Faculty of Electrical Technology and Engineering

DESIGN AND DEVELOPMENT OF A PESTICIDE SPRAYING APPLICATION ROBOT FOR VEGETABLES FARM USING RASPBERRY PI

IQMAL ZIKRY BIN MOHD AZUDDIN

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

2023

DESIGN AND DEVELOPMENT OF A PESTICIDE SPRAYING APPLICATION ROBOT FOR VEGETABLES FARM USING RASPBERRY PI

IQMAL ZIKRY BIN MOHD AZUDDIN

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

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN AND DEVELOPMENT OF A PESTICIDE SPRAYING APPLICATION ROBOT FOR VEGETABLES FARM USING RASPBERRY PI

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Name (if any)

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DEDICATION

To my beloved mother,

Junaidah Binti Halim,

and

father,

Mohd Azuddin Bin Parman

ABSTRACT

This thesis describes the design and development of a robot for spraying pesticides on vegetable plantations. This project aims to develop a robotic system that can spray pesticides on crops efficiently and precisely, thereby reducing the need for manual labour and increasing the efficiency of pesticide application. The robot's primary controller is a Raspberry Pi, equipped with several sensors and a pesticide dispensing system. The literature review examines extant pesticide spraying robots in agriculture and highlights their deficiencies, highlighting the need for an optimized solution. The methodology section describes the overall system architecture and justifies the selection of particular hardware components. Design considerations for the pesticide sprinkling mechanism and the creation of control algorithms and software implementation are described. Integrating sensors for environmental perception and the communication system between the robot and a central control centre is also addressed. The segment on system design and implementation discusses the robot's mechanical design and construction and the mechanism for spraying pesticides. The software architecture, implementation particulars and sensor and actuator integration are provided. Calibration and testing procedures are in place to ensure precise and reliable performance. The robot's precision, efficiency, and coverage performance are assessed and compared to existing solutions or standards. The results are interpreted and discussed in the discussion section, which evaluates the robot's effectiveness in the environment of a vegetable farm, as well as its feasibility, dependability and practicability. The designed automaton has the potential to enhance crop protection practices, reduce manual labour and optimize pesticide consumption, which will ultimately benefit the agricultural industry. This thesis is to observe the performance of the robot regarding the movement of wheels and the performance of pesticide spraying application build in the robot. Speed of robot, distance of pesticide distribution, time taken to empty tank, flow rate of pesticide distribution and coverage of pesticide on plant are the parameters to observe the pesticide spraying application.

ABSTRAK

Tesis ini menerangkan reka bentuk dan pembangunan robot untuk menyembur racun perosak di ladang sayuran. Projek ini bertujuan untuk membangunkan sistem robotik yang boleh menyembur racun perosak pada tanaman dengan cekap dan tepat, seterusnya mengurangkan keperluan untuk buruh manual dan meningkatkan kecekapan penggunaan racun perosak. Pengawal utama robot ialah Raspberry Pi, dilengkapi dengan beberapa penderia dan sistem pendispensan racun perosak. Kajian literatur mengkaji robot penyembur racun perosak yang masih ada dalam pertanian dan menyerlahkan kekurangannya, menonjolkan keperluan untuk penyelesaian yang dioptimumkan. Bahagian metodologi menerangkan seni bina sistem keseluruhan dan mewajarkan pemilihan komponen perkakasan tertentu. Pertimbangan reka bentuk untuk mekanisme percikan racun perosak dan penciptaan algoritma kawalan dan pelaksanaan perisian diterangkan. Mengintegrasikan sensor untuk persepsi alam sekitar dan sistem komunikasi antara robot dan pusat kawalan pusat juga ditangani. Segmen mengenai reka bentuk dan pelaksanaan sistem membincangkan reka bentuk dan pembinaan mekanikal robot dan mekanisme untuk menyembur racun perosak. Seni bina perisian, butiran pelaksanaan dan penyepaduan sensor dan penggerak disediakan. Prosedur penentukuran dan ujian disediakan untuk memastikan prestasi yang tepat dan boleh dipercayai. Ketepatan, kecekapan dan prestasi liputan robot dinilai dan dibandingkan dengan penyelesaian atau piawaian sedia ada. Hasilnya ditafsir dan dibincangkan dalam bahagian perbincangan, yang menilai keberkesanan robot dalam persekitaran ladang sayuran, serta kebolehlaksanaan, kebolehpercayaan dan kebolehpraktikannya. Automat yang direka bentuk berpotensi untuk meningkatkan amalan perlindungan tanaman, mengurangkan buruh manual dan mengoptimumkan penggunaan racun perosak, yang akhirnya akan memberi manfaat kepada industri pertanian. Tesis ini adalah untuk melihat prestasi robot berkenaan pergerakan roda dan prestasi binaan aplikasi penyemburan racun makhluk perosak dalam robot. Kelajuan robot, jarak pengedaran racun perosak, masa yang diambil untuk mengosongkan tangki, kadar aliran pengedaran racun perosak dan liputan racun pada tumbuhan adalah parameter untuk memerhatikan aplikasi penyemburan racun perosak.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Ts. Khalil Azha Bin Mohd Annuar for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) which enables me to accomplish the project. Not forgetting my fellow colleague, Muhammad Haziq Bin Mohd Khairul Sam, Muhammad Aiman Bin Mohd Azam, Arif Hakimi Bin Abdul Muhaimin, Muhammad Salim Bin Mathadi and others for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents, Junaidah Binti Halim and Mohd Azuddin Bin Parman, and family members, Izzatul Abdah Binti Mohd Azuddin, Idzhan Arief Bin Mohd Azuddin and Izz Irfan Bin Mohd Azuddin for their love and prayer during the period of my study.

Finally, I would like to thank all fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

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LIST OF SYMBOLS

t	-	Time elapsed
v	-	Speed
d	-	Distance
Q	-	Flow rate
V	-	Volume

LIST OF ABBREVIATIONS

m	-	Meter
s	-	Seconds
min	-	Minute
L	-	Litre

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture has been an integral element of human civilisation since the Neolithic period, also known as the New Stone Age. As the global population continues to rise rapidly, there is a growing demand for sustenance. Vegetable cultivation is essential to agriculture, as it contributes to a healthy and balanced diet.

Vegetables provide essential vitamins, minerals, and dietary fibre, making them essential to a healthy diet and lifestyle. The demand for fresh and safe vegetables is growing, necessitating more efficient cultivation techniques. Figure 1.1 depicts the global population size and annual growth from 1950 to 2022 and the medium scenario from 2022 to 2050 [1]. Figure 1.2 depicts the proportion of individuals by age who consume vegetable servings [2].

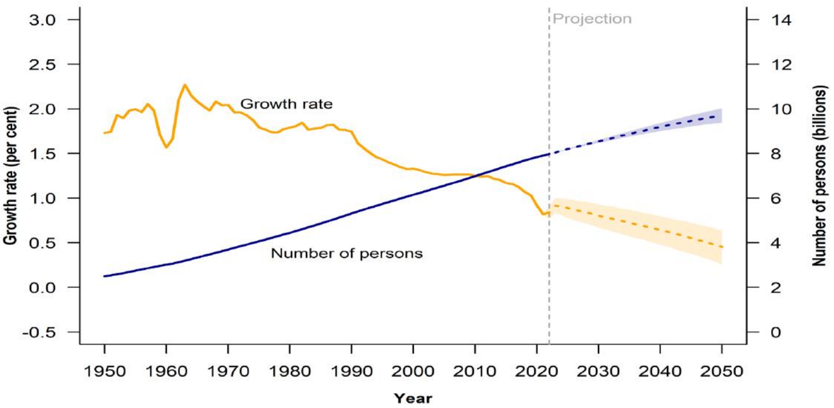


Figure 1.1 The global population size and annual growth from 1950-2022 and medium scenario with intervals from 2022-2050.

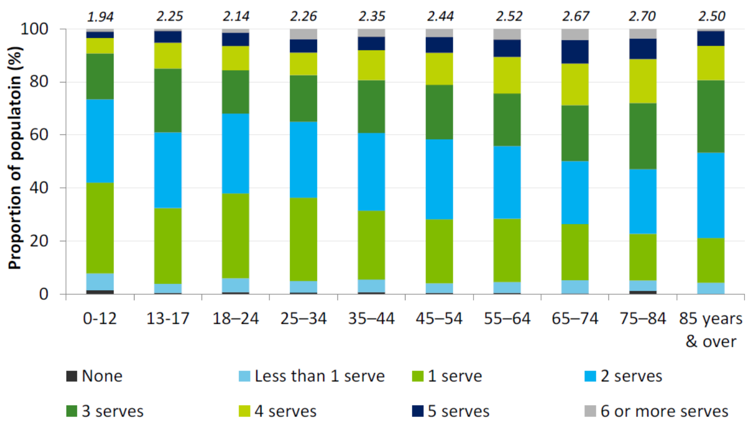


Figure 1.2 The proportion consuming serves of vegetables by age.

The earlier labour force was especially proficient at managing agricultural tasks. Today, automation has been developed to assist farmers in executing agricultural tasks to boost efficiency and productivity. Pesticide spraying, an important agricultural activity, has been automated using robots.

Among the insect pests that assault vegetable crops are aphids, caterpillars, mites and beetles. Pesticides control these pests by destroying them on contact or through systemic action, where the pesticide is absorbed by the plant and consumed by the pests. It may contribute to the prevention of crop injury, the reduction of yield losses and the improvement of vegetable quality. Figure 1.3 shows the common insect pests that attack vegetable crops in vegetables farm.

(a) Aphid

(b) Caterpillar

(c) Mites

(d) Beetle

Figure 1.3 Insect pests that attack vegetable crops in vegetables farm.

In vegetable cultivation, pesticides are frequently used to protect crops from insects, diseases, and plants. Moreover, numerous diseases caused by fungi and bacteria can harm plants. Fungicides and bactericides are utilized to prevent and control the spread of these diseases. They can be utilized as preventative measures before the emergence of the disease or as curative remedies once the infection has taken hold.

Applying pesticides for disease control helps maintain crop health, increase yield and preserve the market value of vegetables. Spraying plants with pesticides to defend them from pests and diseases is known as pesticide spraying. The pesticides shown in Figure 1.5 can affect vegetables.

(a) Fungicide

(b) Bactericide

Figure 1.4 Pesticides that can affect vegetable crops.

1.2 Societal and Global Issues and Sustainable Development

Farmers often rely on manual labor in conventional farming to transport and apply pesticides to produce. This procedure requires physically applying pesticide to each crop, which can be time-consuming and labor-intensive. Farmers work assiduously to ensure that their crops are adequately protected from pests and diseases, from carrying the heavy pesticide tank to spraying each plant precisely.

Despite the difficulties, these devoted farmers persevere, recognizing pesticides' crucial role in protecting their crops and maximizing agricultural yields. However, as agricultural technology develops, there is a growing interest in investigating more efficient and automated pesticide application methods that could reduce the burden on producers and increase field productivity. Instead of bearing a pesticide tank on your shoulders and walking to each plant, robots can spray pesticides. Figure 1.5 illustrates an example of a heavy pesticide spraying vessel that farmers must carry.

Figure 1.5 Example of heavy tank need to be caried by farmers for pesticide spraying.

Research will be conducted to surmount the difficulties and disadvantages of pesticide spraying. To gain a deeper understanding of the pesticide spraying application automaton, research objectives and a literature review will be established. Component and system configuration analysis would be utilized to develop a prototype for pesticide application practices. Data would be collected and analyzed to determine the robot's effectiveness and efficacy. A conclusion would be drawn to conclude the endeavour.

1.3 Problem Statement

Agriculture is a crucial industry for human survival and food security, and pest and weed management is one of its main challenges. Traditional agricultural pesticide application procedures are labour-intensive, time-consuming, and expose workers to hazardous chemical substances. Pesticides are applied manually using traditional methods, handheld sprayers, or comparable equipment. It may require personnel to bodily traverse vast areas, frequently over great distances, while carrying heavy equipment. Due to its manual nature, the technique is time-consuming and physically demanding. Aside from that, consistent coverage and accurate pesticide application are crucial for effective pest management. Alternatively, traditional sprinkling methods may need to be more accurate and consistent. It may be challenging for employees to apply pesticides uniformly across designated areas, resulting in insufficient or over-application. Repeated passes or adjustments may be necessary to provide adequate coverage, increasing the required time and effort. In addition, pesticides can harm human health, so workers must employ fundamental safety measures. It is required to wear protective clothing, masks and spectacles and to adhere to specified handling and disposal procedures. These precautions prolong and confound the spraying process. Therefore, a more efficient and effective solution that is cost-effective, environmentally friendly and reduces the need for human labour is necessary. This thesis will discuss and concentrate on developing a pesticide spraying robot that will benefit vegetable farmers by demonstrating or applying pesticide spraying to plants and crops.

1.4 Project Objective

The specific objectives of the project are as follows:

a) To design and develop a pesticide spraying application robot using Raspberry Pi.

b) To evaluate the performance of the robot's movement and mobility.

c) To analyse the performance of the pesticide spraying application build in the robot regarding the condition of plant for vegetable farm.

1.5 Scope of Project

The aim of this thesis is to design and construct a robotic system for pesticide spraying. The following aspects will be included in the project:

a) The size of the prototype will be 59.5 cm × 53 cm area.

b) The pesticide spraying application robot could move forward, reverse, left and right in the testing. The performance of robot which include the speed of robot, distance of pesticide distribution, time taken to empty tank and flow rate of pesticide distribution would be analysed.

c) The prototype will be tested on a chilli plant. Coverage of pesticide distribution on plant would be analysed.

d) The project consists of microcontroller programming and IoT platform configuration. The microcontroller is Raspberry Pi 4 Model B and the IoT platform will be Node-RED.

e) The system will be functioning in the Wi-Fi coverage range.

1.6 Report Structure and Organization

The thesis contains five chapters. Each chapter would comprise relevant information and materials for this project. In Chapter 1, the history of robot-spraying pesticides on vegetable farms will be discussed. Based on the encountered problem description, a few objectives are outlined as a guide for future reference.

A literature evaluation is conducted in Chapter 2 to provide knowledge and comprehension of other research to reduce unresolved issues and prevent project repetition. Earlier research efforts are compared to ascertain the advantages and disadvantages of each approach. In Chapter 3, the components to build the prototype are selected. The selection of components is divided to 4 which are mechanical part, electronic part, software part and body and tank.

In Chapter 4, interim findings that should be attained by the designed system following component testing are presented. This result will serve as a guide for future work in the second task of the senior project. This project's efforts and labour and summaries of all processes completed within this project will be concluded in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This section analyzes and discusses the general concept and theory of the pesticide sprinkling robot for vegetable farms. The concept and theory are utilized to determine and presume the project's title's problems and solutions. In this section, previous and current research are explained and summarized. As the primary source of information, articles, journals and case studies are compiled based on their similarity to the project's scope.

2.2 Introduction of Pesticide Spraying Robot

The pesticide sprinkling robot is a device that facilitates the application of bactericides, fungicides, herbicides and insecticides to crops. A pesticide spraying robot is outfitted with spray nozzles, a pesticide pump, a microcontroller or microprocessor, wheels and sensors to move effortlessly and evenly distribute pesticides to all crops.

Some robots that apply pesticides are autonomous and can navigate and spray pesticides without human intervention. It indicates that the robots are programmed and act based on the microcontroller or microprocessor and sensors. There are also semi-automated pesticide-spraying robots that are controlled by humans and can navigate and apply pesticides. Figure 2.1 depicts an example of an agricultural pesticide sprinkling robot.

Figure 2.1 Pescticide Spraying Robot example.

2.3 Pesticide Spraying Techniques

Pesticide spraying techniques include a wide range of methods and technologies for applying chemical substances known as pesticides. These techniques aim to effectively control or eradicate pests that can cause significant damage to agricultural commodities, harm livestock, or pose health risks to humans. Several factors, which are the type of insect, the crop or area to be sprayed, environmental considerations and efficacy requirements, are considered when determining the best spraying technique. Aerial spraying, ground spraying, thermal fogging, misting and localized spot applications are typical pesticide spraying techniques. Each technique has benefits and drawbacks, including coverage area, precision, cost-effectiveness and potential environmental impacts. The development of more efficient and targeted application methods, such as precision agriculture and integrated pest management, which aim to minimize pesticide use while maximizing pest control efficacy, has been spurred by technological advancements.

2.3.1 Pesticide Spraying Machine

Pesticide spraying devices, also known as sprayers, are indispensable in agricultural and pest control practices for the efficient and effective application of chemical pesticides. These devices are designed to disperse pesticides in pesticide or aerosol form over specific areas, such as crops, fields or structures, to control or eliminate pests. Pesticide spraying equipment varies in size, intricacy, and functionality, from handheld sprayers for small-scale applications to large tractor-mounted or aerial sprayers for extensive agricultural operations. They include storage containers for pesticides, pumps or compressors for generating pressure, nozzles or atomisers for creating the desired spray pattern, and controls for regulating the spray volume and distribution. The design and selection of pesticide spraying machines are determined by variables such as the type of pesticide, the target pest, the application area, the desired coverage, and environmental considerations, emphasising achieving effective pest control while minimising pesticide usage and potential adverse impacts.

2.3.1.1 Hand Sprayer

The hand sprayer is a low-capacity pneumatic sprayer with a brass cylinder plated with chromium. The fundamental operation of this pump is carried out by an air pump housed within the reservoir. A short delivery tube with an adjustable nozzle is affixed to the sprayer. The reservoir is typically filled to approximately 70 per cent capacity and pressurized with an air pump for spraying. When the trigger is depressed, the pesticide mixture is expelled by compressed air. It is commonly used in tiny nurseries and residential gardens [3]. Figure 2.2 shows the example of hand sprayer used for pesticide spraying.

Figure 2.2 Hand sprayer example.

2.3.1.2 Knapsack Sprayer

In the phytosanitary control phase of many arable crops, manually-operated knapsack sprayers are used to apply insecticides and bio-fertilizers, among other substances. Spray discharges are produced by initiating and releasing pesticide particles to combat parasites, increase farm productivity, and contribute to global agricultural production. Due to their versatility, small, medium and large-scale producers use knapsack sprayers frequently. This equipment satisfies rural requirements because it is inexpensive and adaptable to the needs of specific communities [4]. A person maintains tank pressure by pushing air and directing the spray lance recommended lever strokes per minute range between 20 and 30 and 10 to 25. Maintaining constant pressure is difficult with a manual knapsack sprayer, whose extremely weighty, bulky structure causes operator fatigue [5]. Figure 2.3 shows an example of a knapsack sprayer.

Figure 2.3 Knapsack sprayer example.

2.3.1.3 Boom Sprayer

In developed nations, boom sprayers were created to assist farmers in eradicating plant parasites. A boom sprayer is a device propelled by a four-wheel tractor, with the operator merely controlling the sprinkling results [6]. Typically, sprayer pole lengths range from 12 to 40 m. [7]. When sprayer tires traverse uneven topography in the field, unintended boom motions commonly occur during operation. [8]. It may not only affect spraying but also cause the boom to meet the crop canopy or the ground, resulting in disastrous crop and boom damage. [9]. The best way is to monitor and regulate the distance between the boom and crop canopy to maintain an appropriate height to increase the uniformity of pesticide deposition and decrease the dispersion of droplets. [10]. Figure 2.4 shows an example of boom sprayer.

Figure 2.4 Boom sprayer example.

2.3.2 Advancement in Pesticide Spraying Techniques

Pesticide application techniques have evolved to increase efficiency, reduce environmental impact, and increase the efficacy of pest control measures. Precision agriculture techniques necessitate the creation of accurate field maps utilizing cutting-edge technology such as global positioning systems (GPS), remote sensing, and geographic information systems (GIS). These maps aid producers in identifying pest-infested areas, allowing for the targeted application of pesticides. This method reduces pesticide use by administering it only when required, reducing the environmental impact.

2.3.2.1 Back propagation neural network analysis of fluorescence spectra

Fluorescence spectroscopy, which measures the wavelength of light, is an additional method for detecting a particular type of pesticide. The light beam excites electrons in the sample molecules, causing them to emit light, which is then analyzed by a backpropagation neural network. A backpropagation neural network (BP) is a technique for machine learning that employs weighted hidden layers. We can also adjust the layer weights according to the error [11]. The technique of fluorescent spectroscopy is utilized to detect boscalid pesticides in grapes.

The wavelength of light required to detect the boscalid pesticide was determined to be 356 nanometers, where a peak indicated the presence of the pesticide [12]. The backpropagation neural network has high accuracy because it iteratively adjusts the hidden layer's weights to reach the required threshold. The greatest drawback is that it is time-consuming, as the number of repetitions depends on the desired data. The neural network can achieve greater precision and be utilized in numerous ways [13]. Figure 2.5 shows a fluorescent spectroscopy [14].

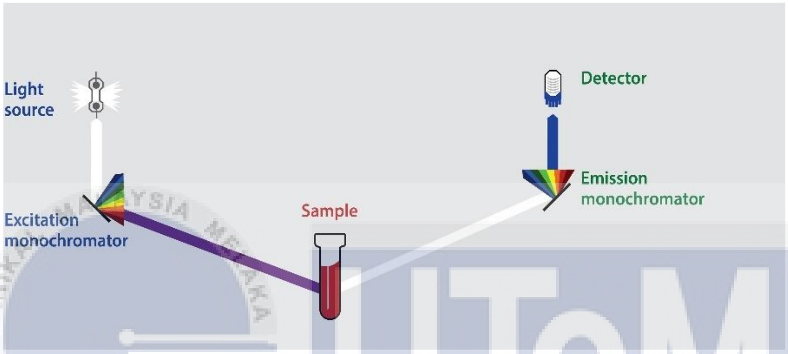


Figure 2.5 Flourescent spectroscopy.

2.3.2.2 Hyperspectral Imaging Sensor

That spectroscopy is the basis for hyperspectral imaging, which captures multiple images of a specific area at varying wavelengths. Hyperspectral imaging is a method that employs the electromagnetic spectrum to produce a spectrum of red, green, and blue (RGB) colours [15]. Hyperspectral imaging utilizes a camera that examines photographs over time-sequential bands canners (spectral scanning) to acquire photographs of a region at different wavelengths. An electron-multiplying charge-coupled device (EMCCD) camera captures the image. After passing through the hyperspectral spectrograph, the RGB light spectrum is polarized and displayed on the screen [16]. Figure 2.6 shows the working of hyperspectral imaging sensor.

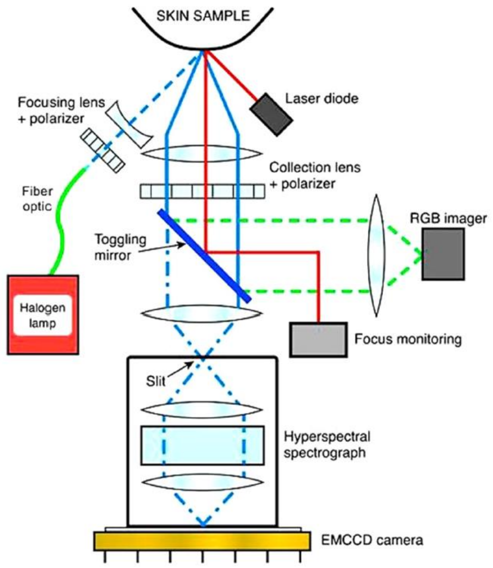


Figure 2.6 Working of hyperspectral imaging sensor.

2.3.2.3 Use of Embedded Technology

An embedded system is a combination of microprocessor-based hardware and software that is used to accomplish a given task either independently or as part of a more extensive system. Figure 2.7 shows the block diagram of detection system.

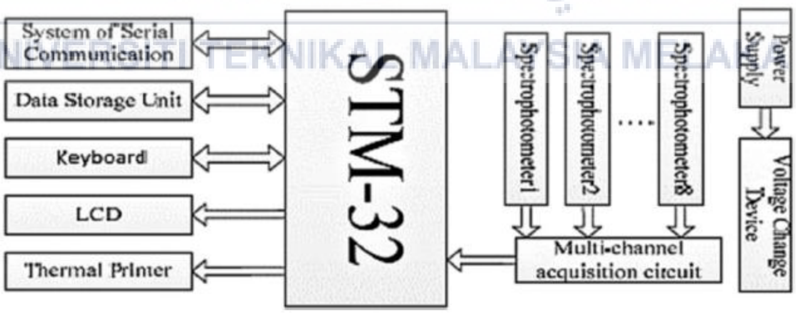


Figure 2.7 Block diagram of detection system.

That the optical channels contain a 412 nm monochromatic LED light, a colour compare pool, photoelectric detection, and a control circuit. A dim environment contains the optical component. It is capable of effectively avoiding the effects of stray light. Throughout the interaction, Microchip STM-32 is used as the primary regulator in the framework.

Advanced RISC processors (ARM) Cortex-M3 design is highlighted by STM-32's exceptional, low-cost, and low-force utilisation. Advanced RISC processors (ARM) Cortex-M3 design is underscored by STM-32's unique, low-cost, and low-force utilisation.

Incorporating a steady force supply into the peripheral circuit, the information memory, input/yield circuit, 320 * 240 thin-film transistor (TFT) touch screen, console, and other sequential terminals of the Peripheral circuit can communicate directly with the work area and finish information preparation. The device is powered by batteries or 220 V and weighs less than one kilogramme. It can detect pesticide residue within two minutes or less. The Op-amp circuit is composed of TLC2254T components. It has a low utilisation rate and a high rate of open-circle acquisition. Programming examples include analogue-to-digital conversion, touch-screen operation, data processing, file transfer, and system initialisation. [17].

2.4 Parts of Sprayers

In agricultural practices, pesticide sprayers are crucial in delivering pesticides to crops for insect control. These sprayers are comprised of several essential parts. The tank functions as the reservoir for the pesticide solution, and it is equipped with filling and draining fittings. It is typically made of polyethene or fibreglass. A gasoline- or electric-powered pump generates the necessary pressure to propel the pesticide solution through the system. The sprayer's nozzles, strategically placed along the boom or affixed to handheld wands, atomize the solution into tiny droplets to ensure optimal coverage and adhesion to the target surfaces. Pressure instruments and control systems allow operators to monitor and adjust application parameters. In addition, protective equipment and shielding mechanisms protect operators from exposure to hazardous chemicals. Pesticide sprayers are indispensable devices that improve the efficacy, safety, and efficiency of pesticide application in agricultural contexts.

2.4.1 Nozzles

Nozzles are indispensable in agricultural applications such as crop spraying, irrigation, and fertilisation. Various farming practices and equipment may necessitate multiple types of nozzles to achieve the desired results. Farmers and farming professionals frequently consider spray coverage, droplet size, flow rate and dispersion reduction when selecting the best nozzle for their application.

2.4.1.1 Fan Nozzle

The standard pressure range for a flat-fan orifice is between 30 and 60 pounds per square inch (psi), with 30 to 40 psi preferred. Even flat fan nozzles offer uniform coverage throughout the entire width of the discharge pattern. They are utilised for banding and should not be employed for transmission. The discharge angle and nozzle release height can be used to control the bandwidth.

The extended-range flat-fan nozzle offers adequate drift control when operating at less than 30 pressures. This nozzle is ideal for a user who prefers the uniform distribution of a flat-fan nozzle but requires reduced operating pressures to control drift. Extended-range nozzles can be used on sprayers with flow controls because they provide superior spray dispersion over a wide pressure range (15 to 60 psi).

For boom-end nozzles, special-feature fan nozzles, such as the off-centre fan, are utilised to make the swath homogenous end-to-end instead of tapering at the edges. The twin-orifice fan generates two discharge patterns, one 30 degrees forward and one 30 degrees aft. The particles are minute as a result of atomisation via two-minute orifices. Two spray directions and smaller droplets enhance coverage and penetrability when administering postemergence contact herbicides, insecticides, and fungicides. Figure 2.8 depicts the spraying patterns and varieties of fan nozzles [18].

Figure 2.8 Example of fan nozzle.

2.4.1.2 Flood Nozzle

Flood nozzles are commonly used to administer suspension fertilisers when an obstruction is a concern. At pressures between 10 and 25 psi, these nozzles produce large particles. The distance between nozzles should be at most 60 inches. Adjustments should be made to the nozzle spacing, orientation, and release height to enable complete overlap. The spray patterns are optimal when the emitters are 30 to 40 inches apart. Pressure influences the discharge patterns of flood nozzles more than fan nozzles. However, the discharge pattern is less uniform than with fan nozzles, and careful consideration must be given to nozzle orientation and overlap. In addition to fertiliser suspensions, these nozzles are used with soil-incorporated herbicides, preemergence-without-contact herbicides, and spray kits affixed on tillage instruments [18]. Figure 2.9 shows an example of flood nozzle.

Figure 2.9 Example of flood nozzle.

2.4.1.3 Raindrop Nozzle

At pressures between 20 and 50 psi, raindrop nozzles produce enormous, hollow-cone-shaped droplets at 20 to 50 psi. The RA Raindrop nozzles are typically attached to tillage implements and are used to incorporate herbicides. When utilising nozzles for broadcast applications, they must be angled 30 degrees from the horizontal. To ensure uniform dispersion, spray patterns must be fully overlapping. These nozzles are unsuitable for postemergence or non-incorporated herbicides because the droplet size is excessively enormous [19]. Figure 2.10 shows an example of raindrop nozzle.

Figure 2.10 Example of raindrop nozzle.

2.4.1.4 Hollow-Cone Nozzle

When foliage penetration and complete leaf surface coverage are required, hollow-cone nozzles are commonly used to administer insecticides and fungicides to field crops. These injectors have a pressure range of 40 to 100 psi. Because hollow-cone nozzles produce tiny droplets, their spray drift potential is more significant than other nozzles. In general, this nozzle should not be used to administer herbicides.

If drift is a concern, wide-angle, full-cone nozzles are an excellent alternative to flood nozzles because they produce larger particles. Full-cone nozzles (Figure 2G) are typically favoured to flood nozzles when applying soil-incorporated herbicides. Full-cone nozzles have a pressure range of 15 to 40 psi and are suitable for flow-controlled sprayers.

Fine hollow-cone nozzles have a wide angle of between 80 and 120 degrees. These nozzles are utilised with postemergence contact herbicides that require a finely atomised spray to thoroughly cover plants or weeds [19]. Figure 2.11 shows an example of hollow-cone nozzle.

Figure 2.11 Example of hollow-cone nozzle.

2.4.2 Tanks

Spray tanks may be constructed from stainless steel, polyethene plastic, or fibreglass. Some pesticides and pesticide fertilisers corrode aluminium, galvanised steel and stainless steel spray tanks. When the tank cover is secured, it must form a pesticidetight seal to prevent leakage. All tanks must be equipped with a drain stopper and shut-off valves at their lowest point to contain any pesticide without escaping if the pump, strainers or other system components require maintenance. For the correct quantity of pesticide to be added, tank capacity indicators must be precise. A clear plastic tube (sight gauge) is attached to metal containers [20]. Figure 2.12 shows an example of tank that is used for pesticide spraying.

Figure 2.12 Example of tank for pesticide spraying.

2.4.3 Agitators

Agitation is required to uniformly blend the components of the spray mixture and, in some formulations, to maintain the pesticides in suspension. If there is insufficient agitation, the pesticide application rate may alter as the tank empties. Mechanical and hydraulic agitation are the most common varieties. The required flow rate for agitation is dictated by the chemical used. Wettable granules demand vigorous agitation, whereas solutions and emulsions require minimal agitation. A discharge rate of 6 gallons per minute per 100 gallons of tank capacity is sufficient for jet agitators [20]. Figure 2.13 shows an example of agitator that is used for pesticide spraying.

Figure 2.13 Example of agitator for pesticide spraying.

2.4.4 Pumps

A pump generates the necessary pressure for atomization and aerosol penetration on most sprayers. Roller pumps, piston pumps, and diaphragm pumps are frequently used pumps. When applying pesticides or fungicides, sprayers use diaphragm or piston compressors to generate the higher pressures (700 kPa or 100 psi) required for complete plant coverage (100 psi or 700 kPa). Multiply the sprayer's maximum anticipated application rate by an adequate volume for agitation and an additional 25 per cent volume to account for pump degradation to determine the pump's capacity.

Flow should always be present in the bypass line, indicating that the pump has adequate capacity to send excess pesticide to the tank. Take note of the pump's utmost rpm and never exceed it by adjusting the tractor's throttle. Since increasing the pump's RPM increases its output, the tractor's throttle setting must be fixed during calibration and sprayer operation. Operating at a too-low rpm can reduce the pump's output below the level required by the sprayer [21]. Figure 2.14 shows the type of pumps that are used for pesticide spraying.

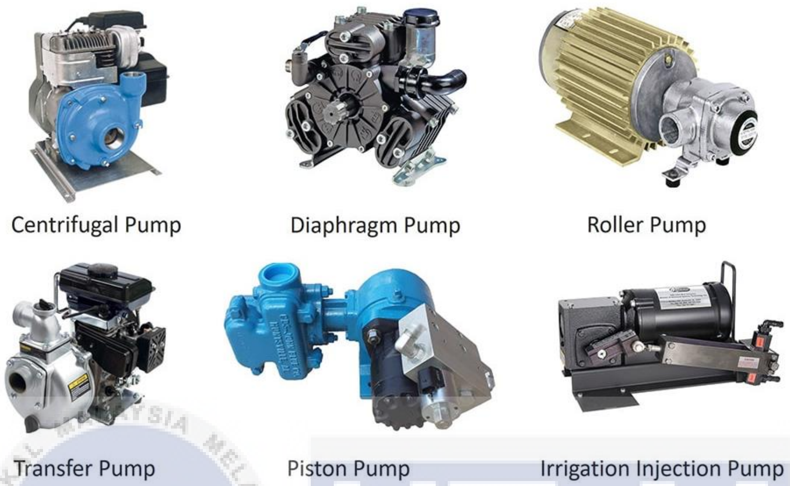


Figure 2.14 Type of pumps for pesticide spraying.

2.4.5 Hose

Suction hoses (from the tank) must be reinforced to prevent collapse, resistant to chemicals and grease, and of the same diameter as the pump's inlet opening. The same conduit may be used for the bypass line. Hoses on the pressure side of the pump must withstand higher pressures than the intended application, preferably up to the pump's maximum pressure. Before closing off the flow to the boom, the relief or unloading valve should be opened to reduce hose pressure [21]. Figure 2.15 shows an example of hose that is used for pesticide spraying.

Figure 2.15 Example of hose for pesticide spraying.

2.5 Wheeled Locomotion

Types of wheeled locomotion will be discussed in this section. Wheeled travel increases the robot system's adaptability on various surfaces. Three forms of wheeled movement, namely differential drive, omnidirectional directional drive and tracked slip locomotion, are discussed.

2.5.1 Differential Drive

The differential drive is a widely utilized locomotion system in robotics, providing versatile movement capabilities for various robotic platforms. This system comprises two wheels on opposite sides of the robot that are independently driven. By controlling the pace and direction of each spin, the robot can perform a variety of motions, including forward and reverse movement and turning.

The superb manoeuvrability of the differential drive system is one of its primary advantages. By adjusting the speed and direction of the robot's wheels, it can manoeuvre through tight spaces, make precise turns, and effectively alter its orientation. This manoeuvrability is especially advantageous in settings where agility and spatial awareness are essential, such as indoor settings or congested environments.

Additionally, the robot's differential propulsion system provides stability. The robot is less prone to tipping or losing balance when traversing uneven terrains or confronting obstacles due to its wide wheelbase. This stability is essential for maintaining control and guaranteeing the safety of the robot and any cargo it may transport.

In addition, the differential drive system is renowned for its simplicity and affordability. Compared to more complex locomotion systems, this system requires fewer mechanical components, making it simpler to implement and maintain. The independent control of each wheel simplifies the control scheme and reduces the intricacy of the robotic platform, resulting in decreased expenses and increased dependability.

Nevertheless, the differential drive system has a few limitations. Due to the need for additional mechanisms for active adaptation to the ground, it might confront difficulties traversing particular types of terrain, such as rough or uneven surfaces. The absence of a dedicated steering mechanism can also make precise control more difficult during certain manoeuvres, such as rotating in position.

In spite of these limitations, the differential drive system remains a popular option for mobile robots, robotic vehicles, and agricultural robots. Its manoeuvrability, stability, simplicity, and cost-effectiveness make it an adaptable and practicable solution for numerous robotics applications.

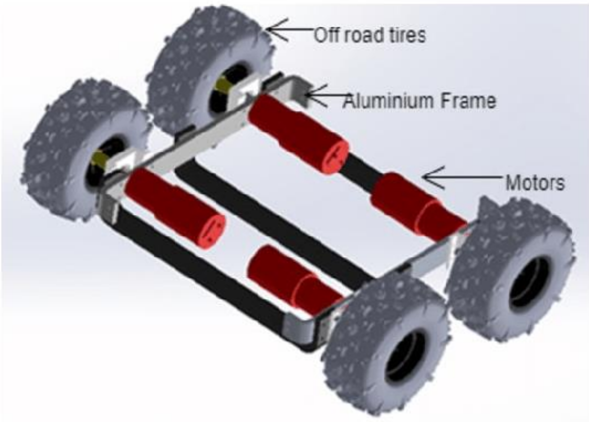


Figure 2.16 Example of four-wheel different drive with four motors.

2.5.2 Omnidirectional Drive

Movement in all directions is crucial for complete manoeuvrability. Holonomic robots are robots capable of moving in any order at any time. They can be accomplished by utilising spherical or Swedish wheels.

2.5.2.1 Omnidirectional Locomotion with Three Spherical Wheels

Each of the three spherical wheels on the omnidirectional robot is propelled by a single motor. In this configuration, the spherical wheels are suspended by three contact points, two of which are spherical bearings and one of which is a wheel affixed to the motor axle. This concept has a basic design and provides excellent manoeuvrability. However, it is limited to flat surfaces and light weights, and locating round wheels with high friction coefficients is challenging [22]. Figure 2.17 shows an example of robot using omnidirectional locomotion with three spherical wheels.

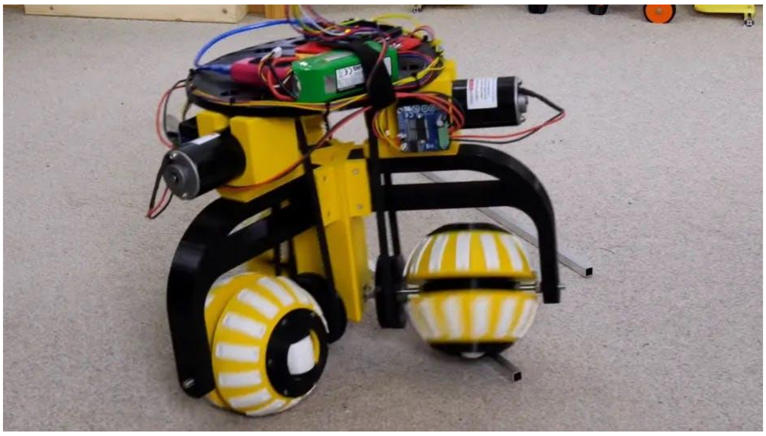


Figure 2.17 Example of robot using omnidirectional locomotion with three spherical wheels.

2.5.2.2 Omnidirectional Locomotion with Four Swedish Wheels.

Numerous research robots, including the Carnegie Mellon Uranus, have utilised the omnidirectional layout successfully. Each of these four Swedish 45-degree wheels is propelled by its own motor. By altering the direction of rotation and relative speeds of the four wheels, the robot can move along any plane trajectory while concurrently rotating around its vertical axis. For instance, if all four wheels are spinning "forward" or "backward," the robot will move in a straight line forward or backwards. When one diagonal pair of wheels rotates in the same direction as the other diagonal pair, the automaton moves laterally. [22]. Figure 2.18 shows the Uranus robot from Carnegie Mellon University which is an omnidirectional robot with four powered-swedish 45 wheels.

Figure 2.18 The Uranus robot from Carnegie Mellon University is an omnidirectional robot with four powered-swedish 45 wheels.

2.5.3 Tracked slip/skid locomotion.

In the wheel configurations discussed previously, wheels cannot slide against the surface. Slip/skid steering is an alternate method of steering. The robot can be reoriented by spinning wheels facing the same direction at various speeds or in opposite directions. This is how a military tank operates.

Compared to conventional wheeled robots, treaded robots have significantly larger ground contact areas, substantially improving their manoeuvrability on loose terrain. Due to the large ground contact patch, however, changing the robot's orientation frequently necessitates a skidding turn in which a substantial portion of the track must travel on the surface.

The issue with such arrangements is that they involve slip/skid steering. Due to the tremendous amount of slippage during a turn, it is difficult to predict the precise centre of rotation of the robot, and the specific change in position and orientation is also subject to fluctuations due to ground friction. Therefore, dead reckoning on such machines needs to be more accurate.

This is the cost of exceptional manoeuvrability and traction over uneven, loose terrain. Moreover, a slip/skid technique on a surface with a high coefficient of friction can rapidly exceed the torque capacity of the employed motors. This strategy is effective on the lost ground but extremely inefficient elsewhere in terms of energy consumption. [22]. Figure 2.19 shows the use of tracked slip/skid locomotion on army tank.

Figure 2.19 Example of the use of tracked slip/skid locomotion on army tank.

2.6 Previous Researchers Work Comparison

In this section, past research that related to the project's title will be discussed and compared based on the method, advantages and disadvantages. A number of four research have been collected based on the project's title. Table 2-1 shows the previous researchers work comparison.

Table 2.1 Previous researchers work comparison.

No.	Authors	Year	Title	Method	Advantages	Limitations
1	Murugan, Kalpana Shankar, B. Jaya Sumanth, A. Sudarshan, C.Venkata [23]	2020	Smart Automated Pesticide Spraying Bot	Arduino Uno, L293D module, Bluetooth module, pesticide pump, spraying arm, MIT App Inventor.	• More efficient use of pesticides. • Faster and more accurate diagnosis of plant diseases.	• Regular maintenance and repairs to keep it functioning properly.

					• Increased productivity. • Cost-effective.	• Risk of environmental impact if the chemicals.
2	Eze Ozgul Ugur Celik [24]	2018	Design and Implementation of Semi-autonomous Anti-pesticide Spraying and Insect Repellent Mobile Robot for Agricultural Applications	Lynxmotion Rover Kit, Bayite 12 V DC Pesticide pump, solar panel	• Tasks more accurate. • Enhance sustainable farming conditions. • Reduce human risks.	• Difficulty on controlling tires on uneven terrain. • Width of the canal affects the performance.

3	Arati Nimbalkar Anam Shaikh Jayashree Hogale Manisha Gite [25]	2020	Autonomous Agricultural Bot	Atmega2650 microcontroller, L293D motor driver, DC motor, servo motor, DHT11, pesticide pump	• Capability to perform automated system. • Efficient ultilization of resources.	• Small tank size. • No agricultural calibration studies.
4	K. Gayathri Devi C. Senthil KumarB. Kishore [26]	2022	A Survey on the Design of Autonomous and Semi-Autonomous Pesticide Sprayer Robot	IPC/104 bus, ARM7 microcontroller, Zigbee module, OTOS system, MAX23 IC	• Improve efficiency and precision. • Faster and consistent spraying.	• Vulnerable to mechanical failures or software errors. • High initial cost.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methods for completing the assignment gradually. This chapter aims to provide information and substantiation regarding the project's execution. Designing and developing a robot for spraying pesticides on a vegetable farm employs both hardware and software. These ideas were effectively implemented, resulting in an aesthetically pleasing system output that provided proper and precise movement when the machine was operated.

3.2 Project Flow

This section describes the research approaches used to construct the project and achieve its objectives. To keep the project on track, extensive research was conducted on the used hardware to better understand its operation and determine the best model. A thorough comprehension of the project flowchart was considered vital. The procedural flow is extensively developed, followed by a detailed discussion of the hardware requirements.

3.2.1 Process Flow Chart

To fully complete the project, a precisely produced flow chart was created to systematically plan and execute all areas of the task. Figure 3.1 visualizes the project's overall process flow, providing an organized and complete perspective of the sequential steps and relationships involved. This visual depiction is an essential tool for both project planning and implementation, giving a clear path for team members and stakeholders to grasp the process, dependencies, and critical milestones.

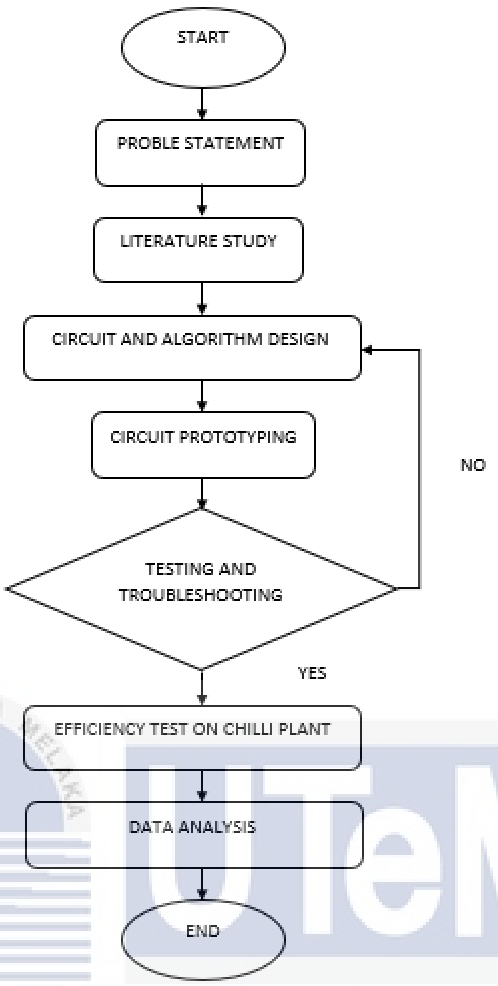


Figure 3.1 General process flow chart.

3.2.2 Component of Pesticide Spraying Robot

This section describes the type of component that has an elaborate function. The component is listed based on the literature study. Figure 3.2 shows the study on components process flow.

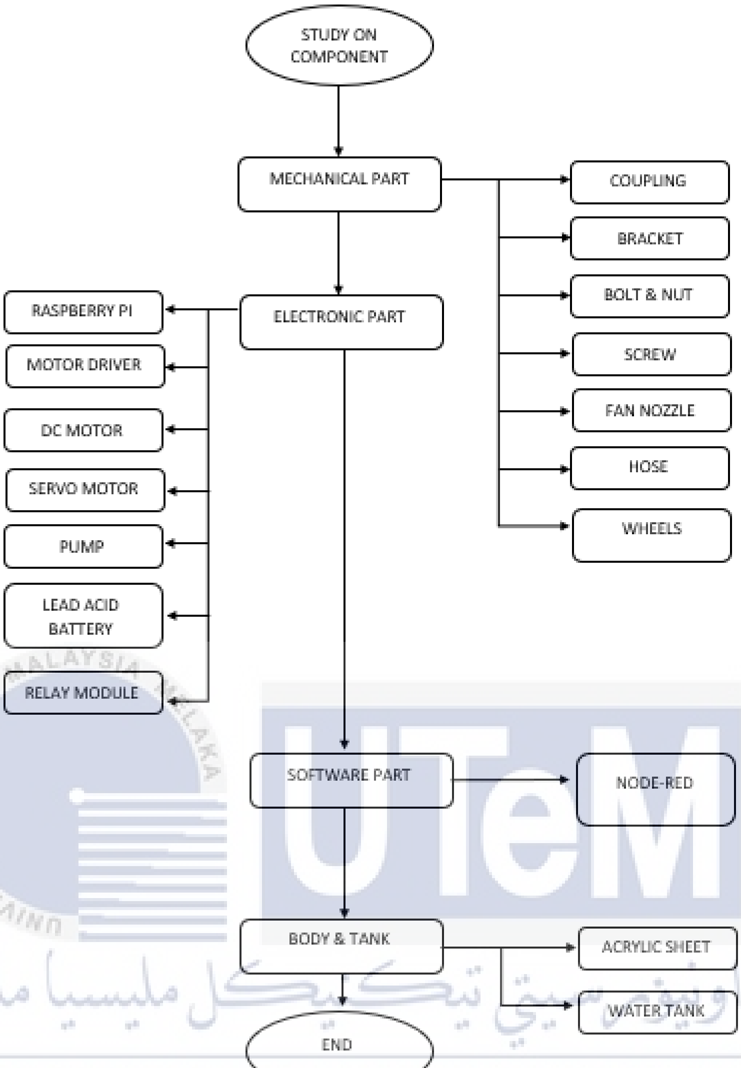


Figure 3.2 Study on component process.

3.2.3 Block Diagram

Block diagram the pesticide spraying application robot is illustrated in Figure 3.3 below. The block diagram offers a functional perspective of the system. It aids in creating linkages within a system and helps to comprehend its functioning better.

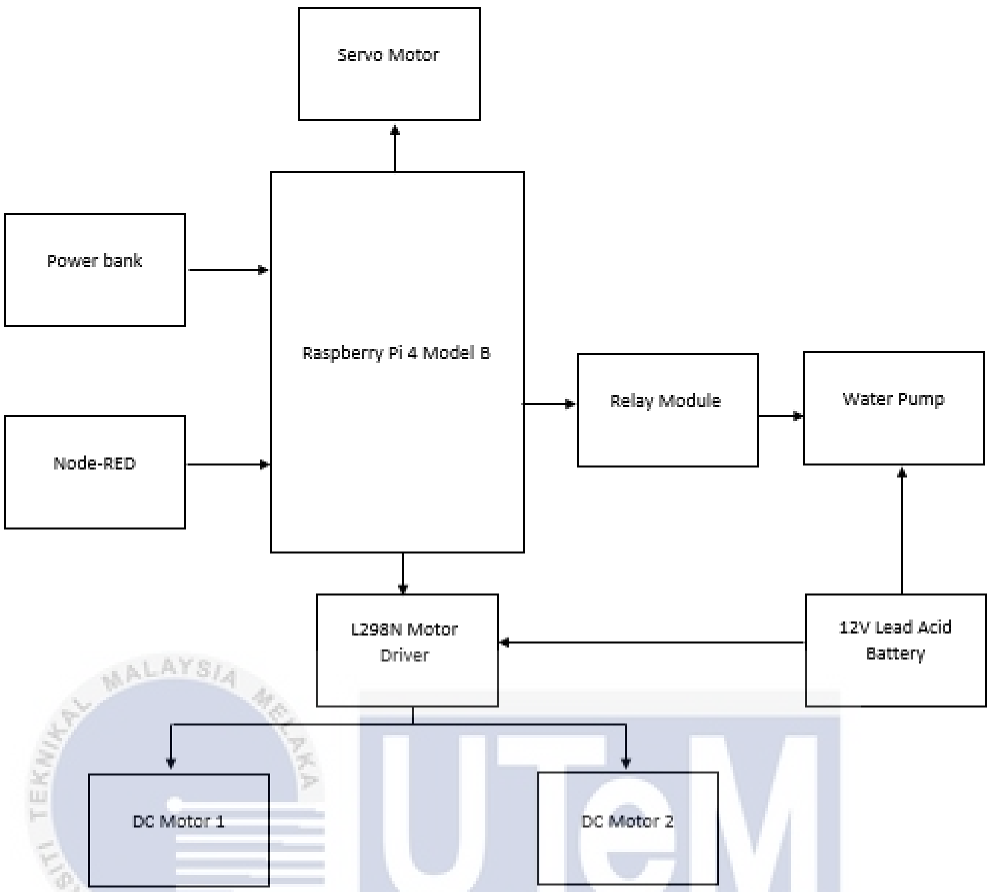


Figure 3.3 Block diagram of a pesticide spraying robot.

3.3 Components' specifications.

The component specs contain precise information about the essential components used in a system or project. These specs usually include important parameters like size, material composition, power requirements, and performance characteristics. Understanding component specifications is critical for successful system design, as it ensures compatibility, dependability, and optimal functionality. It helps to make informed judgments during the choosing process, considering elements such as speed, capacity, and connectivity. Accurate documenting of component specifications makes seamless integration within the overall system architecture possible, allowing engineers and developers to meet project requirements efficiently and achieve desired performance outcomes. A thorough understanding of these requirements is critical to successful hardware and software integration.

3.3.1.1 Mechanical Part

This section will discuss the mechanical components utilised in this undertaking. Multiple aspects will be addressed. The components were chosen based on a review of the relevant literature.

3.3.1.2 Coupling

Couplings are mechanical components that connect the motor shaft to the tyre shaft. Due to its durability, resistance to corrosion, and high conductivity, brass is a commonly employed material. This enables a secure and tight connection between the motor and the tyre. As the interior diameter of the motor shaft is 5mm, the diameter of the coupling is also 5mm. There will be four couplings, as four wheels and four motors will be utilised. Figure 3.3 depicts a brass hexagon coupling example.

Figure 3.4 Example of brass hexagon coupling.

3.3.1.3 Bracket

A motor bracket is a mechanical component to securely mount and support a stationary electric motor. Within a system or piece of equipment, it is intended to provide stability, eradicate excessive vibrations, and ensure proper motor alignment. The body was attached to the wheel using an L-type universal horizontal motor base mounting bracket. The selection of steel was based on its high tensile strength and durability. Figure 3.4 depicts an example of a flat L-type universal motor base mounting device.

Figure 3.5 L-type universal horizontal motor base mounting bracket.

3.3.1.4 Bolt and Nut

Bolt and nut are mechanical fasteners used to connect components together securely. The bolt has a threaded shank and a threaded head, whereas the nut has a threaded opening that permits tightening and loosening with a wrench or socket. The bolts and screws secure the motor bracket to the chassis. Figure 3.5 demonstrates the mechanism of the bolt and nut.

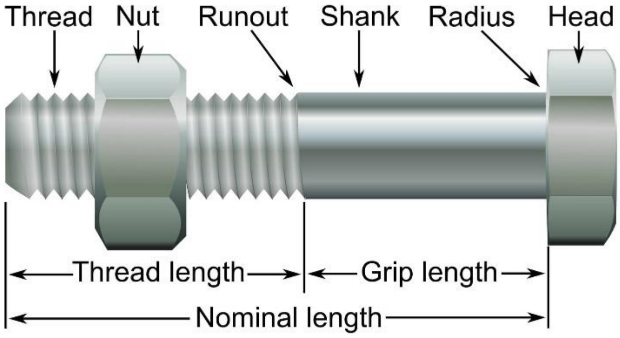


Figure 3.6 Bolt and nut mechanism.

3.3.1.5 Screw

A screw is a cylindrical fastener with external threads and a tapered or pointed end. It is designed to be driven with a screwdriver or power instrument into a material, such as wood or metal. Its threads create a threaded track as the screw is pushed in, resulting in a secure and snug connection. Screws are frequently used to connect or secure objects, construct structures, and provide support. The Phillips head and 5mm screw diameter were chosen because they are suitable for connecting the motor to the bracket. Figure 3.6 illustrates a 5mm Phillips-head fastener.

Figure 3.7 A 5mm Phillip headed screw.

3.3.1.6 Fan Nozzle

A fan nozzle is used in various applications to distribute fluid or air in a comprehensive, fan-shaped pattern. A fan nozzle consists of a hollow body with an entrance on one side and an exhaust with a specific shape on the other. The outlet generates a broad, flat pattern when fluid or air passes through it. Instead of a concentrated stream, the fan nozzle produces a discharge pattern in the shape of a fan. Fan apertures are designed to distribute fluids or air efficiently over a large area. They provide efficient coverage while minimising waste or overspray. Figure 3.7 illustrates a fan nozzle.

Figure 3.8 Example of fan nozzle.

3.3.1.7 Hose

A flexible tube or pipe that conveys pesticide from the robot's pesticide tank to its spray nozzles. The hose is flexible, allowing it to easily deform and manoeuvre as the robot traverses the sprayed field or region. This adaptability promotes smooth operation and prevents pesticide flow restrictions or irregularities. The used fitting size is 13 mm because it is compatible with the nozzle. To ensure compatibility with pesticides and withstand outdoor use's rigours, the hose is frequently made from chemical-resistant and durable materials. PVC material should be optimal due to its durability. Figure 3.8 demonstrates an example of hose.

Figure 3.9 Example of hose.

3.3.1.8 Wheels

A 130 mm-diameter, high-friction wheel with a grip rubber tyre and rim is used in robotics and mechanical systems requiring traction and control. The diameter of the wheel is 130 millimetres, which dictates its size and surface contact area. The wheel is designed to generate significant friction with the earth or rolling surface. This increased friction enhances traction, prevents slipping, and enhances control and manoeuvrability. The wheel's rubber tyre is renowned for its traction and durability. The tyre may have a unique tread pattern or design that improves traction and adhesion on various terrains. It may be suitable for a vegetable agricultural track. Figure 3.9 depicts an example of a tyre used for robotic applications.

Figure 3.10 Example of wheel.

3.3.2 Electronic Part

This section will discuss the electronic components used for this undertaking. Multiple aspects will be addressed. The components were selected based on a review of relevant literature.

3.3.2.1 Raspberry Pi 4 Model B

The Raspberry Pi 4 Model B with 4GB of RAM is a flexible single-board computer that surpasses its predecessors in functionality and performance. Pi 4 Model B is propelled by a 1.5 GHz quad-core Broadcom BCM2711 ARM Cortex-A72 (64-bit) processor. This processor is significantly quicker than its predecessors, allowing faster task completion and enhanced multitasking capabilities. It comes with 4GB of LPDDR4 RAM. Increased RAM capacity permits smoother multitasking, improved performance in memory-intensive applications, and the ability to perform more demanding duties. It comes with 4GB of LPDDR4 RAM. Increased RAM capacity permits smoother multitasking, enhanced performance in memory-intensive applications, and the ability to perform more demanding duties. The Raspberry Pi 4 Model B's VideoCore VI GPU supports OpenGL ES 3.0 graphics.

It supports 4K video playback and offers superior graphical performance compared to previous models.

The 4GB RAM option permits additional memory allocation to graphics-intensive programmes and duties. It features dual-band 2.4 GHz and 5 GHz 802.11ac Wi-Fi, Gigabit Ethernet, Bluetooth 5.0, and USB 3.0 interfaces for enhanced connectivity. These capabilities make connecting to networks, peripherals, and other devices simpler, resulting in faster data transfer rates and a more robust connection overall. The Raspberry Pi 4 Model B retains the microSD card port for primary storage. The Pi 4 Model B supports dual-monitor configurations, allowing you to connect two monitors via the micro HDMI connectors. It supports up to 4K resolutions at 60 frames per second, making it suitable for media centre applications and high-resolution displays.

As with previous Raspberry Pi models, the Pi 4 Model B includes a 40-pin GPIO header for connecting various sensors, expansion boards, and other hardware components, enabling the construction of many projects. The Raspberry Pi 4 Model B is compatible with multiple operating systems, such as Raspberry Pi OS (previously Raspbian), Ubuntu, and numerous Linux variants. This flexibility allows customers to choose the best operating system that suits their needs. The Raspberry Pi 4 Model B board is illustrated in Figure 3.10.

Figure 3.11 Raspberry Pi 4 Model B.

3.3.2.2 L298N H-Bridge Motor Driver

The well-known L298N H-Bridge motor driver integrated circuit (IC) enables the control and operation of DC or stepper motors. The L298N is an H-Bridge, which consists of four switches (transistors or MOSFETs) arranged in the configuration of an H. This design allows the motor driver to control the direction and pace of the motor. The L298N can drive either two DC motors or one bipolar stepper motor. It provides forward, reverse, and brake/stop functionality for engines. By adjusting the H-Bridge switches, the L298N can vary the polarity and voltage applied to the motor terminals, allowing for precise motor speed and direction control.

As the L298N can accommodate a wide range of motor supply voltages, typically up to 46V, it is well-suited for various motor types and applications. It also features a 5V output voltage regulator that can be used to power external logic components or microcontrollers. The L298N is capable of supplying substantial current to the actuators. It has a maximum continuous current rating of approximately 2A per channel and a maximum peak current rating of 3A, making it suitable for operating medium-sized DC or stepper motors.

The L298N includes a set of control inputs that enable you to alter the motor's direction and speed. Typically, two digital inputs (per motor) are needed to control the direction (high or low signals), and a PWM (Pulse Width Modulation) input is required to maintain the motor speed. The L298N incorporates protective features such as temperature shutoff and overcurrent protection to safeguard the IC and connected motors. These precautions ensure safe operation even under extreme conditions. The L298N can generate heat during the process, particularly when driving large currents. To prevent the motor driver from overheating, employing a heat absorber or providing sufficient ventilation is preferable. Figure 3.11 depicts an L298N H-Bridge motor driver example.

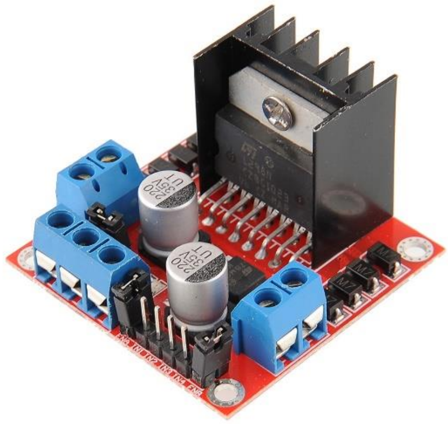


Figure 3.12 L298N H-Bridge motor driver.

3.3.2.3 Relay Module

A 5V relay module is an electrical component specifically created to connect low-voltage microcontrollers or digital systems with high-power devices. The device has a relay switch that reacts to a 5V control signal, efficiently turning electrical circuits on or off. LED indicators provide visual proof of the status by offering load terminals for connecting high-power equipment. Optoisolation improves safety by separating control and load circuits. Supplementary functionalities may encompass jumper settings for customization, mounting alternatives, and adaptability to diverse tasks. The 5V power supply activates the relay coil and internal circuitry. These modules enable the management of appliances, motors, or other electrical equipment in many electronic applications.

Figure 3.13 Example of relay module.

3.3.2.4 DC Motor

The JGB37 20 RPM DC motor is a component of the JGB37 series, which consists of a 37mm diameter brushed DC motor equipped with an integrated gearbox. The parameter "20 RPM" indicates that the device rotates at a speed of 20 revolutions per minute. This motor is well-suited for tasks that demand gradual and precise movement. Widely employed in robotics, automation, and other precision systems, its architecture enables consistent and dependable performance in activities that require a precise and constant rotational output. The incorporation of a gearbox increases the adaptability of the JGB37 20 RPM DC motor, rendering it ideal for a wide range of applications in different industries.

Figure 3.14 Example of DC motor.

3.3.2.5 Metal Gear Servo Motor

The MG996 servo motor is extensively utilised in robotic and automation applications, such as the rotation of nozzles in robots that apply pesticides. It is renowned for its enduring performance, high torque output, and metal gear construction. A DC motor, a control circuit, and a set of metal gearing comprise the MG996 servo motor, which is a small motor. Metal gears increase the motor's durability and sturdiness, allowing it to withstand heavier burdens while maintaining precise alignment. The MG996 servo motor's high torque output enables it to rotate larger objects, such as the nozzle on a robot for dispensing pesticides. Depending on the model and manufacturer, the actual torque rating is determined. The motor's speed may vary dependent on the applied voltage and load.

The MG996 servo motor's angular range is between 0 and 180 degrees. This means the orifice can be rotated from fully closed to fully open or any point in between. The rotational angle can be controlled by sending the servo motor the correct PWM signals. Signals employing Pulse Width Modulation (PWM) are used to operate the MG996 servo motor. By modulating the PWM signal's duration, you can command the motor to rotate to a specific position within its range. For example, a pulse width of 1.5 milliseconds may correspond to a neutral or centred position, whereas shorter or longer pulse widths can instruct the motor to rotate in various directions.

The MG996 servo motor mechanically connects the nozzle of the pesticide-spraying automaton to the nozzle. This can be accomplished via a linkage mechanism or by joining the motor shaft directly to the nozzle. The connection should transmit the rotational motion of the motor to the nozzle efficiently and securely. The MG996 servo motor can be incorporated into the control system of the pesticide-spraying robot. The robot's control software or microprocessor may send PWM signals to the servo motor, instructing it to rotate the nozzle to the correct position for optimum spray coverage. Figure 3.14 depicts an example of an MG996 (0-180 Deg) metal gear servo motor.

Figure 3.15 Example of MG996 metal gear servo motor (0-180 Deg).

3.3.2.6 Pneumatic Diaphragm Pesticide Pump Motor

A DC 12V pneumatic diaphragm pesticide pump motor is an electrical device that employs compressed air to drive a diaphragm to transport pesticide. The motor's direct current (DC) power supply is 12 volts, making it suitable for low-voltage applications typically powered by batteries or DC power sources. The pump employs a pneumatic diaphragm, which consists of a flexible membrane that moves in response to changes in air pressure.

The movement of the diaphragm, which causes a vacuum on one side and pressure on the other, enables the pumping action. The primary function of the pump is to deliver pesticides to the orifice. A DC 12V pneumatic diaphragm pesticide pump motor is depicted in Figure 3.16.

Figure 3.16 Example of DC 12V pneumatic diaphragm pesticide pump motor.

3.3.2.7 Lead Acid Battery

A 12V lead-acid battery can power the pesticide pump of a pesticide-spraying automaton equipped with a Raspberry Pi for operation and control. A lead-acid battery with a voltage of 12 volts consists of lead plates immersed in an electrolyte solution and encapsulated in a plastic or rigid container. The battery's design permits the conversion of chemical energy to electrical energy.

The battery's nominal voltage is 12V, which is sufficient to power the pesticide pump. The compressor may require a specific voltage range that a 12V lead-acid battery can easily accommodate. Lead-acid batteries are available in a range of ampere-hour (Ah) capacities. Using a 12V lead-acid battery, the pesticide pump on the pesticide spraying automaton can obtain a consistent and stable power supply. The battery's voltage meets the requirements of the pesticide pump, guaranteeing its efficient operation. Figure 3.17 represents a 12V lead acid battery.

Figure 3.17 Example of 12V lead acid battery.

3.3.3 Software Part

This section will discuss the software utilised for this undertaking. Node-RED is the software packages used for the project.

3.3.3.1 Node-RED

Node-RED is a freely available tool for creating flow-based programs that enable visual programming of the Internet of Things (IoT) and automation workflows. Utilizing Node.js as its foundation, this platform streamlines the development of interconnected apps by enabling users to connect devices, APIs, and internet services via a web-based interface. Users may effortlessly create and implement intricate workflows without the need for considerable coding, thanks to a wide range of pre-built nodes available in the library. Its adaptability encompasses IoT, home automation, and data integration applications, rendering it a favored option for novices and professionals alike. The visual methodology employed by Node-RED simplifies the process of development, facilitating the quick creation of prototypes and the effective deployment of interconnected systems. Figure 3.18 shows the official logo of Nod-RED.

Figure 3.18 Logo of Node-RED.

3.3.4 Chassis & Tank

In this section, the chassis and tank utilised in the construction of the pesticide-spraying automaton are described. An acrylic sheet is chosen to construct the robot's chassis as the base. 5 litre pesticide tank is selected as the pesticide storage component.

3.3.4.1 Acrylic Sheet

A robot's body that sprays pesticides can be constructed from an acrylic sheet. Acrylic, Plexiglas or Perspex is a transparent thermoplastic material that offers several benefits when used to build robot bodies. Acrylic sheets are transparent, allowing you to examine the interior components and processes of the pesticide spraying automaton. This can aid in monitoring and troubleshooting the operation of the robot. Acrylic is a more lightweight material than metal or wood. This feature makes the robot simpler to manipulate and control, ensuring efficient movement and reducing its overall mass.

Acrylic sheeting is renowned for its durability and resistance to impact. They are less susceptible to cracking or fracturing, making them ideal for outdoor applications where the pesticide dispensing robot may encounter challenging terrain or obstacles. Acrylic is impervious to environmental factors, including UV radiation, moisture, and temperature fluctuations. The robot's body is resistant to sunlight, pesticide, and other environmental variables, which makes it suitable for outdoor applications. Using standard tools such as saws or laser cutters, acrylic sheets can be effortlessly cut, sculpted, and moulded into various shapes and sizes. This adaptability enables the robot body to be designed in multiple shapes and sizes to meet the specific requirements of the pesticide-spraying robot.

The chemical resistance of acrylic sheeting is advantageous for a pesticide-spraying robot. They are relatively resistant to common pesticides and cleansing solvents. Acrylic sheets are less expensive than metals and other materials. Acrylic is a popular material for prototype development and small-scale endeavours due to its low cost. Figure 3.21 illustrates an acrylic sheet.

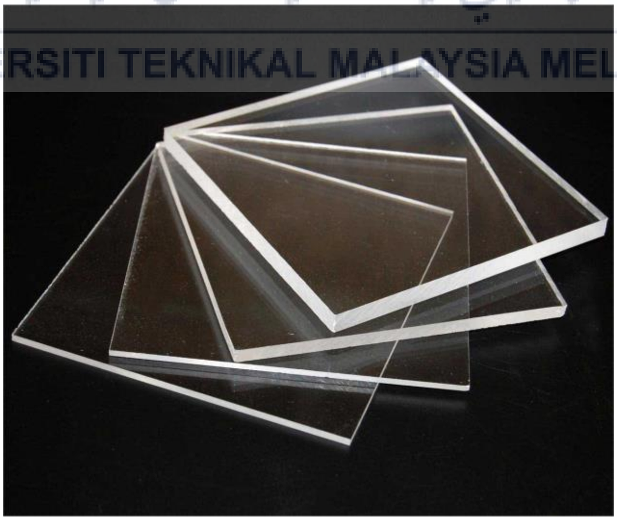


Figure 3.19 Example of acrylic sheets.

3.3.4.2 Pesticide Tank

A pesticide tank is a container used to store and supply pesticide for a variety of purposes. Pesticide tanks are often composed of plastic, fiberglass, or metal and come in a variety of sizes and shapes. These tanks, which are commonly used in home, agricultural, and industrial uses, store pesticide from a variety of sources, such as wells or municipal supplies, for use during times of scarcity or as a backup. They frequently include distribution outlets as well as filling inlets. Pesticide tanks are critical for guaranteeing a steady pesticide supply, reducing shortages, and supporting a wide range of applications, including domestic consumption, irrigation, and disaster preparedness. Figure 3.20 shows the example of pesticide tank.

Figure 3.20 Example of pesticide tank.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This section describes the results and analyses of the laundry notification system's development. It includes results from simulation testing performed before to data collection, operating scenarios, and extensive data analysis. The definitive findings from these exams and assessments serve as a baseline for measuring the project's performance. The assessments include simulations of the Raspberry Pi 4 and the Node-RED application, which provide a full overview of the project's functioning. This documentation seeks to examine if the project's objectives were met and acts as a thorough reference for understanding the system's performance with the specified technologies.

4.2 Project's Schematic

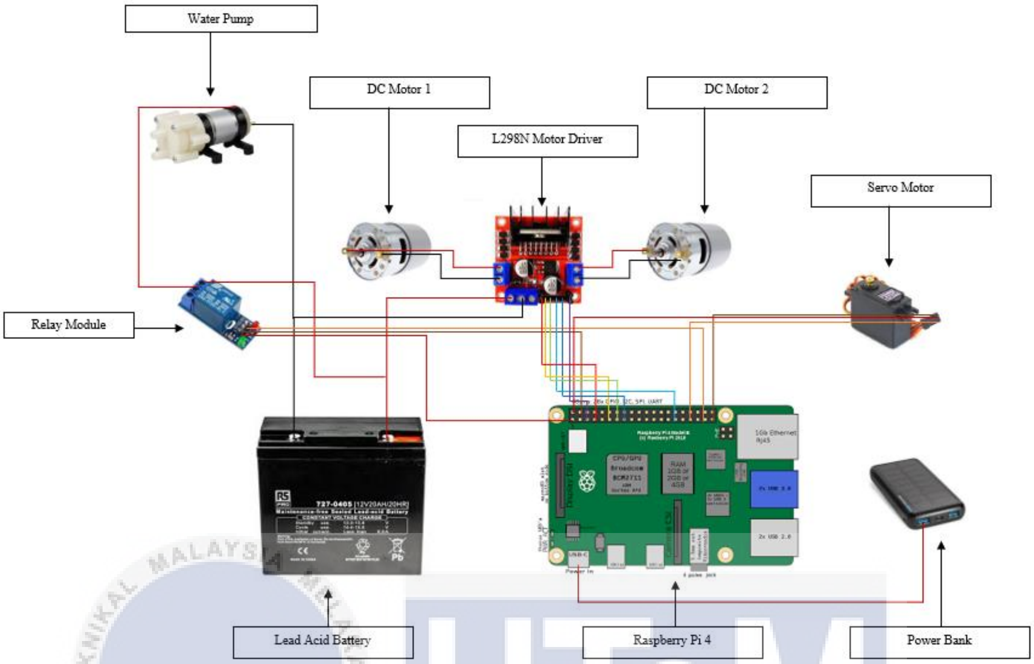


Figure 4.1 Project's Schematic Diagram

Figure 4.1 shows the schematic of the project. Raspberry Pi 4 is a microprocessor that acts as the 'brain' of the robot and manage other components based on the desired conditions. There are 4 outputs in the project which two of them are DC motors, a pesticide pump and a servo motor. The DC motors are controlled by a motor driver which is guided by Raspberry Pi 4. The pesticide pump is controlled by a relay module which triggered the pesticide pump if signal is given by Raspberry Pi 4. The servo motor is controlled directly by Raspberry Pi 4 as the voltage of servo motor is only 5V compared to the other 3 components which are 12V. Lead acid battery is used to supply power to the DC motors and pesticide pump while the power bank is used to supply power to Raspberry Pi 4. Table 4.1, Table 4.2, Table 4.3, Table 4.4 and Table 4.5 shows the connections configuration of the project.

Table 4.1 DC motor IO pins to motor driver.

DC Motor	From DC Motor	Connections to motor driver
1	Positive	OUT 1
	Negative	OUT 2
2	Positive	OUT 3
	Negative	OUT 4

Table 4.2 Motor driver pins to Raspberry Pi and lead acid battery.

Motor Driver Pins	Connections
+12V	Positive of lead acid battery
GND	Negative of lead acid battery
ENABLE A	GPIO 4
IN 1	GPIO 17
IN 2	GPIO 27
IN 3	GPIO 5
IN 4	GPIO 22
ENABLE B	GPIO 3

Table 4.3 Lead acid battery and pesticide pump to relay module.

Component	Pole	Connections
Lead acid battery	Positive	NO (Relay Module)
	Negative	Negative pole of pesticide pump
Pesticide pump	Positive	COM (Relay Module)
	Negative	Negative pole of lead acid battery

Table 4.4 Relay module to Raspberry Pi 4.

Relay Module Pins	Connections
DC+	3.3V
DC-	GND
IN 1	GPIO 26

Table 4.5 Servo motor to Raspberry Pi 4.

Servo Motor Pins	Connections
Black cable	GND
Red cable	5V
Orange cable	GPIO 13

4.3 Software Development

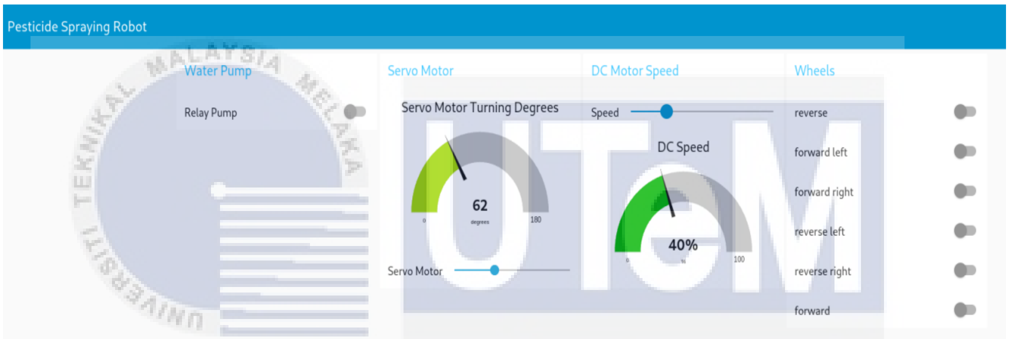
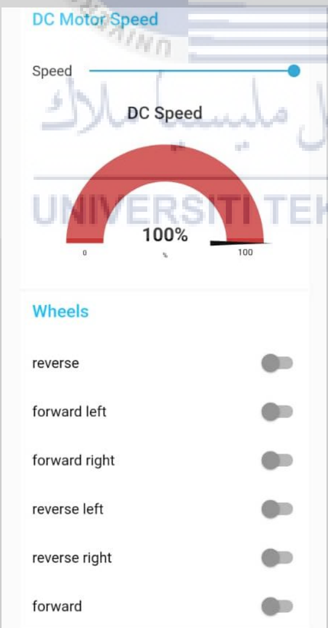


Figure 4.2 Project's Dashboard on Node-RED

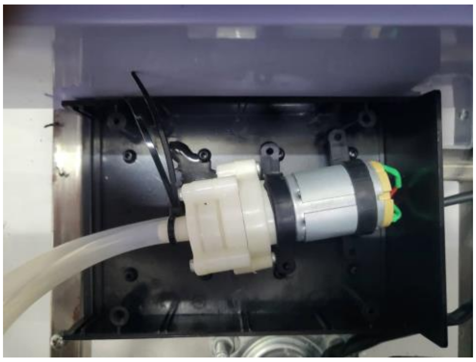
Figure 4.2 shows the project's dashboard within the Node-RED user interface. Node-RED, a program designed for remote output control, allows users to manipulate outputs based on their preferences. Node-RED, which is particularly well-suited for usage with Raspberry Pi because to its integration, makes it easier to create user interfaces for controlling the robot's pesticide pump, servo motor, and DC motors. This configuration makes the control procedure easier for users. Refer to Table 4.6 for information on the Node-RED widgets used and their functionalities.

Table 4.6 Widget used in Node-Red.

<table>
<tr><th>Widget</th><th>Function</th></tr>
<tr><td>
</td><td>The switch is used to control the relay module whether turn on or turn off.</td></tr>
<tr><td>
</td><td>The gauge is used to observe the angle turned by the servo while the slider is used to control the angle of the servo.</td></tr>
<tr><td>
</td><td>The slider is used to set the speed of DC motors while the gauge is used to observe the speed of DC motors visually. The switches is used to control the movement of DC motors and direction of the robot.</td></tr>
</table>

4.4 Hardware Development

(a) Circuit configurations



(b) Pesticide pump configuration

(c) Pesticide tank placement

(d) Nozzle and servo motor

Figure 4.3 Hardware configurations of the project

Figure 4.3 depicts a thorough representation of the project's hardware configurations. The precisely designed circuits find safe sanctuary within a junction box, stressing the critical role of ensuring the robot's overall safety. To reduce the risk of pesticide exposure, the pesticide pump is housed in a specialized junction box. The strategic location of the pesticide tank, which houses critical pesticides, outside both junction boxes improves accessibility for rapid replenishing when the tank is empty. Furthermore, the nozzle is delicately tied to the PVC and attached to the servo motor, allowing for seamless rotation at the necessary angles. This extensive hardware layout demonstrates a thorough approach, combining usefulness and preventive precautions.

4.5 Prototype Development

(a) Top view

(b) Front view

(c) Left view

(d) Right view

Figure 4.4 Different view of prototype

Figure 4.4 shows different view of prototype. The prototype is designed based on the suitability of components placed on the robot. The size of the prototype is 59.5 cm × 53.0 cm which is suitable to move around the chilli fertigation farm lane. Swivel tyre is placed at the front in order to smoothen the mobility of the robot to turn in any direction. The junction boxes which contain electronic components are placed at the back while the nozzle is placed at the front. The pesticide tank is placed in the middle. This arrangement is being done to avoid the nozzle distribute pesticide on the components' side and make it easy for the pesticide pump to flow the pesticide from the tank to the nozzle. This ensures the safety of the robot.

4.6 Data Analysis

In this section, data would be collected to observe the performance of the pesticide spraying robot. There are several parameters to measure the performance of the robot which are speed of robot, distance of pesticide distribution, time taken to empty the tank, flow rate of pesticide and coverage of pesticide on the plants.

4.6.1 Speed of Robot

Figure 4.5 Speed of robot testing.

Figure 4.5 shows the testing for speed of robot. In this part, the robot would be tested to move with the highest speed in different surfaces. The length of distance covered would be set the same for all which is 1.00 m. Time taken for the robot to travel across each surface would be measured. Each surface would have 3 readings. This is to observe whether the consistency on the data collected for speed of robot is high or low. Table 4.7, Table 4.8 and Table 4.9 shows the speed of robot on different surfaces results.

Table 4.7 Speed of robot on cement surface.

Readings	Time taken to travelled 1.00 m, t (s)	Speed, v (ms^{-1}) distance/ time elapsed
1	15.13	0.07
2	15.57	0.06
3	15.37	0.07
4	15.23	0.07
5	15.76	0.06
Average	15.41	0.06

Table 4.8 Speed of robot on tar surface.

Readings	Time taken to travelled 1.00 m, t (s)	Speed, v (ms^{-1}) distance/ time elapsed
1	16.65	0.06
2	16.43	0.06
3	16.32	0.06
4	16.51	0.06
5	15.97	0.06
Average	16.38	0.06

Table 4.9 Speed of robot on soil surface.

Readings	Time taken to travelled 1.00 m, t (s)	Speed, v (ms^{-1}) distance/ time elapsed
1	16.57	0.06
2	16.73	0.06
3	16.47	0.06
4	16.21	0.06
5	16.61	0.06
Average	16.52	0.06

Based on the graphs above, the time taken for the robot to travel across 1.0 m on each surface which were cement, tar and soil were being collected. From the data, we could observe that the average time taken to travel across 1.0 m on each surface was not a big difference. Although the shortest time taken for the robot to travel was on cement surface and the longest time taken was on soil surface, the average speed remained the same which was 0.06 ms^{-1}. This indicates that the speed maintains although in different surfaces. Figure 4.6 shows graphs for speed of robot on different surface.

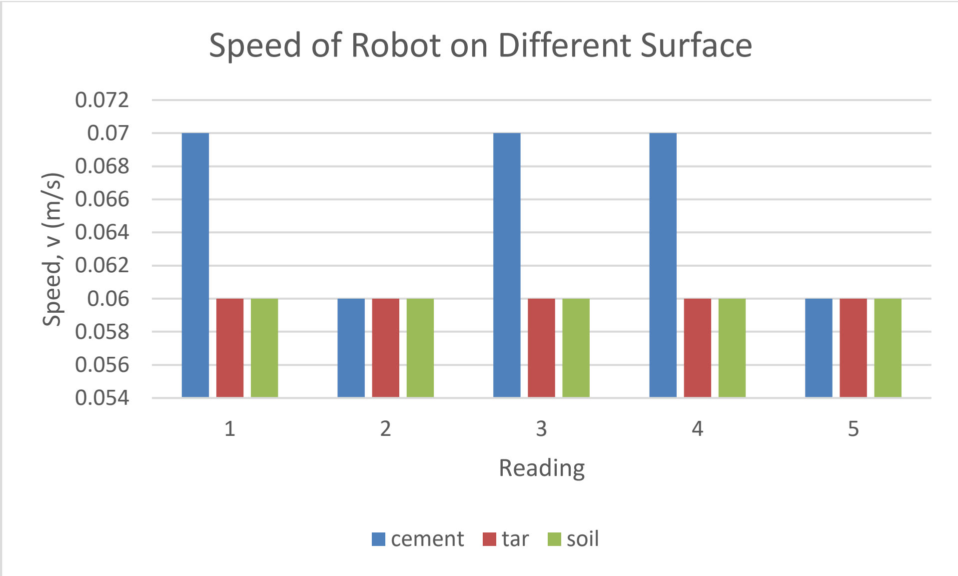


Figure 4.6 Speed of robot on different surface.

4.6.2 Distance of Pesticide Distribution

Figure 4.7 Distance of pestcide distribution testing.

Figure 4.7 shows the testing for distance of pesticide distribution. In this part, the robot would be tested to distribute pesticide in normal condition. Distance of pesticide distribution would be measured. There would have 5 readings to ensure the consistency on the data collected for the parameter. Table 4.10 shows the distance of pesticide distribution results.

Table 4.10 Distance of pesticide distribution.

Readings	Distance, d (m)
1	3.58
2	3.51
3	3.55
4	3.54
5	3.50
Average	3.54

From the data, we could observe that the difference between the lowest distance measured which is 3.50 m on reading 5 and the highest distance measured which is 3.58 m are not a big difference. The average distance of pesticide distribution is 3.54 m. This indicates the consistency of the measurement for distance of pesticide distribution is high. Figure 4.8 shows the graph for distance of pesticide distribution. Based on graph, the distance of pesticide distribution was being collected.

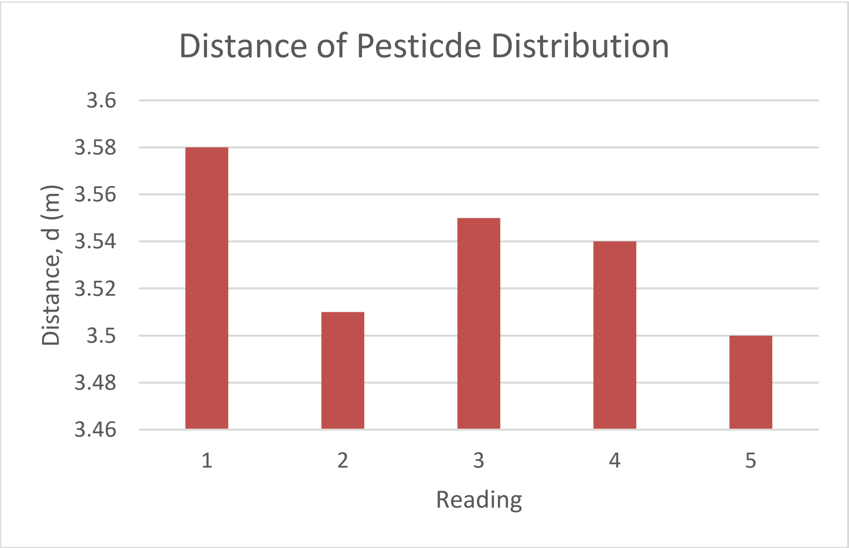


Figure 4.8 Distance of pesticide distribution.

4.6.3 Time Taken to Empty the Tank

Figure 4.9 Time taken to empty tank testing.

Figure 4.9 shows testing for the time taken to empty tank. In this part, the robot would be tested to empty the tank as the tank is filled fully with pesticide. The time taken to empty the tank would be measured. The volume of pesticide would be the same which is 3.51 litre There would have 5 readings in order to observe the parameter. Table 4.11 shows the time taken for emptying the tank results.

Table 4.11 Time taken emptying the tank.

Readings	**Time taken to empty the tank, t (min)**
1	4.13
2	4.07
3	4.11
4	4.18
5	4.13
Average	4.12

Based on the graph, the time taken for emptying the tank was being measured. From the data, we could observe that the difference between the lowest time taken which is 4.07 min and the highest time taken which is 4.18 min have quite a marginal difference. Although the difference is marginal, the average time taken to empty the tank which is 4.12 min should indicates the measurement taken is quite consistent. Figure 4.10 shows the graph for time taken to empty tank.

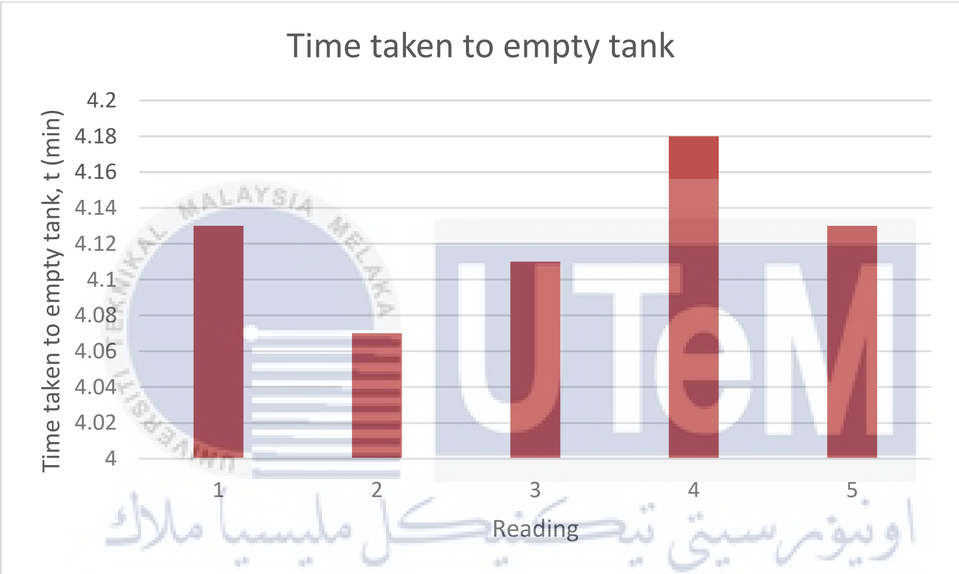


Figure 4.10 Time take to empty tank.

4.6.4 Flow Rate of Pesticide

Figure 4.11 Flow rate of pesticide testing.

Figure 4.11 shows the testing for flow rate of pesticide. In this part, the robot would be tested to distribute pesticide for 5 seconds and then observed the volume of pesticide remaining would be measured. The remaining volume of pesticide would be deducted by the initial volume of pesticide. The flow rate of pesticide could be calculated by multiply the volume of pesticide and time. Table 4.12 shows the flow rate of pesticide measured results.

Table 4.12 Flow rate of pesticide.

Readings	**Initial volume, V (L)**	**Remaining volume, V (L)**	**Flow Rate, Q (L/min)** **Q = volume/time elapsed**
1	3.51	3.38	1.56
2	3.35	3.22	1.56
3	3.19	3.06	1.56
4	3.03	2.90	1.56
5	2.87	2.74	1.56
Average	1.56		

Based on the graph, the flow rate of pesticide was being measured. From the data, we could observe that the average of flow rate is 1.56 L/min which indicates that the flow rate of the system is precise. The normal flow rate for the fan nozzle is from 0.92 L/min to 1.6 L/min. Figure 4.12 shows the graph for flow rate of pesticide distribution.

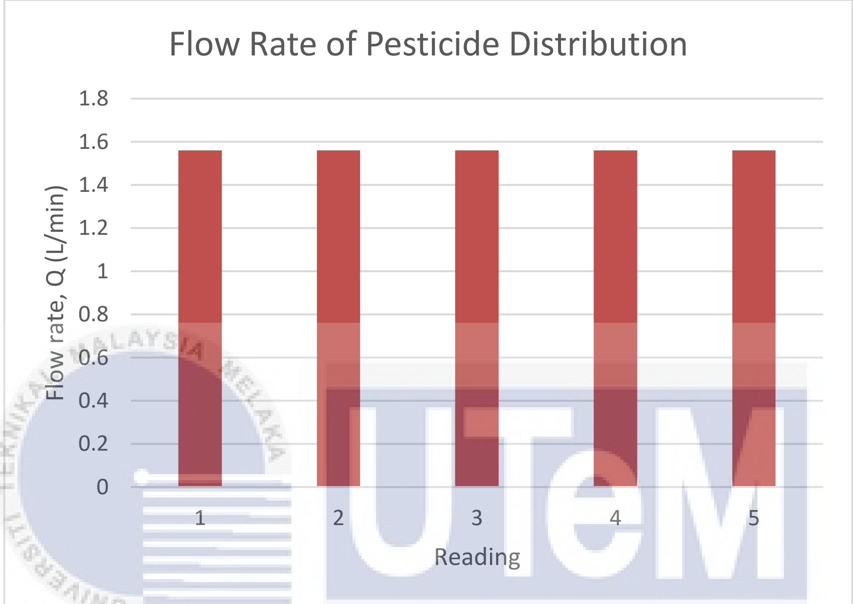


Figure 4.12 Flow rate of pesticide distribution

4.6.5 Coverage of Pesticide on the Plants

Figure 4.13 Coverage of pesticide on plant testing.

Figure 4.13 shows the testing for the coverage of pesticide on chilli plant. This part, the robot would be tested to distribute pesticide to plant. Then, the coverage of pesticide on the plant would be observed visually. The distance between the robot and the plant would be manipulated on each reading to observe the parameter. Table 4.13 shows the coverage of pesticide on the plant results.

Table 4.13 Coverage of pesticide on the plant.

Readings	Distance, d (m)	Coverage of pesticide
1	1.0	Covers all parts of plant
2	1.5	Cover all parts of plant
3	2.0	Cover all parts of plant
4	2.5	Cover all parts of plant
5	3.0	Cover bottom of the plant with 0.22 m high

Based on the Table 4.13, the coverage of pesticide on the plant was recorded based on our visual. From the data, we could observe that the coverage of pesticide depends on the distance between the robot and the plant. The measurement started at the distance of 1.0 m until 3.0 m with an increment of 0.5 m. From 1.0 m to 2.5 m, the pesticide distribution covers all parts of the plant while from 3.0 m, the pesticide distribution just covers the bottom of the plant which the height cover is 0.22m. The higher the distance, the lower the coverage of pesticide on the plant.

4.7 Summary

Based on the data analysis, there are five parameters that have been collected the data and being discussed the observations. The average speed of robot is 0.06 ms^{-1} shows that the robot could move consistently compared to human which will feel tired after doing couple of workloads that can affect the stamina. The average distance of pesticide distribution is 3.54 m shows that the nozzle used which is fan nozzle is suitable for distributing pesticides at vegetable farms which the distance between plant to plant is near. The average time taken to empty the tank is 4.12 min shows that the tank could last long for a trip and supply enough pesticide to every crop. The average flow rate of pesticide distribution is 1.53 L/min . The coverage of pesticide on plant based on the distance between the robot and plant and based on the distance of pesticide distribution. From the discussion, the pesticide spraying application robot is a good system to implement in vegetables farm.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis presents an alternative product to help farmers implement pesticide spraying method in an efficient way. The proposed methodology is based on the important parameter of pesticide spraying method which is nozzle selection. Fan nozzle is selected because of its production of uniform droplets with high accuracy. This parameter has then been implemented in the robotic system. The proposed analytical measures the performance of the system which included speed of robot, distance of pesticide distribution, time taken to empty the tank, flow rate of pesticide distribution and coverage of pesticide on plant.

Overall, the design and development of a pesticide spraying application robot for vegetables farm using Raspberry Pi was completed with success. Users are served with effective user interface which was made using Node-RED to control the robot and enable it spray pesticide around their vegetables farm. As the pesticide spraying application robot is being implemented, people like farmers and even disables could done pesticide spraying task consistently.

5.2 Future Works

As future works, sensors such as ultrasonic could be implemented to detect obstacle near the robot. As implementing the sensor, the robot could be autonomous and could be controlled without human interactions. In the other hand, the size of tank could be enhanced so that the capacity of pesticide carried by the robot would be greater and could serve bigger farms.

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APPENDICES

Appendix A Gantt Chart PSM 1

Month	March			April				May				June		
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Registration														
Pesticide Analysis														
Mobile Robot Analysis														
Spraying Analysis														
Buy Part														
Component Testing														
Report Writing														
Final Report														
Presentation														

Appendix B Gantt Chart PSM 2

Month	October			November				December				January		
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hardware development														
Programming and Software Development														
Testing and Analysis														
Report Writing														
Final Report														
Presentation														

Appendix C Node-RED Flow