# DESIGN AND DEPLOYMENT OF AN IOT-BASED AGRICULTURE PESTICIDE SPRAYING SYSTEM FOR CUCUMIS MELO

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# DESIGN AND DEPLOYMENT OF AN IOT-BASED AGRICULTURE PESTICIDE SPRAYING SYSTEM FOR CUCUMIS MELO

**CHAN YAN KANG**

**A report submitted
in partial fulfilment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours**



**Faculty of Electrical Technology and Engineering**

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**2024**

**DECLARATION**

I declare that this thesis entitled "DESIGN AND DEPLOYMENT OF AN IOT-BASED AGRICULTURE PESTICIDE SPRAYING SYSTEM FOR CUCUMIS MELO" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : CHAN YAN KANG

Date : 16 / 6 / 2024

**APPROVAL**

I hereby declare that I have checked this report entitled "DESIGN AND DEPLOYMENT OF AN IOT-BASED AGRICULTURE PESTICIDE SPRAYING SYSTEM FOR CUCUMIS MELO", and in my opinion, this thesis fulfils the partial requirement to be awarded the degree of Bachelor of Mechatronics Engineering with Honours

| | | |
|---|---|---|
| Signature | : | |
| Supervisor Name | : | Prof. Madya Dr. Muhammad Herman Bin Jamaliddin |
| Date | : | 16 / 6 / 2024 |

## DEDICATIONS

To my beloved mother and father

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# ABSTRACT

In this project, it is aims to design and deployment of an IoT-based agriculture pesticide spraying system for Cucumis Melo. The motivation of this project is to solve the manpower shortage in agriculture sector and as a step to speed up the agriculture sector in Malaysia towards industry 4.0. Mechanism function in agriculture pesticide spraying system is the important factor in design and development of an integrated agriculture pesticide spraying system. Generally, there are two types of pesticide spraying system which are mobile-type and fixed-type. Both pesticide spraying systems have their own advantages and disadvantages. Hence, a hybrid-type pesticide spraying system is the final solution to this problem as it integrates the advantages and overcomes the disadvantages of both pesticide spraying system. Therefore, the objectives in this project are to design the structural of IoT-based agricultural pesticide spraying system utilizing linear motion mechanism, develop an IoT-based agricultural pesticide spraying system and construct its mechanism and analyse the performance of agricultural pesticide spraying system in the aspects of its efficiency and reliability. With clear and obvious objectives, the methods to achieve the goals are planned and conducted. To design the pesticide spraying system, the conceptual design of the system is sketched in SolidWorks software for hardware part while the schematic diagram of the system is designed in Proteus software for software part. Then, bill of materials is listed out for the deployment of the system and the control panel of the system is designed and built with Arduino Cloud. To develop a reliable pesticide spraying system, an exclusive PCB for the system is designed by using Altium Designer software. After that, the analysis of the agriculture pesticide spraying system proceed in the experiment planned to obtain important data for further improvement. From the findings, the percentage of slippage on timing belt is 3.52% which considered as minimal slippage in timing belt. For the functionality of system, the probability of system failure is obtained in 0% which had proven the feasible design and develop in IoT-based agriculture pesticide spraying system. For functionality of automation control of system, the system had operated punctually and periodically in all the time slots set in the IoT platform.

# *ABSTRAK*

Dalam projek ini, ia bertujuan untuk mereka bentuk dan melaksanakan sistem penyemburan racun perosak berasaskan IoT untuk Cucumis Melo. Motivasi projek ini adalah untuk menyelesaikan kekurangan tenaga kerja dalam sektor pertanian dan sebagai langkah untuk mempercepat sektor pertanian di Malaysia ke arah Industri 4.0. Secara umumnya, terdapat dua jenis sistem penyemburan racun perosak iaitu jenis mudah alih dan jenis tetap. Kedua-dua sistem penyemburan racun perosak ini mempunyai kelebihan dan kekurangan masing-masing. Oleh itu, sistem penyemburan racun perosak jenis hibrid adalah penyelesaian akhir kepada masalah ini kerana ia menggabungkan kelebihan dan mengatasi kekurangan kedua-dua sistem penyemburan racun perosak tersebut. Objektif dalam projek ini adalah untuk mereka bentuk struktur sistem penyemburan racun perosak pertanian berasaskan IoT yang menggunakan mekanisme gerakan linear, membangunkan sistem penyemburan racun perosak pertanian berasaskan IoT dan membina mekanismenya serta menganalisis prestasi sistem penyemburan racun perosak pertanian dari segi kecekapan dan kebolehpercayaannya. Dengan objektif yang jelas, kaedah untuk mencapai matlamat tersebut dirancang dan dilaksanakan. Untuk mereka bentuk sistem penyemburan racun perosak, reka bentuk konseptual sistem dilakar dalam perisian SolidWorks untuk bahagian perkakasan manakala diagram skematik sistem direka dalam perisian Proteus untuk bahagian perisian. Kemudian, senarai bahan disediakan untuk pelaksanaan sistem dan panel kawalan sistem direka dan dibina dengan Arduino Cloud. Untuk membangunkan sistem penyemburan racun perosak yang boleh dipercayai, PCB eksklusif untuk sistem direka menggunakan perisian Altium Designer. Selepas itu, analisis sistem penyemburan racun perosak pertanian diteruskan dalam eksperimen yang dirancang untuk mendapatkan data penting untuk penambahbaikan selanjutnya. Daripada penemuan, peratusan gelinciran pada tali sawat adalah 3.52% yang dianggap sebagai gelinciran minimum pada tali sawat. Bagi fungsi sistem, kebarangkalian kegagalan sistem diperoleh pada 0% yang membuktikan reka bentuk dan pembangunan sistem penyemburan racun perosak pertanian berasaskan IoT yang berdaya maju. Untuk fungsi kawalan automasi sistem, sistem telah beroperasi dengan tepat dan berkala dalam semua slot masa yang ditetapkan di platform IoT.

# TABLE OF CONTENTS

**LIST OF TABLES**

# LIST OF FIGURES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| IP | - | Ingress Protection Rating |
| PA | - | Polyamide |
| ABS | - | Acrylonitrile Butadiene Styrene |
| UV | - | Ultraviolet |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Agriculture is defined as the practice of cultivating the soil for growing the crops and the rearing of animals to provide food [1]. It has been an essential part of human civilization for thousands of years up until now. Nowadays, even though the world generally focuses on the development of industrial sector but agriculture sector also being concentrated because agriculture sector acts as a backbone of a country which can lead to many of advantages and solve for many problems [2-4].

Agriculture sector plays a significant role in food production which can maintain the food supply in the local or global market [5][6]. A stable and consistent food supply is important as it was able to control the price of food directly and ensure the consumers obtain the food with low and reasonable price. Therefore, it can relieve the burden for low-income population and help to mitigate food price rising issue around the world.

From a national perspective, a strong agriculture sector is crucial for national food security because of low dependency on imported food [7]. Normally, the flood, drought, locusts, war and other factors around the world will cause food shortage problems in a country especially for those import food to sustain their food supply in the long term [8]. This is because the global food supply chain is being affected when the disasters is happening. Hence, a strong agriculture sector is important to avoid food shortage problem occurs and provide significant portion of food to maintain national food supply stability which become less vulnerable to external food supply disruption.

Moreover, agriculture sector is a key for economic contribution as it has high potential to increase the gross domestic product (GDP) [9]. It is undeniable that agriculture products are the most common products of a country's export portfolio because the agriculture goods always in high demand [5]. Additionally, agriculture sector is important in poverty alleviation as it generates a lot of income opportunities for rural communities due to agriculture sector had derived many of related industries such as agribusiness, food processing, tourism and others [5].

In 21st century, Fourth Industrial Revolution (IR 4.0) in agriculture sector is a main topic to enhance the working scheme and improve human life. Thus, agriculture sector is going to be digitalised which Internet of Things (IoT), big data, artificial intelligence (AI) and automation are integrated. Then, most of the agriculture technology will be based-on IoT technology which can optimise the automation level and productivity compared to the existing combination of agriculture and machine technology with human-controlled [10][11]. Therefore, IR 4.0 in agriculture is believed can help agriculture sector leaps to a new high level which benefits for the mankind. In this thesis, the experiment target is Cucumis melo where an IoT-based agriculture pesticide spraying system is designed and developed to control the pests from destroying the Cucumis melo.

## 1.2 Motivation

The project of design and deployment of an IoT-based agriculture pesticide spraying system for Cucumis melo aims to solve the manpower shortage and as a step to speed up agriculture sector in Malaysia towards industry 4.0. As a developing country, manpower is important to drive the agricultural works such as farming, fertilizing, spraying pesticide and harvesting in Malaysia because the lack of automation system. However, employment in the agriculture sector declines obviously from 1991 to 2021.


*Source: World Bank (modeled ILO estimate)*

**Figure 1.1: Employment in Agriculture in Malaysia in 1991 to 2021 (% of Total Employment)**

The high unemployment rate resulted in the growth in the agriculture sector slowdown and falling behind neighbouring country [13].



Undoubtedly, agriculture sector as a main sector has high potential to help Malaysia in increasing gross domestic product (GDP) and the transition to high-income status. This can be proven by 45.4% share of GDP in the agriculture sector in 1961 which had recorded $863 million in a total of $1.9 billion [14].


*Source: World Bank National Account Data and OECD National Account Data Files*

**Figure 1.2: Agriculture, Forestry and Fishing, Value Added (% of GDP)**

However, the GDP shared by agriculture decreases continuously and recorded less than 10% since 2000 [15]. Hence, adoption of industrial revolution 4.0 (IR4.0) in the agriculture sector is crucial as it could minimize the production cost of crops, improve the quality of agricultural products, reduce the dependency of labour force and so on, finally improve the GDP share in the agriculture sector [16].

This project consists of *smart technology and systems* in 10 of socio-economic drives and *sensor technology* in 10 of science and technology drivers in MySTIE (Science, Technology, Innovation and Economic) as the IoT-based agriculture pesticide spraying system is equipped with sensor for autonomic operation. Figure 1.3 shows the relationship between smart technology and sensor technology in MySTIE.

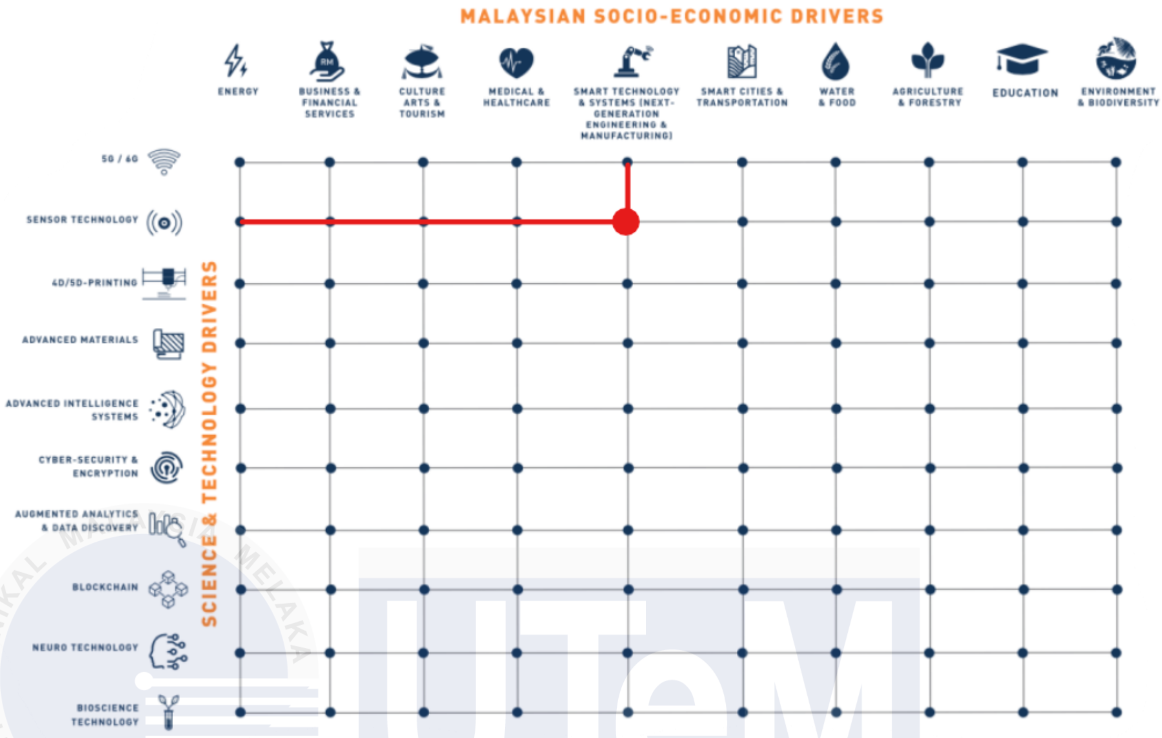



**Figure 1.3: MySTIE**



This project also consists of *decent work and economic growth*, the 8th goal in SDGs (Sustainable Development Goals) as it has high potential to mitigate manpower shortage from decrease the labour force dependency meanwhile create more high-skill level and high- income careers. Figure 1.4 shows the logo of decent work and economic growth.

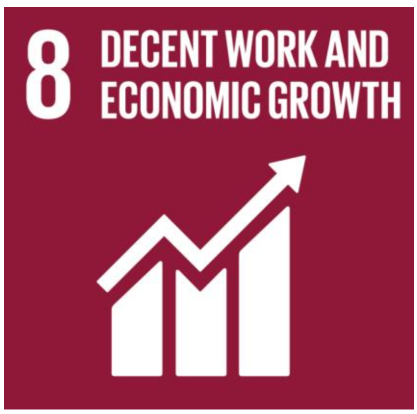



**Figure 1.4: Decent Work and Economic Growth**

## 1.3 Problem Statement

There is a most important factor leading to the design and development of an integrated agriculture pesticide spraying system using IoT-based technology which is the mechanism function in agriculture pesticide spraying system. Due to Cucumis melo is a trailing plant, hence it needs specific pesticide spraying mechanisms differ in spraying angle, distance and volume in order to achieve a comprehensive protection layer on Cucumis melo plant. Generally, there are both mobile-type and fixed-type pesticide spraying systems being utilized in the agriculture sector as shown in Figure 1.5 and Figure 1.6. Both systems have their own advantages and disadvantages. For fixed-type agriculture pesticide spraying system, it has quite similar design compared to irrigation system which each of the nozzles are implemented at a fixed place. The pesticide is sprayed towards the crops through the set-up nozzles in the fixed direction. This system has a simple design and the pesticide applied area is wide enough through the increase of nozzles, but it is hard to apply the pesticide efficiently as the system is immobilized. For mobile-type pesticide spraying system, drone-type pesticide spraying system is the best representative to this type of system. This system can apply the pesticide efficiently because of its mobility, however it needs quite large area for moving, so it is not suitable to be applied at limited area. To solve the problems stated above, a hybrid-typed of pesticide spraying system is design to integrate both of their strengths meanwhile eliminate their weaknesses.

**Figure 1.5: Fixed-Typed Pesticide Spraying System**

**Figure 1.6: Mobile-Typed Pesticide Spraying System**

**Table 1.1 : The Advantages and Disadvantages of Fixed-Typed and Mobile-Typed Spraying System**

| System Advantages and Disadvantages \ Types of Pesticide Spraying | **Fixed-Typed** | **Mobile-Typed** |
|---|---|---|
| **Advantages** | Non-limited tank capacity | Multi directional spraying |
| | Suitable for limited space operation | Available for multitasking |
| | Simple on operation control | Wide-area coverage |
| **Disadvantages** | Fixed directional spraying | Limited tank capacity |
| | Focus on single task | Not suitable for limited space operation |
| | Limited-area coverage | Complex on operation control |

## 1.4 Objective

The objectives in this project are:

1. To design the structural of IoT-based agricultural pesticide spraying system utilizing linear motion mechanism.

2. To develop an IoT-based agricultural pesticide spraying system and construct its mechanism.

3. To analyse the performance of agricultural pesticide spraying system in the aspects of its efficiency and reliability.

## 1.5 Scope of Project

There are some limitations of study of this project:

1. This project focuses on the design and development of pesticide spraying system.

2. The experiment target is Cucumis Melo.

3. This project is carried out in Cucumis Melo plots.

4. The total length of pesticide spraying system is about 5 m.

5. Total of 20 samples is taken in each of the analysis parts.

6. This project takes 6 months to be completed.

## 1.6 Report Outline

The outline of the project as follows:

Chapter 1 illustrates the introduction of the project. It includes the background about agriculture, the motivation leads to this project, problem statement related to the design and development of agriculture pesticide spraying system and the objectives of this project. Also, the scope of the project section had listed all the limitations in this project to give a clear and obvious understanding for all the readers.

Chapter 2 illustrates the study on literature review. Previous research and studies conducted by professionals regarding the linear motion mechanism, types of microcontrollers, types of motors and types of sensors are discussed in this section. All the information is then gathered and synthesized to find out the best solution for the issues discussed.

Chapter 3 illustrates the entire project workflow and the design of methods to carry out the objectives stated previously. Each objective has its respective proposed method along with the required equipment and orderly procedures. The Gantt Chart regarding the project is shown in this section for better understanding of the flow of this project.

Chapter 4 illustrates the achievement of the methods discussed in Chapter 3. The results obtained are analysed and discussed for further improvement on the methodology to carry out the objectives in the project.

Chapter 5 illustrates the conclusion of the overall project. This section consists of the results on the project and recommendations to improve the topic being investigated. Meanwhile, the further improvement on this project is discussed to give a sense on the requirements and modifications.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter provides the studies of literature reviews from many of the professionals to find out the best design of the IoT-based agriculture pesticide spraying system.

## 2.2 Cucumis Melo

Cucumis melo, sometimes known as melon as shown in Figure 2.1, is a type of trailing plant in the Cucurbitaceae family. It needs vertical support structure to help the sprawling of vines and saving the space such as fence, rope, wall and others as shown in Figure 2.2. Additionally, the vertical growth on Cucumis melo can improve air circulation around the plant to reduce the disease risk by keeping the fruits off the ground (keep away from the pest on the ground) [17].

Cucumis melo typically take around 2-3 month to grow and harvest. However, it is susceptible to various diseases, especially Fusarium wilt which is a disease where the wilting spreads to the whole plant and the leaves start to die off without turning yellow at the beginning. This disease is caused by fungal pathogen Fusarium oxysporum which should be controlled by using biocontrol agents, including Trichoderma harzianum, Pochonia chlamydosporia, and Gliocladium virens [18].

Other than that, Cucumis melo also susceptible to many of pests such as thrips, spider mites, aphids, melon fruit fly, cucurbit powdery mildew and melonworms [19][20]. Basically, chemical control is the common method to exterminate the pests, but it easily causes contamination on melon due to excessive pesticide usage. Hence, the exploration on precise control on the volume of pesticide to protect Cucumis melo from the pest but not inflicts human health is important.

**Figure 2.1: Cucumis Melo**

**Figure 2.2: The Rope as Vertical Support for Cucumis Melo Growth**

## 2.3 Linear Motion Mechanism

### 2.3.1 Linear Motor

A linear motor as shown in Figure 2.3 is an electromagnetic device that generates straight-line motion rather than circular motion. Its main components are a stator and a mover, which interact via electromagnetic induction principles. Linear motors, as opposed to traditional motors with mechanical linkages, do not require intermediary components, resulting in a more direct and efficient conversion of electrical energy into linear motion.

A linear motor's basic operation includes the interplay of magnetic fields. The stator generates a fixed magnetic field, whereas the mover generates a moving magnetic field. When current travels through the stator windings, it creates a magnetic field that interacts with the mover's magnetic field. This contact generates a force that propels the mover along the stator's length. In the aspect of performance, different magnets arrangement will definitely results in different performance of control so that the design of magnets arrangement is an important study to improve the present linear motor operation [21][22].

There are many advantages of linear motors where linear motors offer unrivalled precision and accuracy in motion control. This makes them perfect for applications requiring precise placement and controlled movement, such as manufacturing and robotics. Furthermore, linear motors require less maintenance than typical rotary motors since they have fewer mechanical components and sources of friction. As a result, dependability improves and operating lifespans extend.

The introduction of linear motors heralded a new age of efficiency, accuracy, and adaptability in a variety of sectors. Linear motor uses are projected to develop as technology advances, pushing innovation and advancements in automation, transportation, and beyond.



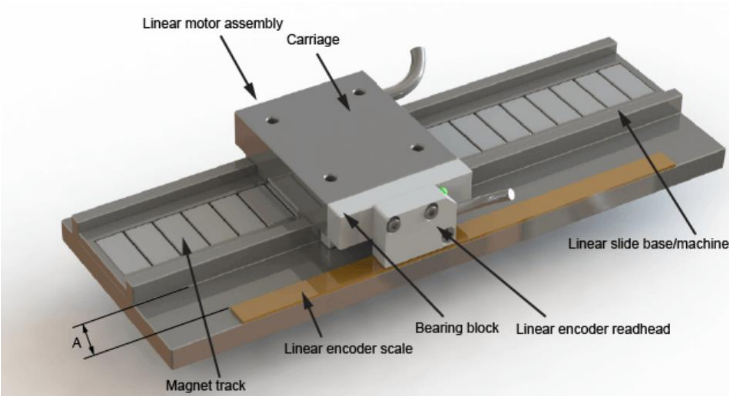



**Figure 2.3: Linear Motor**

### 2.3.2 Timing Belt and Pulley

The timing belt and pulley system as shown in Figure 2.4 is intended to convey rotational motion from one shaft to another while converting it to synchronous linear motion. The timing belt, a toothed belt composed of a durable material like rubber, and pulleys, also known as sprockets, with teeth that mesh with the belt, are crucial components of this system.

For the advantage of timing belt and pulley system, the toothed design of the belt and pulleys guarantees accurate motion synchronization. This is critical in applications requiring precise positioning and timing, such as CNC machines and robots. When compared to systems with friction-based components, the low slippage between the belt and pulleys results in improved efficiency.

By consideration, timing belt has better performance compared to V-belt due to transmission belt looseness factor. Hence, many of the machines will choose timing belt as the first choice in implementation as precision control in timing belt.

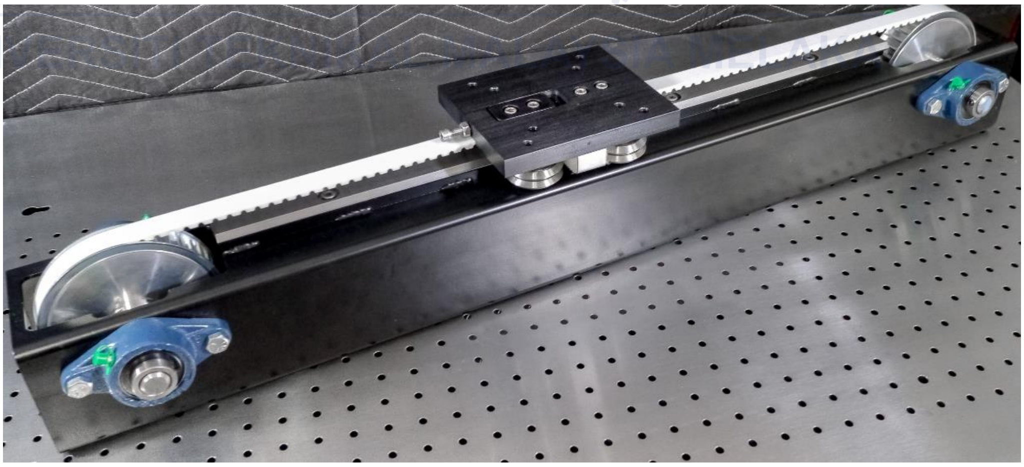


**Figure 2.4: Timing Belt and Pulley**

### 2.3.3 Rack and Pinion

The rack and pinion system as shown in Figure 2.5 is the interaction of a linear gear, called a rack, and a rotary gear, called a pinion. The rack is a straight-toothed bar, usually made of metal or other robust material, and the pinion is a tiny gear with teeth that mesh with the racks. As the pinion spins, its teeth connect with the rack's teeth, converting rotational motion into linear motion.

The working principle of rack and pinion system brings advantages from several aspects. One of benefits is its simplicity and efficiency. The rack and pinion system's simple design adds to its ease of production, installation, and maintenance. The direct transfer of rotary to linear motion also improves its efficiency. Besides that, the rack and pinion's toothed engagement enables precise control over linear movement. This capability is critical in applications requiring precision and controlled motion, such as steering systems and CNC machines [23][24].

Rack and pinion system always applied in many of fields such as automobile, household and others. For example, rack and pinion system is applied in steering system nowadays due to its simplicity and dependability .

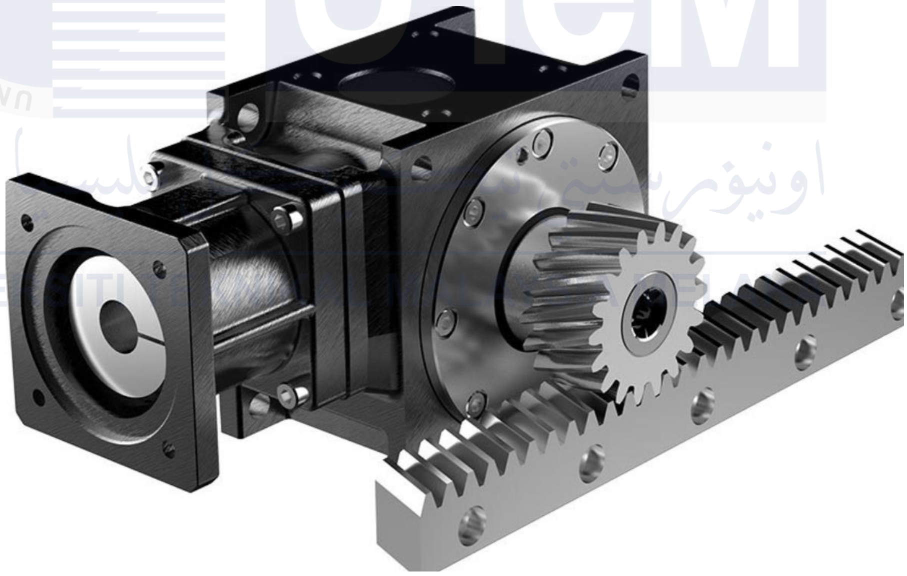


**Figure 2.5: Rack and Pinion**

### 2.3.4 Lead Screw

A lead screw as shown in Figure 2.6 is a threaded rod that connects to a corresponding threaded nut. The rod and nut threads are finely machined to provide for seamless engagement. The nut moves down the length of the lead screw as it turns, converting rotational action into linear motion. The lead is the distance the nut moves in one rotation of the lead screw, and it is a vital parameter in determining the system's accuracy.

For the advanced improvement on lead screw system, magnetic lead screw is introduced. A magnetic lead screw combines the properties of a standard lead screw with the effect of magnetic forces. A threaded rod, a nut with embedded magnets, and a stator with coils are typical components of the system. A magnetic field is created when electric current flows through the coils in the stator. Because of the magnetic interaction between the stator and the magnets in the nut, the nut moves along the threaded rod. The magnetic lead screw has overcome the weakness of conventional lead screw such as friction, noise, heat generation and others [25][26].

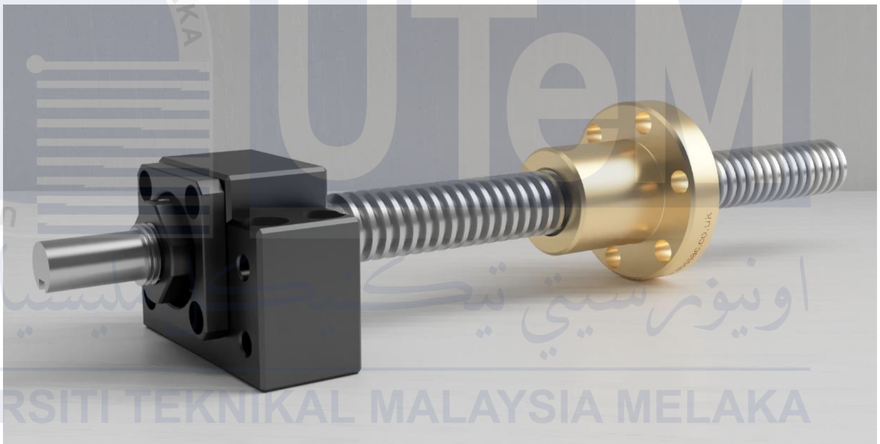


**Figure 2.6: Lead Screw**

## 2.4 Types of Microcontrollers

### 2.4.1 Arduino UNO

The Arduino UNO as shown in Figure 2.7 is an open-source microcontroller board that has become a staple for electronics enthusiasts, amateurs, and professionals alike. The Arduino UNO, designed with simplicity and adaptability in mind, enables users to bring their creative ideas to life through a user-friendly platform that seamlessly blends hardware and software.

The Arduino UNO is built on the ATmega328P microprocessor, giving it a tough and dependable alternative for a variety of projects. What distinguishes Arduino is its user-friendly environment, which streamlines the process of creating code and uploading it to the board. The Arduino IDE (Integrated Development Environment) is a user-friendly interface for both novice and professional developers.

Arduino UNO are applied in many of the project such as automatic room temperature control system which the Arduino UNO as microcontroller used along with temperature sensor [27]. Also, the automatic irrigation system also implemented by using Arduino UNO due to the low cost and wide versatile in Arduino UNO[28].


**Figure 2.7: Arduino UNO**

### 2.4.2 ESP32 Microcontroller

The ESP32 as shown in Figure 2.8 is a strong and adaptable component that has expanded the capabilities of embedded systems. The ESP32, created by Espressif Systems, has acquired popularity because to its dual-core processor, built-in wireless networking, and extensive collection of peripherals.

Due to it is able in wireless connectivity, hence ESP32 can be related to many of the projects such as monitoring photovoltaic panels via low-power Bluetooth communication, hazard detection with ESP32 and LoRa and others [29][30].

**Figure 2.8: ESP32 Development Board**

### 2.4.3 Raspberry Pi

The Raspberry Pi, a credit card-sized single-board computer created by the Raspberry Pi Foundation as shown in Figure 2.9, has become a ubiquitous force in the realm of DIY computing and embedded systems. The Raspberry Pi, with its small size and impressive capabilities, serves as a versatile platform for a wide range of applications, from educational initiatives introducing programming and electronics to students all over the world to sophisticated projects ranging from home automation and media centres to Internet of Things (IoT) solutions. Its wide connection and compatibility for several operating systems make it an accessible and powerful tool that has captivated the imagination of enthusiasts, educators, and professionals alike, democratising computing and stimulating innovation in a variety of disciplines.

Usually, Raspberry Pi involves in the project that needs more advanced processing capability. For example, machine learning based project and deep learning system are able in Raspberry Pi platform [31][32].

**Figure 2.9: Raspberry Pi**

## 2.5 Types of Motors

### 2.5.1 DC Motor

Direct Current (DC) motors as shown in Figure 2.10 are vital components in the realm of electromechanical systems, powering anything from toys and appliances to industrial machinery. These motors, which are admired for their simplicity and dependability, are critical in transforming electrical energy into mechanical motion.

The interplay of magnetic fields and electric currents is at the heart of DC motors. The basic mechanism entails producing rotational motion by creating a magnetic field within the motor's core, which is accomplished by passing direct current via coils or windings.



With the advent of Industry 4.0 and the Internet of Things (IoT), DC motors are becoming smarter, combining with sensors and control systems for better automation, efficiency, and real-time monitoring [33][34].

**Figure 2.10: DC Motor**

### 2.5.2 Stepper Motor

Stepper motors, renowned for their accuracy and control in motion systems, have emerged as critical components in a wide range of applications, including 3D printers and CNC machines, as well as robotics and automation as shown in Figure 2.11. These motors function on a novel concept, offering a degree of precision and dependability that distinguishes them from other electromechanical devices.

Stepper motors move in distinct steps, each of which corresponds to an angular revolution. This exact control is achieved by sequentially energising coils, forcing the motor to move in a predictable and measurable manner.

Undeniably, stepper motor is an important device in development of IoT as it always implemented with microcontroller to achieve the precise control on it [35]. Also, stepper motor play important role in industrial applications as it can applied on various types of machines with the sub system to achieve desired operation [36].

**Figure 2.11: Stepper Motor**

### 2.5.3 Servo Motor

Servo motors as shown in Figure 2.12 have become essential components in a wide range of applications, from robotics and industrial automation to aerospace and consumer electronics due to their precise control and adaptability. These motors are notable for their ability to retain precise control of position, speed, and torque, making them vital in situations requiring accuracy and responsiveness.

Servo motors use a closed-loop control system to receive data about their current location and alter their movement accordingly. This feedback loop distinguishes servo motors from other types of motors by ensuring accurate positioning and allowing for real-time modifications.

However, servo motors have limitation as they only can move in fixed angle each a time which make their application less compared to stepper motor and DC motor and usually applied on specific project which need their fixed angle rotation [37][38].



**Figure 2.12: Servo Motor**

## 2.6 Types of Sensors

### 2.6.1 Laser Sensor

Laser sensors as shown in Figure 2.13 stand out as strong instruments capable of giving accurate and dependable measurements across a wide range of applications in the vast landscape of sensing technologies. These sensors, which use laser technology principles, have found applications in sectors ranging from manufacturing and robotics to healthcare and beyond.

Laser sensors use laser light to determine the distance, movement, or existence of an item. These sensors generate a laser beam and analyse the reflected light to determine the target's position or properties, providing a non-contact and high-precision sensing approach.

Laser sensors aid with navigation, object detection, and obstacle avoidance in robotics and automation. They let robots to observe their surroundings with great precision and adapt to dynamic changes in real time.

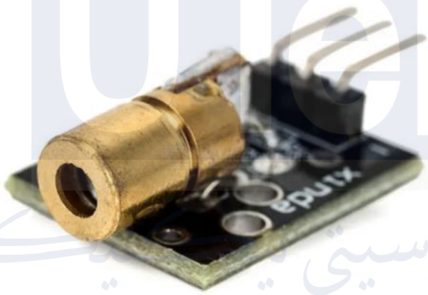


**Figure 2.13: Laser Sensor**



### 2.6.2 Ultrasonic Sensor

Ultrasonic sensors as shown in Figure 2.14 have emerged as important instruments in a variety of sectors, enabling non-contact distance measuring and object identification capabilities by harnessing the force of sound waves beyond the range of human hearing. These sensors work on the echolocation concept, which is how bats navigate in the dark.

Ultrasonic sensors generate high-frequency sound waves, generally above 20,000 hertz, and time how long it takes for the waves to bounce back after colliding with an object. The sensor can compute the distance to the item by evaluating the time delay, delivering precise and consistent readings. Generally, ultrasonic sensor is applied for object localization resolution as it is great in identifying the presence of an object [39].

**Figure 2.14: Ultrasonic Sensor**

### 2.6.3 Limit Switch

Limit switch as shown in Figure 2.15 detect the presence or absence of an item from the movement limit indication within a mechanism. Limit switches are commonly used in industrial environments and machinery to control the motion of moving parts, ensuring they operate within predefined parameters.



Limit switchs play an important part in automation in position control, safety interlock and counting operation due to its characteristics of precision, durability, reliability and versatility. In summary, limit switches are crucial components in automated systems, providing essential control and safety functions that enhance the efficiency and reliability of industrial processes.

**Figure 2.15: Limit Switch**

## 2.7 Synthesis and Evaluation of Information

Based on the above information, there are total of 4 factors need to be considered in design and deployment of IoT-based agriculture pesticide spraying system for Cucumis melo which are linear motion mechanism, types of microcontrollers, types of motors and types of sensors. From the research, timing belt is the best method to solve with the linear motion mechanism as its highly precise in motion and economical to be implemented in medium and long-distance transmission working scheme.

For the aspect of microcontrollers, ESP32 is the best solution to be applied in pesticide spraying system due to it is compatible with wireless connectivity which can connect with Wi-Fi and Bluetooth. Furthermore, some of the ESP32 development boards are equipped with GPRS/GSM module. Hence, there is an alternative way to solve the low Wi-Fi signal problem.

For actuators, stepper motor is the most suitable solution for the system designed. Due to precise transmission is the primary factor in the overall system, so stepper motor which it able to move in distinct step through the energizing of coils controlled by microcontroller is selected. Both DC motor and servo motor are not suitable to be applied in this system as the characteristic of DC motor motion is focused on speed while servo motor is focused on torque.

For sensor application, limit switch is selected because it provides a precise and versatile sensing approach. By comparing with other sensors, ultrasonic sensor usually performs in uncertainty conditions and simply block by existing obstacles. On the other hand, laser sensor is very complicated in implementation and sensitive to other light source, hence it is not suitable to be implemented at outdoor.

## 2.8 K-Chart

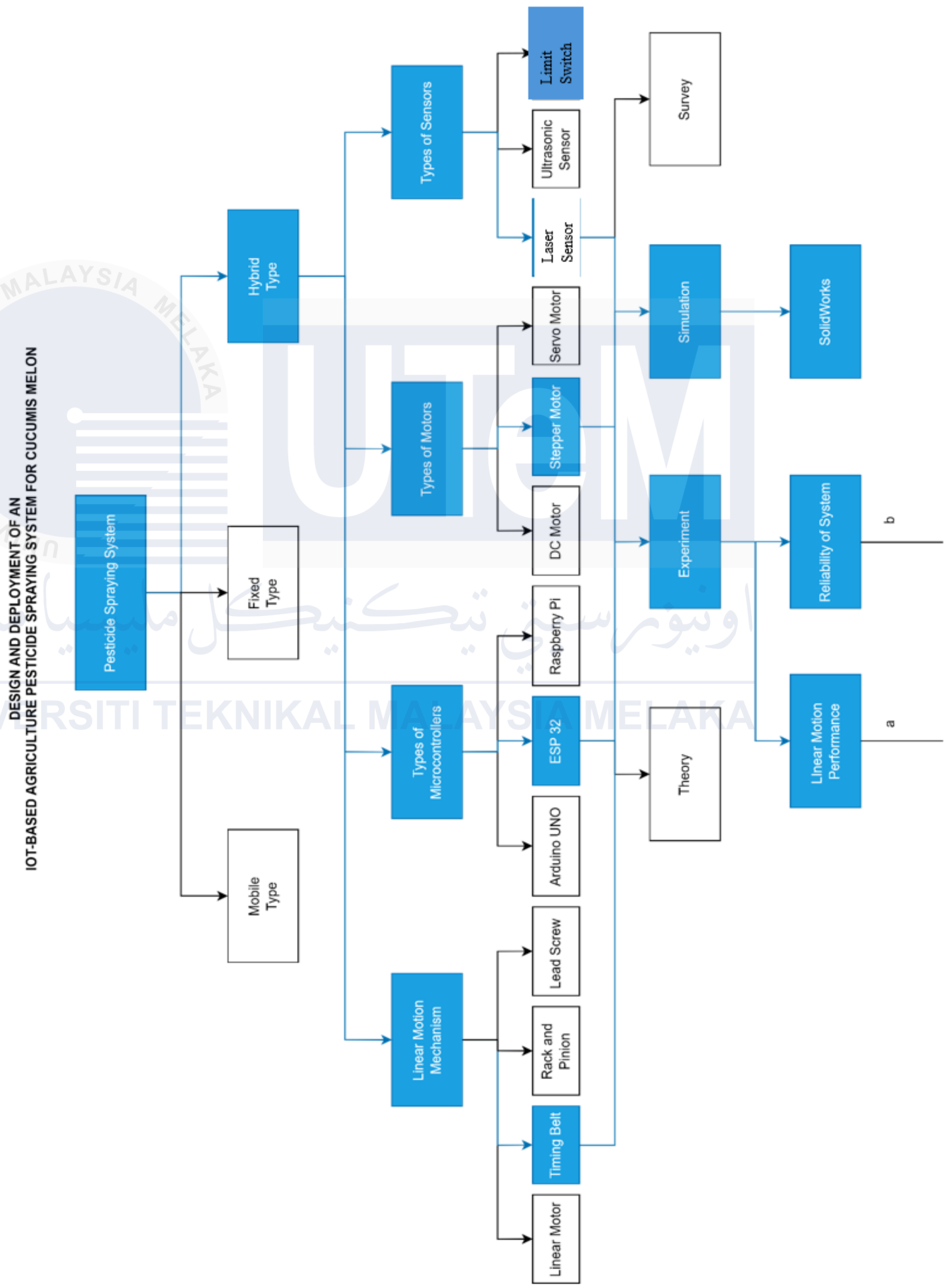





**Figure 2.16: K-Chart (1)**

a

| Number of times | Distance between the notation and pully upward | The percentage of slippage |
|---|---|---|
| 1st | | |
| 2nd | | |
| 3rd | | |
| Average | | |

b

| Number of Times | The Failure on System Control | Percentage |
|---|---|---|
| 1st | | |
| 2nd | | |
| 3rd | | |
| 4th | | |
| 5th | | |
| Average | | |

**Figure 2.17: K-Chart (2)**

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter provides a comprehensive understanding of the project's overview and the methods that were implemented to achieve the goals.

## 3.2 Project Overview

FYP projects always take a long period to accomplish hence excellent planning and sequential procedure are essential as it can lead the project towards success. The project workflow diagram below shows a clear point of view on this project from the beginning until the end.

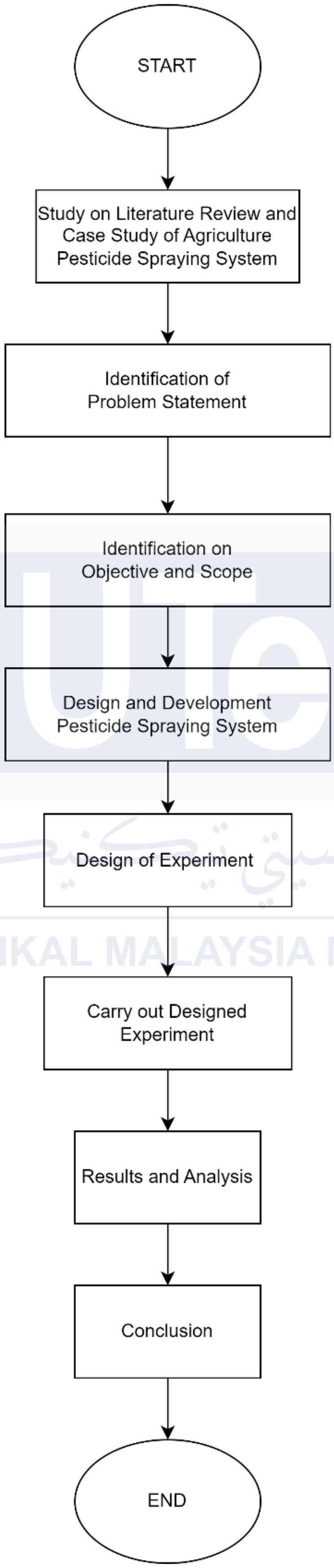



**Figure 3.1: Project Workflow**

## 3.3 Design of IoT-Based Agricultural Pesticide Spraying System (Objective 1)

To design an IoT-based agricultural pesticide spraying system, it includes the design in hardware and software parts. For the system's hardware part, SolidWorks is used to build the component structures and layout the system implementation. On the other hand, Proteus is used to perform the connection of all the components in the system, then the information is used for PCB design purposes.

### 3.3.1 3D Rendering on Agriculture Pesticide Spraying System

SolidWorks, a computer-aided design (CAD) software is used in the design of IoT-based agricultural pesticides spraying system as shown in Figure 3.2. The purposes of design in SolidWorks software are to expose the detail of design in the system neatly meanwhile ease to replace or edit the dimension and orientation of components in designing process. Other than that, the motion study in SolidWorks is well to perform the designed system motion mechanisms and functions.



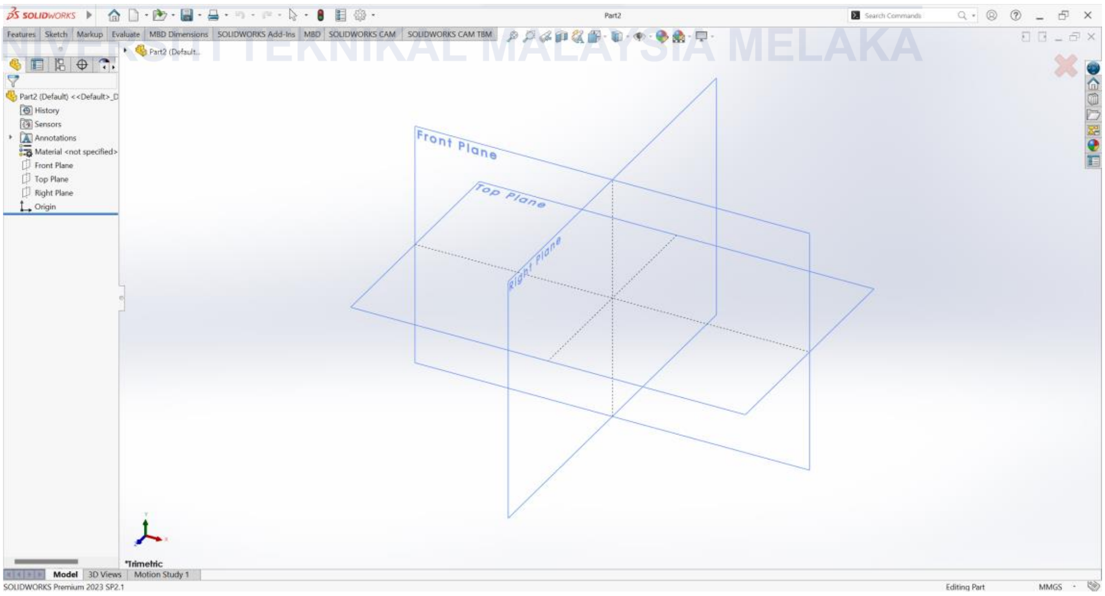



**Figure 3.2: SolidWorks Premium 2023 SP2.1**

### 3.3.2 Schematic Diagram Representation of Agriculture Pesticide Spraying System

Proteus, a software tool suits primarily used for circuit measurement, electronic design and building system schematic diagram as shown in Figure 3.3. In the design of pesticide spraying system, Proteus is used to draw the schematic diagram of the overall system. From the schematic diagram, the implementation and connection of the components can be illustrated clearly and the information can also be further used for PCB design.


**Figure 3.3: Proteus 8.15 SP1**

## 3.4 Develop of IoT-Based Agricultural Pesticide Spraying System (Objective 2)

To develop an agricultural pesticide spraying system, both material selection and component selection are important factor to achieve the goal. The material selection should take consideration on the durability and reliability of the material in different environments while component selection important to realize the function of the system in low error rate.

For this project, Arduino Cloud, an IoT platform is crucial to receive and send the control to the system. The function and control of the system is concentrated in this platform. In addition, an exclusive PCB is designed by using Altium Designer to replace the dot board, a type of prototyping board in order to enhance the system reliability.

### 3.4.1 Material Selection

Material selection is an important part to define the materials used in the design. As the system is located at outdoor hence weatherproof materials should be chosen to avoid or slow down the material deterioration process such as corrosion (metal), degradation (plastics), rot (wood) and others. Not at all, all the materials selected in the design are based on suitable parameters by taking reliability into consideration. As an example, the suitable hardness of material should be chosen to avoid bending, shearing, cracking and other material failures.

### 3.4.2 Component Selection



Component selection is a crucial part to determine the suitable components used to carry out the function. As an example, an appropriate torque of stepper motor is likely to be chosen to drive the total load applied. The parameters of component are taken consideration in this project are:

i. The types of microcontrollers
ii. The size of timing belt
iii. The size of pully
iv. The torque of stepper motor
v. The types of stepper motor drivers

### 3.4.3 IoT Platform

Arduino Cloud, a versatile IoT platform to build, control and monitor the IoT project for many types of microcontrollers as shown in Figure 3.4. It makes the user ease from building the specific user interface, UI to control the device. Meanwhile, Arduino Cloud is enabled on web browsers and also APP on smartphone. In this project, Arduino Cloud is selected to be IoT platform for agricultural pesticide spraying system.

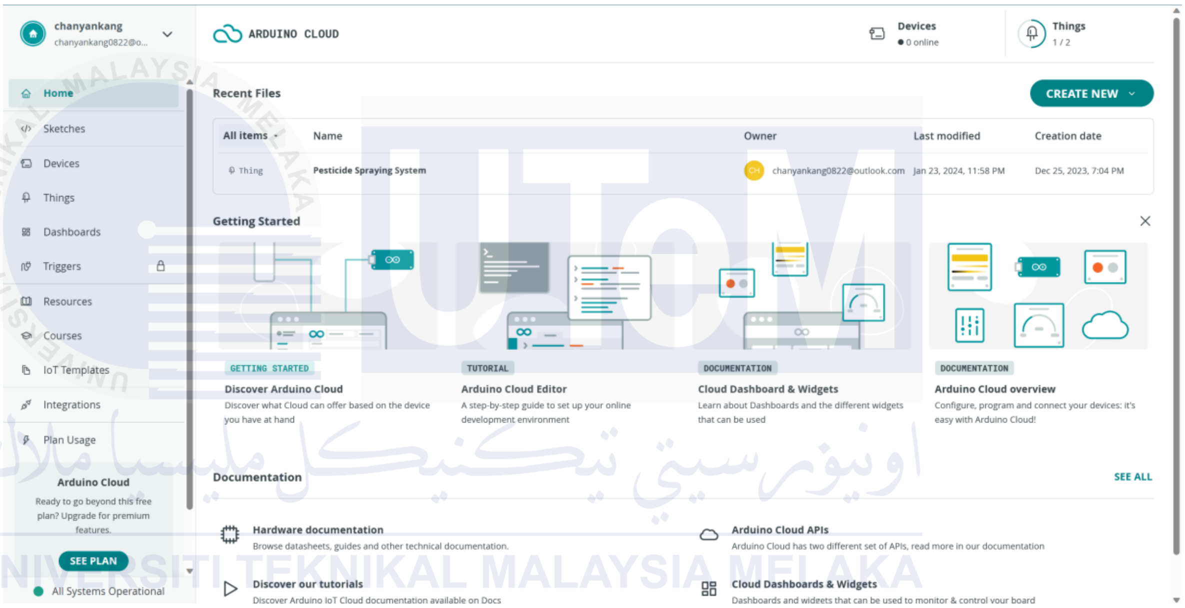



**Figure 3.4: Arduino Cloud**

### 3.4.4 PCB Design

Altium Designer, a PCB design automation software as shown in Figure 3.5. It has a very powerful and user-friendly function to help the beginner to design their own PCB which is provided with a wide components' library. In this project, Altium Designer used to design a PCB for reliable connection of microcontroller and other electronic components.

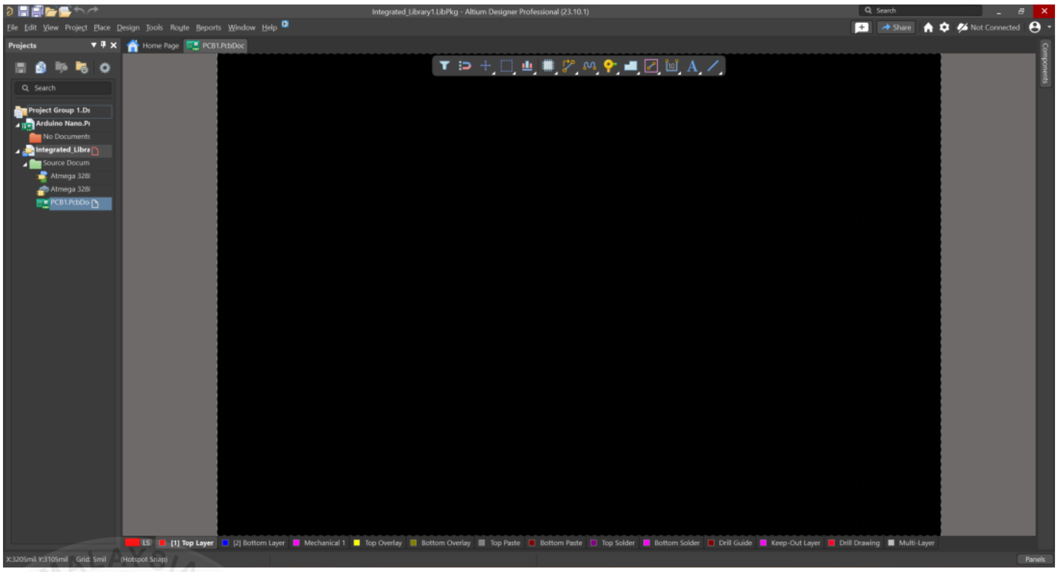


**Figure 3.5: Altium Designer**

## 3.5 Analysis on the Performance of Agricultural Pesticide Spraying System (Objective 3)

Analysis on the performance of agricultural pesticides spraying system is important to detect and troubleshoot the problems in the system. There are many of analysis can be conducted to test the system designed and developed. In this project, the percentage of slippage on timing belt and the system's reliability is going to be tested.

### 3.5.1 The Percentage of Slippage on Timing Belt

The purpose of this experiment is to measure the slippage in the timing belt transmission with load (pipes and nozzle contain with pesticide).

*This experiment is conducted with stepper motor speed 20000 pulse/rev

**Procedures**

1. The program set to move forward 1m.

2. A notation marked on masking tape at the roller and c-channel 1m from the stepper motor (front) respectively as shown in Figure 3.6.

**Figure 3.6: Notations on Roller and C-channel**

3. The system actuated from control dashboard.

4. The distance between notations on roller and c-channel measured by using digital caliper as shown in Figure 3.7.



**Figure 3.7: Measurement of Distance between Notations**

5. The system actuated to move reverse until front sensor is triggered.

6. Step 2 to 5 repeated 19 times.

7. The average percentage of slippage on timing belt calculated and displayed on graph.

**Table 3.1: Percentage of Slippage on Timing Belt**

| Number of times | Distance between the notations on roller and c-channel | The percentage of slippage |
|---|---|---|
| $1^{st}$ | | |
| $2^{nd}$ | | |
| $3^{rd}$ | | |
| ⋮ | ⋮ | ⋮ |
| Average | | |

### 3.5.2 The Functionality of System

The purpose of this experiment is to determine the percentage of failure of the system control.



**Procedures**

1. The system controlled to start the water pump through the control dashboard.
2. The system controlled to move forward until end sensor is triggered
3. The system controlled to move reverse until front sensor is triggered.
4. The water pump turned off.
5. The entire process of the system is recorded.
6. Step 1 to 5 repeated 19 times.
7. The probability of system failure is calculated and displayed on the graph.

**Table 3.2: The Probability of System Failure (Loss Control)**

| Number of Times | Failure on System Control | Percentage |
|---|---|---|
| 1st | | |
| 2nd | | |
| 3rd | | |
| 4th | | |
| ⋮ | ⋮ | ⋮ |
| Average | | |

### 3.5.3 The Functionality of Automation Control of System

The purpose of this experiment is to validate and testing the functionality of 'Scheduler' function in the system.

**Procedures**

1. The system is set to operate automatically and repeatedly with time interval of 15 minutes.
2. The entire process of the system is recorded.
3. The probability of system failure is calculated and displayed on the graph.



**Table 3.3: The Probability of 'Schedular' Function Failure (Loss Control)**

| Time | Failure on 'Scheduler' Function |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

### 3.6 Safety Precautions

The safety precautions taken in this project are wearing safety shoes and gloves as well as applying sunblock. The purpose of safety shoes and gloves is to prevent physical injuries from the site because the poor management in Cucumis Melo plot had resulted in the many of rubbish and construction equipment left on the land. Moreover, the gloves provide high levels of safeguard from electrical shock while connecting electrical wires.

For electrical components implementation, all the non-waterproof components are installed in the junction box and the connection of electrical wire is applied with power splitter threading box to avoid from overload issue. For the exposed wires in the system, all of them are covered with shrink tube to prevent short circuit problem. Furthermore, an emergency stop button is applied near to the power distribution box to provide emergency electrical cut-off solution for safety purpose.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Overview

This chapter provides the whole design of IoT-based agriculture pesticide spraying system and its findings from the analysis discussed in the methodology part. The results obtained are displayed graphically to give a clear sense of the system's performance. Then, the details of problems that exist in the system developed are discussed comprehensively according to real condition in the experiment.

## 4.2 Assembly Design of IoT-Based Agricultural Pesticide Spraying System

This section shows the conceptual and practical design of IoT-based agricultural pesticide spraying system. For the system part need to be developed by 3D printing technique is provided with isometric drawing which contains actual parameter. After that, the practical design of IoT-based agriculture pesticide spraying system is shown as the final work in the system design.



### 4.2.1 Conceptual Design of IoT-Based Agricultural Pesticide Spraying System

Figures below show the 2 conceptual designs of IoT-Based agriculture pesticide spraying system. One is unilateral (single side) stepper motors installation and the other is bilateral (double side) stepper motors installation for linear motion mechanism. Each conceptual design consists of different design on pipe hanging part and pipe attaching part.

**<u>1st Conceptual Design</u>**

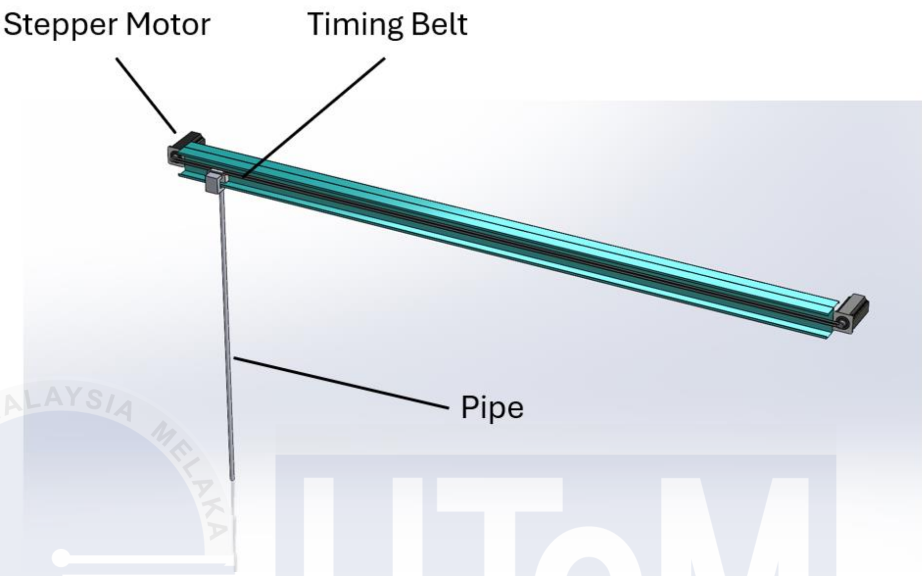



**Figure 4.1: 1st Conceptual Design on IoT-Based Agriculture Pesticide Spraying System**

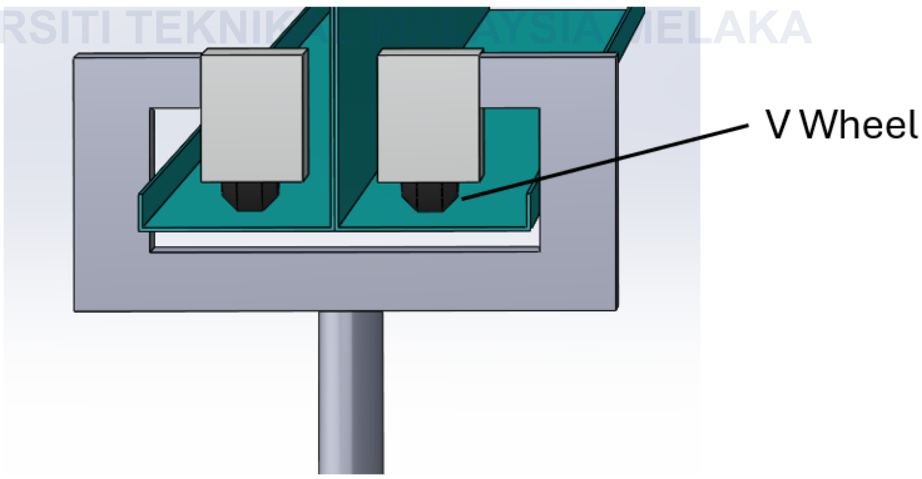



**Figure 4.2: Detailed Design on Pipe Hanging Part**

**2nd Conceptual Design**

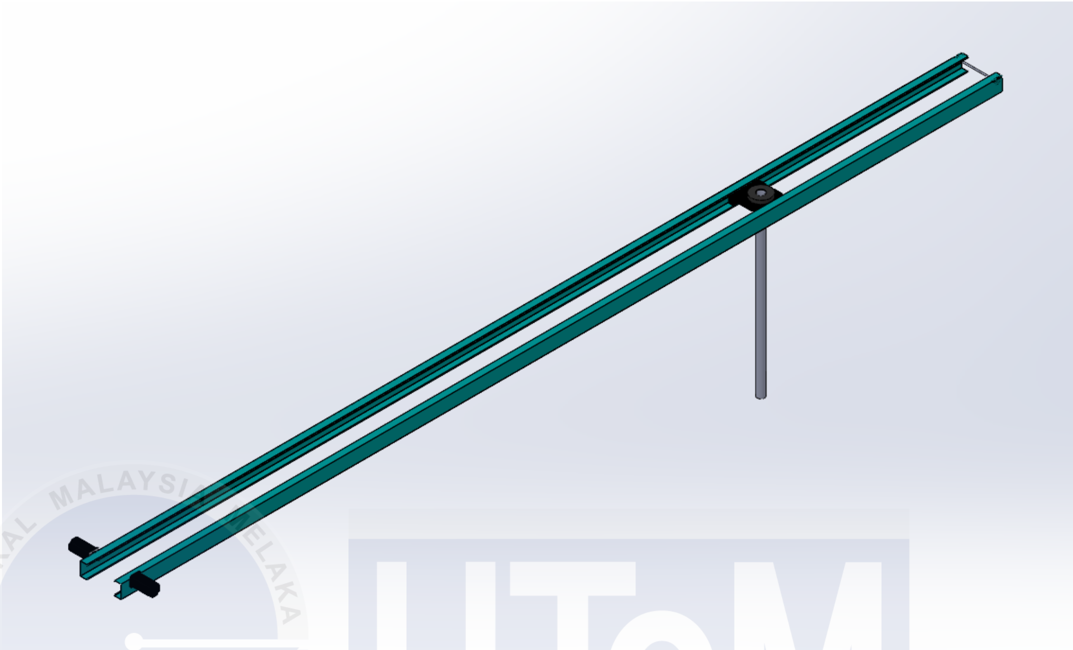


**Figure 4.3: 2nd Conceptual Design on IoT-Based Agriculture Pesticide Spraying System**

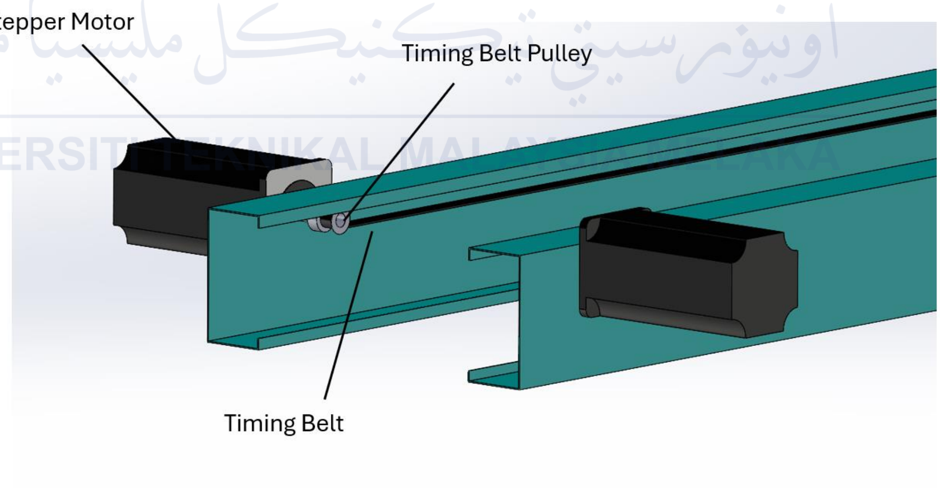



**Figure 4.4: Detailed Design on Front Side**

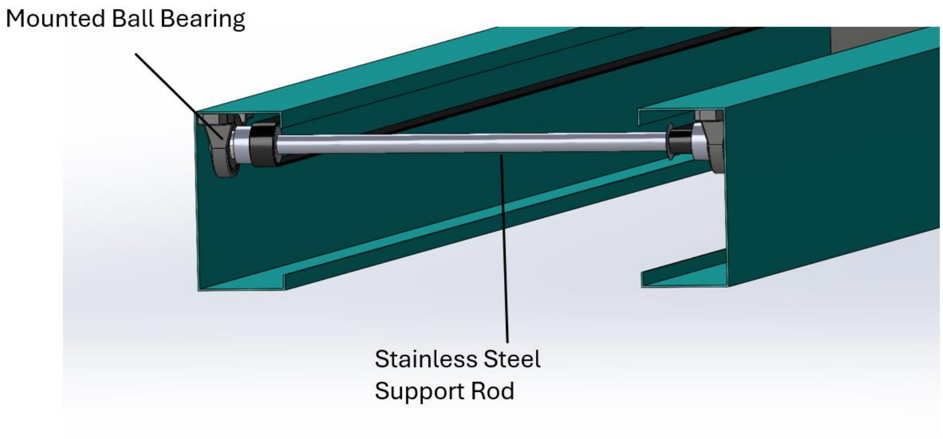



**Figure 4.5: Detailed Design on Rear Side**

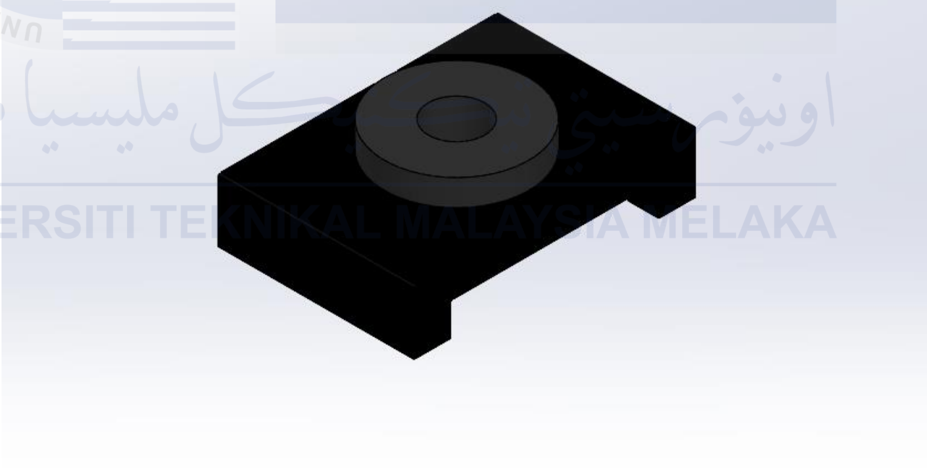


**Figure 4.6: Detailed Design on Pipe Hanging Part**

From the conceptual designs shown above, the second design of IoT-based agricultural pesticide spraying system is selected because the synchronous and bilateral operation on stepper motors provides more steady and stable linear motion mechanism compared to first design which the stepper motors only attach to single side of pipe hanging part. Other than that, the second design of the IoT-based agriculture pesticide spraying system is more robust due to the larger surface area in pipe hanging part compared to first design provides better load stress performance.

### 4.2.2 Design on Part of IoT-Based Agriculture Pesticide Spraying System

In the design of IoT-based agriculture pesticide spraying system, pipe hanging part and pipe attaching part should be manufactured by using 3D printing technique to fulfill the complex and specific design on it. Figure 4.7 and Figure 4.8 show the isometric view and actual parameter on the design parts.

**<u>Pipe Hanging Part</u>**

There are two main sections in pipe hanging part design which are the length of the pipe hanging part related to the distance between c-channel and the wheel installation space. The end-to-end distance between c-channel is about 215 mm from the site investigation, hence the length for pipe hanging part is designed in 215 mm. The V-wheels used in this project are 10.2 mm wide and 23.90 mm in diameter hence, the wheel space is designed 12 mm wide and 28 mm in diameter.



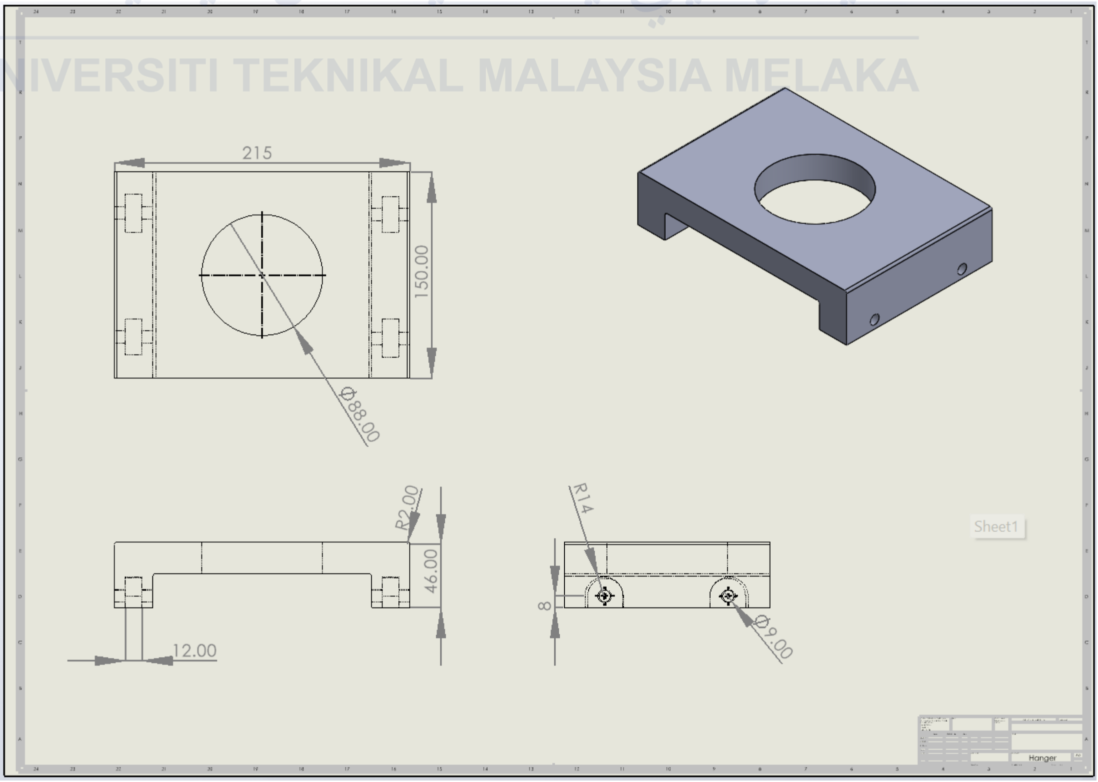



**Figure 4.7: Isometric Drawing of Pipe Hanging Part**

**Pipe Attaching Part**

From Figure 4.3, the diameter of support pipe for spraying nozzle part is about 40 mm, hence the diameter of central hole of pipe attaching part is design in 43 mm after taking into account the tolerance factor of 3D printing. From Figure 4.7, the central hole of pipe hanging part is about 88 mm, hence the diameter of lower side and upper side of pipe attaching part are designed in 87 mm and 110 mm after taking into account the tolerance factor of 3D printing. Figure 4.8 shows the detailed design of pipe attaching part.

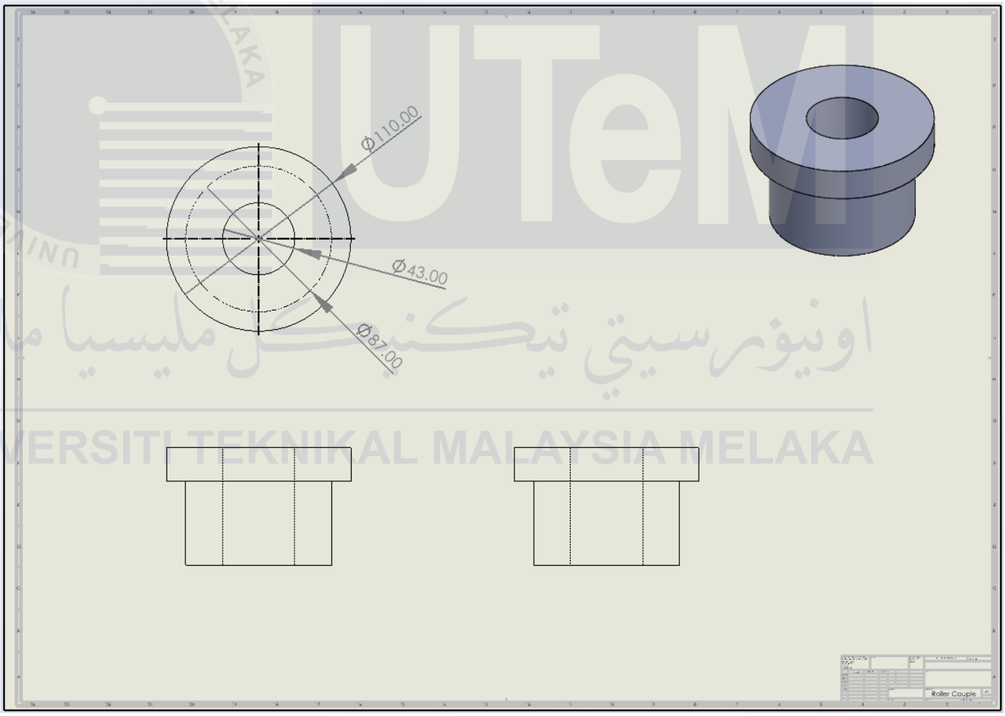





**Figure 4.8: Isometric Drawing of Pipe Attaching Part**

### 4.2.3 Assembly Design of Spraying Nozzle Part

Figure 4.9 shows the conceptual design of spraying nozzle in order to fulfill the pesticide spraying task for Cucumis Melo. There are 2 PVC ball valves designed to limit the pesticide spraying according to the altitude of Cucumis Melo plant. Due to the mist nozzle's thread size is 12.7 mm (0.5 inch), there should be always connected with nozzle adapter connectors (from 12.7 mm to 14mm) to the standard size PVC fittings (14mm thread size). From site investigation, the distance between the plot line is about 0.8 m, hence mist nozzle with 1-3 m spraying radius is selected in this case.

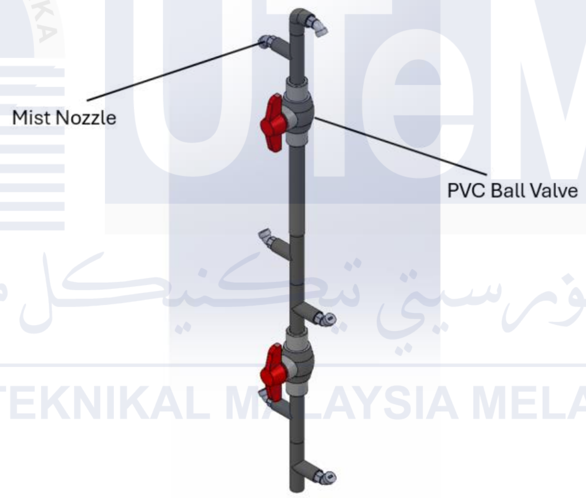



**Figure 4.9: Detailed Design of Spraying Nozzle Part**

### 4.2.4 Practical Design of IoT-Based Agriculture Pesticide Spraying System

Figure 4.10 shows the installation of IoT-based agriculture pesticide spraying system in Cucumis Melo plot. The c-channels are fixed below at the structure of the Cucumis Melo plot shed. The white junction box in the diagram contained the control panel of the whole system.

**Figure 4.10: Practical Design of IoT-Based Agriculture Pesticide Spraying System**

## 4.3 Components Installation of IoT-Based Agriculture Pesticide Spraying System

This section shows the schematic diagram of the IoT-based agriculture pesticide spraying system and the practical component installation in the real environment.

### 4.3.1 Schematic Diagram of IoT-Based Agriculture Pesticide Spraying System

The connection of the electronic components and devices are shown in Figure 4.11. Due to the stepper motor driver is powered by DC 24V, it is connected to AC to DC power supply (230/240V to 36V) for power gain. Meanwhile, the NodeMCU ESP32 powered by DC 3.3V is connected to AC to DC power supply (230/240V to 5V) for power gain (due to built-in voltage regulator to step down the input voltage to 3.3V).

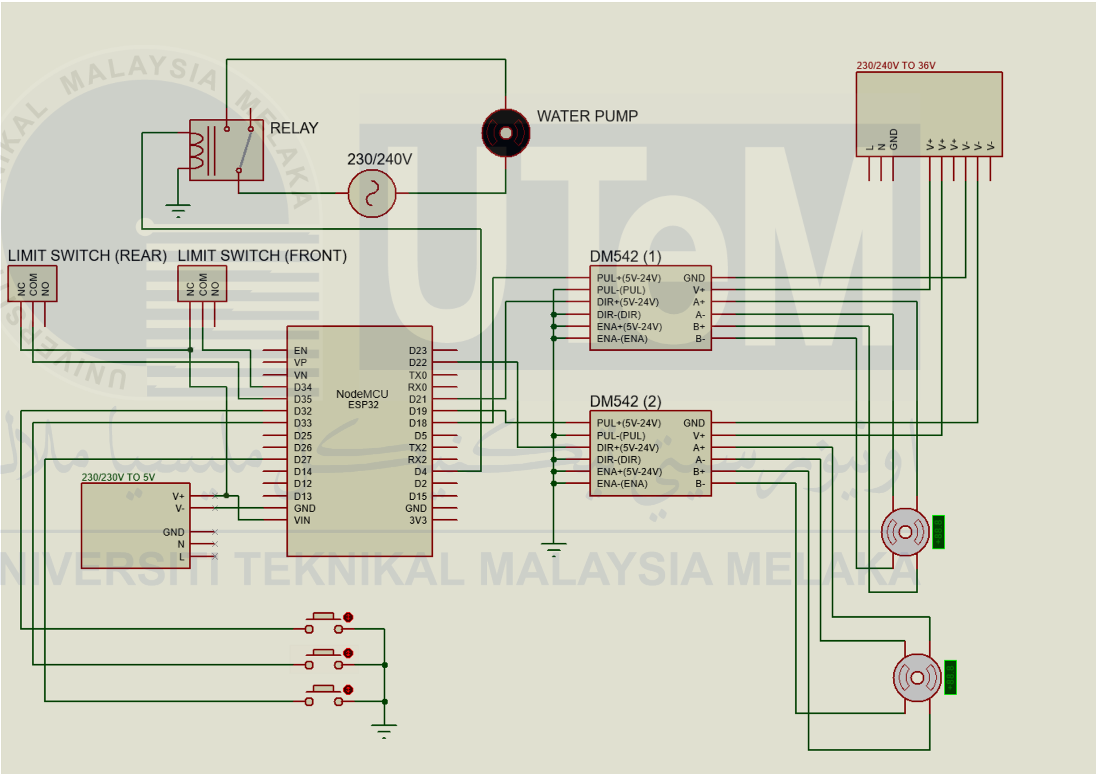



**Figure 4.11: Schematic Diagram of Agriculture Pesticide Spraying System**

### 4.3.2 Practical Connection of IoT-Based Agriculture Pesticide Spraying System

The figures below show the practical connection between the electrical and electronic components. There is an emergency stop button as a safety mechanism to break the electric supply immediately. The purpose of the power splitter threading box installation is to avoid electrical overload.


**Figure 4.12: Power Distribution Box**

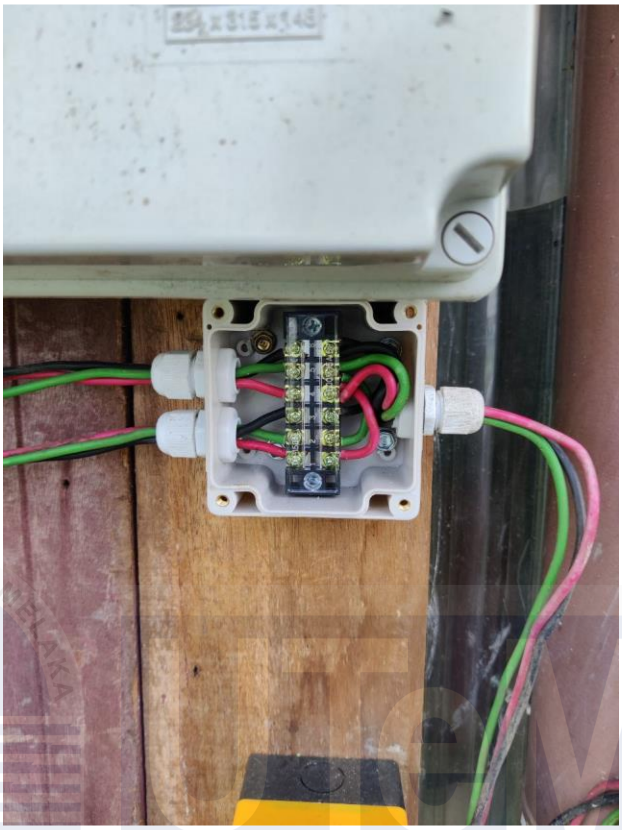


**Figure 4.13: Wire Connection in Power Splitter Threading Box**

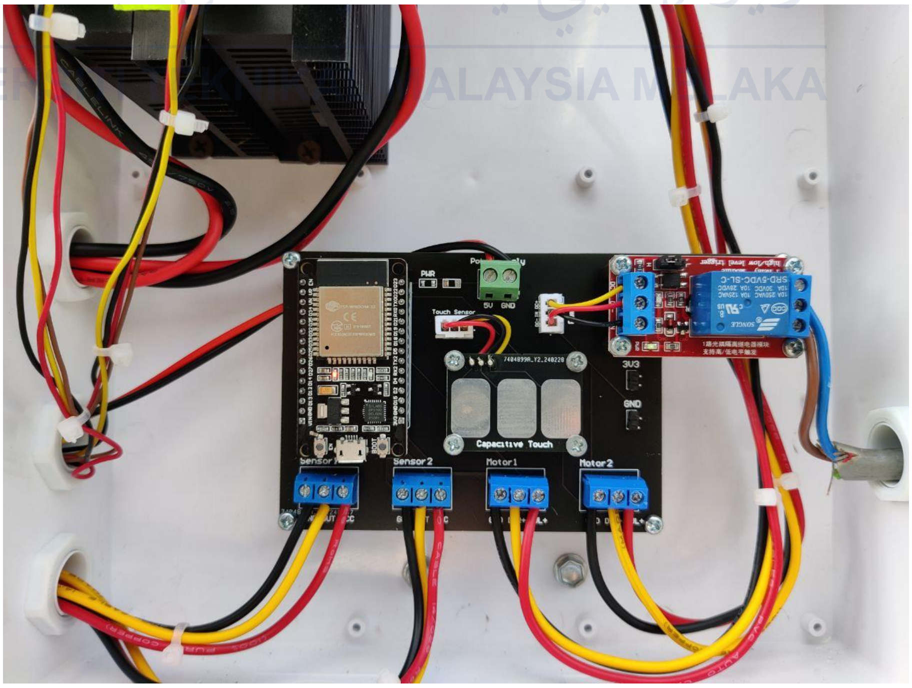



**Figure 4.14: Wire connection in Control Panel**

## 4.4 PCB Fabrication

In PCB fabrication, all the I/O pins and connections should be designed in schematic diagram at first as shown in Figure 4.15. After that, the size of the PCB is determined and the electronic components information is inserted into PCB profile for routing and footprints layout purposes as shown in Figure 4.16 and Figure 4.19 in the board planning process. Finally, the PCB design information is exported as Gerber file for manufacture process.

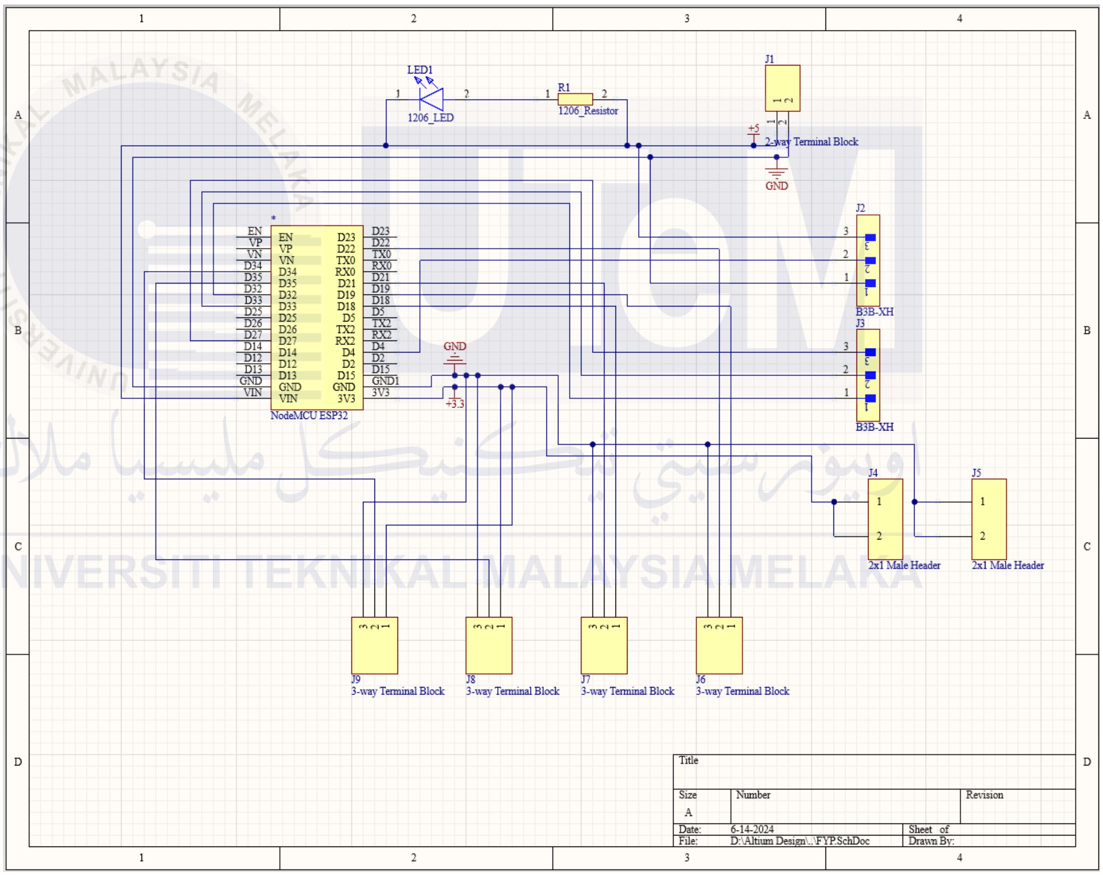



**Figure 4.15: PCB Schematic Representation**

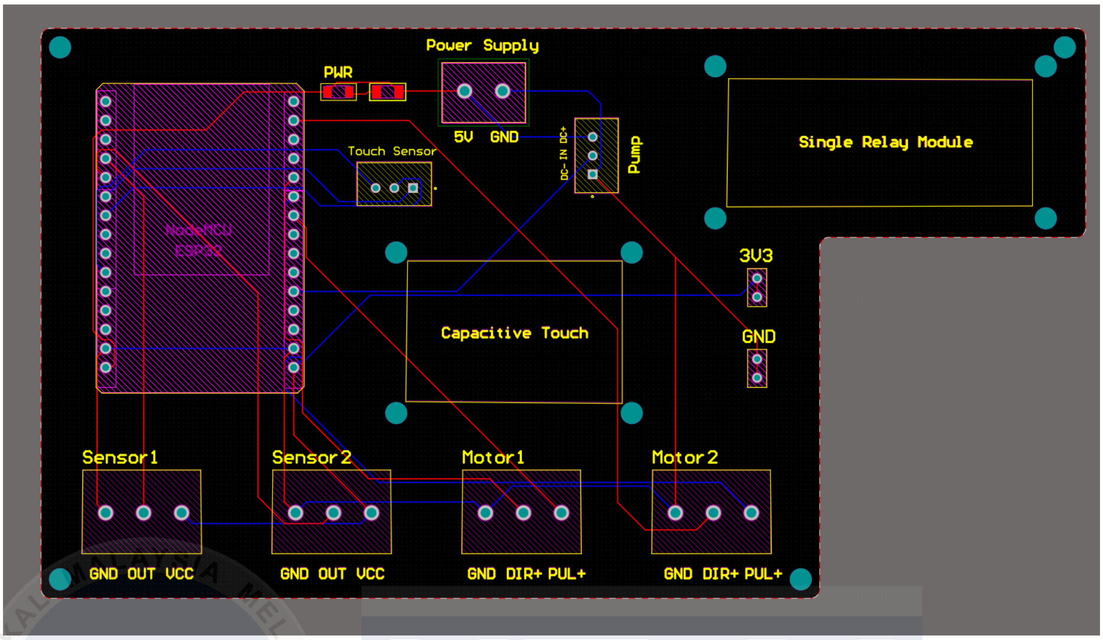



Figure 4.16: 2D PCB Layout

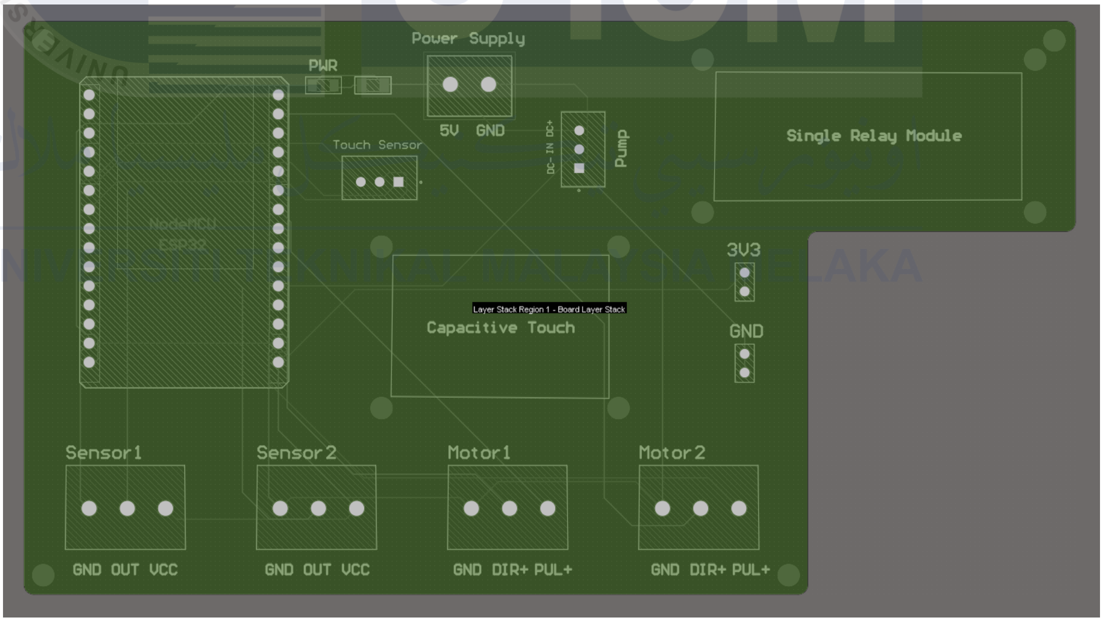



Figure 4.17: Board Planning Layout

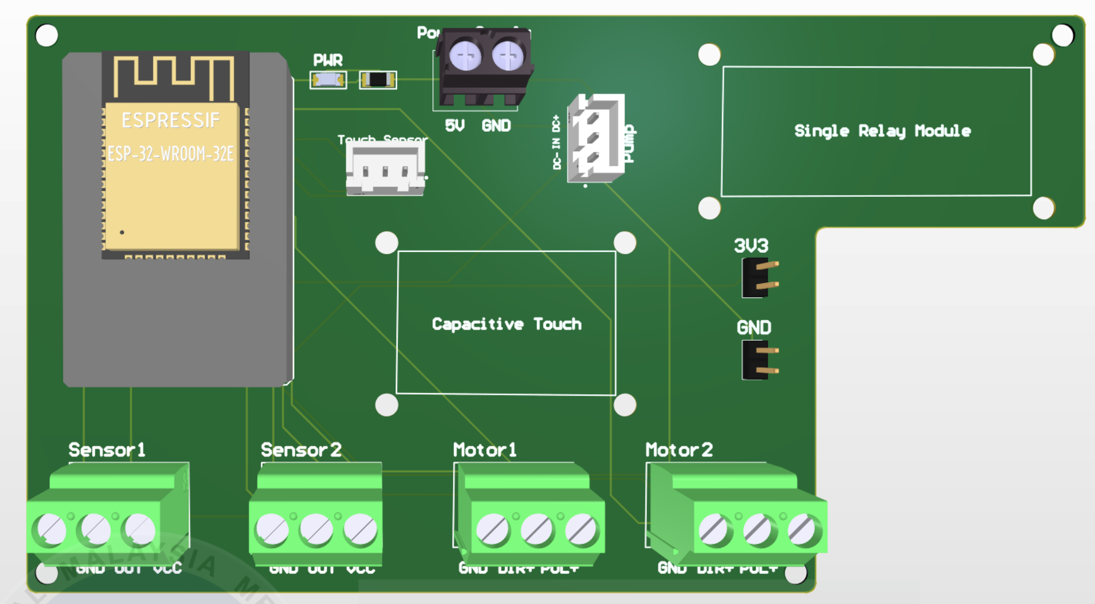



Figure 4.18: 3D PCB Layout

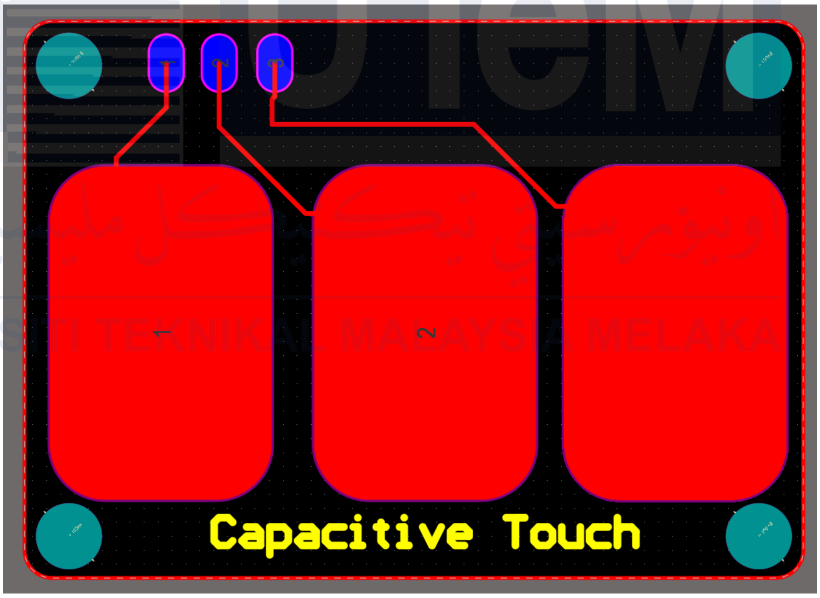



Figure 4.19: 2D PCB Layout (Capacitive Touch Panel)

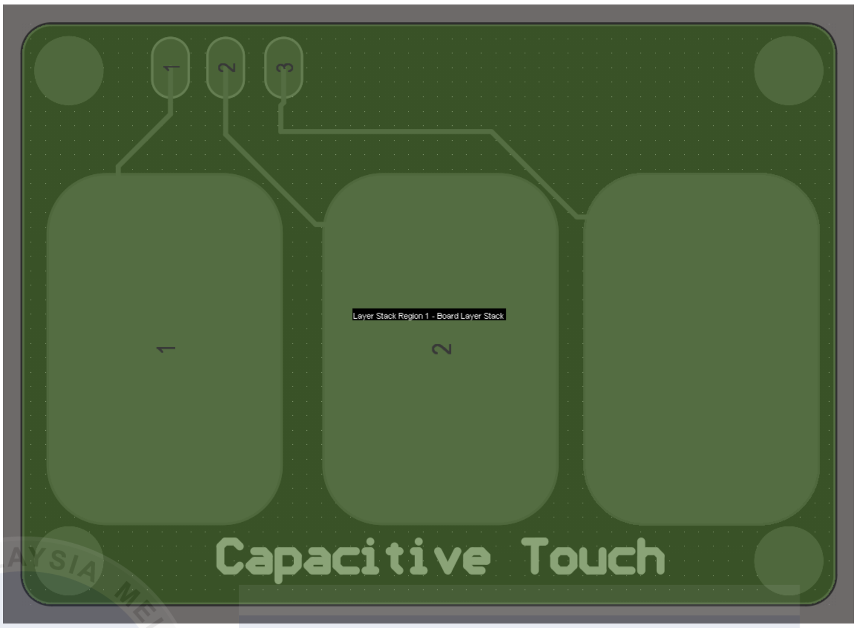



**Figure 4.20: Board Planning Layout (Capacitive Touch Panel)**


**Figure 4.21: 3D PCB Layout (Capacitive Touch Panel)**

## 4.5 Material and Component Selection

The material selected to deploy the agricultural pesticide spraying system are based on weatherproof and UV resistance such as galvanized steel, PVC, stainless steel and other materials resistant to corrosion. For some hydrophilic or non-waterproof devices, the cover is used to prevent them from contact with water. Otherwise, these devices are implemented under the shed.

The materials and standards of components in IoT-based agriculture pesticides spraying system with high resistance are stated below:

1. Junction box: IP66 standard and UV resistant ABS material
2. Cable gland: IP66 standard and nylon PA66 plastic
3. C-channel: galvanized steel
4. PVC pipe: Class 7 (Good in UV resistance and heat tracing)
5. Steel rod: Stainless steel
6. Mist nozzle: Stainless steel
7. Nozzle Adapter Connector: Brass
8. Timing belt pulley: Stainless steel

The rest of the components not stated above are applied with materials and standards low resistance in harsh environments. For the exposed wire are covered with shrink tube to prevent from contact with water.



The component selection in IoT-based agriculture pesticide spraying system is stated below:

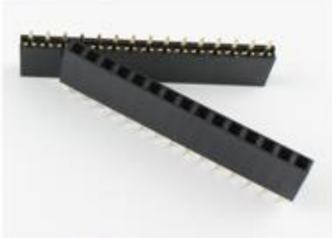
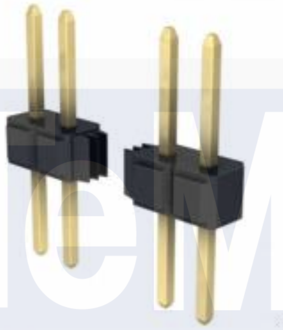
i. Types of microcontrollers: NodeMCU ESP32
ii. Torque of stepper motor: 3 Nm (4.2A)
iii. Types of stepper motor drivers: DM542
iv. Size of timng belt: 10 mm width
v. Size of pulley: 10 mm width

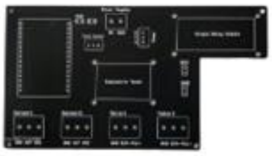
Based on the parameters of components selected as above, NodeMCU ESP32 is selected due to versatile utilization on many projects and cheap. From the pipe hanging part designed in IoT-based agriculture pesticide spraying system, the total weight is about 2 - 3 kg (19.62 – 29.43 N), hence the torque in stepper motor > 0.75 Nm (installed with 50.9 mm in diameter of timing belt pulley) is selected. In this project, the stepper motors are driven with 4.2 A, hence stepper motor driver which provide output current in range of 1.5 – 4.5 A is chosen. According to the technical information, 10mm PU material timing belt provides maximum load with 870 N which overrode 3Nm NEMA 23 stepper motor selected above (provides with 118 N after installed with 50.9 mm in diameter of timing belt pulley) is selected. Meanwhile, 10 mm width timing belt pulley is selected according to the size of timing belt.

All the components used to develop the agricultural pesticide spraying system are shown in Table 4.1.

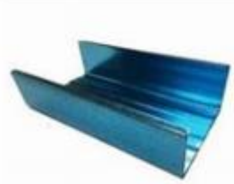
**Table 4.1: Bill of Materials**

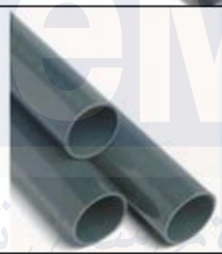
| No. | Component | Diagram | Qty |
|---|---|---|---|
| **Control Panel** | | | |
| 1 | NodeMCU ESP32 |  | 1 |
| 2 | 1 channel 5V relay module |  | 1 |
| 3 | 2 way terminal block |  | 1 |
| 4 | 3 way terminal block |  | 4 |

| | | | |
|---|---|---|---|
| 5 | JST XH 2.54 3-pin connector |  | 2 |
| 6 | 15-pin female header |  | 2 |
| 7 | 2-pin male header |  | 2 |
| 8 | M3 hexagonal female spacer 25mm |  | 4 |
| 9 | M3 hexagonal female spacer 12mm |  | 4 |
| 10 | M3 screw |  | 8 |

| | | | |
|---|---|---|---|
| 11 | M3 nut |  | 8 |
| 12 | PCB |  | 1 |
| 13 | PCB (capacitive touch) |  | 1 |
| **Power Distribution Box** | | | |
| 14 | Junction box |  | 2 |
| 15 | Power splitter threading box |  | 1 |
| 16 | Emergency stop button |   | 1 |

| | | | |
|---|---|---|---|
| 17 | Cable gland |  | 8 |
| 18 | AC to DC power supply unit 36V 1A |  | 1 |
| 19 | AC to DC power supply unit 5V 6A |  | 1 |
| 20 | General purpose wire AWG 10 |  | 20 m |
| 21 | General purpose wire AWG 20 |  | 20 m |
| **Main System** | | | |
| 22 | Nema 23 stepper motor |  | 2 |
| 23 | DM542 stepper motor driver |  | 2 |

| | | | |
|---|---|---|---|
| 24 | C-channel |  | 10 m |
| 25 | 10 mm width timing belt pulley |  | 2 |
| 26 | 10 mm width timing belt |  | 20 m |
| 27 | 8mm steel rod |  | 1 |
| 28 | Mounted ball bearing |  | 2 |
| 29 | L-shape steel plate |  | 6 |

| | | | |
|---|---|---|---|
| 30 | Roller |  | 1 |
| 31 | Pipe coupling |  | 1 |
| 32 | V-wheel |  | 4 |
| 33 | PVC pipe (Class 7) |  | 3m |
| 34 | PVC fittings |  | 7 |
| 35 | PVC ball valve |  | 2 |
| 36 | Nozzle Adapter Connector |  | 6 |

| | | | |
|---|---|---|---|
| 37 | Fan Mist Nozzle |  | 6 |
| 38 | Water pump |   | 1 |
| 39 | Hose pipe |  | 8 m |
| 40 | Self-drilling screw |  | - |
| 41 | Limit switch |  | 2 |

## 4.6 UI Design on IoT Platform

Figure 4.22 shows the UI design regarding to agricultural pesticide spraying system in Arduino Cloud. From the diagram, there is a button to energize the relay to actuate the water pump to allow the water flow to the nozzle. Then, there are two virtual push buttons to control the stepper motors motion which are in forward or reverse. The messege window is designed to give notice according to the function running process as shown in Figure 4.24. After that, there is a window named 'Schedular' designed for setting the pesticide spraying function periodically and automatically as shown in Figure 4.25.




**Figure 4.22: Dashboard of Agricultural Pesticide Spraying System IoT Platform (Desktop Layout)**

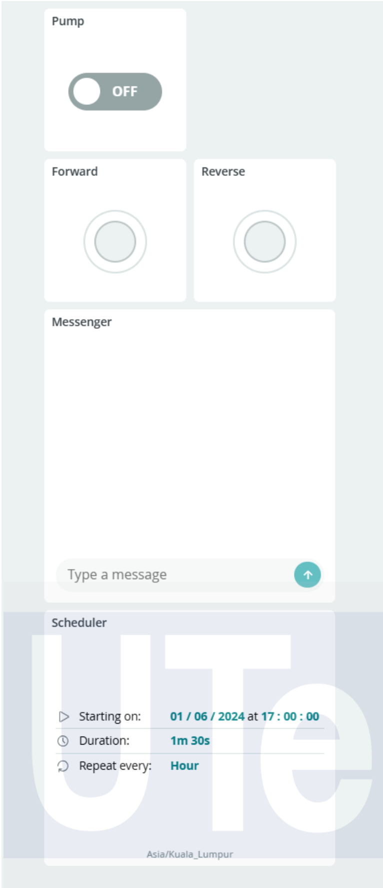



**Figure 4.23: Dashboard of Agricultural Pesticide Spraying System IoT Platform (Mobile Layout)**

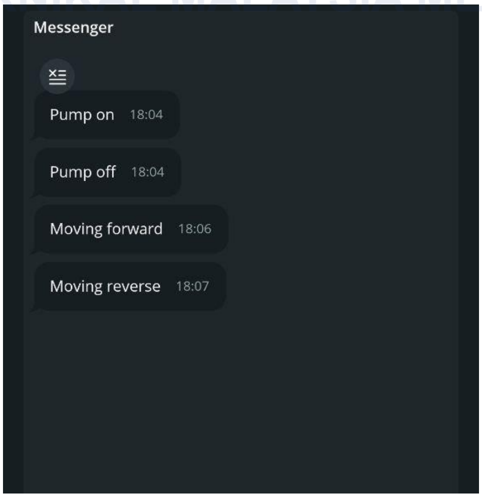



**Figure 4.24: Notification in IoT Platform**

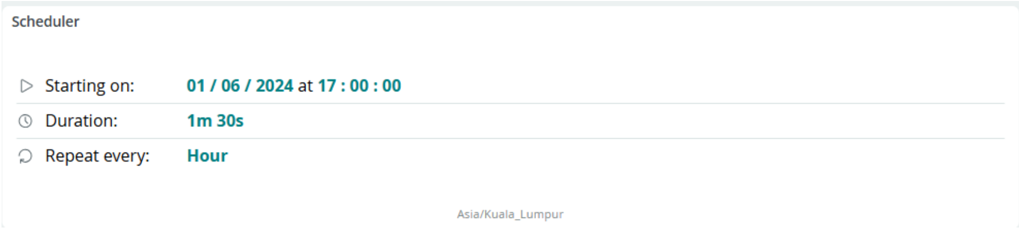



**Figure 4.25: 'Schedular' Function in IoT Platform**

## 4.7 System Operation

This section provides the process flow and program of IoT-based agriculture pesticide spraying system.

### 4.7.1 Flow Chart of IoT-Based Agriculture Pesticide Spraying System

There are 2 process flows which are according to the manual and automatic control on IoT-based agriculture pesticide spraying system. For manual control, the pesticide spraying function (includes linear motion mechanism) is control by user through the IoT platform. But, the entire process of pesticide spraying function (includes linear motion mechanism) for automatic control is accordance with the time setting in the IoT platform. Figure 4.26 and Figure 4.27 show the flow chart of manual control and automatic control of IoT-based agriculture pesticide spraying system respectively.

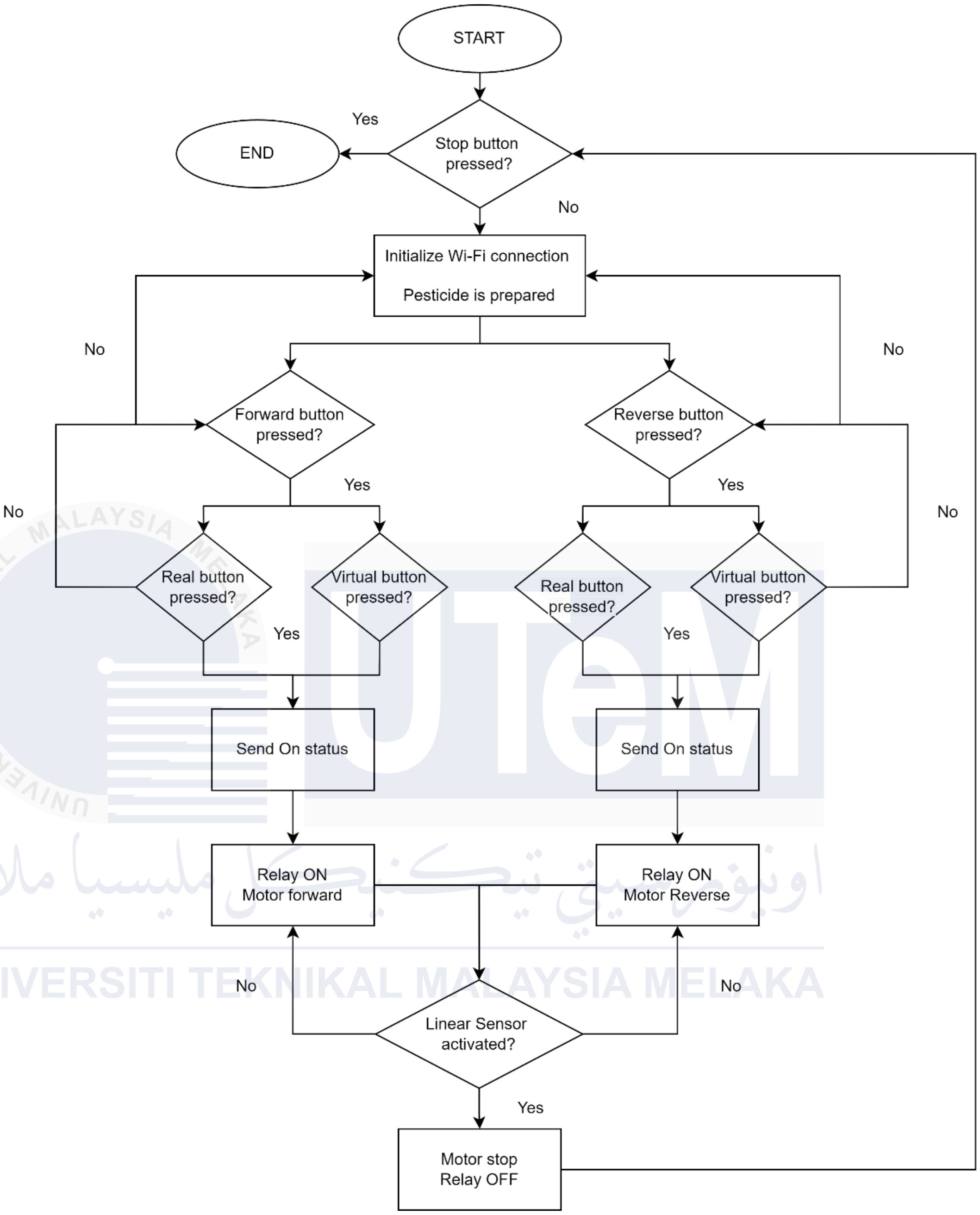



**Figure 4.26: Flow Chart of Manual Control in IoT-based Agriculture Pesticide Spraying System**

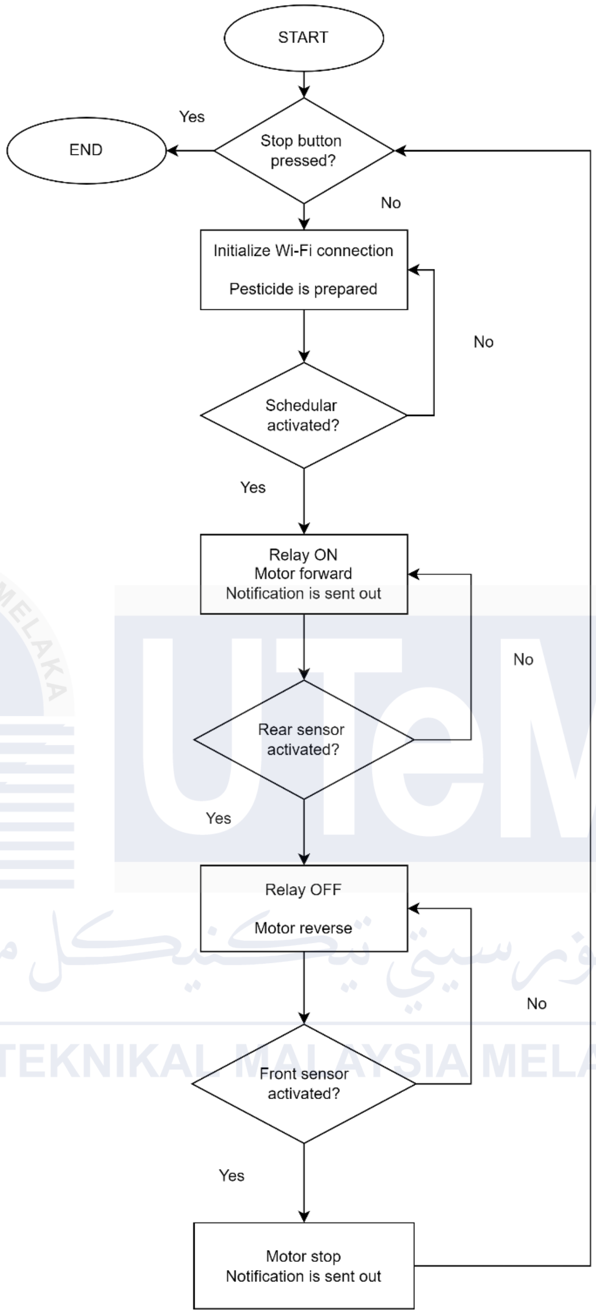



**Figure 4.27: Flow Chart of Automatic Control in IoT-based Agriculture Pesticide Spraying System**

### 4.7.2 Program of IoT-Based Agriculture Pesticide Spraying System

The figures below show the program in IoT-based agriculture pesticide spraying system. The program are consists of manual control on the system with virtual and real buttons scheme, task scheduling function for automatic control and notification feature. At the beginning, the library used for IoT platform in the entire system, 'ArduinoIoTCloud' and 'Arduino_ConnectionHandler' are called. The pin number used in microcontroller to realize the system operation is defined together with Wi-Fi information and device login information in IoT platform as shown in Figure 4.28.

```
#include <ArduinoIoTCloud.h>
#include <Arduino_ConnectionHandler.h>

#define pump 4
#define motor1 18
#define motor2 19
#define motordir1 21
#define motordir2 22
#define frontsensor 34
#define endsensor 35

const char DEVICE_LOGIN_NAME[]  = "e4cbe4d2-abdc-4e39-a738-27d3614b9f2e";

const char SSID[]               = "  ";
const char PASS[]               = "  ";
const char DEVICE_KEY[]  = "5AMq@YyBl8Ulgr2Tz88NKb8oK";
```

**Figure 4.28: Code about Device Login Information and Wi-Fi Connection**

Then, each of the functions related to the changes in IoT platform are declared and called as shown in figures below.

```
void onMotorForwardChange();
void onMotorReverseChange();
void onWaterPumpChange();
void onScheduleChange();
```

**Figure 4.29: Code about Function Calling**



```
void onMotorForwardChange()
{
  if(motor_Forward==1)
  {
    messenger = "Moving forward";
    digitalWrite(motordir1, HIGH);
    digitalWrite(motordir2, LOW);
    for(int k=0; k<5; k++)
    {
      for(int j=0; j<5; j++)
      {
        for(int i=0; i<5000; i++)
        {
          digitalWrite(motor1, HIGH);
          digitalWrite(motor2, HIGH);
          delayMicroseconds(500);
          digitalWrite(motor1, LOW);
          digitalWrite(motor2, LOW);
          delayMicroseconds(500);
          if(digitalRead(endsensor)==LOW)
          {
            break;
            messenger = "Forward function is done";
          }
        }
      }
    }
    delay(500);
  }
}
```

**Figure 4.30: Code about Motor Forward Function**

```
void onMotorReverseChange()
{
  if(motor_Reverse==1)
  {
    messenger = "Moving reverse";
    digitalWrite(motordir1, LOW);
    digitalWrite(motordir2, HIGH);
    for(int k=0; k<5; k++)
    {
      for(int j=0; j<5; j++)
      {
        for(int i=0; i<5000; i++)
        {
          digitalWrite(motor1, HIGH);
          digitalWrite(motor2, HIGH);
          delayMicroseconds(500);
          digitalWrite(motor1, LOW);
          digitalWrite(motor2, LOW);
          delayMicroseconds(500);
          if(digitalRead(frontsensor)==LOW)
          {
            break;
            messenger = "Reverse function is done";
          }
        }
      }
    }
    delay(500);
  }
}
```

**Figure 4.31: Code about Motor Reverse Function**

```
void onWaterPumpChange()
{
  if(water_Pump==1)
  {
    messenger = "Pump on";
    digitalWrite(pump,HIGH);
    delay(500);
  }
  else
  {
    messenger = "Pump off";
    digitalWrite(pump,LOW);
    delay(500);
  }
}
```

**Figure 4.32: Code about Water Pump**

```
void onScheduleChange()
{

}
```

**Figure 4.33: Code about Task Scheduling**

After that, the function about properties of could variable in IoT-based agriculture pesticide spraying system is declared and Wi-Fi connection is setup according to the information defined previously as shown in Figure 4.34.

```
void initProperties()
{
  ArduinoCloud.setBoardId(DEVICE_LOGIN_NAME);
  ArduinoCloud.setSecretDeviceKey(DEVICE_KEY);
  ArduinoCloud.addProperty(messenger, READ, ON_CHANGE, NULL);
  ArduinoCloud.addProperty(motor_Forward, READWRITE, ON_CHANGE, onMotorForwardChange);
  ArduinoCloud.addProperty(motor_Reverse, READWRITE, ON_CHANGE, onMotorReverseChange);
  ArduinoCloud.addProperty(water_Pump, READWRITE, ON_CHANGE, onWaterPumpChange);
  ArduinoCloud.addProperty(schedule, READWRITE, ON_CHANGE, onScheduleChange);
}

WiFiConnectionHandler ArduinoIoTPreferredConnection(SSID, PASS);
```

**Figure 4.34: Code about Properties of Cloud Variable Initialization and Wi-Fi Connection**

Next, the variables and pin modes is executed for system initialization.

```
void setup()
{
  Serial.begin(9600);
  delay(1500);

  pinMode(pump, OUTPUT);
  pinMode(motor1, OUTPUT);
  pinMode(motor2, OUTPUT);
  pinMode(motordir1, OUTPUT);
  pinMode(motordir2, OUTPUT);
  pinMode(frontsensor, INPUT);
  pinMode(endsensor, INPUT);

  initProperties();

  ArduinoCloud.begin(ArduinoIoTPreferredConnection);

  setDebugMessageLevel(2);
  ArduinoCloud.printDebugInfo();
}
```



**Figure 4.35: Code about System Setup**

In continuous code running function, the properties of cloud variable in IoT platform and the change in real buttons is updated continuously to trigger the function of IoT-based agriculture pesticide spraying system as shown in Figure 4.36 and Figure 4.37.

```
void loop()
{
  ArduinoCloud.update();
```

**Figure 4.36: Code about Cloud Variable Update**

```
    if(touchRead(T9)<50)
    {
```

**Figure 4.37: Code about Real Button Changes**

## 4.8 Analysis on the Performance of IoT-Based Agriculture Pesticide Spraying System

The analysis is conducted on the efficiency of linear motion mechanism (percentage of slippage on timing belt) and the reliability of system (percentage of system control failure and 'Schedule' function operation).

### 4.8.1 The Percentage of Slippage on Timing Belt

From the observation, the average slippage is 35.17 mm and total of 3.52 % of slippage on timing belt in IoT-based agriculture pesticide spraying system if it is operated to move 1 m. The detailed information is shown in Table 4.2 and Figure 4.38.

**Table 4.2: Percentage of Slippage on Timing Belt**

| Number of times | Distance between the notations on roller and c-channel (mm) | The percentage of slippage (%) |
|---|---|---|
| 1st | 37.00 | 3.70 |
| 2nd | 32.30 | 3.23 |
| 3rd | 33.50 | 3.35 |
| 4th | 36.90 | 3.69 |
| 5th | 35.00 | 3.50 |
| 6th | 35.40 | 3.54 |
| 7th | 35.50 | 3.55 |
| 8th | 36.00 | 3.60 |
| 9th | 34.30 | 3.43 |
| 10th | 34.30 | 3.43 |
| 11th | 34.70 | 3.47 |
| 12th | 35.80 | 3.58 |
| 13th | 33.10 | 3.31 |
| 14th | 32.90 | 3.29 |
| 15th | 38.10 | 3.81 |
| 16th | 36.60 | 3.66 |
| 17th | 36.20 | 3.62 |
| 18th | 36.80 | 3.68 |
| 19th | 35.10 | 3.51 |
| 20th | 33.90 | 3.39 |
| **Average** | **35.17** | **3.52** |

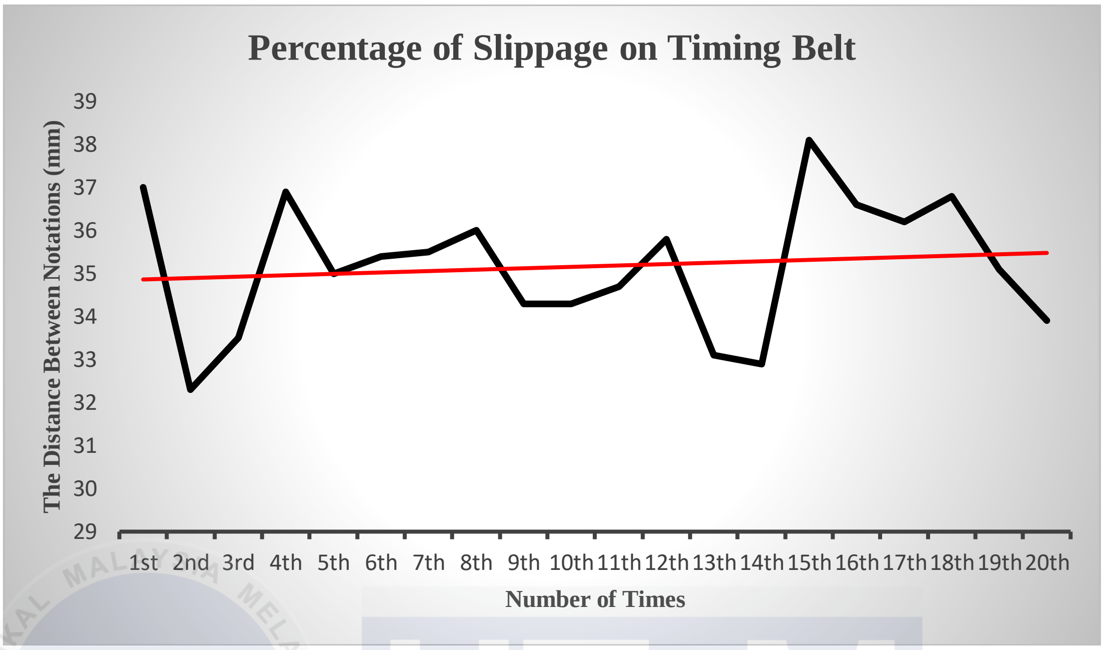



**Figure 4.38: Graph Representation on Percentage of Slippage on Timing Belt**

### 4.8.2 The Probability of System Failure (Loss Control)

The progress of system operation:

1. Water pump turn on: 25%
2. Motor forward: 50%
3. Motor reverse: 75%
4. Water pump turn off: 100%

From the observation, the percentage of system failure is achieved 0%. The system operates in stable condition without any errors. The detailed information is shown in Table 4.3 and Figure 4.39.

**Table 4.3: Probabilty of System Failure (Loss Control)**

| Number of times | Failure of System Control | Percentage (%) |
|---|---|---|
| 1st | No | 100 |
| 2nd | No | 100 |
| 3rd | No | 100 |
| 4th | No | 100 |
| 5th | No | 100 |
| 6th | No | 100 |

| | | |
|---|---|---|
| 7th | No | 100 |
| 8th | No | 100 |
| 9th | No | 100 |
| 10th | No | 100 |
| 11th | No | 100 |
| 12th | No | 100 |
| 13th | No | 100 |
| 14th | No | 100 |
| 15th | No | 100 |
| 16th | No | 100 |
| 17th | No | 100 |
| 18th | No | 100 |
| 19th | No | 100 |
| 20th | No | 100 |

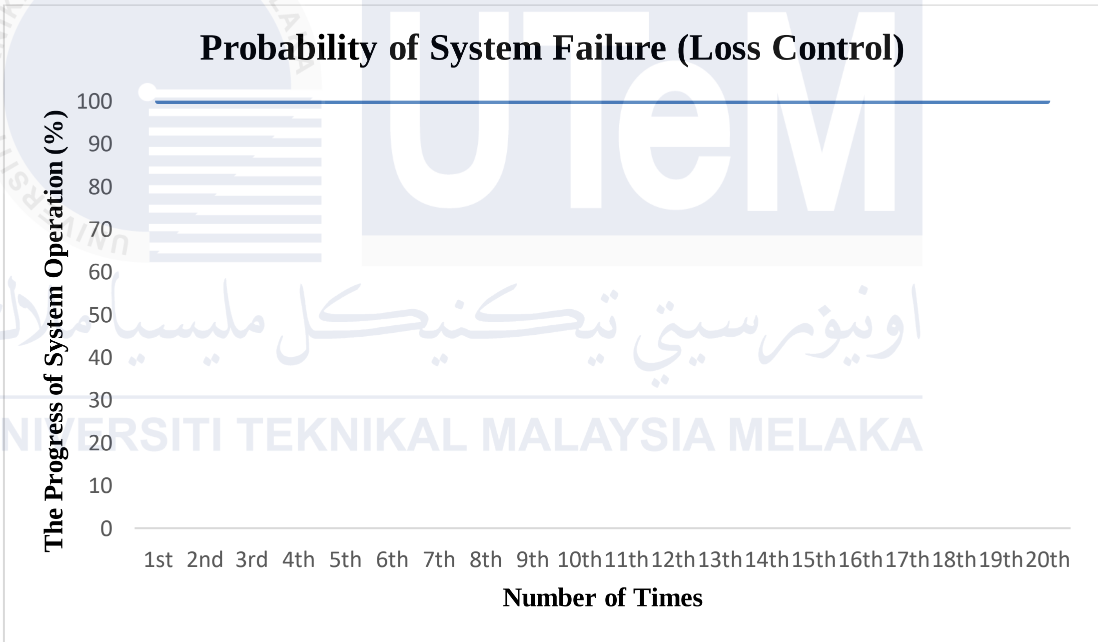



**Figure 4.39: Graph Representation on Probability of System Failure (Loss Control)**

### 4.8.3 The Probability of 'Schedular' Function Failure (Loss Control)

There are total of 9 time slots to run the 'Schedular' function regularly. From the observation, the 'Schedular' function is successfully operated in the time slots according to the setting in the IoT platform. The detailed information is shown in Table 4.4.

Table 4.4: Probabilty of 'Schedular' Function Failure (Loss Control)

| Number of times | Failure of 'Schedular' Function |
|---|---|
| 1300 | No Failure |
| 1315 | No Failure |
| 1330 | No Failure |
| 1345 | No Failure |
| 1400 | No Failure |
| 1415 | No Failure |
| 1430 | No Failure |
| 1445 | No Failure |
| 1500 | No Failure |

## 4.9 Problem Identification on IoT-Based Agriculture Pesticide Spraying System

This section provides the design defect and problems met in IoT-based agriculture pesticide spraying system. The problems are classified into 2 main section, hardware-based and software-based.

### 4.9.1 Hardware-Based Problems

There are 3 hardware-based problems found in the completed IoT-based agriculture pesticide spraying system.

#### 4.9.1.1 Drooping Factor in Timing Belt

In the design of IoT-based agriculture pesticide spraying system, the design defect are found in timing belt application as shown in Figure 4.40. In the project, a total of 10 m timing belt applied on each side. However, the drooping factor appears in the timing belt due to the system design lack of tensioners (idler) being attached in order to keep ideal tension on the belt along its full length.

**Figure 4.40: Drooping in Timing Belt**

#### 4.9.1.2 Timing Belt Broken Problem

In the operation of IoT-based agriculture pesticide spraying system, the broken of timing belt is occured as shown in Figure 4.41. This may be attributed by improper design or operation in the system. The timing belt is broken after more than 100 times of system running.



**Figure 4.41: Timing Belt Broken Problem**

#### 4.9.1.3 Deviation of Pesticide Spraying Pipe

In the design of IoT-based agriculture pesticide spraying system, the pesticide spraying pipe have deviation problem when the system is operating as shown in Figure 4.42. This is because the centre gravity of pesticide spraying pipe could not counteract the pulling force from the hose pipe at below. This issue can be further affecting the linear motion mechanism in system operation which increase the slippage in timing belt.

**Figure 4.42: Pesticide Spraying Pipe Deviation Problem**

### 4.9.2 Software-Based Problems

There are 2 software-based problems found in the completed IoT-based agriculture pesticide spraying system.

#### 4.9.2.1 Server Downtime

In the IoT platform used in IoT-based agriculture pesticide spraying system had found server downtime problem. This problem makes the online control solution suspended which the pesticide spraying system only can be control through practical control panel. Other than that, the task scheduling function also halted due to connection error between the device (microcontroller) and the server.

#### 4.9.2.2 Runtime Error in Program

In the program of IoT-based agriculture pesticide spraying system, the system operation got error in some of the specific values of the number of loops in *for* statement. The system crashes and loses control until RESET button on microcontroller is pressed. This may be caused by the limitation of code writing rules that compatible with ESP32's architecture, so that the generated machine code contributed to a fault in the microcontroller.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Overview

This chapter provides a comprehensive conclusion according to the findings and analysis in this project. Then, recommendations for future work are detailed in accordance with the needs in order to improve the performance and solve the problems in the system.

## 5.2 Conclusion

In this report, it can be concluded that the IoT-based agriculture pesticide spraying system designed and deployed specifically for Cucumis Melo is fulfilled all the requirements and conditions discussed as a prototype. It appeared as a different solution from general fixed-typed and mobile-typed pesticide spraying technology. It provides with automation and manual control which maximize the support on practical conditions in agriculture sector to ease use of system.

In objective 1, the structural of IoT-based agriculture pesticide spraying system utilizing linear motion mechanism is designed with the concept of synchronous and bilateral operation on stepper motors which provides with stable and robust linear motion mechanism in the system. In linear motion mechanism, timing belt and pulley is utilized as the method to convey the pesticide spraying pipe along the Cucumis Melo plot. For pesticide spraying pipe design, fan mist nozzle is applied to expand the pesticide spraying coverage in the aspect of spraying angle and distance while PVC ball valve is added as control valve to limit the pesticide spraying according to the growth status (height) of Cucumis Melo plant in order to reduce the pesticide usage.

In objective 2, the IoT-based agriculture pesticide spraying system is fully developed in Cucumis Melo plot utilizing all the materials in the bill of materials stated in Table 4.1. For IoT platform design and development, Arduino Cloud is used to create, control and monitor the whole system. It had provided desktop and mobile control solution for the system. In physical control panel fabrication, the PCB is design according to the schematic diagram of the entire system then the electronic components are installed on PCB to realize the function in the system.

In objective 3, the analysis on the performance of IoT-based agriculture pesticide spraying system is conducted in aspect of its efficiency and reliability. For the percentage of slippage in timing belt, the results obtained is 3.52% which considered as minimal slippage in timing belt. For functionality of system, the system had achieved 0% in the probability of system failure which means the design and develop in hardware and software are considered feasible because no errors. For functionality of automation control of system, the 'Schedular' function is successfully operated in all the time slots set in IoT platform. Hence, it can be considered the system can be operated punctually and periodically.

## 5.3 Future Work

In this project, timing belt and pulley is not suitable to be applied in linear motion mechanism because long distance in system implementation causes drooping factor in timing belt as discussed in problem identification. It should be replaced by other components or redesign the system configuration to solve this problem. Then, the analysis on the performance of the system is conducted in only one speed in stepper motor. Hence, the analysis on different speed in stepper motor should be carried out to improve the hardware design and develop in the system. Other than that, the runtime error in the system program is essential to be solve through the study in technical sheet of ESP32 in order to reduce the system error.

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# APPENDIX

## APPENDIX A

```
#include <ArduinoIoTCloud.h>
#include <Arduino_ConnectionHandler.h>

#define pump 4
#define motor1 18
#define motor2 19
#define motordir1 21
#define motordir2 22
#define frontsensor 34
#define endsensor 35

const char DEVICE_LOGIN_NAME[]  = "e4cbe4d2-abdc-4e39-a738-27d3614b9f2e";

const char SSID[]               = "COACH_BAHAR_CAFE";
const char PASS[]               = "bcd123pat";
const char DEVICE_KEY[]  = "5AMq@YyBl8Ulgr2Tz88NKb8oK";

void onMotorForwardChange();
void onMotorReverseChange();
void onWaterPumpChange();
void onScheduleChange();

String messenger;
bool motor_Forward;
bool motor_Reverse;
bool water_Pump;
CloudSchedule schedule;

void initProperties()
{
  ArduinoCloud.setBoardId(DEVICE_LOGIN_NAME);
  ArduinoCloud.setSecretDeviceKey(DEVICE_KEY);
  ArduinoCloud.addProperty(messenger, READ, ON_CHANGE, NULL);
  ArduinoCloud.addProperty(motor_Forward, READWRITE, ON_CHANGE,
onMotorForwardChange);
  ArduinoCloud.addProperty(motor_Reverse, READWRITE, ON_CHANGE,
onMotorReverseChange);
  ArduinoCloud.addProperty(water_Pump, READWRITE, ON_CHANGE,
onWaterPumpChange);
  ArduinoCloud.addProperty(schedule, READWRITE, ON_CHANGE,
onScheduleChange);
}
WiFiConnectionHandler ArduinoIoTPreferredConnection(SSID, PASS);
```

```
void setup()
{
  Serial.begin(9600);
  delay(1500);

  pinMode(pump, OUTPUT);
  pinMode(motor1, OUTPUT);
  pinMode(motor2, OUTPUT);
  pinMode(motordir1, OUTPUT);
  pinMode(motordir2, OUTPUT);
  pinMode(frontsensor, INPUT);
  pinMode(endsensor, INPUT);

  initProperties();

  ArduinoCloud.begin(ArduinoIoTPreferredConnection);

  setDebugMessageLevel(2);
  ArduinoCloud.printDebugInfo();
}

void loop()
{
  ArduinoCloud.update();

  if(schedule.isActive())
  {
    messenger = "Pesticide spraying is started";
    digitalWrite(pump, HIGH);
    delay(500);

    digitalWrite(motordir1, HIGH);
    digitalWrite(motordir2, LOW);
    for(int j=0; j<15; j++)
    {
      for(int i=0; i<5000; i++)
      {
        digitalWrite(motor1, HIGH);
        digitalWrite(motor2, HIGH);
        delayMicroseconds(500);
        digitalWrite(motor1, LOW);
        digitalWrite(motor2, LOW);
        delayMicroseconds(500);
        if(digitalRead(endsensor==LOW))
        {
          delay(1000);
          digitalWrite(pump, LOW);
```

```
        digitalWrite(motordir1, LOW);
        digitalWrite(motordir2, HIGH);
        for(int j=0; j<15; j++)
        {
          for(int i=0; i<5000; i++)
          {
            digitalWrite(motor1, HIGH);
            digitalWrite(motor2, HIGH);
            delayMicroseconds(500);
            digitalWrite(motor1, LOW);
            digitalWrite(motor2, LOW);
            delayMicroseconds(500);
            if(digitalRead(frontsensor)==LOW)
            {
              messenger = "Pesticide spraying is done";
              break;
            }
          }
        }
      }
    }
  }
}

if(water_Pump==0)
{
  if(touchRead(T9)<50)
  {
    messenger = "Pump on";
    digitalWrite(pump, HIGH);
    delay(5000);
    messenger = "Pump off";
    digitalWrite(pump, LOW);
    delay(500);
  }
}

if(motor_Forward==0 && touchRead(T8)<50)
{
  messenger = "Moving forward";
  digitalWrite(motordir1, HIGH);
  digitalWrite(motordir2, LOW);
  for (int i=0; i<5000; i++)
  {
    digitalWrite(motor1, HIGH);
```

```
      digitalWrite(motor2, HIGH);
      delayMicroseconds(500);
      digitalWrite(motor1,LOW);
      digitalWrite(motor2,LOW);
      delayMicroseconds(500);
      if(digitalRead(endsensor)==LOW)
      {
        messenger = "Forward function is done";
        break;
      }
    }
    delay(500);
  }

  if(motor_Reverse==0 && touchRead(T7)<50)
  {
    messenger = "Moving reverse";
    digitalWrite(motordir1, LOW);
    digitalWrite(motordir2, HIGH);
    for (int i=0; i<5000; i++)
    {
      digitalWrite(motor1, HIGH);
      digitalWrite(motor2, HIGH);
      delayMicroseconds(500);
      digitalWrite(motor1, LOW);
      digitalWrite(motor2, LOW);
      delayMicroseconds(500);
      if(digitalRead(frontsensor)==LOW)
      {
        messenger = "Reverse function is done";
        break;
      }
    }
    delay(500);
  }

  return;
}

void onMotorForwardChange()
{
  if(motor_Forward==1)
  {
    messenger = "Moving forward";
    digitalWrite(motordir1, HIGH);
    digitalWrite(motordir2, LOW);
```

```
 for(int k=0; k<5; k++)
    {
      for(int j=0; j<5; j++)
      {
        for(int i=0; i<5000; i++)
        {
          digitalWrite(motor1, HIGH);
          digitalWrite(motor2, HIGH);
          delayMicroseconds(500);
          digitalWrite(motor1, LOW);
          digitalWrite(motor2, LOW);
          delayMicroseconds(500);
          if(digitalRead(endsensor)==LOW)
          {
            break;
            messenger = "Forward function is done";
          }
        }
      }
    }
    delay(500);
  }
}

void onMotorReverseChange()
{
  if(motor_Reverse==1)
  {
    messenger = "Moving reverse";
    digitalWrite(motordir1, LOW);
    digitalWrite(motordir2, HIGH);
    for(int k=0; k<5; k++)
    {
      for(int j=0; j<5; j++)
      {
        for(int i=0; i<5000; i++)
        {
          digitalWrite(motor1, HIGH);
          digitalWrite(motor2, HIGH);
          delayMicroseconds(500);
          digitalWrite(motor1, LOW);
          digitalWrite(motor2, LOW);
          delayMicroseconds(500);
          if(digitalRead(frontsensor)==LOW)
          {
            break;
```

```
            messenger = "Reverse function is done";
          }
        }
      }
    }
    delay(500);
  }
}

void onWaterPumpChange()
{
  if(water_Pump==1)
  {
    messenger = "Pump on";
    digitalWrite(pump,HIGH);
    delay(500);
  }
  else
  {
    messenger = "Pump off";
    digitalWrite(pump,LOW);
    delay(500);
  }
}

void onScheduleChange()
{

}
```

APPENDIX B

| | FYP I | | | | | | | | | | | | | | | FYP II | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 | W16 | W17 | W18 | W19 | W20 | W21 | W22 | W23 | W24 | W25 | W26 |
| Study on literature review | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Define problem statement | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Define the objective | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Design of experiment | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Design the system (SolidWorks) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proceed on experiment | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Discuss on initial results and analysis | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conclusion | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Finalization on FYP I report | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Site Investigation | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Redesign on system (SolidWorks) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Procurement process | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Development of system | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Modification & Improvement of System | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Analysis process | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Discussion on findings | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conclusion | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Finalization on report | | | | | | | | | | | | | | | | | | | | | | | | | | |