UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Technology and Engineering

DESIGN AND IMPLEMENTATION OF AN AUTOMATED PLANT IRRIGATION SYSTEM USING SENSORS AND IOT TECHNOLOGY

GOKULAN A/L SELLAPERUMAL

Bachelor of Electronics Engineering Technology with Honours

2024

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek: DESIGN AND IMPLEMENTATION OF AN AUTOMATED PLANT IRRIGATION SYSTEM USING SENSORS AND IOT TECHNOLOGY

Sesi Pengajian: 2023/2024

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DEDICATION

With sincere gratitude, I dedicate this technical report to my supervisor, my family, my friends, and the lab assistants. Their unwavering support, direction, and help have been invaluable to me throughout my project. I sincerely appreciate their support in helping this work succeed as well as their confidence in my abilities, encouragement through difficult times, and contributions. I am sincerely appreciative of their participation in this amazing journey and their presence has been a source of inspiration.

ABSTRACT

This final year project presents the design and implementation of an automated plant irrigation system using sensors and IoT technology. The aim is to optimize plant growth and irrigation practices by monitoring soil moisture levels, humidity, and temperature through an IoT platform. The system integrates strategically placed sensors in the plant environment to collect data, which is transmitted to a centralized IoT platform for analysis. Through a user-friendly interface, including a mobile application, users can remotely access the system, adjust irrigation parameters, and receive notifications. The project addresses the limitations of traditional irrigation methods by leveraging IoT technology for precise monitoring and control. Additionally, the incorporation of grow lights enhances plant growth by providing the necessary light spectrum for photosynthesis. The project's implementation and evaluation validate its effectiveness in optimizing irrigation practices and promoting plant growth. The findings contribute to the field of automated plant irrigation systems, showcasing the potential for improved water usage efficiency and increased crop yields.

ABSTRAK

Projek akhir tahun ini mempersembahkan reka bentuk dan pelaksanaan sistem penyiraman tumbuhan automatik menggunakan sensor dan teknologi IoT. Matlamatnya adalah untuk mengoptimumkan pertumbuhan tumbuhan dan amalan penyiraman dengan memantau tahap kelembapan tanah, kelembapan, dan suhu melalui platform IoT. Sistem ini mengintegrasikan sensor yang diletakkan secara strategik di persekitaran tumbuhan untuk mengumpul data, yang kemudiannya dihantar ke platform IoT yang terpusat untuk analisis. Melalui antara muka yang mesra pengguna, termasuk aplikasi mudah alih, pengguna dapat mengakses sistem secara jarak jauh, mengubahsuai parameter penyiraman, dan menerima pemberitahuan. Projek ini mengatasi kelemahan kaedah penyiraman tradisional dengan memanfaatkan teknologi IoT untuk pemantauan dan kawalan yang tepat. Tambahan pula, penyertaan komponen lampu tumbuh meningkatkan pertumbuhan tumbuhan dengan menyediakan spektrum cahaya yang diperlukan untuk fotosintesis. Pelaksanaan dan penilaian projek ini mengesahkan keberkesanannya dalam mengoptimumkan amalan penyiraman dan mempromosikan pertumbuhan tumbuhan. Hasil kajian ini menyumbang kepada bidang sistem penyiraman tumbuhan automatik, memperlihatkan potensi untuk peningkatan kecekapan penggunaan air dan hasil pertanian yang lebih tinggi.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all individuals who have supported and contributed to the completion of this thesis project.

First and foremost, I would like to thank my supervisor, Ts. Mohd Razali Bin Mohamad Sapiee, for their guidance, expertise, and continuous support throughout the entire research process. Their valuable insights, constructive feedback, and unwavering encouragement have been instrumental in shaping this project. I am immensely grateful to the faculty members of FTKE for providing a conducive academic environment and access to resources that have facilitated my research. Their dedication to education and commitment to fostering a culture of learning have been truly inspiring.

I would also like to thank my family and friends for their unwavering support, understanding, and motivation throughout this academic journey. Their encouragement, belief in my abilities, and willingness to lend a helping hand have been invaluable. I am grateful to all the researchers, scholars, and authors whose work and publications have served as a foundation for this study.

In conclusion, I am deeply thankful for the support and contributions of all those mentioned and unmentioned. This project would not have been possible without their assistance and belief in my abilities. Their collective efforts have left an indelible mark on my academic journey, and for that, I am sincerely grateful.

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LIST OF SYMBOLS

$^{\circ}C$ - Degree Celcius

LIST OF ABBREVIATIONS

lux - Illuminance

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CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, there has been a growing interest in incorporating automation and Internet of Things (IoT) technology into various aspects of our lives, including agriculture. One significant application is the development of automated plant irrigation systems that utilize sensors and IoT technology to optimize water usage, monitor plant health, and enhance crop yield. The efficient use of water resources is crucial in addressing global water scarcity challenges and achieving sustainable agricultural practices.

Traditional irrigation methods often rely on manual intervention or time-based scheduling, leading to inefficient water usage and potential crop damage due to under or over-irrigation. By integrating sensors and IoT technology, it is possible to create a sophisticated and intelligent plant irrigation system that responds to the specific needs of each plant and provides precise and optimal irrigation.

The primary objective of this project is to design and implement an automated plant irrigation system that utilizes soil moisture sensors, humidity sensors, and temperature sensors, along with IoT technology, to monitor and control the irrigation process. The system will continuously measure and analyze the soil moisture level, humidity, and temperature data in real-time. This information will be transmitted to a central IoT platform, where it will be processed and analyzed to make informed decisions regarding irrigation scheduling and water supply.

The IoT platform will act as the central control unit for the irrigation system, integrating the sensor data and implementing smart algorithms to determine the irrigation requirements of the plants. Based on the analyzed data, the system will activate the irrigation mechanism, supplying the appropriate amount of water to the plants. Additionally, the system will incorporate a grow light component to enhance the growth rate of the plants by providing optimized lighting conditions.

By employing this automated plant irrigation system, several advantages can be realized. Firstly, it will significantly reduce water wastage by delivering water only when required, based on the plants' specific needs. Secondly, the system will help prevent under or over-irrigation, ensuring optimal soil moisture levels for plant growth and health. Thirdly, the integration of grow lights will enable faster and healthier plant growth, enhancing crop yields.

This project holds immense significance as it combines advancements in sensor technology, IoT, and automation to address crucial challenges in the agricultural sector. It has the potential to revolutionize traditional irrigation practices and promote sustainable farming techniques by optimizing water usage, conserving resources, and maximizing crop productivity.

In a summary, this project aims to demonstrate the practicality and effectiveness of an automated plant irrigation system that leverages sensors, IoT technology, and grow lights to create an intelligent and efficient solution for plant cultivation.

1.2 Societal/Global Issues & Sustainable Development

The design and implementation of an automated plant irrigation system using sensors and IoT technology not only addresses the immediate challenges of efficient water usage and plant growth but also aligns with broader societal and global issues related to sustainable development. This section highlights the significance of the project in the context of these issues.

Water scarcity and the increasing demand for food production are major global concerns. Traditional irrigation methods often lead to excessive water consumption and inefficient water management practices. By developing an automated plant irrigation system, this project aims to contribute to sustainable water usage by providing precise monitoring and control of irrigation processes. This reduces water wastage, conserves this valuable resource, and promotes responsible agricultural practices.

Furthermore, the project aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 6 (Clean Water and Sanitation). The implementation of an automated system enables more efficient crop cultivation, leading to increased food production and improved food security. By optimizing irrigation practices, the system contributes to sustainable agriculture and supports the goal of ending hunger and achieving food security.

Additionally, the integration of IoT technology and remote access capabilities enhances the system's efficiency and convenience. It allows farmers and agricultural professionals to remotely monitor and manage plant irrigation processes, reducing the need for physical presence and minimizing travel-related carbon emissions. This aspect of the project aligns with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action) by promoting technological innovation and reducing environmental impact.

The societal impact of this project is significant. By optimizing irrigation practices and improving crop yields, the automated system can contribute to economic growth, job creation, and sustainable livelihoods in the agricultural sector. The adoption of such technologies also empowers farmers with better control over their farming operations and promotes knowledge sharing and capacity building within communities.

In conclusion, the design and implementation of an automated plant irrigation system using sensors and IoT technology not only addresses immediate concerns of water efficiency and plant growth but also aligns with broader societal and global issues related to sustainable development. By optimizing irrigation practices, promoting responsible water usage, and contributing to food security, this project has the potential to make a meaningful impact on the agricultural sector and support the achievement of various Sustainable Development Goals.

1.3 Problem Statements

Conventional methods of plant irrigation often rely on manual intervention or time-based schedules, resulting in inefficient water usage, inadequate monitoring of soil conditions, and suboptimal plant growth. Furthermore, the lack of real-time data access and control mechanisms limits the effectiveness and precision of irrigation practices. Additionally, indoor, or controlled environment agriculture faces challenges in providing adequate lighting conditions for plants due to limited natural sunlight. Therefore, there is a need to design and implement an automated plant irrigation system that integrates sensors, IoT technology, and a grow light component to address these issues. This system aims to accurately monitor soil moisture levels, temperature, and humidity in real-time, provide a user-friendly interface for control and monitoring through a mobile application, and optimize lighting conditions through the incorporation of grow lights. By addressing these challenges, the proposed system seeks to enhance water usage efficiency, improve plant health, and maximize crop yields in various agricultural settings.

1.4 Project Objectives

a) To design an automated plant irrigation system that utilizes IoT technology to accurately monitor soil moisture levels, temperature, and humidity.

b) To develop a user-friendly interface for controlling and monitoring the automated plant irrigation system, including a mobile application that allows for remote access and real time data updates.

c) To optimize the lighting conditions and accelerate the plant growth by using grow light.

1.5 Scope of Projects

The project scope encompasses the design and development of an integrated system that combines IoT technology, user-friendly interface, and grow light optimization to enhance plant irrigation and growth. Firstly, the focus will be on designing an automated plant irrigation system that utilizes IoT technology. This system will incorporate sensors capable of accurately monitoring crucial environmental parameters such as soil moisture levels, temperature, and humidity. The collected data will be transmitted to a central system for real-time monitoring and analysis. Secondly, the project will involve the development of a user-friendly interface for controlling and monitoring the automated irrigation system. This will include the creation of a mobile application that enables remote access and provides real-time data updates, allowing users to conveniently manage and monitor the irrigation system from anywhere. Finally, the scope extends to optimizing the lighting conditions for accelerated plant growth. Research will be conducted to identify suitable grow lights for different plant species, and a lighting system will be integrated with the automated irrigation system to provide synchronized operation. By achieving these objectives, the project aims to enhance the efficiency, precision, and overall health of plant growth through a comprehensive IoT-based automated irrigation system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An automated plant irrigation system using sensors and IoT technology is an emerging area of research that aims to improve the efficiency and effectiveness of plant irrigation. This technology involves the use of sensors to monitor soil moisture levels and other environmental factors, such as temperature and humidity, in real-time. This information is then transmitted to an IoT platform, which uses algorithms to analyze the data and automatically trigger irrigation systems when necessary.

The use of such systems offers several benefits, such as reduced water consumption, improved plant health and growth, and increased productivity. As a result, there has been a growing interest in the development and implementation of automated plant irrigation systems using sensors and IoT technology.

This literature review will provide an overview of the current state of research on this topic, including the existing technologies, the benefits and limitations of these systems, and the challenges associated with their implementation. It will also identify the gaps in the literature and provide recommendations for future research in this area.

2.2 Overview of Plant Irrigation

Proper irrigation is crucial for maintaining healthy plant growth and maximizing crop yields. Various irrigation systems have been developed to ensure efficient water delivery to plants. This section provides an overview of different plant irrigation systems that have been used in agriculture.

Mainly, there are two types of irrigation systems namely, sprinkler and drip irrigation system[1]. These methods have been widely employed for many years but have limitations, including water wastage and inefficient water use. This emphasizes the need for more advanced and automated irrigation systems.

The section then discusses the shift towards automated irrigation systems that can adaptively adjust watering schedules based on real-time plant and environmental conditions. These systems offer several advantages over traditional methods. They provide better control over water application, leading to improved water-use efficiency. Therefore, the limitation for flowing water is required to meet uniform irrigation the system[2]. Manual irrigation practices required more labour and cost to manage. This can be overcome by using an automated water irrigation system[3]. Moreover, they enable precise and targeted delivery of water to the plant root zones, minimizing water runoff and soil erosion.

A smart IoT based system can provide an agriculture support mechanism to enhance the efficiency of the irrigation system[4]. IoT-based systems utilize a network of sensors to monitor various parameters such as soil moisture, temperature, humidity, and light intensity.

This real-time data collection enables intelligent decision-making for irrigation control, allowing for optimized watering schedules and resource-efficient irrigation practices.

To support the discussion, the section includes references to relevant studies. For example, a smart agriculture which can access the temperature, soil moisture and relative humidity information by using DHT11 and transfers these data to cloud server for remote access[5]. On other hand, if the temperature and moisture values are beyond the certain limit an alert SMS will be send to the farmer then, if the farmer wishes to control the motor remotely it is possible by pressing the ON and OFF button given in the android application[6].

In summary, this section provides an overview of the different types of irrigation systems, highlights the limitations of traditional methods, and emphasizes the advantages of automated and IoT-based systems for efficient and sustainable plant irrigation.

2.3 Traditional Irrigation Methods

2.3.1 Flood Irrigation

Flood irrigation is one of the oldest and simplest methods of irrigation. It involves the flooding of an entire field with water, allowing it to infiltrate the soil and reach the plant roots. This method is commonly used for crops such as rice, where standing water is beneficial for plant growth. Irrigation by flooding has a low water efficiency, with water losses of up to 60%, while irrigation by sprinkler has water losses of about 25%[7]. These losses can result in inefficient water use and potential environmental concerns.

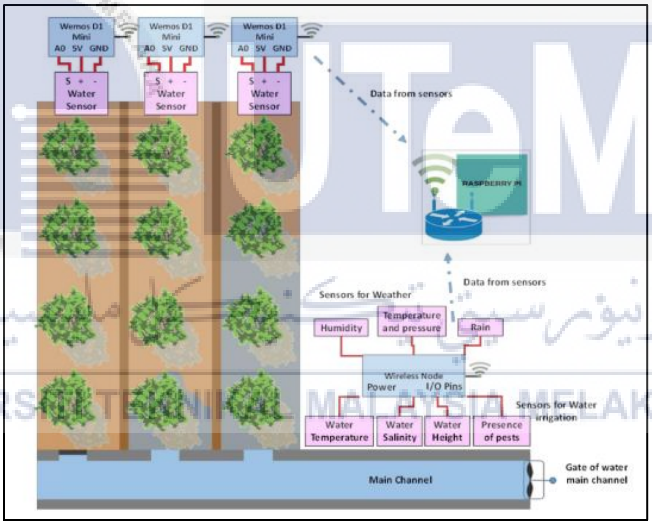


Figure 2.1 Proposed mechanism for managing agriculture's flood irrigation [8].

2.3.2 Furrow Irrigation

Furrow irrigation involves the creation of small channels or furrows along the rows of plants. Water is then released into these furrows, allowing it to flow along the rows and infiltrate the soil. This method provides better control over water application compared to flood irrigation. Furrow irrigation is widely used, demands a huge primary investment, and requires uniform distribution; however, its water use efficiency never exceeds 60-70% with an average of 50-55% and is influenced by such factors as furrow geometric parameters (lengths, slope, and cross-section), flowrate, plant age, and soil texture and structure[9]. Furrow irrigation has been commonly used for crops like corn, cotton, and vegetables.

Figure 2.2 Hydro-flume with Adjustable out-let valves for Furrow Irrigation[9].

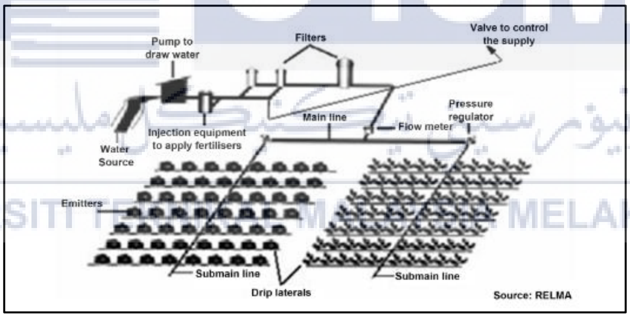
2.3.3 Sprinkler Irrigation

Sprinkler irrigation involves the use of overhead sprinklers that spray water over the field. The water is distributed in the form of fine droplets, mimicking natural rainfall. Sprinkler systems can be designed to deliver water uniformly across the field, reducing water wastage. As sprinkler irrigation saves more than half of water resource compared with other alternative approach does, meanwhile it is appreciated by such superiorities as equilibrium infiltration distribution, cost saving and user friendly, which make it be frequently used in agricultural cultivation or city landscaping[10]. Certain crops may also be sensitive to wet foliage, leading to potential disease issues. Sprinkler irrigation has been widely used for a variety of crops, including fruits, vegetables, and turfgrass.

Figure 2.3 Tested area to correct water sprinkler[10].

2.3.4 Drip Irrigation

Drip irrigation is a more efficient and precise method of water delivery. It involves the slow and targeted application of water directly to the plant root zone through a network of tubes or pipes with emitters. Drip irrigation minimizes water losses through evaporation and runoff since water is applied directly to the plants' root zone. This method is particularly suitable for areas with limited water availability and for crops that have specific water requirements. Controlled irrigation methods such as drip irrigation is typically the most efficient method of water/fertilizer distribution which allows precise timing, controlled distribution of water and applied nutrients than traditional methods (surface flooding and furrow irrigation) because it applies frequent irrigation to crops in root zone and reduces adverse effects of over irrigation and water stress problems[11]. It is commonly used in horticultural crops, orchards, and greenhouse production systems.



Source: RELMA

Figure 2.4 Layout of drip irrigation system[12].

Each of these traditional irrigation methods has its advantages and limitations. While they have been widely practiced for many years, there are challenges associated with water wastage, uneven water distribution, and increased labour requirements. These challenges have led to the exploration and development of more advanced and efficient automated irrigation systems that leverage technologies like sensors and IoT.

2.4 Advancements in Automated Plant Irrigation

In recent years, significant advancements have been made in the field of automated plant irrigation systems. This section explores some of the key developments and technologies that have revolutionized the way plants are irrigated.

2.4.1 Sensor Technology

One of the major advancements in automated plant irrigation is the integration of sensor technology. Sensors, such as soil moisture sensors, temperature sensors, humidity sensors, and light sensors, are used to monitor key environmental and plant parameters. These sensors provide real-time data on the moisture level in the soil, ambient temperature, humidity, and light intensity, allowing for precise and efficient irrigation scheduling. While the advantage of the proposed system by Mehta et al. (2018) is that it has been built to receive the real-time data of their crops soil moisture, the environment temperature and sunlight intensity level values[5].

2.4.2 Internet of Things

The Internet of Things (IoT) has played a crucial role in advancing automated plant irrigation systems. IoT technology enables the connection and communication between different devices and sensors used in the irrigation system. The remote operation of the pumps using IoT can solve the problem of irregularity in power supply timings and unattained locations[13]. IoT-based plant irrigation systems offer greater flexibility, scalability, and efficiency compared to traditional manual systems.

2.4.3 Precision Irrigation Techniques

Another significant advancement in automated plant irrigation is the development of precision irrigation techniques. The concept of precision irrigation is the accurate use of irrigation water resources according to soil moisture and plant growth periods[14]. These techniques involve delivering water with high precision and accuracy directly to the root zone of plants, minimizing water losses and improving water-use efficiency. Precision irrigation techniques include micro-irrigation methods such as drip irrigation, micro-sprinklers, and precision sprinklers.

These advancements in automated plant irrigation systems have revolutionized the way farmers and growers manage irrigation practices. The integration of sensor technology, IoT, data analytics, and precision irrigation techniques has led to more efficient water use, improved crop yields, and reduced environmental impact. As a result, automated plant irrigation systems are becoming increasingly popular and widely adopted in agriculture.

2.5 Sensor Technologies for Plant Irrigation

Sensor technologies play a critical role in automated plant irrigation systems by providing real-time data on environmental conditions and plant parameters. This section explores some of the key sensor technologies used in plant irrigation and their applications.

2.5.1 Soil Moisture Sensors

Soil moisture sensors are widely used in plant irrigation systems to measure the moisture content in the soil. These sensors can be deployed at different depths within the root zone to provide information about the soil moisture distribution. By continuously monitoring soil moisture levels, farmers can determine when to initiate irrigation and the duration of watering. Soil moisture sensors enable precise irrigation scheduling, preventing under- or over-watering, and optimizing water-use efficiency.

Figure 2.5 Capacitive soil moisture sensors[5]**.**

2.5.2 Weather Sensors

Weather sensors are used to collect data on various meteorological parameters that influence plant water requirements. These sensors measure parameters such as temperature, humidity, wind speed, and solar radiation. Weather data, combined with plant-specific factors, can help estimate crop evapotranspiration rates and determine irrigation needs. By integrating weather sensors into the irrigation system, farmers can adjust irrigation schedules based on prevailing weather conditions, ensuring that plants receive the right amount of water.

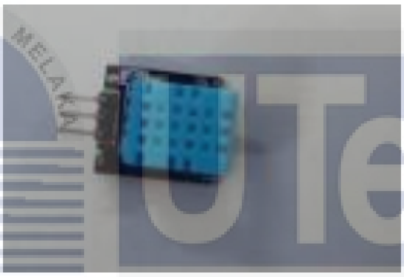


Figure 2.6 Temperature and humidity sensor DHT 11[15]**.**

2.6 IoT Technology and Its Applications in Agriculture

The Internet of Things (IoT) has emerged as a transformative technology in various industries, including agriculture. The Internet of Things (IoT) refers to the network of interconnected devices, sensors, and objects that can communicate with each other and exchange data over the internet. In the agricultural sector, IoT technology has gained significant attention due to its potential to enhance efficiency, productivity, and sustainability. IoT-enabled systems provide real-time monitoring, data collection, and analysis, enabling farmers and growers to make informed decisions and optimize agricultural practices. This section delves into the concept of IoT and explores its applications in agriculture, specifically in the context of automated plant irrigation systems.

In the context of automated plant irrigation systems, IoT technology plays a vital role in improving water management and overall crop health. Here are some key applications of IoT in agriculture which consists of Remote Monitoring and Control, Data-Driven Decision Making, Optimized Resource Management and Early Detection of Plant Stress and Disease.

2.6.1 Remote Monitoring and Control

IoT allows for remote monitoring and control of irrigation systems. Sensors deployed in the field, such as soil moisture sensors, weather sensors, and flow meters, collect data on various environmental parameters and irrigation system performance. This data is transmitted wirelessly to a central control unit or a cloud-based platform, where it can be accessed by farmers or agricultural experts. Rajkumar et al. proposed an irrigation monitoring system operated by Arduino and GSM network that allows pump control through SMS and Bluetooth[16].

2.6.2 Data-Driven Decision Making

IoT-enabled agricultural systems generate a vast amount of data. This data, combined with advanced analytics and machine learning algorithms, allows for data-driven decision making. Farmers can analyse historical data, monitor trends, and identify patterns to optimize irrigation strategies, crop management, and resource allocation. An algorithm with threshold values of soil moisture is to be maintained continuously[17].

2.6.3 Optimized Resource Management

IoT technology enables precise resource management in agriculture. By integrating data from various sources, including soil moisture sensors, weather forecasts, and crop water demand models, IoT-based systems can optimize water usage, minimize waste, and reduce energy consumption. Furthermore, the use of communication and sensing by means of automated data collection, recording, and strategic farm management decisions may reduce waste and have a positive impact on the environment[16]. This leads to improved water-use efficiency, cost savings, and reduced environmental impact.

2.6.4 Early Detection of Plant Stress and Disease

IoT-enabled sensors can provide early detection of plant stress and disease symptoms. By monitoring various environmental factors, such as temperature, humidity, and light intensity, along with plant physiological parameters, IoT systems can detect anomalies or deviations from normal conditions. This early warning system enables timely intervention, allowing farmers to take appropriate measures to prevent crop losses and optimize plant health. For example, if the soil is dry, an alert message is sent “MOTOR ON” to the mobile through voice or text water pump starts which leads to water to flow[17].

The application of IoT technology in agriculture offers tremendous opportunities to optimize plant irrigation systems, improve resource management, and enhance overall agricultural practices. By leveraging real-time data, remote monitoring capabilities, and data analytics, IoT-based systems enable farmers to make informed decisions, conserve resources, increase productivity, and promote sustainable agriculture.

2.7 Existing Automated Plant Irrigation Systems

Numerous automated plant irrigation systems have been developed and implemented to optimize water usage, improve crop productivity, and simplify irrigation management. This section provides an overview of some existing automated plant irrigation systems and their key features.

2.7.1 Micro-Irrigation Systems

Micro irrigation is one of the most recent innovations in irrigation which gives the precise water application in agriculture[18]. Micro-irrigation systems encompass both drip irrigation and micro-sprinkler systems. These systems apply water in small, controlled quantities, directly targeting the plant root zone. Micro-irrigation systems provide water and nutrients efficiently, reducing water losses due to evaporation and runoff. They are particularly suitable for areas with limited water resources and are known to improve water-use efficiency and crop yield. Micro-irrigation systems can be automated using timers or sensors to ensure optimal water application.

2.7.2 Smart Irrigation Controllers

Smart irrigation controllers combine sensor technology, weather data, and advanced algorithms to optimize irrigation scheduling. These controllers gather information from soil moisture sensors, weather stations, and other environmental sensors to determine the irrigation needs of plants. By integrating real-time data, these controllers can adjust irrigation schedules based on current weather conditions, soil moisture levels, and plant water requirements. Smart irrigation controllers enable precise irrigation management, reduce water waste, and adapt to changing environmental conditions.

2.7.3 Wireless Sensor Networks

Wireless sensor networks (WSNs) are used in automated plant irrigation systems to collect and transmit data from various sensors deployed in the field. WSNs consist of multiple sensors connected wirelessly to a central data collection and processing unit. These networks enable real-time monitoring of soil moisture, temperature, humidity, and other environmental parameters. The collected data is then used to control and optimize irrigation operations. WSNs provide a cost-effective and scalable solution for remote sensing and monitoring in large agricultural areas. Avatade and Dhanure have developed an automated irrigation system using WSN, an ARM microcontroller, and GPRS where the system is designed based on an integrated platform that uses the ARM microcontroller to control the water irrigation system and it can measure and monitor the soil moisture level and temperature through multiple ARM microcontroller-based wireless sensor nodes[19].

These existing automated plant irrigation systems have demonstrated their effectiveness in improving water-use efficiency, reducing labour requirements, and enhancing crop yields. They serve as valuable references for designing and implementing automated plant irrigation systems using sensors and IoT technology.

2.8 Integration of Grow Lights for Enhanced Plant Growth

One of the key considerations in indoor or controlled environment agriculture is providing sufficient lighting conditions for optimal plant growth. Integration of grow lights has been widely adopted to address the challenges associated with limited natural sunlight. For instance, light intensity, spectrum controlling, and photoperiod are related to vegetable growth, productivity, and size[20]. These artificial light sources play a crucial role in providing consistent and adequate lighting conditions, especially in environments where sunlight is limited or inaccessible.

Numerous studies have demonstrated the positive impact of grow lights on plant growth and development. An experimental investigation suggested that the addition of 24% green LED light can enhance the growth of the vegetable[20]. From the experimental data, the average weight of packcoy with additional light from LED grow light for 10 hours a day with a growing period of 40 days was 47.88 grams, while packcoy without additional LED grow light had an average weight of 20.22 gram[21].

Integration of grow lights within automated plant irrigation systems offers several advantages. By customizing the light spectrum and intensity, growers can provide plants with the ideal lighting conditions for specific growth stages or plant species. Additionally, within the visible light spectral range (400–700 nm), many researchers have focused on studying the role of red (R) (600–700 nm) and blue (B) (400–500 nm) light and on defining their optimal combination ratios because their wavelengths are close to the absorbance of photosynthetic pigments that effectively drive photosynthesis[22].

In the wide view, the integration of grow lights in automated plant irrigation systems enhances plant growth and development by providing consistent and optimized lighting conditions. The choice of grow light technology and the selection of appropriate light spectra are crucial factors that contribute to the success of this integration.

Figure 2.7 Reflected light from the vegetable for uplink communications[20].

2.9 Critical Analysis of Relevant Studies

To gain a comprehensive understanding of the current state of research in automated plant irrigation systems using sensors and IoT technology, a critical analysis of relevant studies is conducted. This section presents a summary of key findings from selected studies and provides a critical evaluation of their contributions.

A literature matrix table is provided below to summarize the relevant studies, their objectives, methodologies, and key findings.

STUDY	OBJECTIVE	METHODOLOGY	KEY FINDINGS
Arif Bin Azlan M (2018).[23]	To make farming easier for the farmer, who can also keep an eye on the moisture content of the water in the soil to make sure the plants are getting enough water to flourish.	Data collection using IoT sensors, statistical analysis on soil moisture.	The data from the sensor will be sent to Node MCU and sent to a webpage. The information can then be used to decide whether there is not enough water and to activate a water pump to irrigate the plant.

Daniyan L, Nwachukwu E, Daniyan I, Bonaventure O (2019).[1]	To create a system with good automation and control, a variety of electronic timing systems, soil feedback sensors, and wireless communication systems were used.	Soil moisture sensor installation at different types of soil, data analysis for water requirement based on soil moisture, humidity and temperature.	Due to the structure of the soil, clay has a great capacity to retain water, which accounts for its high moisture content. Clay is followed by loamy soil and finally sandy soil in terms of moisture content.
Al-Sammarraie M, Akbar Ali A, Muqdad Hussein N (2021).[14]	To research and test the use of global positioning systems with applications for precision irrigation in agricultural operations.	Simulation study, integration of weather data into irrigation models, performance evaluation.	In this study, the soil type, plant species, and climate all played a role. Instead of utilising predictive algorithms based on the data to determine plant water consumption and irrigation. The direct approach was used, and (Burunkaya) measurement was used.

Table 2.1 Critical analysis of relevent studies

2.10 Summary

Chapter 2 provides a comprehensive literature review on automated plant irrigation systems, focusing on advancements in sensor technology, IoT, data analytics, and precision irrigation techniques. The review highlights the limitations of traditional irrigation methods and explores the potential benefits of integrating these technologies in agriculture. It discusses the role of IoT in remote monitoring, data-driven decision making, and optimized resource management. Sensor technologies, including soil moisture and weather sensors, are examined for their importance in accurate irrigation management. Existing systems such as drip irrigation and smart controllers are evaluated. The integration of grow lights for enhanced plant growth is discussed. The review critically analyzes relevant studies, highlighting the positive impact of these technologies on plant growth and resource utilization. The chapter establishes the foundation for the design of an automated plant irrigation system using sensors and IoT technology to optimize plant growth and improve agricultural practices.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology section of this project presents a detailed overview of the approach taken to design and implement the automated plant irrigation system using sensors and IoT technology. This section outlines the step-by-step process followed to ensure the successful development and integration of various components within the system. The methodology encompasses the selection and evaluation of tools for sustainable development, system architecture, hardware components, and software implementation, providing a comprehensive understanding of the approach taken to develop this innovative solution for domestic agriculture.

The main goals of this chapter are to detail the systematic procedures followed in designing and constructing the automated plant irrigation system. By elucidating the chosen approach, readers will acquire a comprehensive understanding of the system's overall structure, the selection of hardware components, and the process of software implementation.

The methodology applied in this project aims to integrate Internet of Things (IoT) technology for developing an efficient and sustainable automated plant irrigation system. Through the use of microcontroller technology and an array of sensors, the objective is to monitor and regulate crucial environmental parameters within the irrigation system, ultimately optimizing plant growth and agricultural productivity.

To provide a thorough understanding, this chapter is segmented into various sections. Initially, the system architecture and design are introduced, outlining the overall structure and components of the automated plant irrigation system. This encompasses the central microcontroller, ESP32, and the chosen sensors such as the temperature and humidity sensor (DHT22), light intensity sensor (LDR), capacitive soil moisture sensor, and float sensors.

Subsequently, the hardware components are explored in depth, elucidating their individual roles and functionalities within the system. This section explains the purpose of each sensor and how they collectively contribute to the effective monitoring and control of the irrigation system. Discussions include the utilization of the temperature sensor to activate fans and misting pumps, the light sensor for automated lighting based on darkness conditions, the soil moisture sensor for irrigation control, and the float sensors for managing water levels in the tank.

Moreover, the chapter addresses the software implementation aspect, detailing how the ESP32 microcontroller is programmed to gather data from the sensors, establish communication, and execute control algorithms. The software implementation is crucial in collecting and processing data, as well as enabling remote monitoring and control through IoT connectivity.

In summary, this chapter serves as a comprehensive guide to the methodology employed in developing the IoT-based automated plant irrigation system using sensors. Through an understanding of the system architecture, hardware components, and software implementation, readers will gain a deeper insight into the technical aspects of this innovative solution. The methodology lays the foundation for subsequent chapters, where the results and discussion analyze the system's performance and draw conclusions for future work.

3.2 Selecting and Evaluating Tools for Sustainable Development

The selection and evaluation of tools for sustainable development plays a crucial role in the design and implementation of the automated plant irrigation system. This section outlines the methodology used to identify and assess the tools necessary to achieve the project's sustainability objectives.

To begin with, an extensive review of available tools and technologies related to plant irrigation and sustainable agriculture was conducted. This involved a comprehensive literature search, consultation with experts, and exploration of existing solutions in the field. The focus was on identifying tools that align with sustainable development principles, such as water conservation and environmental impact reduction.

Criteria were established to evaluate the suitability of the identified tools for the project. These criteria included factors such as reliability, cost-effectiveness, scalability, ease of integration, and compatibility with the overall system design. Each tool was assessed based on its performance, features, and potential impact on achieving sustainable development goals.

Based on the evaluation, a set of tools was selected that best met the project's sustainability objectives. This included hardware components, software platforms, and communication protocols that support efficient irrigation management, sensor integration, and remote monitoring capabilities. Special consideration was given to tools that offer durable construction and compatibility with IoT technology.

After selecting the tools, a detailed analysis of their technical specifications and capabilities was conducted. This involved examining the documentation, manufacturer's guidelines, and user reviews to ensure that the chosen tools met the project's requirements. Any necessary modifications or customizations were identified to ensure seamless integration within the overall system architecture.

Moreover, the selected tools were evaluated for their potential environmental impact. Factors such as energy consumption, material composition, and end-of-life disposal considerations were considered. Tools that demonstrated a commitment to sustainability, such as using recyclable materials or employing energy-saving features, were prioritized.

The final selection of tools was made based on a comprehensive assessment of their technical suitability, alignment with sustainability principles, and compatibility with the project's overall objectives. This process ensured that the chosen tools would contribute to the efficient and sustainable operation of the automated plant irrigation system.

In summary, the methodology for selecting and evaluating tools for sustainable development involved conducting a thorough review of available options, establishing evaluation criteria, analyzing technical specifications, and considering environmental impact. The selected tools will serve as integral components in achieving the project's goals of water conservation and overall sustainable agriculture practices.

3.3 System Architecture and Structure Design

3.3.1 System Architecture

The IoT-based automated plant irrigation system follows a distributed model shown in Figure 3.1, utilizing the ESP32 microcontroller as the central processing unit. The system incorporates various sensors such as temperature and humidity, light intensity, soil moisture, and float sensors strategically placed within the plant.

The ESP32 microcontroller collects data from the sensors and executes control algorithms based on predefined thresholds. The integration of Blynk IoT enables remote monitoring, data collection, and control capabilities. Users can access real-time data, receive notifications, and control the surrounding environment of the plant through the Blynk mobile application or web interface.

The design of the system ensures seamless integration with Blynk IoT, utilizing the Blynk library and establishing communication between the ESP32 microcontroller and the

Blynk server. The system allows for real-time data synchronization, remote control, and historical data analysis. Overall, the system architecture and design provide an effective framework for data acquisition, control, and communication, enabling remote monitoring and control of the surrounding environment of the plant.

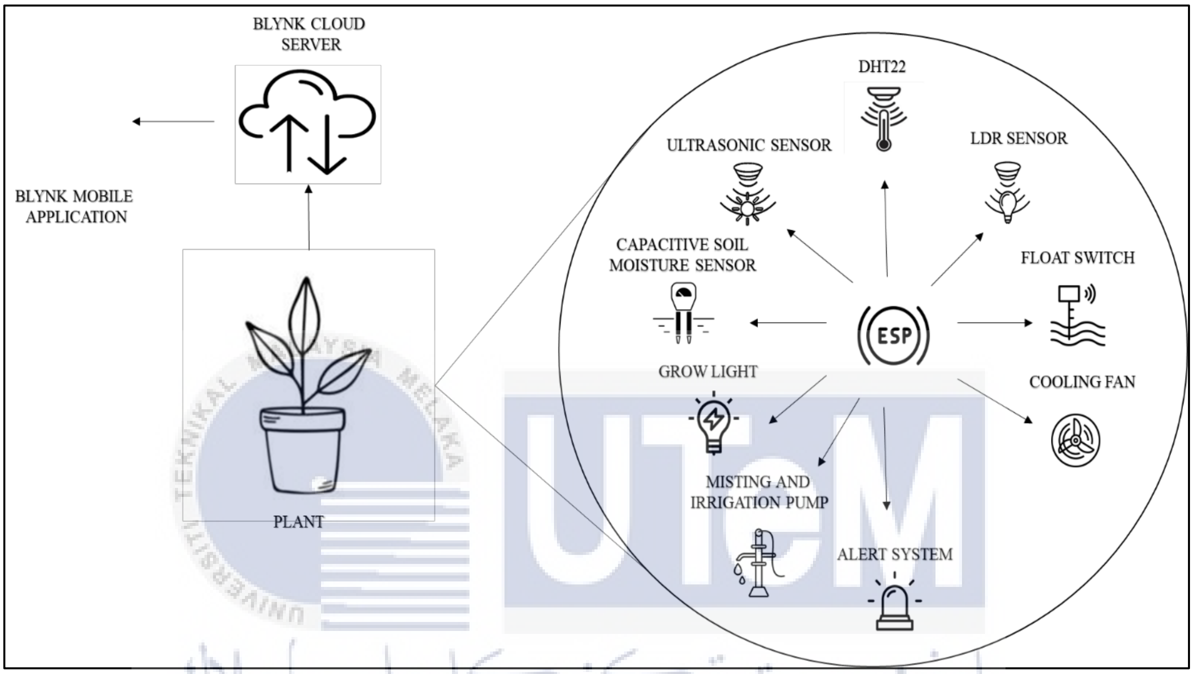


Figure 3.1 System architecture and design

3.3.2 Structure Design

Furthermore, meticulous attention has been given to the design and dimensions of the structure using Tinkercad to accommodate the placement of plants. Illustrated in Figure 3.2, the structure has a length of 62 cm, a width of 25 cm, and a height of 32 cm (L x W x H). The design is inclusive of a comprehensive structure that incorporates a storage box.

Both the 3D models and tangible representations of the structure have been crafted using Tinkercad software. The dimensions outlined in the diagram ensure ample space for plants and the essential tools required for storage. The precision in designing and visualizing the structure with Tinkercad guarantees that it aligns with the specific requirements of the project.

This well-thought-out structure significantly contributes to the overall efficiency and effectiveness of the IoT-based automated plant irrigation system for domestic agriculture. Its incorporation into the system enhances functionality, emphasizing the project's commitment to meeting the unique needs of plant cultivation in a domestic setting.

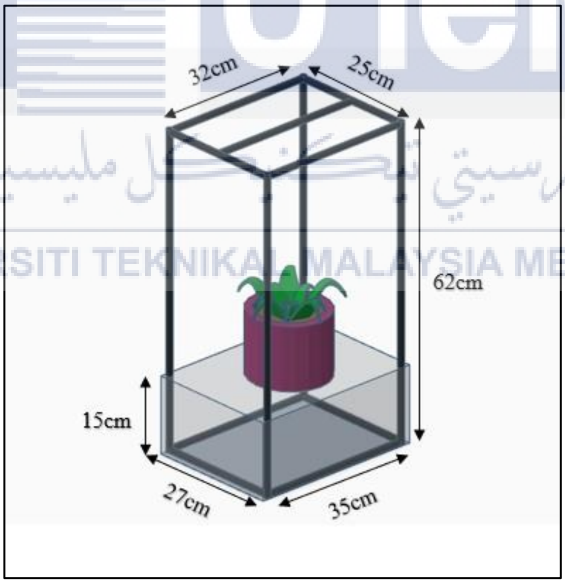


Figure 3.2 Structure Design

3.4 Block Diagram and Wiring Diagram

3.4.1 Block Diagram

In Figure 3.3, the ESP32 microcontroller serves as the main processing unit. It is responsible for interfacing with the various sensors deployed within the plant, collecting data from them, and executing control algorithms based on predefined thresholds and conditions. The ESP32 also enables wireless communication, allowing the system to be remotely monitored and controlled via an internet connection.

The sensors integrated into the system play a vital role in capturing essential environmental parameters. The temperature and humidity sensor (DHT22) provides accurate readings of the ambient temperature and humidity levels, allowing for precise control of the climate around the plant. The light intensity sensor (LDR) detects changes in the illumination within the system, enabling automated lighting control based on natural light conditions. The capacitive soil moisture sensor measures the moisture content in the soil, ensuring that plants are watered appropriately. Additionally, the float sensors are strategically placed in the water tank to monitor water levels for efficient water management.

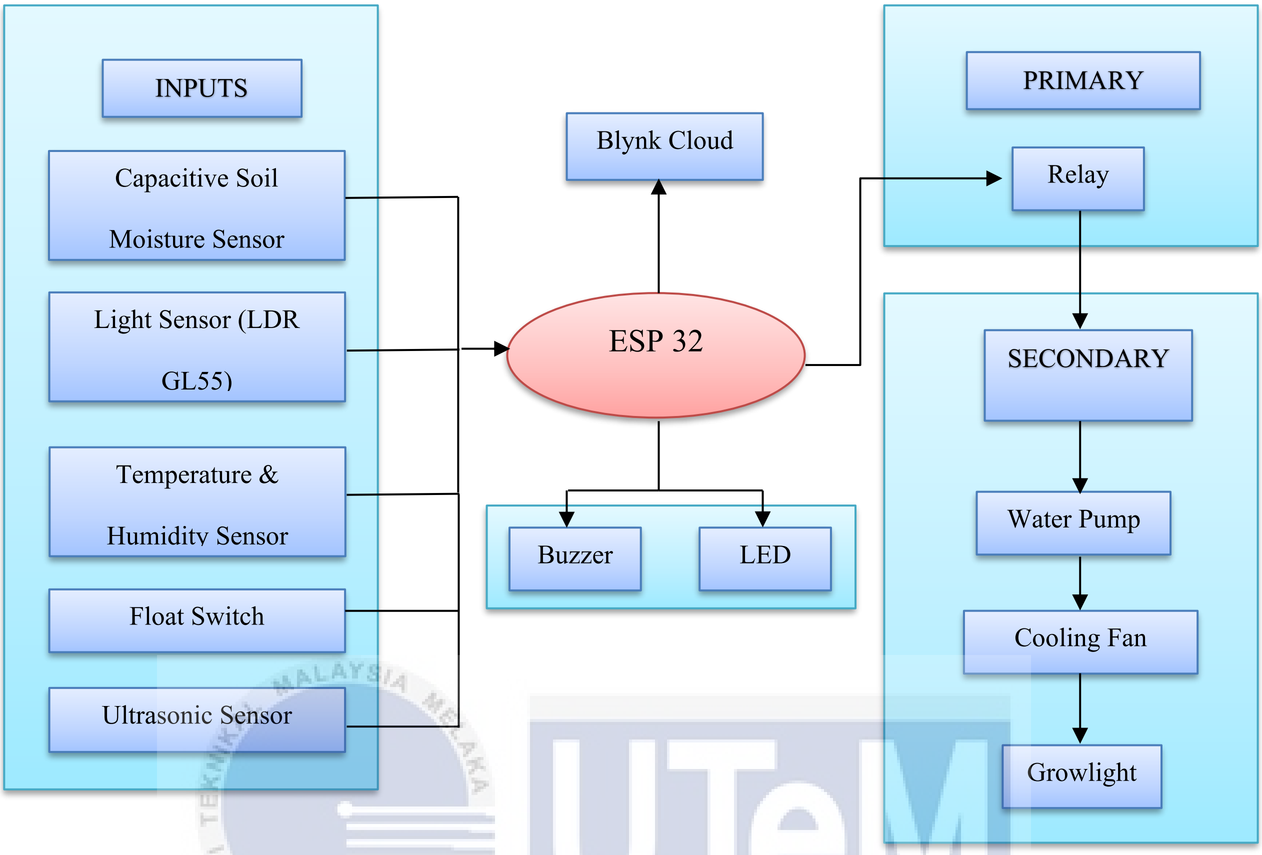


Figure 3.3 System block diagram

3.4.2 Wiring Diagram

In Figure 3.4, the wiring diagram of the irrigation system's wiring is depicted. In this IoT-based automated plant irrigation system, the ESP32 microcontroller receives power through a USB cable. The sensor connections involve the DHT22 temperature and humidity sensor, LDR light sensor, and float switch, which are linked to the 3.3V VCC pin on the ESP32. However, LED and buzzer were connected along with resistor which is linked to 3.3 V VCC pin on the ESP 32. On the user hand, the capacitive soil moisture sensor and ultrasonic sensor are connected to the 5V VCC pin on the ESP32.

Specific pin assignments for each component are as follows: the DHT22 sensor is connected to pin 22, the fans relay to pins 26 and 27, the misting motor relay to pin 12, the LDR light sensor to pin 35, the light relay to pin 14, the capacitive soil moisture sensor to pin 32, and the irrigation pump relay to pin 13. The float switch is connected to pin 23, the LED and buzzer to 18 and 19 respectively. All components, including the ESP32, share a common ground.

The output hardware, comprising the fan, lights, and pumps, is linked to an 8-channel 5V relay controlled by the ESP32. This relay enables the microcontroller to activate or deactivate specific hardware components based on sensor readings and predetermined control logic. Additionally, the output hardware components (fan, lights, and pumps) are connected to a 5V adapter through separate channels from the breadboard.

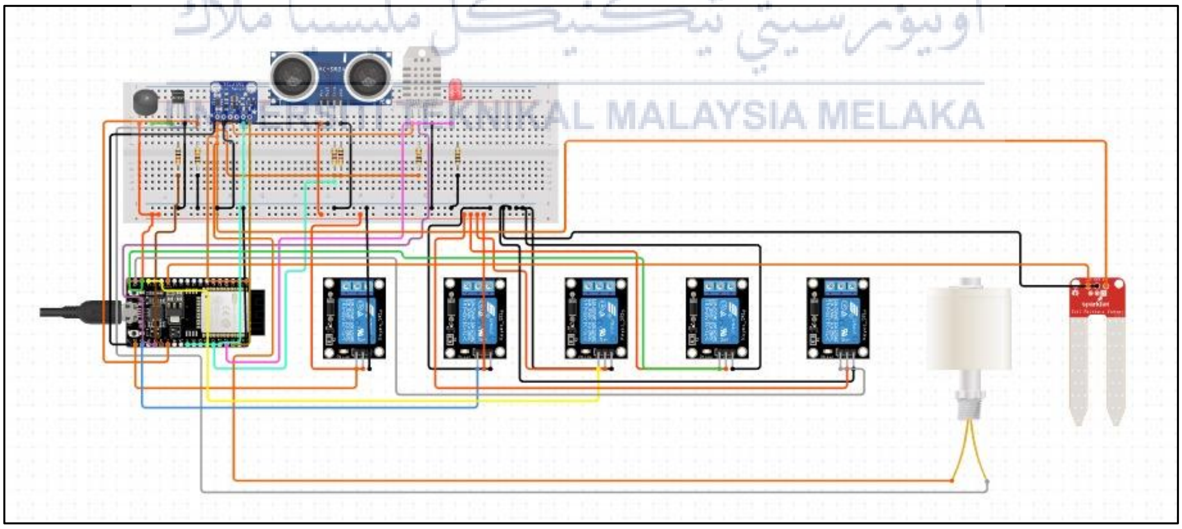


Figure 3.4 Wiring Diagram Using Circuito Simulation

3.5 Hardware Components

This section provides a detailed overview of the hardware components utilized in the IoT-based automated plant irrigation system. Each component plays a specific role in data acquisition, control, and system functionality. The following subsections describe the key hardware components used in the system.

3.5.1 ESP32 Microcontroller

The ESP32, featured in Figure 3.5, acts as the central processing unit in the system, responsible for collecting data from diverse sensors and executing control algorithms based on predefined thresholds. With built-in Wi-Fi and Bluetooth capabilities, the ESP32 facilitates wireless communication with Blynk IoT, enabling remote monitoring and control of the plant's surrounding environment. Its robust processing power and versatility make it an ideal choice for efficiently managing sensor data and executing control operations, contributing to the overall effectiveness of the automated plant irrigation system.

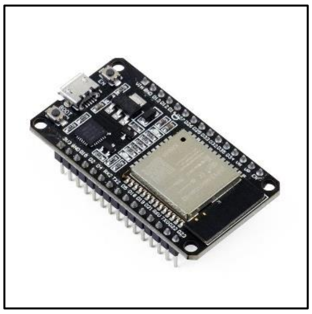


Figure 3.5 ESP 32 Microcontroller

3.5.2 Temperature and Humidity Sensor (DHT22)

The DHT22 sensor, depicted in Figure 3.6, is employed to gauge the ambient temperature and humidity levels surrounding the plant. This sensor furnishes accurate and dependable readings, facilitating meticulous control over the plant's environment. Utilizing a digital interface, the sensor communicates seamlessly with the ESP32 microcontroller, ensuring real-time acquisition of temperature and humidity data. Notably, when the temperature reading recorded by the DHT22 sensor reaches or exceeds 32 degrees Celsius, it activates the Fans and Misting Pump.

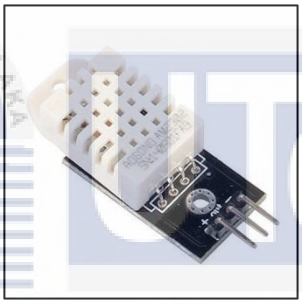


Figure 3.6 DHT 22 Sensor

3.5.3 Light Intensity Sensor (LDR)

The Light Dependent Resistor (LDR), depicted in Figure 3.7, serves to identify fluctuations in light intensity surrounding the plant. This component plays a pivotal role in automating the lighting control system by discerning instances where supplementary artificial lighting becomes necessary. Connected to the ESP32 microcontroller through an analog pin, the LDR enables continuous monitoring of light levels. It functions to activate lights when the detected light levels surpass predetermined thresholds, ensuring an automated response to varying lighting conditions within the plant environment.

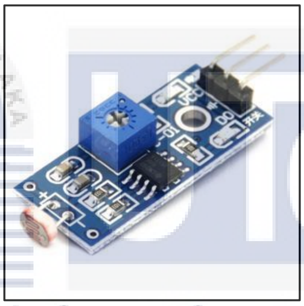


Figure 3.7 LDR Sensor

3.5.4 Capacitive Soil Moisture Sensor

The capacitive soil moisture sensor depicted in Figure 3.8 is designed to gauge the moisture content within the soil, playing a crucial role in guaranteeing optimal water supply for plants by continuously monitoring soil moisture levels. Interfacing with the ESP32 microcontroller through an analog pin connection, the sensor furnishes real-time data on soil moisture. This data is instrumental in facilitating the automated regulation of the irrigation system, ensuring precise control based on the current soil moisture conditions.

Figure 3.8 Capacitive Soil Moisture Sensor

3.5.5 Float Switch

The float switch, depicted in Figure 3.9, serves the purpose of monitoring water levels in the tank. Positioned strategically at the bottom of the tank, this float sensor operates as switch. When the water level drops, they trigger both an LED and a buzzer, providing an alert. Additionally, notification is sent through the Blynk application to prompt the tank refill. To facilitate efficient water management, the float switch is connected to the ESP32 microcontroller through a digital pin.

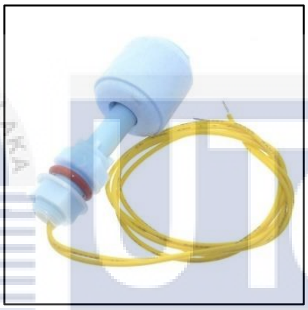


Figure 3.9 Float Switch

3.5.6 Ultrasonic Sensor

The ultrasonic sensor, as depicted in Figure 3.10, is used to calculate, and monitor the height of the plant. Initially, the system's height is manually measured. This value is then subtracted from the distance to an object, determined using ultrasonic sound waves, to ascertain the plant's height. The sensor communicates this height data to the ESP32 microcontroller, connected via a digital pin.

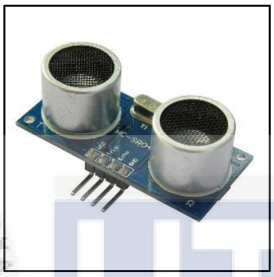


Figure 3.10 Ultrasonic Sensor

3.5.7 Water Pumps

The system incorporates 5V DC water pumps, as depicted in Figure 3.11, designed for misting and irrigation purposes. These pumps play a crucial role in supplying water to the plants and ensuring optimal moisture levels and temperature. Control over these pumps is facilitated by the ESP32 microcontroller, which regulates their operation based on sensor readings. Both the irrigation pump and misting pump are linked to the digital pin of the ESP32 microcontroller through a relay. Specifically, the misting pump activates when the temperature reading surpasses 32 degrees Celsius, while the irrigation pump initiates operation when the soil moisture level reaches 25%. This setup allows for responsive and automated control of the water pumps, contributing to efficient plant care and environmental control.

Figure 3.11 5V DC Water Pump

3.5.8 Fans

The fans depicted in Figure 3.12 are integrated into the system to manage the temperature surrounding the plants. These fans play a crucial role in dispersing excessive heat and promoting ventilation, thereby establishing an optimal environment for plant growth. The operation of these fans is regulated by a relay connected to the ESP32 microcontroller, which is in turn controlled by digital pin inputs based on temperature sensor readings. Specifically, when the temperature reading from the DHT22 sensor equals or exceeds 32 degrees Celsius, the relay triggers the activation of the fans, ensuring effective temperature control within the plant environment.

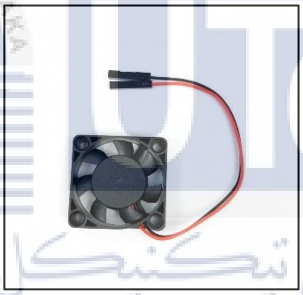


Figure 3.12 5V DC Fan

3.5.9 Grow Light

The 5V plant growth light, depicted in Figure 3.13, serves as supplemental artificial lighting to enhance plant photosynthesis, and stimulate growth. Controlled by the ESP32 microcontroller and connected to a digital pin, the light is activated based on the readings from the Light Dependent Resistor (LDR). Specifically, it is switched on when the LDR reading exceeds 3200, ensuring that the additional light is provided when ambient conditions warrant its contribution to optimal plant development.

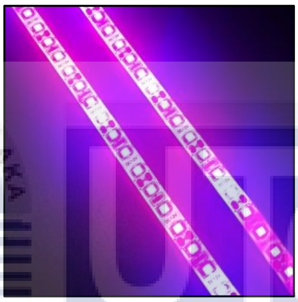


Figure 3.13 5V DC Grow Light

3.6 System Flow Chart

The flowchart presented in Figure 3.14 illustrates the operational framework of the control and monitoring system, highlighting the utilization and status assessment of five distinct sensor types. The system incorporates the following sensors: DHT22 (measuring temperature and humidity), LDR light sensor, capacitive soil moisture sensor, ultrasonic sensor, and float switch. Each sensor contributes uniquely to the acquisition of information and the automation processes within the context of an automated plant irrigation system.

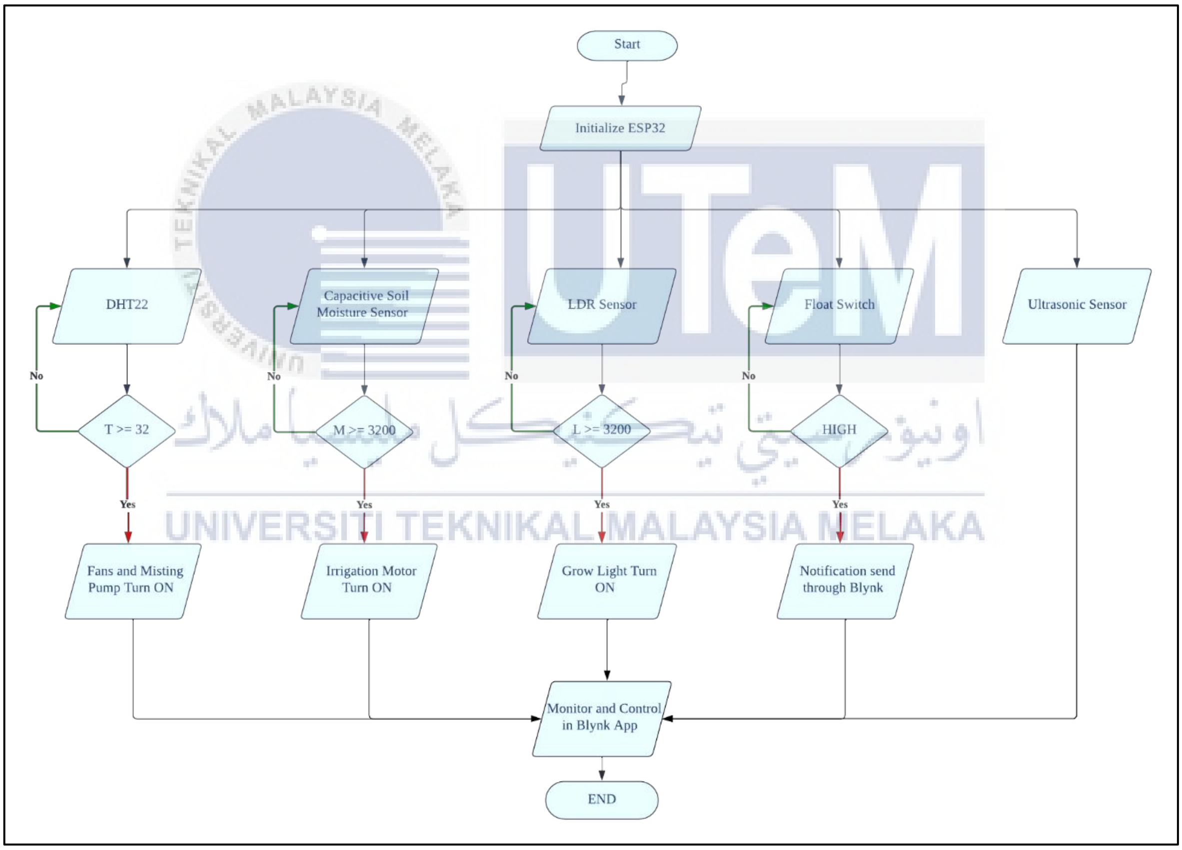


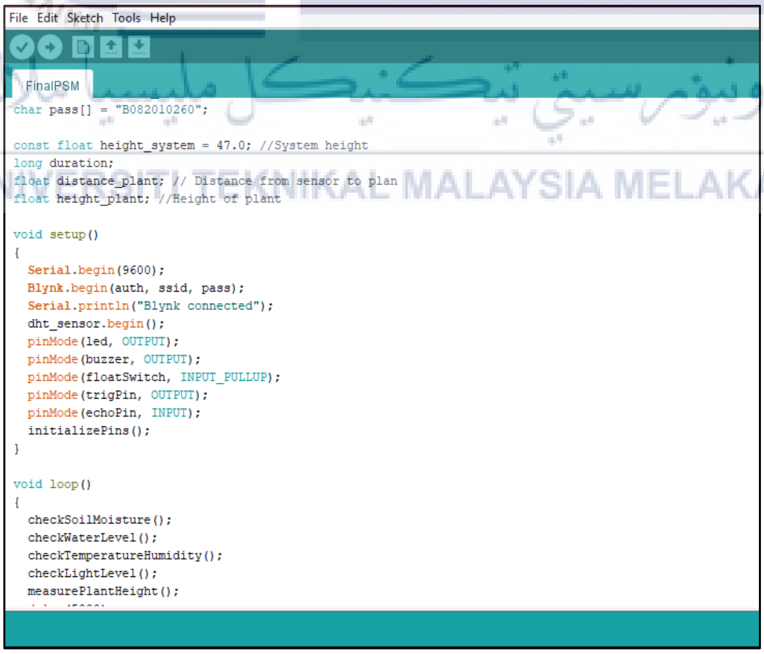
Figure 3.14 System Flowchart

In Figure 3.14, the flowchart delineates the operational sequence of the Automated Plant Irrigation system. The ESP32 microcontroller is initialized and establishes a connection to the internet and the Blynk cloud. Utilizing the DHT22 sensor, the system collects temperature and humidity data, activating the fan and misting pump when the temperature hits 32 degrees Celsius. The fan operates continuously, while the misting pump turns on in tandem. Subsequently, the LDR sensor monitors changes in light intensity around the plants, initiating the grow light when the sensor's analog value reaches 3200 to optimize plant growth. Additionally, the capacitive soil moisture sensor gauges soil moisture levels, triggering the irrigation pump when the moisture value surpasses 3200 to ensure optimal soil conditions for plant growth. The float switch in the water tank maintain stable water levels, with signaling a buzzer and LED activation when in the HIGH position, alerting the user via the Blynk application. Lastly, all the data from the sensor and outputs from the system can be monitored and controlled by the user using the Blynk application.

3.7 Software Implementation

3.7.1 Arduino IDE

The Arduino IDE serves as the programming software for Arduino boards and associated hardware components. Functioning as a desktop application, it facilitates the tasks of code writing, compilation, and code uploading to Arduino and compatible boards. Boasting a user-friendly interface, the IDE provides a rich repository of code examples, board configurations, and comprehensive documentation. Regular updates are implemented to ensure ongoing compatibility with forthcoming projects. Moreover, the framework supports seamless integration with Internet of Things (IoT) applications, making it particularly well-suited for systems such as the IoT-based Automated Plant Irrigation System, as illustrated in Figure 3.15 of the Arduino Framework.



```
char pass[] = "B082010260";

const float height_system = 47.0; //System height
long duration;
float distance_plant; // Distance from sensor to plan
float height_plant; //Height of plant

void setup()
{
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
  Serial.println("Blynk connected");
  dht_sensor.begin();
  pinMode(led, OUTPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(floatSwitch, INPUT_PULLUP);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  initializePins();
}

void loop()
{
  checkSoilMoisture();
  checkWaterLevel();
  checkTemperatureHumidity();
  checkLightLevel();
  measurePlantHeight();
```

Figure 3.15 Arduino IDE

3.7.2 Blynk

Blynk, depicted in Figure 3.16, is an Internet of Things (IoT) platform that empowers users to craft personalized mobile applications for the supervision and control of their hardware devices. Comprising a mobile app, a server, and hardware components, Blynk allows users to design the app interface utilizing widgets, establishing communication channels between these widgets and the hardware via the Blynk server. The server assumes responsibility for managing data exchange, authentication, and security. Hardware devices establish a connection with the server by employing Blynk-compatible firmware. This setup enables users to remotely manipulate their hardware by engaging with the app's widgets, facilitating streamlined development of IoT applications, and offering real-time monitoring capabilities.

☐	Name	Auth Token	Device Owner	Status	Last Reported At	Organization	Actions
	Automated Plant Irrigation System	UtdxvZ845oGn0DfRrpxAGD4F1hD...	gokulansellaperumal98@gmail.c...	Online	3:38 AM Today	My organizat	

Figure 3.16 Blynk IoT Platform

3.8 Project Costing

No	Components	Unit	Cost (RM)
1.	ESP 32	1	29.90
2.	DHT 22	1	28.00
3.	Capacitive Soil Moisture Sensor	1	4.00
4.	Ultrasonic Sensor	1	5.50
5.	LDR GL55	1	4.90
6.	Float Switch	1	4.60
7.	5V Adapter	1	28.00
8.	Jumper wire	as much needed	15.00
9.	Breadboard	2	6.50
10.	5V DC fan	2	20.00
11.	5V submersible water pump	1	3.50
12.	5V aquarium water pump	1	22.80
13.	5V DC grow light	1	13.95
14.	8–channel 5V relay module	1	16.90
15.	Storage tank	2	28.50
16.	PVC conduit pipe and connectors	as much needed	22.80
17.	Plant watering kit (30pcs)	1	17.00
18.	Plant seeds	1	15.00
19.	Nursing pot	1	10.00
20.	Organic soil	1	10.00
TOTAL			306.85

Table 3.1 Project Costing

3.9 System Integration and Testing

System integration encompasses the interconnection of all hardware elements, comprising the ESP32 microcontroller, sensors, and power sources. After the successful integration of these hardware components, the next step involves uploading the requisite software onto the ESP32 microcontroller. Subsequently, the system is prepared for testing and evaluation.

Testing encompasses the validation of the overall system's functionality and performance. This process entails verifying the precision of sensor readings, assessing the responsiveness of pumps, and confirming seamless communication with the Blynk server. Diverse scenarios and environmental conditions are simulated during testing to guarantee that the system functions according to its intended design.

During this chapter, a comprehensive account of the software implementation procedures will be provided. This includes ESP32 programming, data acquisition, communication protocols, formulation and application of control algorithms, and the overall integration and testing of the system. These details aim to highlight the effective execution of the IoT-based automated plant irrigation system.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This section unveils the findings derived from the IoT-driven automated plant irrigation system, shedding light on the comprehensive analysis of the accumulated data. The system incorporates a diverse array of sensors, including those for temperature, humidity, soil moisture, light, and ultrasonic measurements. These sensors have consistently gathered information pertaining to the ambient conditions enveloping the plant. Subsequently, the gathered data undergoes scrutiny to evaluate the system's efficacy and its influence on the overall growth of the plant.

4.2 Prototype Outcome

This is the outcome of the developed system’s prototype in terms of software and hardware. This IoT-based automated plant irrigation system is incorporated using sensors and components which are temperature sensor DHT 22, LDR Sensor, Capacitive Soil Moisture sensor and ultrasonic sensor. The main control unit is done using the micro-controller ESP32 which is purposed to trigger the outputs which will alert the user with notifications when the parameters are reached. Figure 4.1 below shows the prototype of the system and Figure 4.2 below shows the IoT alert notification.

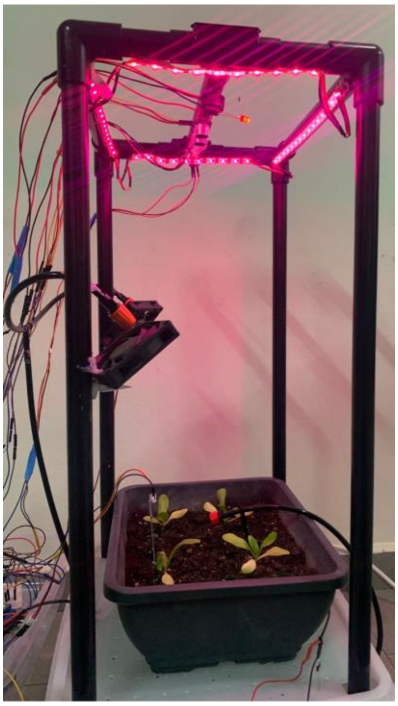
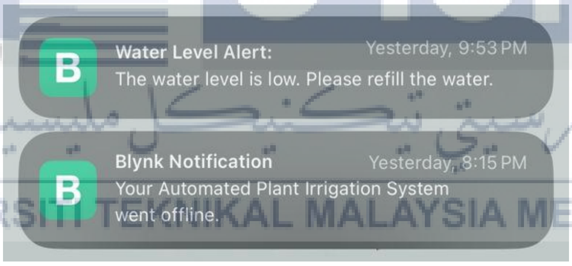


Figure 4.1 Prototype of the system



Water Level Alert: Yesterday, 9:53 PM
The water level is low. Please refill the water.

Blynk Notification Yesterday, 8:15 PM
Your Automated Plant Irrigation System went offline.

Figure 4.2 IoT alert notification

4.3 Data Collection and Analysis

4.3.1 Temperature Analysis

As per the data presented in Table 4.1, the primary objective of the system revolves around establishing a regulated environment conducive to optimal plant growth, with the maintenance of elevated temperatures identified as a pivotal factor in attaining this goal. Temperature emerges as a critical determinant in the growth and development of plants, exerting influence over a spectrum of physiological processes. The ensuing discussion outlines several ways in which temperature impacts the plants within the system.

i. Photosynthesis: The rate of photosynthesis, the process by which plants convert light energy into chemical energy for growth, is directly affected by temperature. The optimal temperature range for photosynthesis in most plants is between 68°F (20°C) and 86°F (30°C). Temperatures in this range can boost the rate of photosynthesis while promoting plant growth.

ii. Metabolism: Temperature influences plant metabolic processes such as nutrient absorption, enzyme activity, and respiration. Warmer temperatures generally increase the metabolic rate of plants, allowing for better nutrient uptake and overall growth.

Transpiration: The process by which plants release water vapor through their leaves is known as transpiration. Higher temperatures in a greenhouse can cause increased transpiration rates. This can be beneficial because it maintains humidity levels and prevents excessive moisture buildup, lowering the risk of fungal diseases

SYSTEM TEMPERATURE °C			
TIME	DAY 1	DAY 2	DAY 3
0:00	28.2	28.1	27.2
1:00	28.1	27.4	26.3
2:00	28.1	27.6	26.9
3:00	27.9	27	25.3
4:00	27.9	26.8	25
5:00	26.7	26.9	25.4
6:00	26.4	26.5	25.8
7:00	27.5	26.8	27.7
8:00	34.2	33.4	34.7
9:00	41.9	40.6	42.6
10:00	45	42.3	44.84
11:00	47.6	43.4	46.9
12:00	48.9	45.2	50.1
13:00	48.7	45.3	49.5
14:00	47.5	46.6	47.8
15:00	46.8	45.3	47.5
16:00	45.7	44.5	45.4
17:00	41.2	40.4	40.8
18:00	37.1	35.5	35.9
19:00	32.7	32.9	31.9
20:00	30.7	30.4	30.6
21:00	30.3	29.7	29.5
22:00	29.5	29.4	29.2
23:00	28.4	28.9	29

Table 4.1 Temperature reading from the system

According to Figure 4.3, the system can maintain higher temperatures environment, resulting in an optimal growing environment for plants. Higher temperatures improve plant growth by promoting photosynthesis, metabolic processes, and nutrient uptake. Increased transpiration aids in humidity regulation and the prevention of fungal diseases.

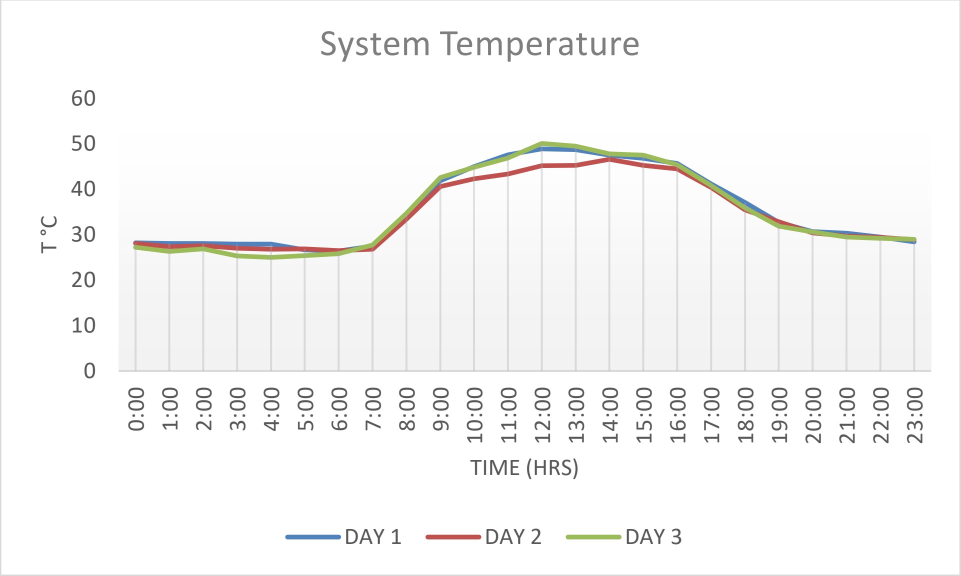
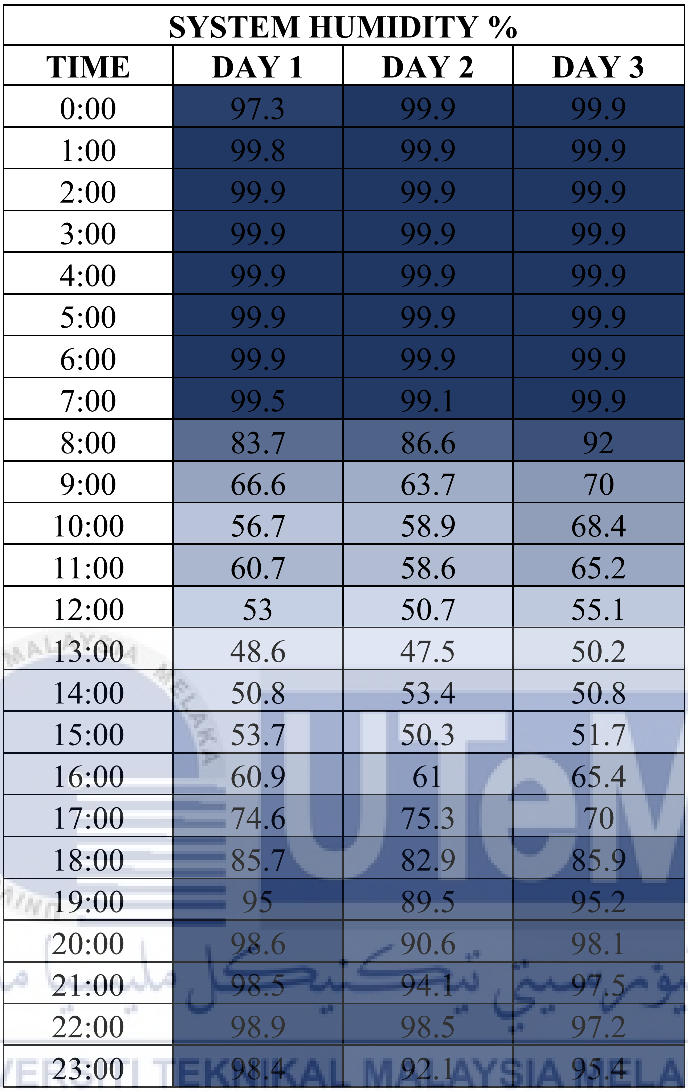


Figure 4.3 Temperature graph from the system

4.3.2 Humidity Analysis

Based on the Table 4.2 shows data for humidity from the system, here's an analysis of the humidity levels over the course of three days:

The system humidity remains consistently high throughout the day, with values close to or at 99.9% for most hours. During the nighttime (0:00 to 6:00), the humidity levels remain consistently high, indicating a stable and moist environment within the plant in the system. There is a slight dip in humidity during the morning hours (8:00 to 9:00) of Day 1, Day 2, and Day 3, where the values drop to around 83.7 %, 86.6 %, and 92 % respectively. This may be due to ventilation or external factors influencing the humidity levels.The humidity levels in the greenhouse gradually increase during the afternoon hours and remain high until the evening. Then the humidity started to stabalize to normal range after 19:00



SYSTEM HUMIDITY %			
TIME	**DAY 1**	**DAY 2**	**DAY 3**
0:00	97.3	99.9	99.9
1:00	99.8	99.9	99.9
2:00	99.9	99.9	99.9
3:00	99.9	99.9	99.9
4:00	99.9	99.9	99.9
5:00	99.9	99.9	99.9
6:00	99.9	99.9	99.9
7:00	99.5	99.1	99.9
8:00	83.7	86.6	92
9:00	66.6	63.7	70
10:00	56.7	58.9	68.4
11:00	60.7	58.6	65.2
12:00	53	50.7	55.1
13:00	48.6	47.5	50.2
14:00	50.8	53.4	50.8
15:00	53.7	50.3	51.7
16:00	60.9	61	65.4
17:00	74.6	75.3	70
18:00	85.7	82.9	85.9
19:00	95	89.5	95.2
20:00	98.6	90.6	98.1
21:00	98.5	94.1	97.5
22:00	98.9	98.5	97.2
23:00	98.4	92.1	95.4

Table 4.2 Humidity reading from the system

Based on Figure 4.3 shown below, the system maintains a high level of humidity, providing a favorable environment for plant growth. The consistent high humidity levels indicate efficient moisture retention within the plant. Monitoring and maintaining optimal humidity levels are essential for promoting plant health and growth, as different plants have specific humidity requirements.

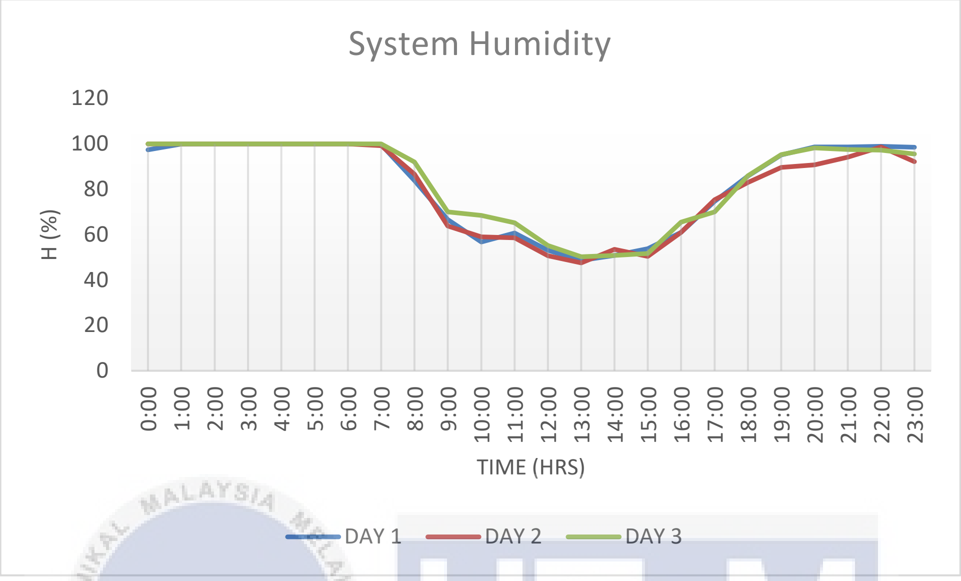


Figure 4.4 Humidity graph from the system

4.3.3 Soil Moisture Content Analysis

In this section, data collected from the soil moisture sensor in the system is presented and analyzed in Table 4.3. The soil moisture sensor continuously measures the moisture content in the soil, providing valuable insights into the water availability for plant growth.

SYSTEM SOIL MOISTURE CONTENT			
TIME	DAY 1	DAY 2	DAY 3
0:00	65.4	65.8	65.6
1:00	65.3	65.8	65.9
2:00	65.4	65.3	65.7
3:00	65.3	65.5	65.1
4:00	65.2	65.2	65.2
5:00	65.3	65.9	65.4
6:00	65.5	65.3	65.8
7:00	65.6	65.9	65.3
8:00	65	65.7	65.7
9:00	72.4	73.2	72.6
10:00	72.1	72.8	72.3
11:00	68.4	68.5	69.3
12:00	66.3	66.5	67.4
13:00	65.4	65.1	65.4
14:00	65.3	65.2	65.5
15:00	65.7	65.7	65.9
16:00	64.3	65.8	64.3
17:00	64.5	65.7	64.4
18:00	64.9	65.2	65.2
19:00	65.2	65.1	64.3
20:00	65.4	65.7	65.6
21:00	64.8	65.9	65.5
22:00	65.6	65.7	65.7
23:00	65.3	65.6	65

Table 4.3 Soil moisture content of the plant in the system

The data in Table 4.3 show that the system can maintain a more stable moisture content in the soil. The moisture content of the plant in the system remains relatively constant throughout the day, with only minor fluctuations. The percentages range from 65 % to 65.9 %. This stability implies that the environment of the system has better control over moisture levels, reducing the impact of external factors like evaporation and weather conditions. The soil moisture reading is increasing by the range of 70 % to 73 % around the time (8:00 to 9:00) is just because the scheduled watering for the plant occurs. So then, the content of water in the soil moist. During the night and early morning hours (0:00 to 6:00), the soil of the plant in the system have higher moisture content. During these periods, soil consistently retains higher moisture levels. This shows that the system is efficient at retaining moisture, resulting in a more stable environment for plant growth.

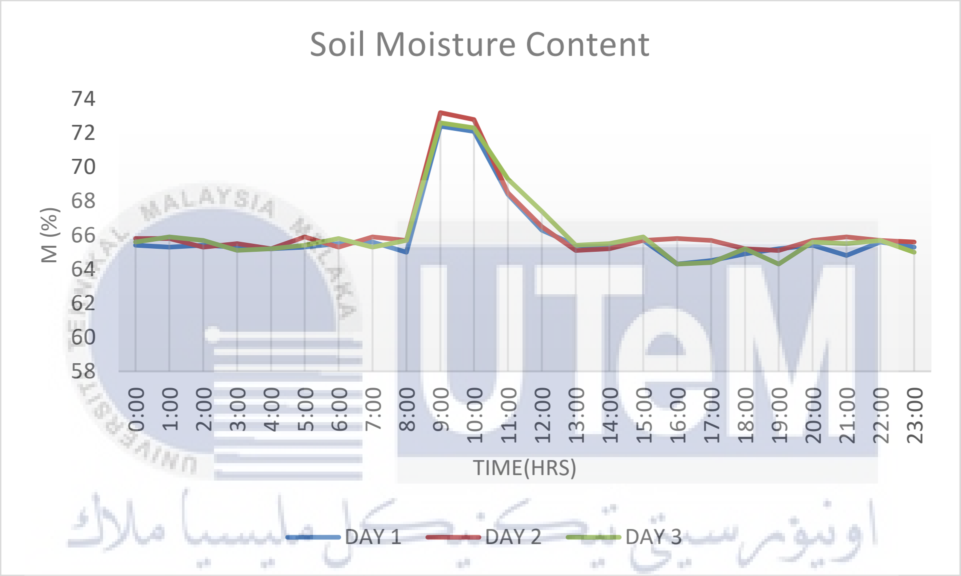


Figure 4.5 Soil moisture content of the plant in the system

4.3.4 Light Intensity and Plant Growth Analysis

In this section, data collected from the ldr sensor and ultrasonic sensor in the system is presented and analyzed in Figure 4.6 and Figure 4.7 respectively. The ldr sensor continuously measures the light intensity in the system, providing healthy plant growth. The ultrasonic sensor continuously measures and calculates the height of the plant to observe the growth of the plant.

According to Figure 4.6, light intensity measurements were recorded at 4-hour intervals. The morning sunlight was utilized by the plant for photosynthesis, promoting its growth. During nighttime, a grow light was employed to sustain the photosynthesis process.

Figure 4.7 illustrates the plant's height measured over time to monitor its growth. The plant required a total of 20 days to reach harvest (shown in Figure 4.8), with the initial 4 days dedicated to seedling development from the seed. Additionally, maintaining a minimum distance of 3 cm to 5 cm between plants was crucial to ensure each received adequate sunlight for healthier growth.

In summary, the use of a grow light proved more effective in enhancing plant growth and yielding favorable results. Furthermore, the ultrasonic sensor played a crucial role in providing real-time updates on the plant's growth progress.

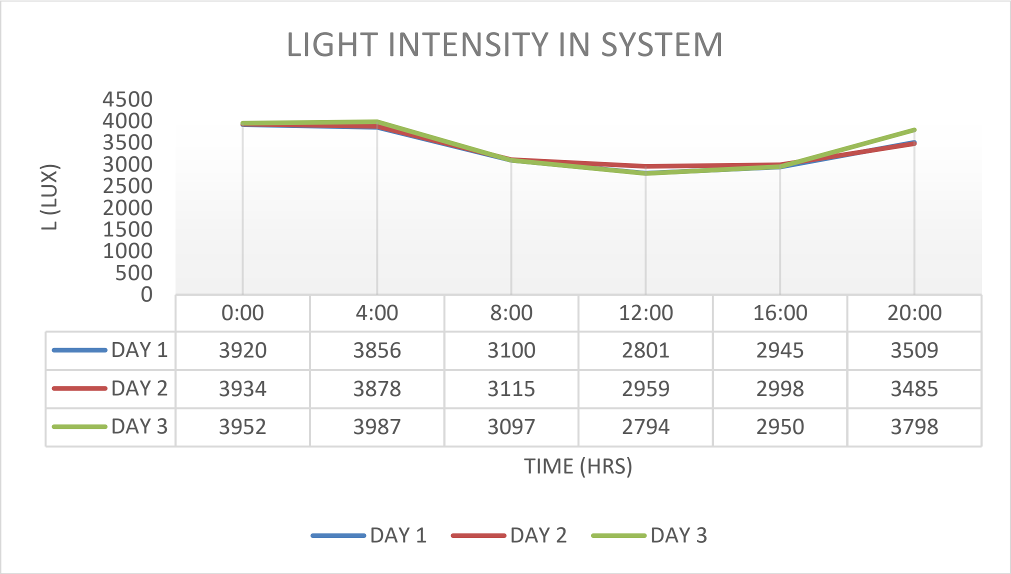


Figure 4.6 Graph of light intensity in system

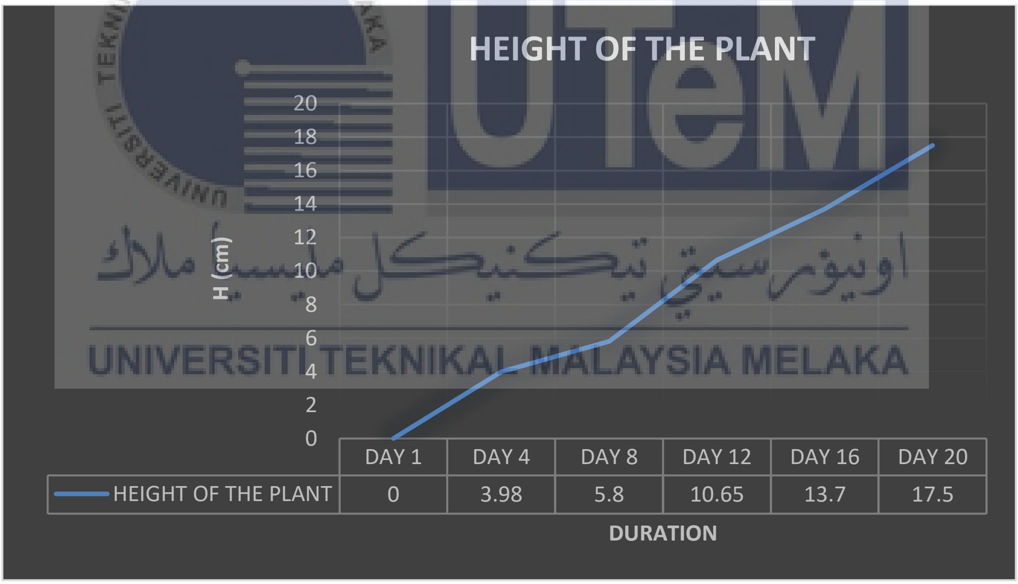


Figure 4.7 Graph the height of the plant

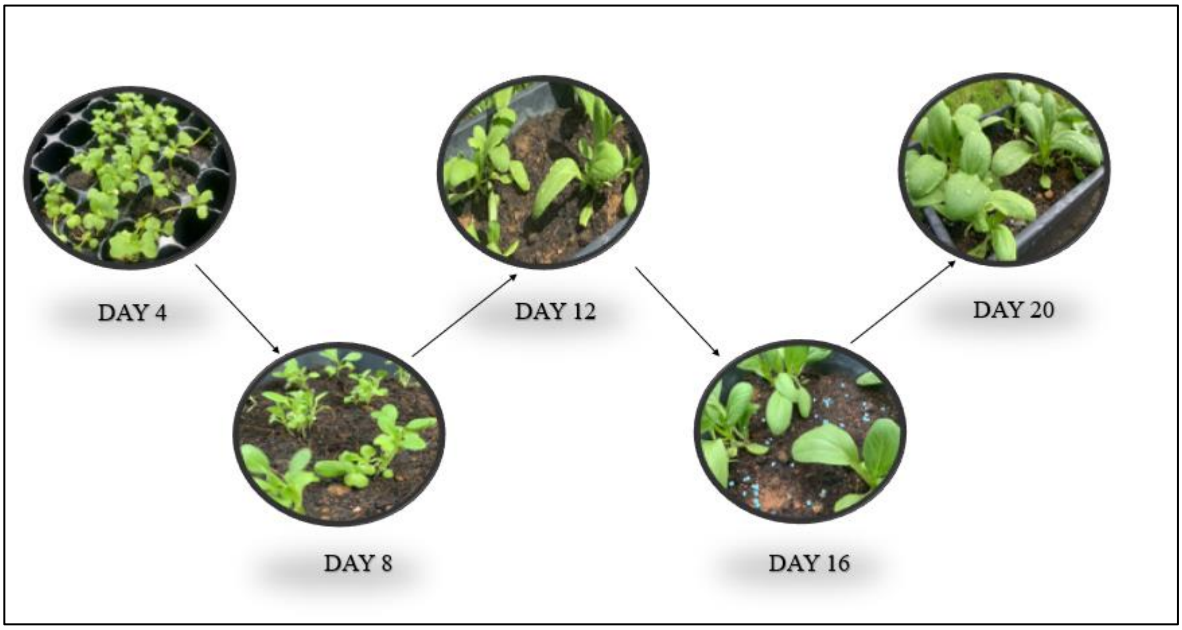


Figure 4.8 Growth of the Plant in 20 days

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the design and implementation of an automated plant irrigation system using sensors and IoT technology have shown immense potential in addressing the challenges of traditional plant irrigation methods. The system successfully monitored soil moisture levels, temperature, and humidity in real-time, allowing for efficient and precise irrigation control. The integration of a grow light component further enhanced plant growth by providing optimal lighting conditions. Through the utilization of IoT technology, the system demonstrated improved water usage efficiency, reduced water consumption, and increased crop yields.

The project highlighted the importance of sustainable development in the field of agriculture and plant cultivation. By employing sensors and IoT technology, the system promoted sustainable practices by optimizing water usage and reducing wastage. It contributed to addressing global issues such as water scarcity and environmental conservation by minimizing the ecological footprint associated with plant irrigation.

5.2 Future Recommendations

To build upon the achievements of the current project, several recommendations for future research and development have been identified, focusing on crucial aspects of sustainability and efficiency. A primary area of improvement centers around energy efficiency. Exploring innovative techniques and technologies will enable researchers to find more efficient ways to power the system, ultimately reducing energy consumption and lessening its environmental impact. This research aligns with the increasing global emphasis on sustainable practices and green technologies, contributing to the long-term sustainability of agricultural systems.

Another promising avenue for expansion involves incorporating smart water management strategies. Expanding on the system's existing capabilities, researchers can explore features like rainwater harvesting, water recycling, and intelligent irrigation scheduling based on real-time weather forecasts. These additions aim to enhance water usage efficiency in agriculture, addressing the growing strain on global water resources. Implementing smart water management practices holds the potential to optimize agricultural operations significantly, promoting responsible and resource-conscious practices.

Additionally, the thesis suggests exploring the integration of fertigation and pestigation into the system. Fertigation involves delivering nutrients to crops through irrigation systems, while pestigation focuses on the intelligent application of pesticides. By utilizing advanced algorithms and sensors, the system can be enhanced to precisely administer fertilizers and pesticides, tailoring their distribution based on specific crop needs. This targeted approach not only improves crop health but also minimizes the environmental impact associated with excessive or indiscriminate use of agricultural inputs. This dual approach to smart fertilization and pest control contributes to sustainable farming practices and ecological balance.

In conclusion, the outlined future research and development recommendations provide a comprehensive guide for advancing the capabilities of the agricultural system. Improvements in energy efficiency, smart water management, and intelligent fertigation and pestigation collectively contribute to a more sustainable, resource-efficient, and environmentally conscious agricultural framework. These areas of exploration hold significant potential for shaping the future of precision agriculture in alignment with broader global sustainability goals.

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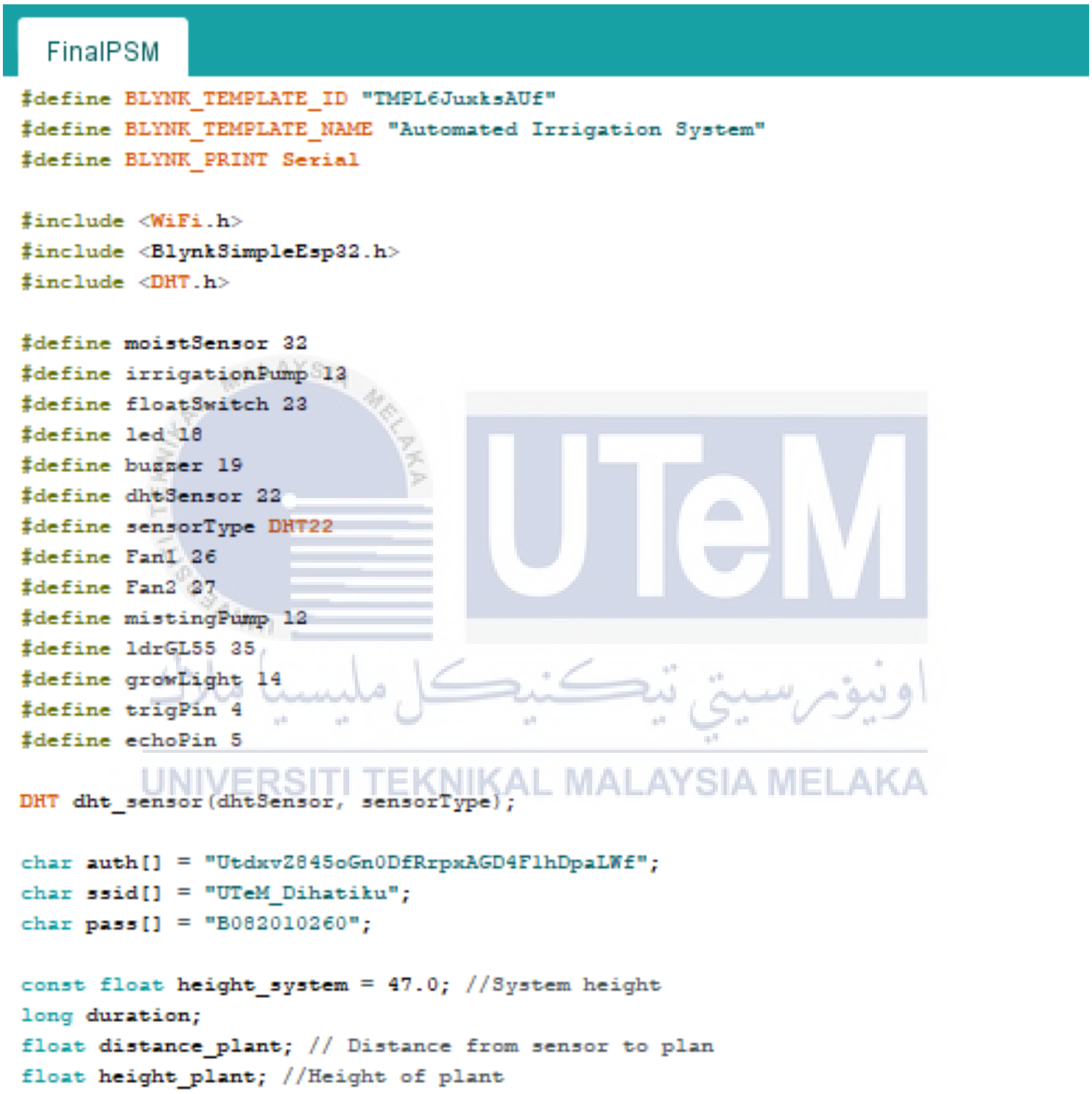
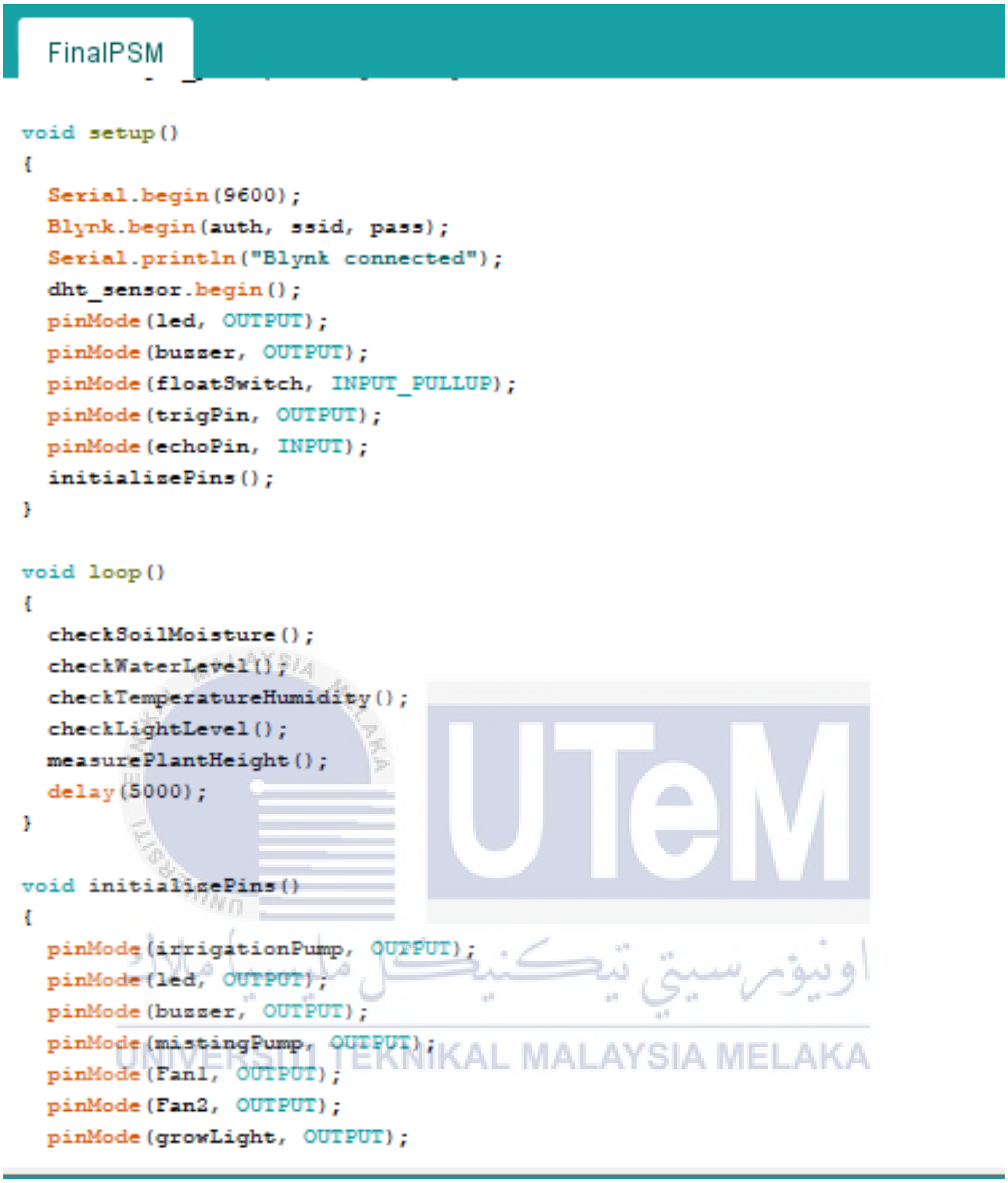
APPENDICES

Appendix A Coding Program for ESP32

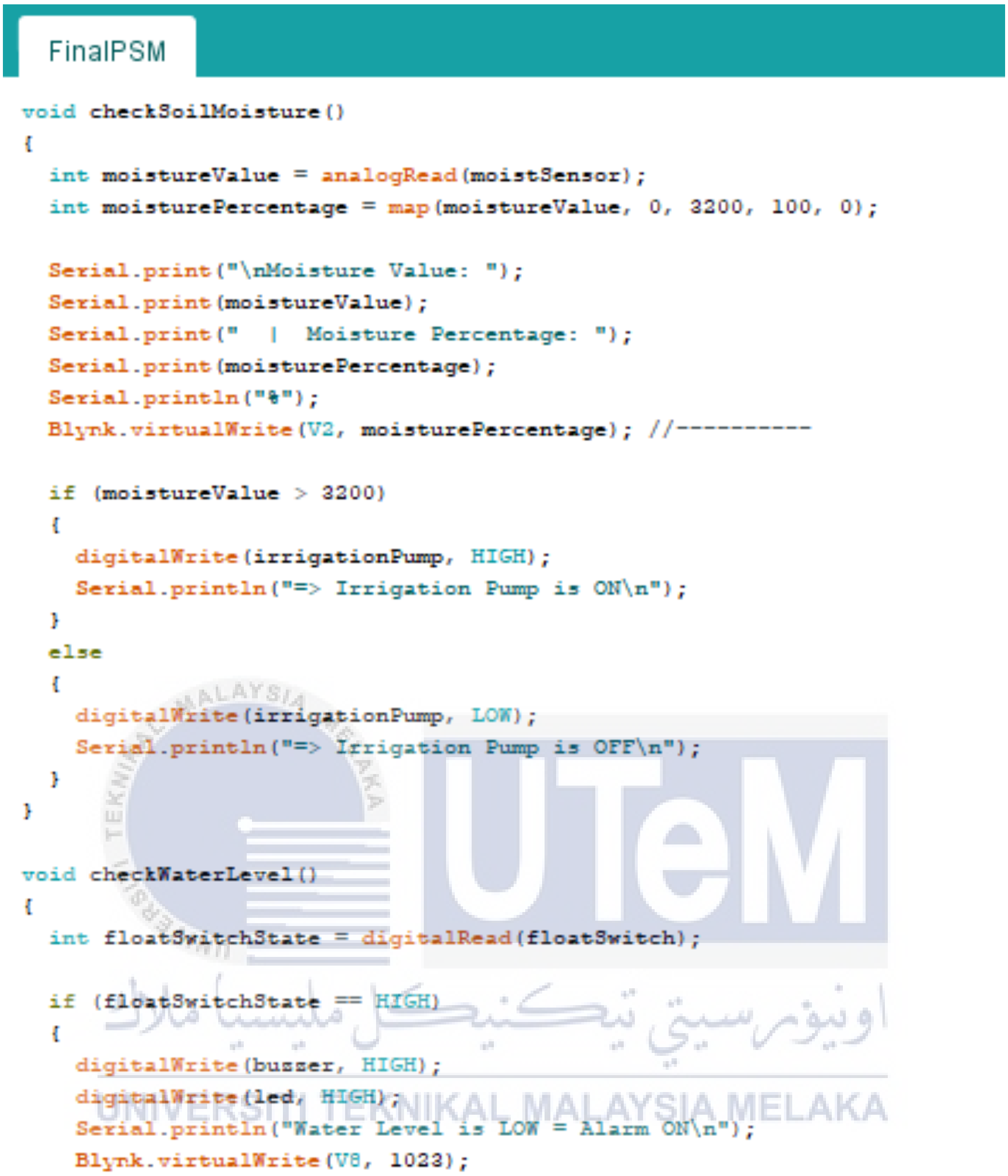


```
#define BLYNK_TEMPLATE_ID "TMPL6JuxksAUf"
#define BLYNK_TEMPLATE_NAME "Automated Irrigation System"
#define BLYNK_PRINT Serial

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

#define moistSensor 32
#define irrigationPump 13
#define floatSwitch 23
#define led 18
#define buzzer 19
#define dhtSensor 22
#define sensorType DHT22
#define Fan1 26
#define Fan2 27
#define mistingPump 12
#define ldrGL55 35
#define growLight 14
#define trigPin 4
#define echoPin 5

DHT dht_sensor(dhtSensor, sensorType);

char auth[] = "UtdxvZ845oGn0DfRrpxAGD4FlhDpaLWf";
char ssid[] = "UTeM_Dihatiku";
char pass[] = "B082010260";

const float height_system = 47.0; //System height
long duration;
float distance_plant; // Distance from sensor to plan
float height_plant; //Height of plant
```



```
void setup()
{
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
  Serial.println("Blynk connected");
  dht_sensor.begin();
  pinMode(led, OUTPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(floatSwitch, INPUT_PULLUP);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  initializePins();
}

void loop()
{
  checkSoilMoisture();
  checkWaterLevel();
  checkTemperatureHumidity();
  checkLightLevel();
  measurePlantHeight();
  delay(5000);
}

void initializePins()
{
  pinMode(irrigationPump, OUTPUT);
  pinMode(led, OUTPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(mistingPump, OUTPUT);
  pinMode(Fan1, OUTPUT);
  pinMode(Fan2, OUTPUT);
  pinMode(growLight, OUTPUT);
```

```
  digitalWrite(irrigationPump, LOW);
  digitalWrite(led, LOW);
  digitalWrite(buzzer, LOW);
  digitalWrite(mistingPump, LOW);
  digitalWrite(Fan1, LOW);
  digitalWrite(Fan2, LOW);
  digitalWrite(growLight, LOW);
}

BLYNK_WRITE(V6) {  // Button to control Fan1
  int fan1State = param.asInt();
  digitalWrite(Fan1, fan1State);
}

BLYNK_WRITE(V7) {  // Button to control Fan2
  int fan2State = param.asInt();
  digitalWrite(Fan2, fan2State);
}

BLYNK_WRITE(V4) {  // Button to control Misting Pump
  int mistingPumpState = param.asInt();
  digitalWrite(mistingPump, mistingPumpState);
}

BLYNK_WRITE(V5) {  // Button to control Irrigation Pump
  int irrigationPumpState = param.asInt();
  digitalWrite(irrigationPump, irrigationPumpState);
}

BLYNK_WRITE(V10) {  // Button to control Grow Light
  int growLightState = param.asInt();
  digitalWrite(growLight, growLightState);
}
```



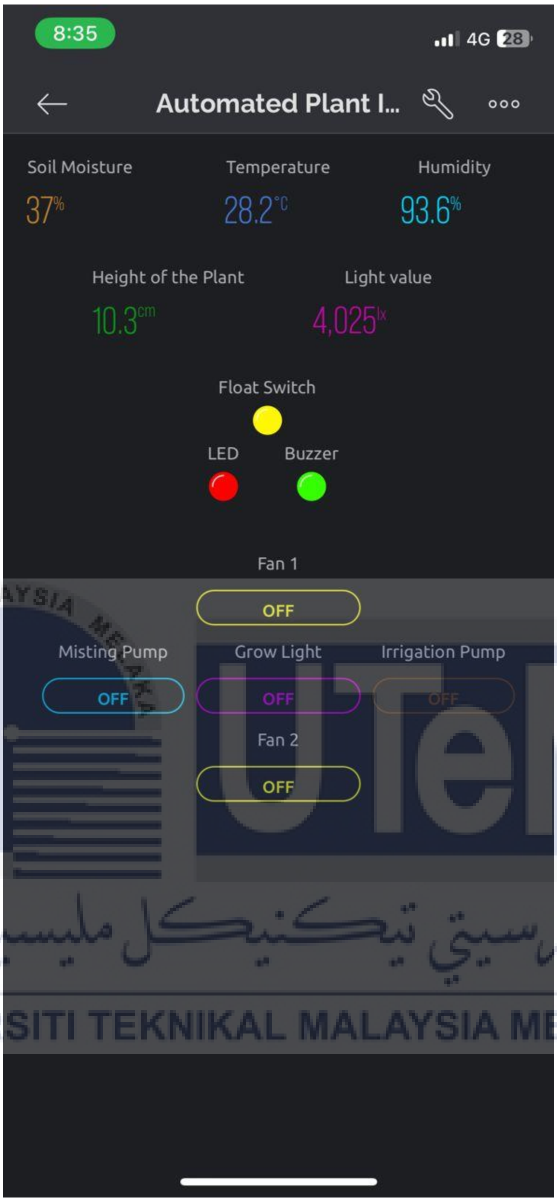
```
void checkSoilMoisture()
{
  int moistureValue = analogRead(moistSensor);
  int moisturePercentage = map(moistureValue, 0, 3200, 100, 0);

  Serial.print("\nMoisture Value: ");
  Serial.print(moistureValue);
  Serial.print("  |  Moisture Percentage: ");
  Serial.print(moisturePercentage);
  Serial.println("%");
  Blynk.virtualWrite(V2, moisturePercentage); //----------

  if (moistureValue > 3200)
  {
    digitalWrite(irrigationPump, HIGH);
    Serial.println("=> Irrigation Pump is ON\n");
  }
  else
  {
    digitalWrite(irrigationPump, LOW);
    Serial.println("=> Irrigation Pump is OFF\n");
  }
}

void checkWaterLevel()
{
  int floatSwitchState = digitalRead(floatSwitch);

  if (floatSwitchState == HIGH)
  {
    digitalWrite(buzzer, HIGH);
    digitalWrite(led, HIGH);
    Serial.println("Water Level is LOW = Alarm ON\n");
    Blynk.virtualWrite(V8, 1023);
```

```
    Blynk.virtualWrite(V9, 1023);
    Blynk.virtualWrite(V11, 1023);
  }
  else
  {
    digitalWrite(buzzer, LOW);
    digitalWrite(led, LOW);
    Serial.println("Water Level is NORMAL = Alarm OFF\n");
    Blynk.virtualWrite(V8, 0);
    Blynk.virtualWrite(V9, 0);
    Blynk.virtualWrite(V11, 0);
  }
}

void checkTemperatureHumidity()
{
  float humi = dht_sensor.readHumidity();
  float temp = dht_sensor.readTemperature();

  if (isnan(humi) || isnan(temp))
  {
    Serial.println("Error reading from DHT22 sensor!");
    return;
  }

  Serial.print("Humidity: ");
  Serial.print(humi);
  Serial.print("%  |  Temperature: ");
  Serial.print(temp);
  Serial.println(" °C");

  if (temp > 32 && humi < 60)
  {
    digitalWrite(mistingPump, HIGH);
```

```
    digitalWrite(Fan1, HIGH);
    digitalWrite(Fan2, HIGH);
    Serial.println("=> Cooling System is ON\n");
  }
  else
  {
    digitalWrite(mistingPump, LOW);
    digitalWrite(Fan1, LOW);
    digitalWrite(Fan2, LOW);
    Serial.println("=> Cooling System is OFF\n");
  }
   Blynk.virtualWrite(V0, temp); //----------
   Blynk.virtualWrite(V1, humi); //----------
}

void checkLightLevel()
{
  float lightValue = analogRead(ldrGL55);

  Serial.print("\nAnalog Value = ");
  Serial.print(lightValue);
  Serial.print("\n");

  if (lightValue > 3150)
  {
    Serial.println("=> Light turned on = Dark");
    digitalWrite(growLight, HIGH); // Turn on grow light
    Serial.println("Grow light is ON");
  }
  else
  {
    Serial.print("=> Light turned off = ");
    digitalWrite(growLight, LOW); // Turn off grow light
    Serial.println("Grow light is OFF");
```

```
    if (lightValue > 2000)
      Serial.println("Light");
    else if (lightValue > 800)
      Serial.println("Bright");
    else if (lightValue > 40)
      Serial.println("Very Bright");
    else
      Serial.println("Extremely Bright");
  }
   Blynk.virtualWrite(V12, lightValue); //---------
}

void measurePlantHeight()
{
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance_plant = duration * 0.034 / 2;
  height_plant = height_system - distance_plant;
  Serial.print("\nPlant height : ");
  Serial.print(height_plant);
  Serial.println(" cm");
  Blynk.virtualWrite(V3, height_plant); //----------
}
```

Appendix B Blynk GUI



Soil Moisture 37%

Temperature 28.2°C

Humidity 93.6%

Height of the Plant 10.3cm

Light value 4,025lx

Fan 1 OFF

Misting Pump OFF

Grow Light OFF

Irrigation Pump OFF

Fan 2 OFF