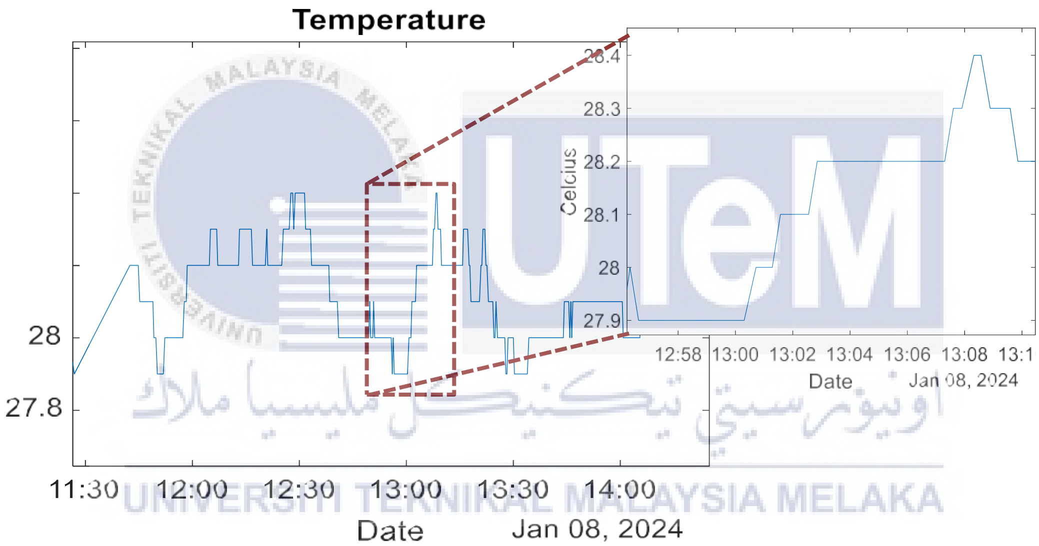

Figure 4.11 Graph data for temperature

4.4.3 Moisture Analysis

Watering the chili plant is very important if know the moisture level of the soil well, so as not to water the plant too much and not leave the plant with an excessively dry condition. As shown through the data graph in Figure 4.12, the value that is focused on is the soil moisture value that increases from 1000 to 2500 where it means that the soil moisture increases due to slightly dry soil. While Figure 4.13 shows the soil moisture value for the other sensor where it shows on the focused data graph that the soil moisture value is decreasing to below 2000, meaning that the soil moisture condition at that time is not wet or being watered.

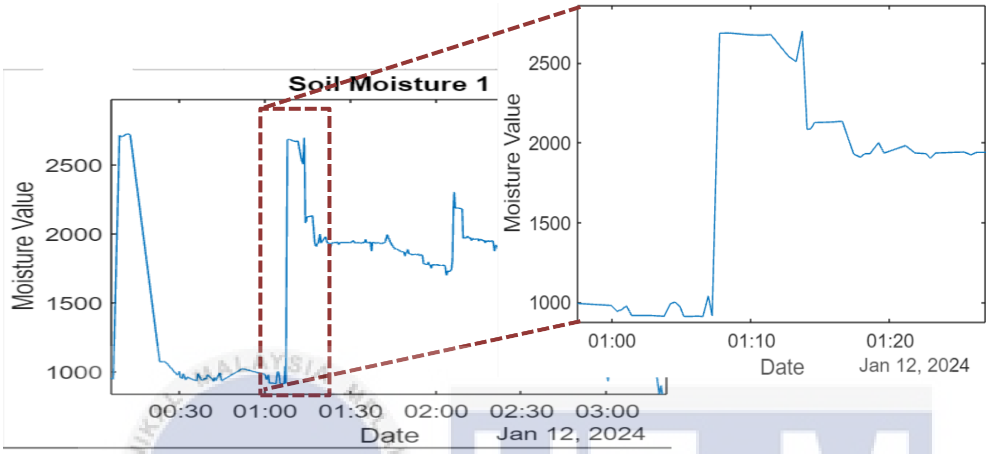

Figure 4.12 Graph data for Soil Moisture 1

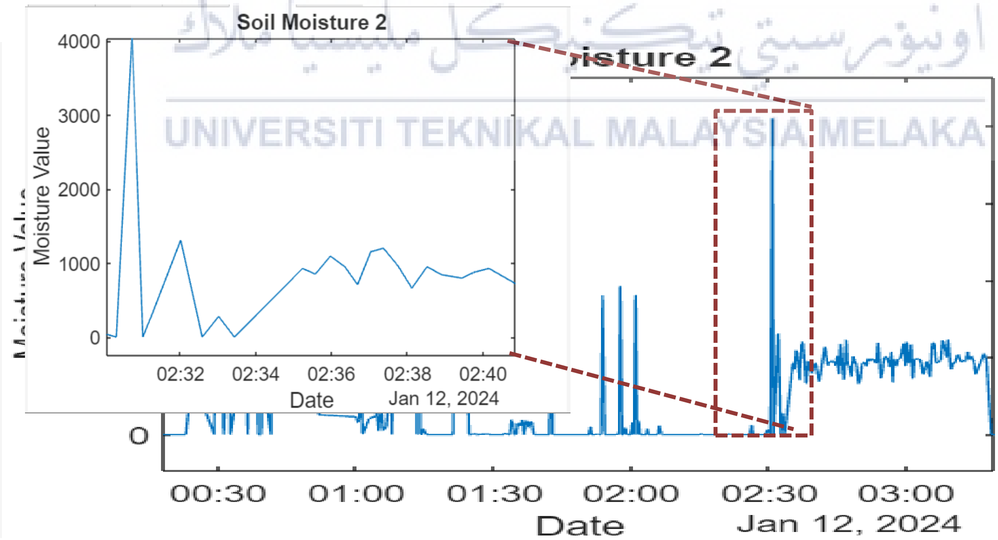

Figure 4.13 Graph data for Soil Moisture 2

4.4.4 Nitrogen Analysis

Nitrogen is an important nutrient for plant vegetative growth, and the optimum value of nitrogen for chili plants is measured in milligrams per kilogram (mg/kg) of soil. To achieve a significant amount of leaf growth on chili plants, maintain the nitrogen level at 30 to 60 mg/kg. The data graph in Figure 4.14 focuses on the rate of nitrogen values that decrease from 8 to 0 mg/kg. However, the optimum level of nitrogen should be reached at least 30 mg/kg. So, this chili plant needs to be fertilized in the appropriate quantity.

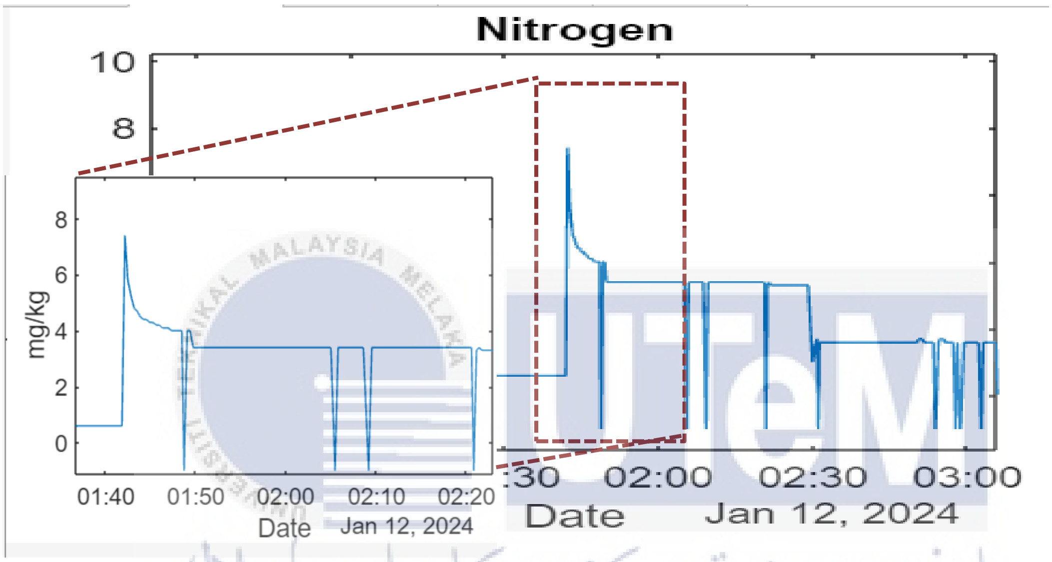

Figure 4.14 Graph data for Nitrogen

Phosphorus Analysis

Phosphorus is also important for healthy plant root growth and good fruit development. The optimum value for phosphorus is usually in the range of 15 to 30 mg/kg soil. Figure 4.15 shows the phosphorus values that are recorded from the Thingspeak application. The data graph focuses on the very low level of phosphorus where the condition of chili plants at that time was not well fertilized. This can cause the root growth of chili plants to be disturbed and unhealthy.

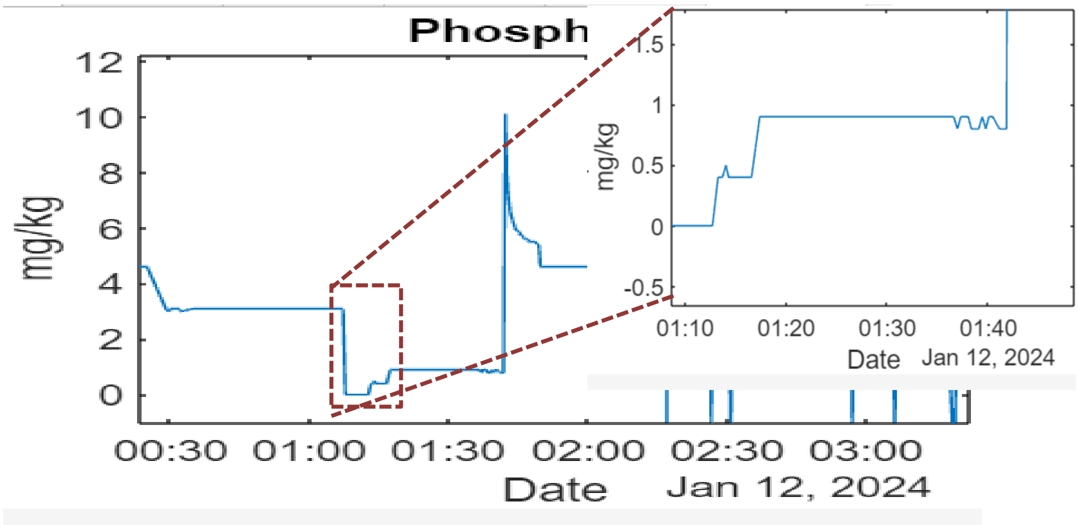

Figure 4.15 Graph data for Phosphorus

4.4.5 Potassium Analysis

Potassium helps in plant resistance to disease, fruit formation, and osmotic pressure regulation. The optimum value for potassium ranges from 15 to 20 mg/kg of soil. The data graph in Figure 4.16 shows that the potassium level is decreasing; as in the focused data, potassium levels are decrease from 25 mg/kg to around 15 mg/kg. However, at this rate, the potassium value in chili plants is in optimal condition because it is not too low (15 mg/kg) and can still produce some chili fruit. But in Figure 4.17 shows that the condition for the potassium value in chili plants is very reduced which is below 10 mg/kg. Therefore, it is not conducive to the growth of chili plants in this situation.

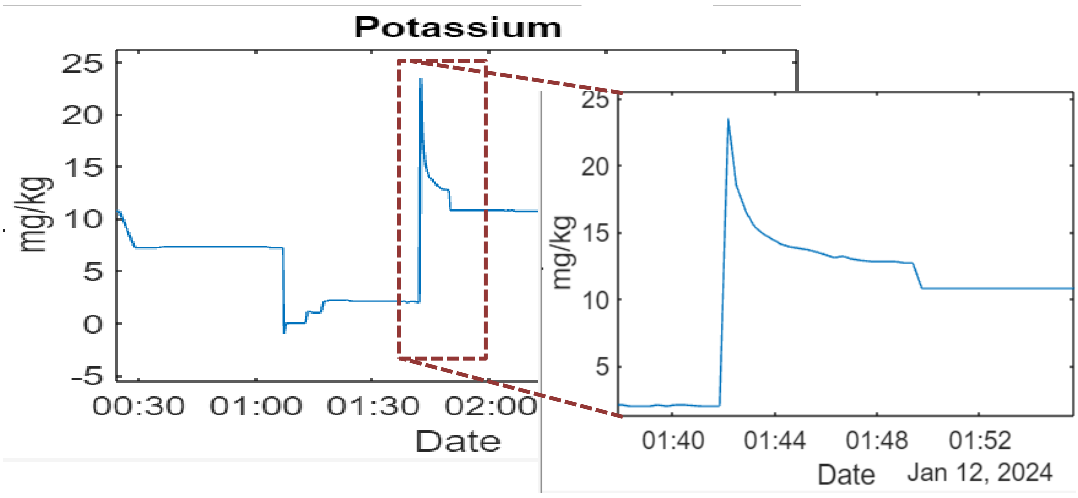

Figure 4.16 Graph data for Potassium

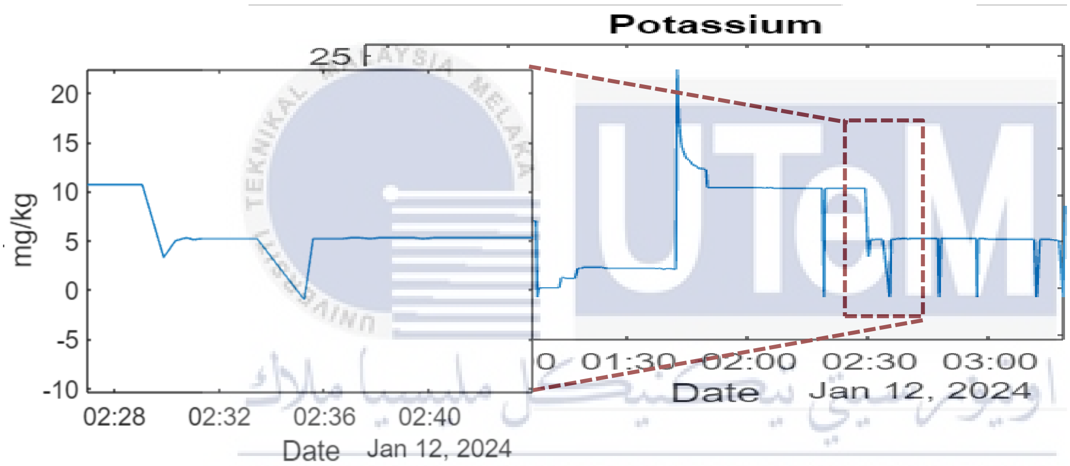

Figure 4.17 Graph Data for Potassium (Low mg/kg)

4.4.6 pH Analysis

When it comes to pH, soil that is slightly acidic to neutral is more suitable for most chili plants. This is because the lower the pH value makes it difficult for the plant to receive nutrients. The ideal soil pH value for chili is between 60 to 70. The focused graph data in Figure 4.19 shows a relatively high pH level, reaching 50 pH. In fact, the pH level of chili plants at that time is still low, indicating acidic soil. Chili plants exposed to soil that is too acidic or too alkaline may have trouble reaching full maturity. Flowers and fruits can also be affected, resulting in less than satisfactory results.

Meanwhile, in Figure 4.19, there is an increase in the pH values from 5.0 pH to reaching 7.0 pH. This indicates that the chili plants have achieved an optimum pH level.

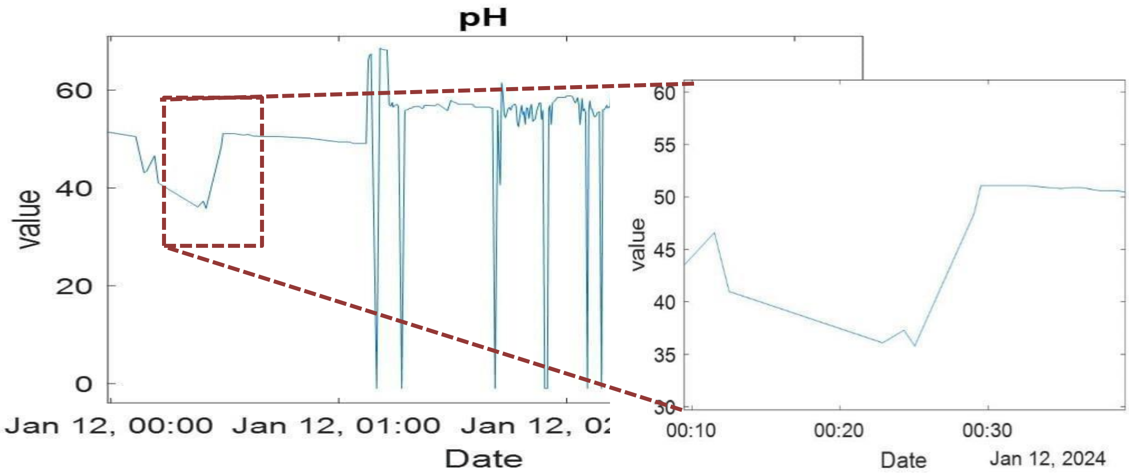

Figure 4.18 Graph data for pH value

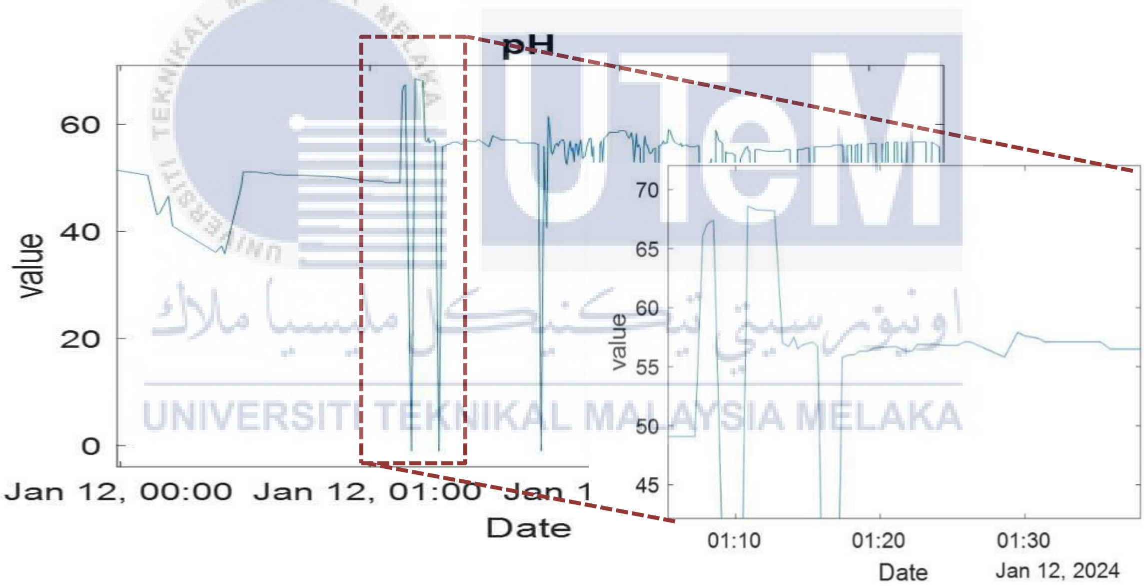

Figure 4.19 Graph Data for pH (Optimal Value)

4.1 Telegram Bot

Every individual surely has the Telegram application on their smartphones. Therefore, this Telegram Bot is created to facilitate users in monitoring and controlling the care of their plants at home. As shown in Figure 4.20, it is a screen display of the plant management system bot where when the user enters the command '/start,' the bot sends the command '/control,' and the user needs to choose what action they want to take.

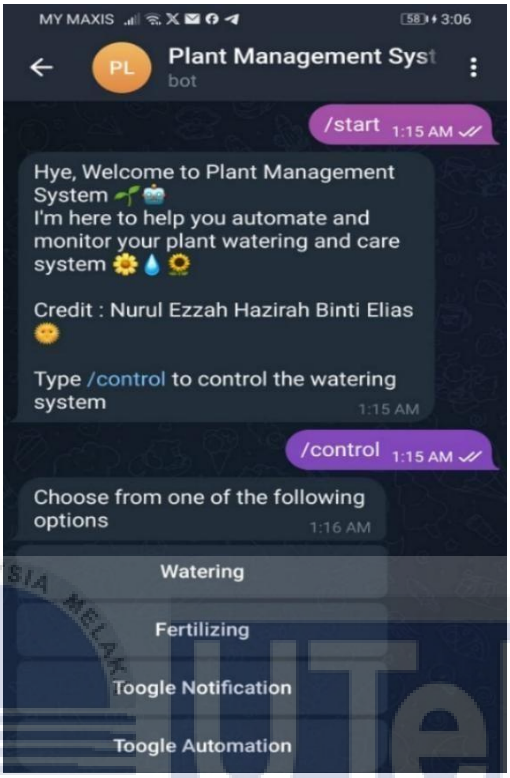

Figure 4.20 Bot Message for Start and Control the System

In Figure 4.21, the bot sends messages every 5 seconds to provide updates on the plant when the toggle notification is activated. Meanwhile, if the toggle notification is selected again, it stops sending messages about the plant updates.

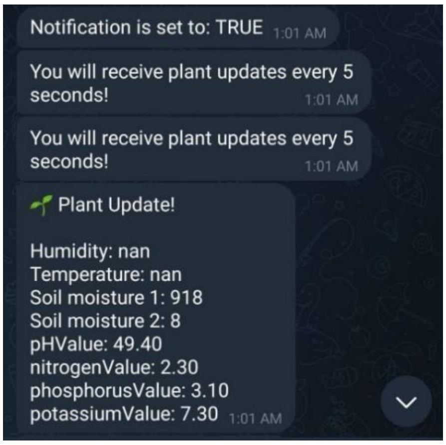

Figure 4.21 Notification Plant Update

If the user wants to control the system automatically, they need to turn on the automation toggle, and it sends all messages automatically until the user turns off the automatic toggle again, as shown in Figure 4.22. When the automation toggle is turned off, the bot sends messages to prompt the user to fertilize and water if the sensors detect that the soil requires watering and fertilizing.

Figure 4.22 Set The System To Control Automatically Or Manually

4.2 Quantitative Survey

In this section, the results of several surveys from 43 respondents are being presented. The surveys were conducted online through the Google Forms Platform. Based on Figure 4.23, the results show respondents from several different age backgrounds. Where 40.5% of the respondents are 21-25 years old and over 35 years old. The rest are respondents aged 26-34% and under 20 years old. Meanwhile, Figure 4.24 shows that 64.3% of the respondents are male and the rest are female. These respondents also come from various work backgrounds, as shown in Figure 4.25.

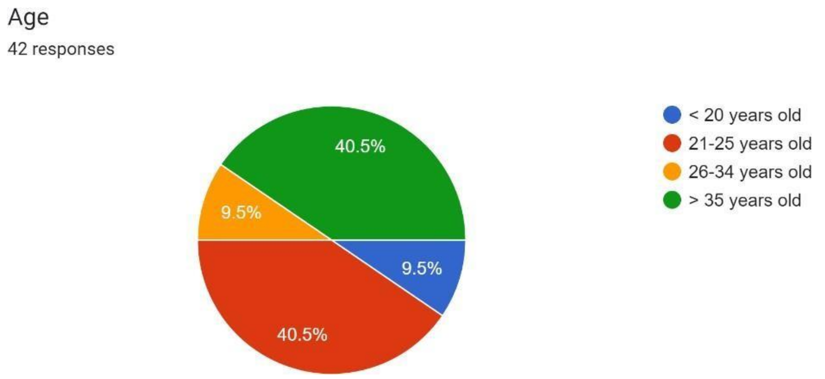

Figure 4.23 Respondent's Age

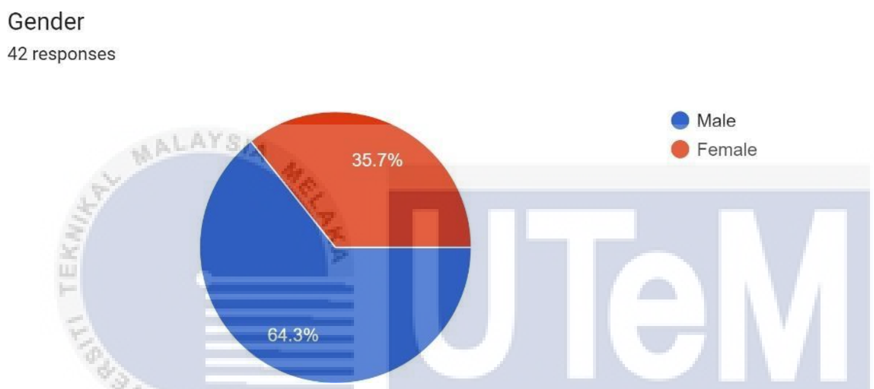

Figure 4.24 Respondent's Gender

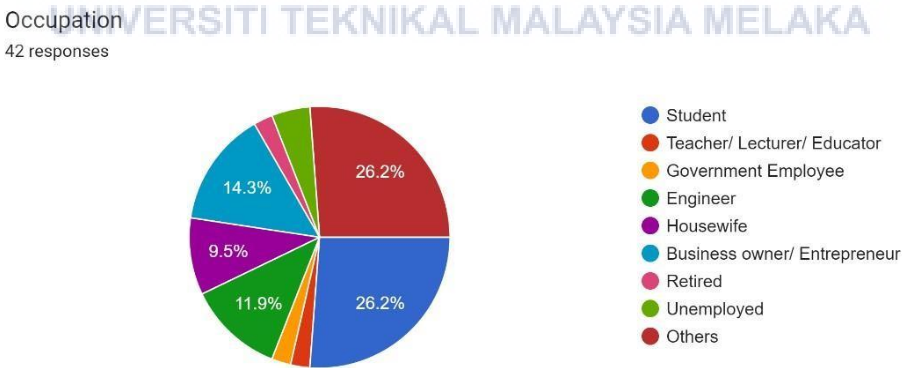

Figure 4.25 Respondent's Occupation

Figure 4.26 shows the survey results for the existence of plants in the respondent's house. 28.6% of respondents have potted plants in their homes and 23.8% have plants growing in their backyard. In fact, the rest do not have any plants in their homes.

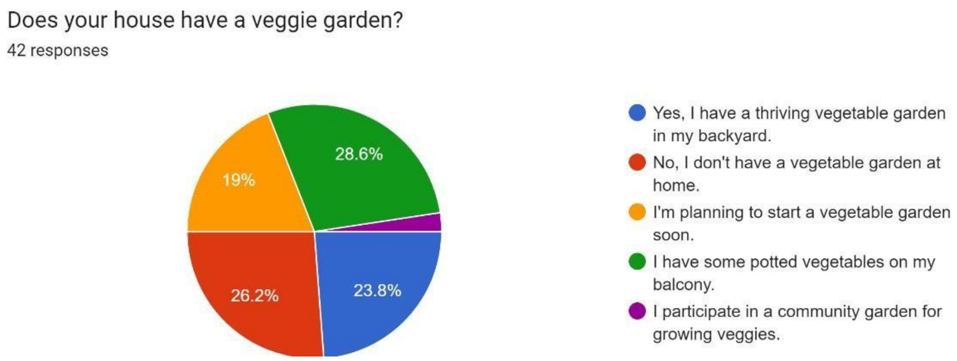

Figure 4.26 The Existence Of Vegetable Plants In The Respondent's Home

Next, the pie chart shown in Figure 4.27 states that 61% of the respondents have difficulties in taking care of their plants because each plant has a different way of care. And 24.4% of respondents think that it is very difficult to maintain the condition of their plants. The rest experienced the same difficulty but these respondents still enjoyed the difficulty to learn and improve how to care for their plants.

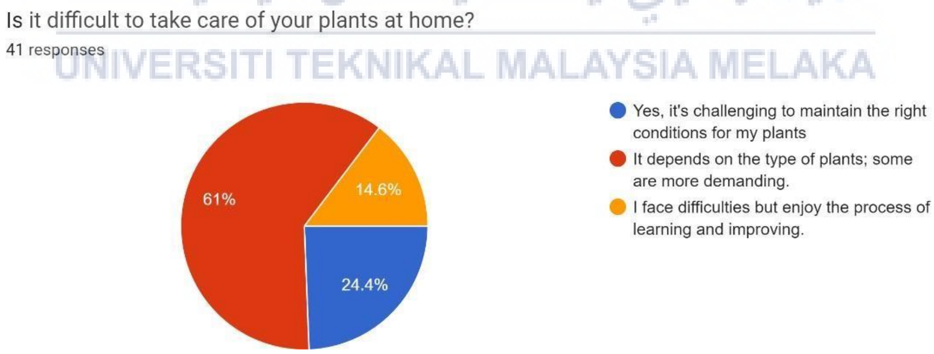

Figure 4.27 The Level Of Difficulty Of Respondents In Taking Care Of Plants.

The frequency that often occurs in plant care at home is frequently forgetting to water and fertilize plants. As shown in Figure 4.28, there are 43.9% of respondents very often forget to water their plants. This may be due to work factors and other things that need to be done so that they forget to pay full attention to their plants.

Figure 4.28 The Frequency Of Respondents Not To Water And Fertilize The Plants

The status of the plant whether it has enough water or fertilization is enough or not is important. But there are some opinions from the respondents also about this status whether it is important or not for them to receive real-time alerts and notifications about the status of their crops as shown in Figure 4.29. There are 48.8% of them who think it is very important to intervene in time so that their plants do not quickly wither and get damaged if they can find out about the status of their plants.

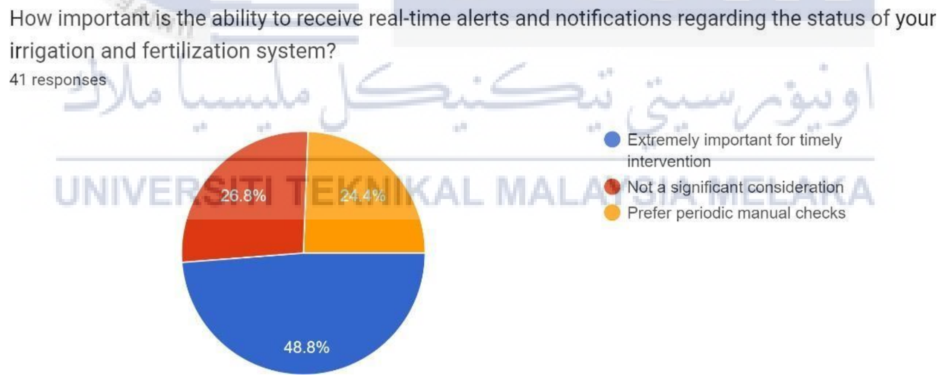

Figure 4.29 The Importance Of Knowing The Status Of The Plant

An automated system is a system that can make it easier for small farmers at home, especially if IoT is placed on the system. So, in Figure 4.30 shows the percentage of respondents who might buy this automatic system for irrigation and fertilization. Where there are 48.8% of the respondents who will buy this automatic system to make it easier for them to monitor and control remotely without worrying about the status of their crops anymore.

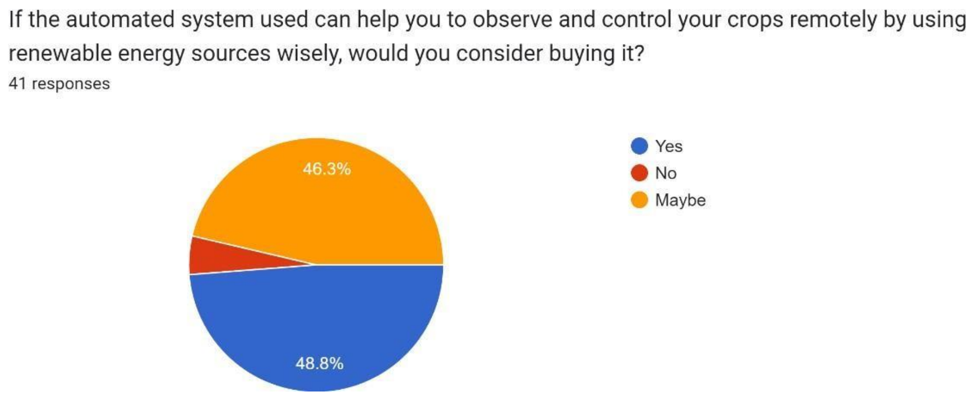

Figure 4.30 Automated System Purchase Considerations

4.3 Conclusion

Overall, the findings from this monitoring session highlight the clarity of the importance of receiving notifications directly through the Telegram application in the context of plant management. Most respondents acknowledge that this approach not only facilitates them in obtaining real-time information quickly but also provides convenience in monitoring and managing their plants without the need to access multiple platforms.

In-depth analysis of user responses indicates that this positive effect can motivate users to be more active and effective in caring for their plants. A system that allows users to receive notifications at the right time can play a crucial role in stimulating appropriate actions, such as watering and fertilizing, to enhance plant health.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this project aims to develop a comprehensive IoT-based plant management system with a focus on fertigation and drip irrigation. The development of IoT in plant management system applications is successfully achieving the outlined objectives. A comprehensive fertigation and irrigation system using drip irrigation is successfully developed, providing an efficient and accurate method of delivering water and nutrients to crops. Therefore, it can promote overall optimal plant growth and these IoT-based systems increase benefits by providing real-time monitoring and control capabilities through sensor integration and connectivity.

Furthermore, the effects of the system on plant growth and health are carefully analyzed and evaluated. The findings show positive results, confirming the effectiveness of the IoT-based plant management system in creating ideal conditions for plant development.

Increased yields result from the system's contribution to improved plant health, demonstrating prospective advantages for farmers and other users. Furthermore, this project also analyzes and evaluates the impact of IoT-based plant management systems on plant growth and health, increased crop yield, and optimizes IoT-based resource allocation.

In summary, the completion of these goals successfully represents a critical turning point in the development of precision agriculture and illustrates how IoT technologies have the ability to transform plant management techniques and improve and sustain agricultural results. This collected data information can help users implement targeted interventions and illustrate how IoT technology can transform plant management techniques and improve and sustain agricultural yields.

5.2 Potential for Commercialization

The development of this IoT-based Plant Management System has significant potential for commercialization due to its ability to address key challenges in agriculture and offer innovative solutions for farmers. The system develops by IoT enables real-time monitoring and control of environmental conditions, irrigation, and fertilization. The farmer's approach to plant management can lead to increased crop yields and optimize resources, thus reducing costs. By providing accurate data on soil moisture, temperature, and other critical factors, this system allows small-scale farmers to optimize their resource usage, reducing water and fertilizer wastage. This efficiency can result in cost savings and more sustainable farming practices.

5.3 Recommendations for Future Work

Based on the stated objectives for this project, here are some potential recommendations for future work:

- Exploring several methods that can further improve the efficiency of the irrigation and fertigation system. This may involve optimizing resource utilization and experimenting with different fertilizer types or refining the drip irrigation system.
- Focusing into the exploration of innovative technologies to understand how these technologies can be utilized to provide predictive analytics and

ultimately enhance decision-making capabilities. This may lead to achieving more precise control over the plant management system.

- Make improvements and expand the functionality of the system with a better platform that is related to agriculture.

These recommendations aim to direct future research and progress and ensure that Internet of Things (IoT) based plant management systems remain current, flexible and beneficial for farmers and the agricultural community.

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APPENDICES

Appendix A Code for ESP32

```
#include <DHT.h>
#include <Wire.h>
#include <ThingSpeak.h>
#include <ArduinoJson.h>
#include <ModbusMaster.h>
#include <SoftwareSerial.h>
#include <Adafruit_Sensor.h>
#include <WiFiClient.h>
#include <WiFiClientSecure.h>
#include <LiquidCrystal_I2C.h>
#include <UniversalTelegramBot.h>

// Plant variables
float humidity;
float temperature;
int soilMoistureValue1;
int soilMoistureValue2;
float pHValue;
float nitrogenValue;
float phosphorusValue;
float potassiumValue;

// Thingspeak
long unsigned int thingspeak_channel = 1;
const char *thingspeak_api = "Y1IY24BNBCZH54VE";

// Wifi
String wifi_ssid = "PatrickStarSU-1-2-02";
String wifi_password = "boboiboy3";

// Telegram BOT
String notification_chat_id = "674613481";
String bot_token = "6897005655:AAEAWrvKRzBSh1RLTvRIb5s1YEUvmZy3KRs";
bool bot_notification = false;
bool bot_automation = false;
unsigned long bot_lasttime;
const unsigned long bot_meantime = 10000;

// Initialize objects
ModbusMaster node;
WiFiClient client;
WiFiClientSecure clientsecure;
```

```
DHT dht(4, DHT22);
SoftwareSerial mod(17, 16);
LiquidCrystal_I2C lcd(0x27, 20, 4);
UniversalTelegramBot bot(bot_token, clientsecure);

void setup() {
  Serial.begin(115200);
  Wire.begin();
  mod.begin(9600);
  dht.begin();

  node.begin(1, mod);
  node.preTransmission(preTransmission);
  node.postTransmission(postTransmission);

  lcd.init();
  lcd.backlight();

  pinMode(19, OUTPUT);
  pinMode(18, OUTPUT);
  digitalWrite(19, LOW);
  digitalWrite(18, LOW);

  pinMode(25, OUTPUT);
  digitalWrite(25, HIGH);
  pinMode(26, OUTPUT);
  digitalWrite(26, HIGH);
  delay(500);

  lcd.setCursor(0, 0);
  lcd.print("IRRIGATION");
  lcd.setCursor(0, 1);
  lcd.print("SYSTEM IS ON ");
  lcd.setCursor(0, 2);
  lcd.print("DHT initialized");
  delay(1000);
  lcd.clear();

  WiFi.mode(WIFI_STA);
  WiFi.begin(wifi_ssid, wifi_password);

  Serial.println("Connecting to WiFi");

  while (WiFi.status() != WL_CONNECTED) {
    delay(100);
    Serial.print(".");
  }
```

```
  Serial.println("\nWIFI Connected!");

  ThingSpeak.begin(client);
  Serial.println("\nThingSpeak initiated!");

  clientsecure.setCACert(TELEGRAM_CERTIFICATE_ROOT);
  Serial.println("\nTelegrom Bot initiated!");
}

void loop() {
  // humidity = random(0,30);
  // temperature = random(0,30);
  // soilMoistureValue1 = random(0,30);
  // soilMoistureValue2 = random(0,30);
  // pHValue = random(0,30);
  // nitrogenValue = random(0,30);
  // phosphorusValue = random(0,30);
  // potassiumValue = random(0,30);

  humidity = dht.readHumidity();
  temperature = dht.readTemperature();
  soilMoistureValue1 = analogRead(35);
  soilMoistureValue2 = analogRead(34);
  pHValue = readModbusValue(0x01, 0x03, 0x0006);
  nitrogenValue = readModbusValue(0x01, 0x03, 0x001E);
  phosphorusValue = readModbusValue(0x01, 0x03, 0x001F);
  potassiumValue = readModbusValue(0x01, 0x03, 0x0020);

  if (isnan(humidity) || isnan(temperature)) {
    Serial.println("Failed to read from DHT sensor!");
    lcd.setCursor(0, 0);
    lcd.print("DHT reading failed");
    lcd.clear();
  }

  telegramLoopHandler();
  displayTemperatureAndHumidity();
  displayValuesNPK();
  displaySoilMoisture();
  startWatering();
  startFertilizing();
  updateThingSpeakFields();
  handleNotification();
}

void preTransmission() {
  digitalWrite(19, HIGH);
```

```
  digitalWrite(18, HIGH);
}

void postTransmission() {
  digitalWrite(19, LOW);
  digitalWrite(18, LOW);
}

void telegramLoopHandler() {
  if (millis() - bot_lasttime > bot_meantime) {
    int numNewMessages = bot.getUpdates(bot.last_message_received + 1);

    while (numNewMessages) {
      handleNewTelegramMessages(numNewMessages);
      numNewMessages = bot.getUpdates(bot.last_message_received + 1);
    }

    bot_lasttime = millis();
  }
}

void handleNotification() {
  if (!bot_notification) {
    return;
  }

  String message;
  message += "🌱 Plant Update! \n\n";
  message += "Humidity: " + String(humidity) + "\n";
  message += "Temperature: " + String(temperature) + "\n";
  message += "Soil moisture 1: " + String(soilMoistureValue1) + "\n";
  message += "Soil moisture 2: " + String(soilMoistureValue2) + "\n";
  message += "pHValue: " + String(pHValue) + "\n";
  message += "nitrogenValue: " + String(nitrogenValue) + "\n";
  message += "phosphorusValue: " + String(phosphorusValue) + "\n";
  message += "potassiumValue: " + String(potassiumValue) + "\n";

  Serial.println("Sending plant updates... \n");
  Serial.println(message);

  bot.sendMessage(notification_chat_id, message, "");

  if (soilMoistureValue1 > 2000 && soilMoistureValue2 > 2000) {
    if (bot_automation) {
      bot.sendMessage(notification_chat_id, "It seems like soil moisture is dry, Watering initiated! 💧🌻", "");
      startWatering();
    } else {
```

```
      bot.sendMessage(notification_chat_id, "It seems like soil moisture is dry, we suggest you to /watering now", "");
    }
  }

  if (pHValue < 40.0) {
    if (bot_automation) {
      bot.sendMessage(notification_chat_id, "It seems like acidic soil is low on nutrients, Fertilizing initiated! 💧🌼", "");
      startFertilizing();
    } else {
      bot.sendMessage(notification_chat_id, "It seems like acidic soil is low on nutrients, we suggest you to /fertilizing now", "");
    }
  }

  delay(10000);
}

void startFertilizing() {
  if (pHValue < 40.0) {
    digitalWrite(26, LOW); // Turn on water pump
    Serial.println("Fertilizing initiated! 💧🌼");
    lcd.setCursor(0,  3);
    lcd.print("Fertilizing");

    delay(20000);

    digitalWrite(26, HIGH);
    Serial.println("Fertilizing done! 💧🌼");
    lcd.setCursor(0, 3);
    lcd.print("Not Fertilized");
    lcd.clear();

  } else  {
    digitalWrite(26, HIGH);
    lcd.setCursor(0, 3);
    lcd.print("Not Fertilized");
  }
  return;
}

void startWatering() {
  if (soilMoistureValue1 > 2000 && soilMoistureValue2 > 2000) {
    digitalWrite(25, LOW); // Turn on fertilizer pump
    Serial.println("Watering initiated! 💧🌼");
    lcd.setCursor(0, 0);
    lcd.print("Water Pump is ON ");
```

```
    delay(20000);

    digitalWrite(25, HIGH);
    Serial.println("Watering done! 💧🌻");
    lcd.setCursor(0, 0);
    lcd.print("Water Pump is OFF");

  } else  {
    digitalWrite(25, HIGH);
    lcd.setCursor(0, 0);
    lcd.print("Water Pump is OFF");
  }

  return;
}

void handleTelegramMessage(int i) {
  String client_chat_id = bot.messages[i].chat_id;
  String text = bot.messages[i].text;
  String from_name = bot.messages[i].from_name;

  Serial.println("New message received: " + text);

  if (from_name == "")
    from_name = "Guest";

  if (text == "/start") {
    String startMessage;
    startMessage = "Hye, Welcome to Plant Management System 🌱🤖 \n";
    startMessage += "I'm here to help you automate and monitor your plant
watering and care system 🌼💧🌻 \n\n";
    startMessage += "Credit : Nurul Ezzah Hazirah Binti Elias 🌞 \n\n";
    startMessage += "Type /control to control the watering system \n";

    bot.sendMessage(client_chat_id, startMessage, "Markdown");
  }

  if (text == "/control") {
    String option1 = "{ \"text\" : \"Watering\", \"callback_data\" : \"1\"
}";
    String option2 = "{ \"text\" : \"Fertilizing\", \"callback_data\" :
\"2\" }";
    String option3 = "{ \"text\" : \"Toogle Notification\",
\"callback_data\" : \"3\" }";
    String option4 = "{ \"text\" : \"Toogle Automation\", \"callback_data\"
: \"4\" }";
```

```
    String combinedOptions = "[[" + option1 + "],[" + option2 + "],[" +
option3 + "],[" + option4 + "]]";

    bot.sendMessageWithInlineKeyboard(client_chat_id, "Choose from one of
the following options", "", combinedOptions);
  }

  if (text == "/watering") {
    startWatering();
    bot.sendMessage(client_chat_id, "Begin Watering! 💧🌻");
  }

  if (text == "/fertilizing") {
    startFertilizing();
    bot.sendMessage(client_chat_id, "Begin Fertilizing! 💧🌻");
  }
}

void handleTelegramQuery(int i) {
  String client_chat_id = bot.messages[i].chat_id;
  String selection = bot.messages[i].text;
  String toggleText;

  switch (selection.toInt()) {
    case 1:
      startWatering();
      bot.sendMessage(client_chat_id, "Begin Watering! 💧🌻");
      break;

    case 2:
      startFertilizing();
      bot.sendMessage(client_chat_id, "Begin Fertilizing! 💧🌻");
      break;

    case 3:
      bot_notification = !bot_notification;
      toggleText = bot_notification ? "TRUE" : "FALSE";

      bot.sendMessage(client_chat_id, "Notification is set to: " +
toggleText);

      if (bot_notification) {
        bot.sendMessage(client_chat_id, "You will receive plant updates
every 5 seconds!");
      } else {
        bot.sendMessage(client_chat_id, "You will no longer receive
updates.");
      }
```

```
      break;

    case 4:
      bot_automation = !bot_automation;
      toggleText = bot_automation ? "TRUE" : "FALSE";

      bot.sendMessage(client_chat_id, "Automation is set to: " +
toggleText);

      if (bot_automation) {
        bot.sendMessage(client_chat_id, "System will automatically do job
for you!");
      } else {
        bot.sendMessage(client_chat_id, "System will only send you
suggestions.");
      }

      break;
  }
}

void handleNewTelegramMessages(int numNewMessages) {
  for (int i = 0; i < numNewMessages; i++) {
    if (bot.messages[i].type == "callback_query") {
      handleTelegramQuery(i);
    } else {
      handleTelegramMessage(i);
    }
  }
}

void displayTemperatureAndHumidity() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Temperature: ");
  lcd.print(temperature, 1);
  lcd.print(" C");
  lcd.setCursor(0, 1);
  lcd.print("Humidity: ");
  lcd.print(humidity, 1);
  lcd.print(" %");
  delay(1000);

  lcd.clear();
  Serial.println(F("Humidity: "));
  Serial.print(humidity, 1);
  Serial.print(F("%  Temperature: "));
```

```
  Serial.print(temperature, 1);
  Serial.println(F("°C "));
  delay(500);
}

void displayValuesNPK() {

  lcd.setCursor(0, 0);
  lcd.print("Nitrogen: ");
  lcd.print(nitrogenValue);
  lcd.println(" mg/kg");
  lcd.setCursor(0, 1);
  lcd.print("Phosphorus: ");
  lcd.print(phosphorusValue);
  lcd.println(" mg/kg");
  lcd.setCursor(0, 2);
  lcd.print("Potassium: ");
  lcd.print(potassiumValue);
  lcd.setCursor(0, 3);
  lcd.print("Soil pH: ");
  lcd.println(pHValue);
  delay(1000);

  Serial.print("Nitrogen: ");
  Serial.print(nitrogenValue);
  Serial.println(" mg/kg");
  Serial.print("Phosphorous: ");
  Serial.print(phosphorusValue);
  Serial.println(" mg/kg");
  Serial.print("Potassium: ");
  Serial.print(potassiumValue);
  Serial.println(" mg/kg");
  Serial.print("Soil pH: ");
  Serial.println(pHValue);
  delay(500);
}

void displaySoilMoisture() {

  lcd.setCursor(0, 1);
  lcd.print("Moisture1: ");
  lcd.println(soilMoistureValue1);
  lcd.setCursor(0, 2);
  lcd.print("Moisture2: ");
  lcd.println(soilMoistureValue2);
  delay(1000);
  lcd.clear();
```

```
  Serial.print(" (");
  Serial.print(soilMoistureValue1);
  Serial.print("),(");
  Serial.print(soilMoistureValue2);
  Serial.println(")");
  delay(500);
}


float readModbusValue(uint8_t deviceAddress, uint8_t functionCode, uint16_t
registerAddress) {
  uint16_t result;

  node.clearResponseBuffer();

  int success = node.readHoldingRegisters(registerAddress, 1);
  if (success == node.ku8MBSuccess) {
    result = node.getResponseBuffer(0);
    return float(result) / 10.0;
  } else {
    return -1.0;  // Error reading value
  }
}

void updateThingSpeakFields() {
  ThingSpeak.setField(1, humidity);
  ThingSpeak.setField(2, temperature);
  ThingSpeak.setField(3, soilMoistureValue1);
  ThingSpeak.setField(4, soilMoistureValue2);
  ThingSpeak.setField(5, nitrogenValue);
  ThingSpeak.setField(6, phosphorusValue);
  ThingSpeak.setField(7, potassiumValue);
  ThingSpeak.setField(8, pHValue);

  int x = ThingSpeak.writeFields(thingspeak_channel, thingspeak_api);

  if (x == 200) {
    Serial.println("Channel update successful.");
  } else {
    Serial.println("Problem updating channel. HTTP error code " +
String(x));
```