Faculty of Electrical Technology and Engineering

DEVELOPMENT OF AN AUTONOMOUS AGRICULTURE ROBOT FOR FERTIGATION USING ARDUINO

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

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I declare that this project report entitled “DEVELOPMENT OF AN AUTONOMOUS AGRICULTURE ROBOT FOR FERTIGATION USING ARDUINO” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours.

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DEDICATION

I dedicate this final year project to those who have been the pillars of support throughout my academic journey.

To my family, for their unwavering love, encouragement, and understanding during the late nights and challenging moments. Your sacrifices have been the driving force behind my pursuit of knowledge.

To my supervisor, for your guidance, expertise, and patience. Your insights have shaped my academic growth and inspired me to push beyond my limits.

To my friends, who have been companions on this academic rollercoaster, sharing both the joys and the hardships. Your camaraderie has added a special flavor to this educational adventure.

To all those who believed in me when I doubted myself, your faith fueled my determination to reach this milestone.

This project is a culmination of not just my efforts but the collective support of a community that stood by me. Thank you for being the wind beneath my wings.

ABSTRACT

Agriculture is about growing things for food, fuel, and other products, involving tasks like planting and harvesting. Fertigation is a process of applying fertilizer to plant crops through an irrigation process which play a key role in agriculture. In red chili farming, challenges like drought and lack of resources affect how much chili is produced. Infectious plant diseases are caused by live agents called pathogens. Microbes like nematodes, fungi, bacteria, and mycoplasmas are some of the culprits that infect plants and lead to diseases. Moreover, traditional agriculture required lots of manpower and hard to maintain in this climate change. The main purpose of this research is to develop an autonomous robot prototype for the advancement of existing fertigation technology. This research also working on the designation of an algorithm of an autonomous robot for path mapping. Finally, a full depth analysis on the performance of the autonomous robot in fertigation. This research oriented on the study of development that have been made by other researcher to find a better solution in fertigation that are economical and environmentally friendly. Arduino microcontroller is used as the command center for the autonomous robot to execute command that have been specified to it. The primary goal of this research is also path mapping because the robot prototype is difficult to manoeuvre because of the irregular path of the crop field. Then, this research also will analyze the effectiveness of the method presented with the robot prototype in fertigation compared with technology that have been prevailed. Automation of the robot will be the main topic discussed in this research to provide semi autonomous robot for fertigation in fertigation.

ABSTRAK

Pertanian adalah tentang menanam sesuatu untuk makanan, bahan api, dan produk lain, melibatkan tugas seperti menanam dan menuai. Fertigasi adalah proses aplikasi baja kepada tanaman melalui proses pengairan yang memainkan peranan penting dalam pertanian. Dalam pertanian cili merah, cabaran seperti kemarau dan kekurangan sumber mempengaruhi berapa banyak cili yang dihasilkan. Penyakit tumbuhan berjangkit disebabkan oleh agen hidup yang disebut patogen. Mikrob seperti nematod, kulat, bakteria, dan mikoplasma adalah antara dalang yang menjangkiti tanaman dan menyebabkan penyakit. Selain itu, pertanian tradisional memerlukan banyak tenaga kerja dan sukar dijaga dalam perubahan iklim ini. Tujuan utama kajian ini adalah untuk mengembangkan prototaip robot autonomi untuk kemajuan teknologi fertigasi sedia ada. Kajian ini juga berusaha merangka algoritma robot autonomi untuk pemetaan laluan. Akhirnya, analisis mendalam dilakukan terhadap prestasi robot autonomi dalam fertigasi. Kajian ini tertumpu pada pengkajian pembangunan yang telah dilakukan oleh penyelidik lain untuk mencari penyelesaian terbaik dalam fertigasi yang ekonomi dan mesra alam. Mikropengawal Arduino digunakan sebagai pusat arahan bagi robot autonomi untuk melaksanakan arahan yang telah ditentukan kepadanya. Tujuan utama kajian ini juga adalah pemetaan laluan kerana prototaip robot sukar untuk dimaneuver kerana laluan tanaman yang tidak teratur. Kemudian, kajian ini juga akan menganalisis keberkesanan kaedah yang dikemukakan dengan prototaip robot dalam fertigasi berbanding dengan teknologi yang telah ada. Automasi robot akan menjadi topik utama yang dibincangkan dalam kajian ini untuk menyediakan robot separa autonomi untuk fertigasi.

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I would like to express my sincere appreciation for the unwavering support and cooperation of my dear friends who stood by me during both challenging and triumphant moments. Their encouragement and camaraderie have been a constant source of strength, lifting me up during my lowest moments and celebrating with me during the highest peaks of this journey

Finally, I extend my thanks to all those individuals who may not be explicitly mentioned but have played a role, directly or indirectly, in the successful completion of this project.

This project has been a significant learning experience, and I am grateful for the contributions of everyone involved.

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^{0}C - Degree Celsius

LIST OF ABBREVIATIONS

V	-	Voltage
DC	-	Direct Current
kg	-	kilogram
g	-	gram
ml	-	milimeter
BCE	-	Before Common Era
pH	-	Pontential of hydrogen
IR	-	Infrared
NPK	-	Nitrogen (N) phosporus (P) and potassium (K)
LCD	-	Liquid Crystal Display
LED	-	Light-emitting diode
UART	-	Universal Asynchronous Receiver Transmitter
PWM	-	Pulse Width Modulation
cm	-	centimetre
I/O	-	Input/Output
mL/s	-	millitres per seconds

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is the practice of cultivating plants, animals, and other organisms for food, fuel, fiber, and other products. It involves a range of activities such as planting, harvesting, irrigation, pest control, and soil management. Agriculture is essential for providing food security and supporting economic development in many parts of the world.

Fertigation, on the other hand, is a technique used in agriculture to apply fertilizers and other nutrients to crops through irrigation systems. From the perspective of cultivation aspects, red chili farming faces various problems such as drought, lack of availability of superior seeds and other input facilities, low skills of farmers, low technology dissemination, low intensity of extension, lack of infrastructure, and low-price guarantees. These have caused chili production tends to fluctuate [1]. It involves the injection of a liquid fertilizer solution into the irrigation water, which is then distributed evenly across the crop fields. This technique is beneficial as it helps to deliver nutrients directly to the plant's roots, leading to better growth and yields. It also reduces the amount of fertilizer and water needed, thereby improving the efficiency of crop production, and reducing environmental impacts such as runoff and leaching. Fertigation is widely used in modern agriculture, especially in areas where water and nutrients are scarce.

Over the past two decades, demand for quality horticultural products is on the rise, propelled by the growing interest of society in fresh products of high organoleptic, nutritional, and functional quality [2]. Effective cultivation practices are essential for sustainable agriculture, as they help to conserve resources, prevent soil erosion and nutrient depletion, and reduce the use of harmful pesticides and fertilizers. Huge amounts of fertilizer and irrigation water is applied to meet the high demand for nutrients and water for the rapid growth of greenhouse vegetables [3].

The primary aim of this project is to design and develop an efficient fertigation system using Arduino. This system consists of an Arduino Mega, ultrasonic sensors, and DC motor. Arduino Mega act as the microcontroller which hosts all the commands, receive all the parameters from the sensors and send output signals accordingly. The ultrasonic sensors will be used for path mapping and object detection. DC motors are used to control robot movement and slider mechanism while DC water pumps are used for fertigation by spraying fertilizer to the crop.

1.2 Problem Statement

Traditional agriculture required lots of manpower and hard to maintain in this climate change and it requires other alternatives to increase its efficiency. Applying nutrients with water has been found to result in greater crop development and yield in both fruit and vegetable crops compared to conventional soil application methods of fertilizer [4]. The downside of fertigation systems nowadays are high upfront cost. Suhaimi (et. al 2016) and Shirgure (2013) stated that the high construction cost is a significant drawback for fertigation systems. The high construction cost is a significant drawback for fertigation systems. Tanks, injectors, backflow protection valves, and timers are frequently required as initial expenses for fertigation [5], [6].

Drip irrigation is the most popular irrigation technology for fertigation [7], a system that is prone to clogging [8]. When possible, it is advised to utilise emitters made to lessen clogging. Utilising the proper fertilizer and high-quality irrigation water is also important

[9]. Water-soluble fertilisers with a pH close to neutral and a low salt index are required to avoid precipitation and clogging. When utilising fertilisers with calcium or magnesium, there is a risk of precipitation in fertigation systems. Before using fertilizers, farmers and operators should make sure that they are compatible.

According to a report conducted by Indonesian Journal Of Social And Environmental Issues (IJSEI), approximately 80.77kg of chiles are lost by chilli producers each year as a result of pests, illness, and heat [10]. Pathogens, or live (biotic) agents, are the culprits behind infectious plant illnesses. An infected plant or plant detritus might transfer these viruses to a healthy plant. Nematodes, fungus, bacteria, and mycoplasmas are a few of the microbes that can infect plants and cause disease [11].

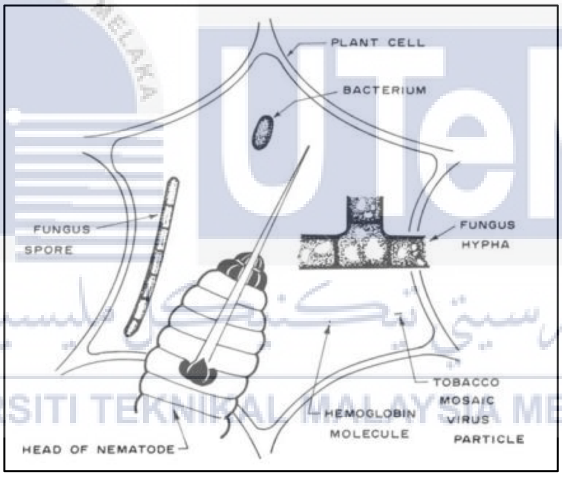

Figure 1.1Illustrations of plant and parasites pathogen

The signs of plant diseases include wilting, spotting (necrosis), mold, pustules, rot, hypertrophy and hyperplasia (overgrowth), deformation, mummification, discoloration, and destruction of the affected tissue [12]. According to Veresoglou (et al. 2013), the severity of plant diseases caused by fungi is altered by fertilization events [13]. This can conclude that, uncontrol fertigation and crop surveilances can become a huge risk that can cost the growth of unhealthy plants. This proposed prototype is created so the risk can be reduced and changed the traditional agriculture ways.

1.3 Project Objective

The main aim of this project is to propose an autonomous systems and effective methodology to enhance plant growth using Arduino technology. Specifically, the objectives are as follows:

a) To develop a prototype of an agriculture robot for fetigation using Arduino.

b) To design an algorithm of path mapping for the autonomous robot.

c) To analyze the performance of the autonomous robot prototype in fertigation system.

1.4 Scope of Project

The scope of this project revolves around the cultivation of chilli pepper plants, exclusively utilizing fertilizers specifically tailored for their needs. The current inventory proudly boasts a substantial volume of liquid fertilizer, standing confidently at 1500 milliliters. Fluid fertilizer limited to 10g each fertigation process. The project focuses on a field crop consisting of precisely 5 carefully selected chilli pepper plants. By establishing these parameters, the project aims to optimize the growth and development of the chilli pepper plants, ensuring their successful cultivation within defined boundaries and limitations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years, automation has become an increasingly important part of many industries. As technology advances, more and more companies are turning to automation products to increase efficiency, reduce costs, and improve the quality of their products and services. Around 1947, the automotive sector began to utilise the term "automation" to characterise the rise in autonomously operating machinery and controls in automated production [14]. According to data from the International Federation of Robotics (IFR), the number of industrial robots per 10,000 workers in Mexico's manufacturing sector climbed by 33% between 2017 and 2019 [15], [16]. This literature review aims to provide an overview of the current research and literature related to automation products. This chapter will discuss the different types of automation products, their benefits and limitations, and the impact of automation on the workforce. Additionally, the review will analyze the factors that influence the adoption of automation products and the challenges faced by industries during the implementation process.

2.2 History of Agriculture

The cultivation of food and goods through farming known as farming, produces the huge supply of food globally. It is thought to have been cultivated irregularly for the previous 13,000 years [17], and has only been widely utilised for 7,000 years [18]. In the length history of humanity, this is a brief period of time compared to the almost 200,000 years that our predecessors were foraging, hunting, and salvaging in the wild. In its brief existence, agriculture has fundamentally altered human society and supported an expanding global population that has increased from 4 million to 7 billion people since 10,000 BCE [19].

Figure 2.1Grave chamber of an Egyptian public official [20]

The oldest fossil evidence of Homo sapiens, anatomically modern humans, is believed to be approximately 196,000 years old, according to paleoanthropologists [21]. Since the beginning of human evolutionary history, we have gotten most of the food is obtained by foraging in the outdoors [17], [22]. Wild plants and fungi, including the wild ancestors of certain species that are commonly cultivated now, were essential foundations of the palaeolithic diet [23]. Although the prehistoric hunt for wild animals is frequently portrayed as an epic battle against woolly mammoths, woolly rhinos, huge elk, and other prehistoric megafauna, primitive humans also engaged in foraging for lowly insects [24] and scavenging from the remains of deceased animals [25].

2.2.1 Agriculture Starting Point

People started gradually moving away from a hunter-gatherer lifestyle towards producing crops and raising animals for food as early as 11,000 BCE. Northern China, Central America, and the Fertile Crescent, an area in the Middle East that cradled some of the earliest civilizations, are among the places in the world where the transition to agriculture is believed to have occurred independently [17]. Most of the farm animals that we are accustomed to today had been domesticated by 6000 BCE [17]. All of the major continents had agriculture by 5000 BCE, except for Australia [18].

Why did people migrate to farming from hunting and gathering? There are numerous possible explanations, all of which probably had an impact at various points in time and in various regions of the world. It may have become too cold or dry due to climatic changes to rely solely on wild food sources [17]. A higher population density may have demanded more food than could be gathered through foraging in the wild; yet, farming, despite requiring more time and effort, produced more food per acre [17], [26]. Woolly mammoths and other megafauna may have gone extinct due to overhunting [27]. Agriculture would have been a more viable way of life since technology changed, such as domesticated seeds [22], [28].

Like many of their modern counterparts, the land was frequently cultivated by early farmers in ways that reduced its fertility. Technology advancements like irrigation (about 6000 BCE) and the plough (around 3000 BCE) led to significant production improvements, but when used carelessly, they damaged the soil—the very foundation that allows agriculture to take place[17], [29] . By the start of the Common Era Roman farmers had damaged their soil to the point where they could no longer produce enough food and were forced to rely on imports from far-off Egypt. One of many cautionary tales about the significance of sustainable agriculture is Rome's inevitable demise [17].

The provision of food has nonetheless kept up with population expansion due to innovations in food production and distribution. Native to the America crops, like corn, sweet potatoes and cassava have spread all over the world. Over the course of the 18th century, a significant rise in population was supported by the nutrients these abundant crops offered in order to prevent malnutrition[29]. Synthetic fertilizers—chemicals manufactured through a process that converts atmospheric nitrogen into a form that can be applied to crops (ammonia)—are undoubtedly the agricultural developments that have made the greatest impact. Synthetic fertilisers, which were first used in the early 1900s and significantly enhanced crop yields (albeit not without drawbacks), are credited for producing the majority of the world's food during the 20th century [30].

Figure 2.2Application of ammonia fertilizer at Iowa farm

2.3 Fertigation

Fertigation is the irrigation-based application of liquid fertilizers to plants. Fertigation is a more effective form of fertilization in agriculture than conventional techniques. Fertigation benefits both farmers and the environment by decreasing fertilizer waste, contaminating the soil, and enhancing crop productivity. It enables agricultural producers to save money by using fertilizer just where it is required, in conjunction with precision farming. Farmers can easily control the rates and schedules of nutrient application thanks to automated fertigation devices.

According to fertilization technology, fertilizers should be sprayed into the precise irrigation system from reservoirs containing water-soluble fertilizers. In most cases, injectors and a pressure-controlled valve are used. Most fertigation systems come with sensors to gauge electric conductivity and pH levels. Injectors for fertigation and irrigation systems can then be adjusted in accordance with the appropriate fertilizer rates that have been determined on the fields.

2.3.1 Fertilizer Used in Fertigation System

Different fertilizer types have varying levels of solubility. Furthermore, temperature has an impact on the degree and rate of solubility. Therefore, it is important to ascertain whether nutrients can dissolve at the field's current temperature. Since the solubility rate will vary in the spring and summer, the season should also be considered.

Additionally, when added in high concentrations to hard water or when the temperature lowers, such as during a cooler season or on cold nights, some fertilizers may precipitate out of solution. When creating and storing solutions in advance, this characteristic is important. Monoammonium phosphate, urea phosphate, or phosphoric acid all exhibit precipitation. Among the fast water-soluble fertilizers are ammonium nitrate, potassium nitrate, urea, and ammonium phosphate.

The solubility capacity of several synthetic fertilizer compounds (g/L) and temperature are correlated in the table below, which is important for smart fertigation technology [31].

Table 2.1 Solubility of Fertilizer with temperature

Compound	0°C	10°C	20°C	30°C
Ammonium nitrate	1183	1580	1950	2420
Ammonium sulphate	706	730	750	780
Calcium nitrate	1020	1240	1294	1620
Di-ammonium phosphate	429	628	692	748
Di-potassium phosphate	1328	1488	1600	1790
Magnesium chloride	528	540	546	568
Magnesium sulphate	260	308	356	405
Mono-ammonium phosphate	227	295	374	464
Mono-potassium phosphate	142	178	225	274
Potassium chloride	280	310	340	370
Potassium nitrate	130	210	320	460
Potassium sulphate	70	90	110	130
Urea	680	850	1060	1330

2.4 Agribot for Fertigation using Arduino

In recent study, Arduino microcontroller is used as the main brain for the system along with several functional sensors. Agribot is created and tested independently for each activity based on functionality before being assembled to produce the desired results [32] .

Automatic agricultural vehicles have four important current capabilities that fall into various groups [33]. The first category is guidance, which describes the strategy these vehicles use to efficiently move through the agricultural field. In the second category, known as detection, these vehicles draw crucial biological properties from their surroundings. The third category, action, deals with the vehicle's capacity to perform the specific tasks for which it was created, such as radicchio harvesting [34]. The fourth category is mapping, which includes the process of making thorough maps of agricultural fields that include the most important details [35]. Automatic agricultural vehicles can increase production and efficiency in farming operations thanks to these features.

These four cores, however, are not independent. The vehicle must be aware of its location within the field and the components of the surrounding environment (mapping) in order to navigate safely and successfully; poor detection could result in an incomplete or invalid map.

2.4.1 Path Mapping

Kachor et al. (2019) utilized a five-sensor infrared (IR) array to facilitate path mapping for an agribot during line-following activities. This ensures the robot stays on course and moves in the intended direction. The IR sensors are capable of reading white lines on dark surfaces even in low light conditions, allowing the Agribot to operate at night, a task that might be unsafe for manual operations [32]. Additionally, two IR sensors on the Agribot's body detect obstacles, specifically pomegranate plants, and are also utilized for weed detection on farms.

According to Sujon et al. (2018), the robot employs ultrasonic sensors for path mapping. It is equipped with three ultrasonic sensors positioned at the front, right, and left sides. Following programmed instructions, the robot initiates in the left lane and, upon reaching the end, uses the front sensor to detect obstacles. Subsequently, it turns right, moves for approximately one second to cross the first lane, and then repeats the process, making right turns and advancing until the completion of the final lane. The robot encounters three predefined obstacles at the end of the last lane, and upon detection, it halts. For a clearer understanding of this mapping process, refer to Figure 2.3.

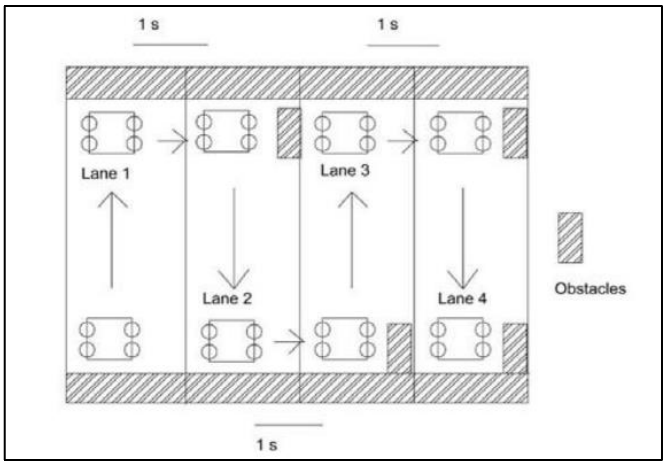

Figure 2.3System Mapping [36]

2.4.2 Action Performed

In order to increase productivity and efficiency [37], robotics and artificial intelligence developments provide fresh approaches to activities in precision agriculture linked to sowing, harvesting, weed management, grove supervision, chemical treatments, and more [38]. The Arduino board can be thought of as a miniature computer that can send and receive analogue and digital signals as well as carry out some processing [39]. Microcontroller can be programmed to carried out different kind of task according to the command given by programmer.

Three of the most fundamental agricultural tasks are ploughing, sowing, and watering as state by Sujon et al (2018) [36]. As the guiding principle, ploughing and seedling take into action while the robot is in motion. Ploughing and seeding would stop if the robot were to stop. Thus, these features have been integrated into the mapping system. After stopping, the robot will start sprinkling water from a nearby tank until the entire area is covered. Figure 2.4 below depicts the block diagram of the farming mechanisms.

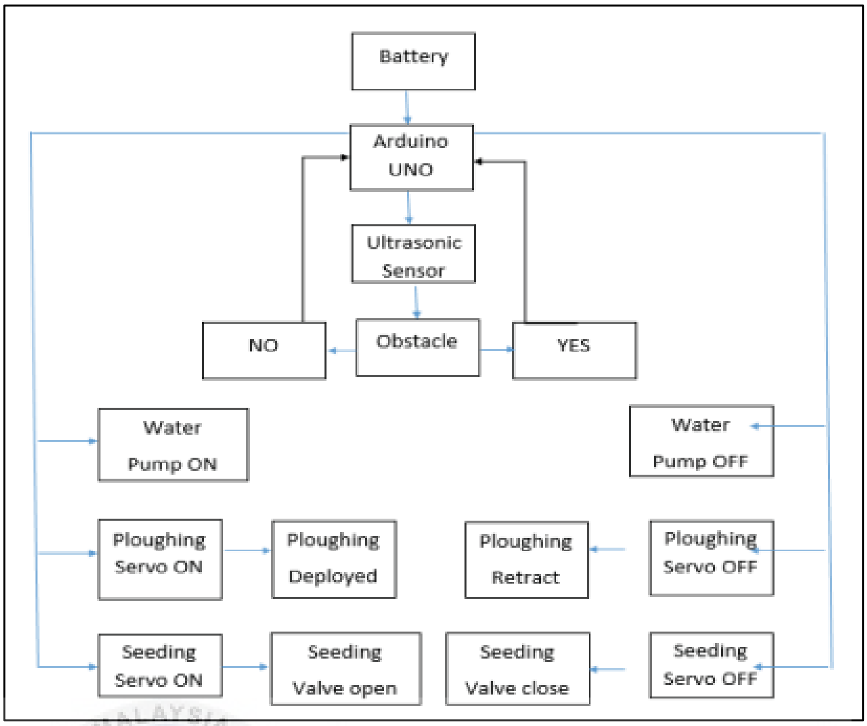

Figure 2.4Action block diagram [36]

As per Kachor et. al (2019), the robotic arm was built to carry out a variety of duties including digging holes in the ground, planting bushes in them, covering their roots, and applying herbicides and predevelopment composts alongside a checking specialist [32]. Depending on the task, the robotic arm's end effector can alter. At the beginning of the process of spraying pesticides, a gripper is used to pick up and position the bush, and blades are used to cut vegetation in the farm.

Fadhaell et al 2022, [40] developed an agriculture vehicle with functional agricultural task. The LCD used for reading and monitoring the value of each action, solenoid valve acting as a switch to regulate the quantities needed for all functions mentioned above that are available on the tanks, and more. The pH, temperature, and soil moisture are each detected individually using a different sensor for each one. This measured value is sent to an Arduino microcontroller, and the farmer decides which fertiliser and how much water to use for planting based on the pH value as well as what level of soil moisture is suitable for seeding [41], [42], [43], [44], [45], [46].

2.4.3 Detection and Guidance

Fadhaell et al. (2022) [40] have developed a control segment for an Arduino-based robot, incorporating various sensors for measuring humidity and temperature, detecting pH values for fertilizer selection, and implementing a water spray mechanism for planting. The framework comprises two primary components: the robot itself and the control segment, both interconnected through web communication technologies. The control area encompasses temperature sensors, pH detectors, humidity sensors, seed allocator, seed capacity indicator, fertilizer storage, fertilizer dispenser, water spray container, water spray capacity indicator, and a mechanical framework with a motor, microcontroller, and power supply. The microcontroller serves as the central processing unit, issuing commands for each task, with specialized programmers handling specific functions [47], [48], [49], [50], [51].

The Moisture Sensor, as suggested by Kachor et al. (2019) [32], is employed to monitor the soil's moisture content. This sensor gauges moisture loss over time due to evaporation and plant absorption, aiding in determining the optimal soil moisture level for effective irrigation control. To conserve water, each plant receives a precise amount of water, and the user has the flexibility to select which valve opens and for how long. All data are transmitted to the user's phone via Bluetooth connection. NPK detection (Nitrogen, Phosphorus, and Potassium) is crucial for overall plant growth. Three Light Emitting Diodes (LEDs) are selected based on the wavelengths at which nitrogen, phosphorus, and potassium are absorbed. The distance between the LED and the photodiode is fine-tuned using a trial-and-error approach to achieve the transducer's maximum sensitivity, with the results displayed in Table 2.2 below.

Table 2.2 Soil absorption value and suitable LED range [32]

Nutrient	Absorption Wavelength (nanometer)	LED	Wavelength (nanometer)
Nitrogen (N)	440-480	LED A	460-485
Phosporus (P)	525-580	LED B	500-574
Potassium (K)	600-670	LED C	635-600

2.5 Automated Smart Irrigation System using IoT

In this paper, the author, Tephia et al. (2022) propose an automatic irrigation system with IoT using a ESP8266 microcontroller module. The paper's key feature is how the sensors mechanism detect changes in the surrounding environment's temperature and humidity, then send a signal to the microcontroller, and automatically deliver water as necessary [52]. The proposed system consists of soil moisture sensor, temperature sensor, and humidity sensor continuously checks the amount of moisture throughout the entire field. Using the Internet of Things, the pump would automatically turn on when the soil moisture fell below a certain level, resulting in the optimal irrigation. Figure 2.5 below shows the block diagram of Smart irrigation method.

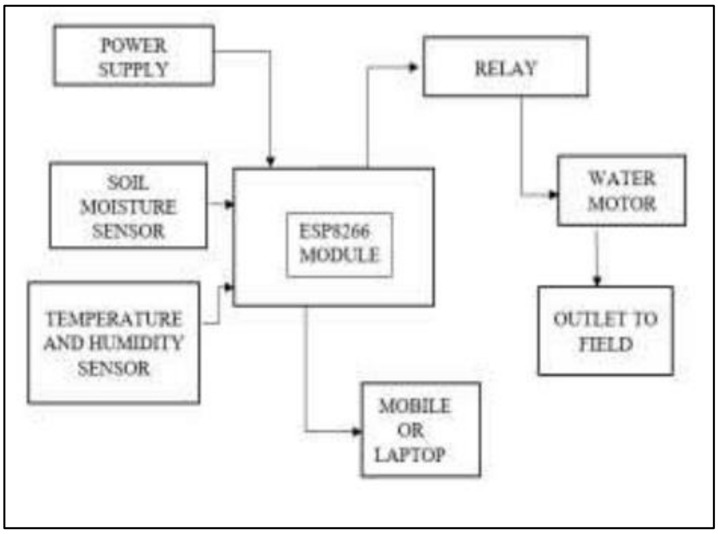

Figure 2.5Block diagram of Smart irrigation method [52]

To control the water flow based on the need for irrigation, an IoT enabled valve is installed at the channel. Each valve is managed by the valve controller. The user connectivity module is used for sending data and notifications to users about any agricultural events. Additionally, it conveys user feedback to the hardware in the form of instructions. Emails and mobile phone applications can be used to receive these notifications and instructions. Figure 2.6 provides architectural setup of the product.

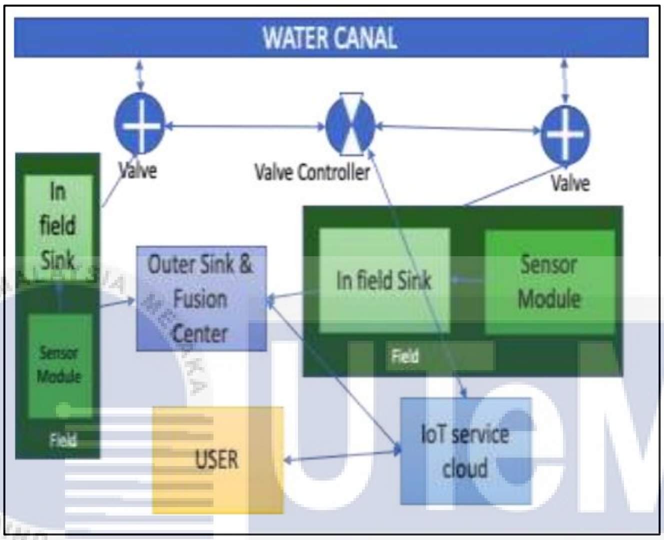

Figure 2.6Architectural Setup [52]

2.6 Smart Irrigation Management and Monitoring System using Raspberry Pi

This paper employs raspberry pi for a quick and simple installation [53]. Rau et al 2017 [54], proposes an irrigation system that relies on the weather and is powered by a Raspberry Pi. Temperature, humidity, wind patterns, and soil radiation patterns are the main causes of water loss in the atmosphere [55]. The optimal water availability is one of several variables that affect a plant's output. Figure 2.7 displays the proposed system's overall block diagram.

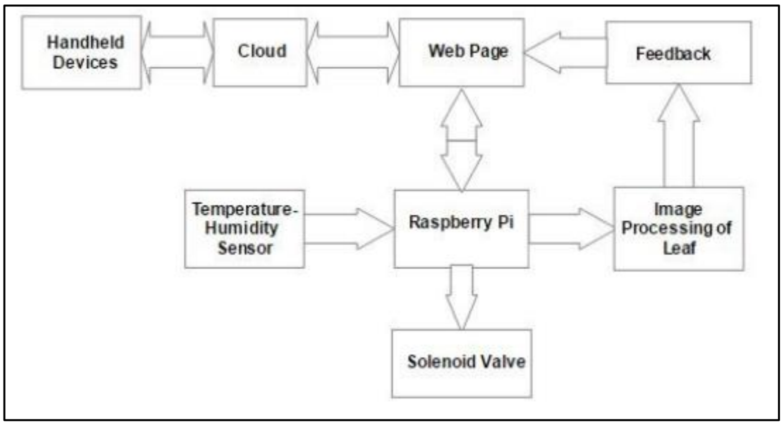

Figure 2.7 Block Diagram of Smart Irrigation System with Raspberry Pi [54]

2.7 Summary

A literature review is crucial for the development of a project because it offers a thorough grasp of the abundance of knowledge and research already done on the subject, allowing the design of relevant techniques, the identification of research gaps, and the making of informed decisions. The researcher papers have been analazyed and some key point have been point out between those paper, so idea of project development can be established. Table 2.2 shows comparison between other researcher and their journal to acquire a broader understanding of the collection of knowledge.

Table 2.3 Journal comparison

No	Year	Title	Methodology
1	2019	Design of microcontroller based agribot for fertigation and plantation	• Line Follower Robot. • Arduino microcontroller. • Robotic arm with different end effector for different task. • Soil sensor and NPK sensor. • Bluetooth and GSM module for communication with Agribot. • Design mobile application for monitoring system.
2	2018	Agribot: Arduino Controlled Autonomous Multi-Purpose Farm Machinery Robot for Small to Medium Scale Cultivation	• Ultrasonic sensor for lane mapping. • Tasks performed were ploughing, seedling, and watering. • Arduino microcontroller

3	2022	Design and development an Agriculture robot for Seed sowing, Water spray and Fertigation	• Temperature sensor, pH sensor, and a soil dampness sensor is used. • The movement of robot is controlled by Android Bluetooth. • Arduino as the brain, connected with Raspberry Pi 3+ used for video streaming of the field with camera attached.
4	2022	Automated Smart Irrigation System using IoT with Sensor Parameter	• Automatic irrigation system using ESP8266 microcontroller. • Utilization of soil moisture sensor, temperature sensor, and humidity sensor. • IoT enable valve to activates pump when parameter is met. • IoT also used as monitoring system.
5	2017	IoT based smart irrigation system and nutrient detection with disease analysis	• Powered by a Raspberry Pi. • Image processing of plant condition for analysis. • Humidity, temperature sensor is used. • IoT used for monitoring by smartphone.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss the steps and process of fabrication of the robot. Scheduled planning must be done for the entire project, from start to finish. This is to ensure that the project can be completed on time. This chapter also represents the methods and concepts that will be used to make the fertigation robot concept design. The best concept of this product also has been chosen by using this method in this chapter. All the research that has been done from the past has to be combined with a better idea and solution for this project.

3.2 Sustainable Development

A concept known as sustainable development seeks to strike a balance between economic growth, environmental conservation, and social well-being, ensuring that current demands are addressed without sacrificing the capacity of future generations to meet their own needs. The concept of sustainable development has been utilized in this project development to ensure the benefits to all members of society by consider the importance of protecting and preserving natural resources, reducing pollution and waste, and also promoting the sustainable use of renewable resources. By using autonomous systems in the project development, it encourages economic growth, as well as long term sustainability, allowing innovation and ethical practices of production and consumption.

3.3 Methodology Process

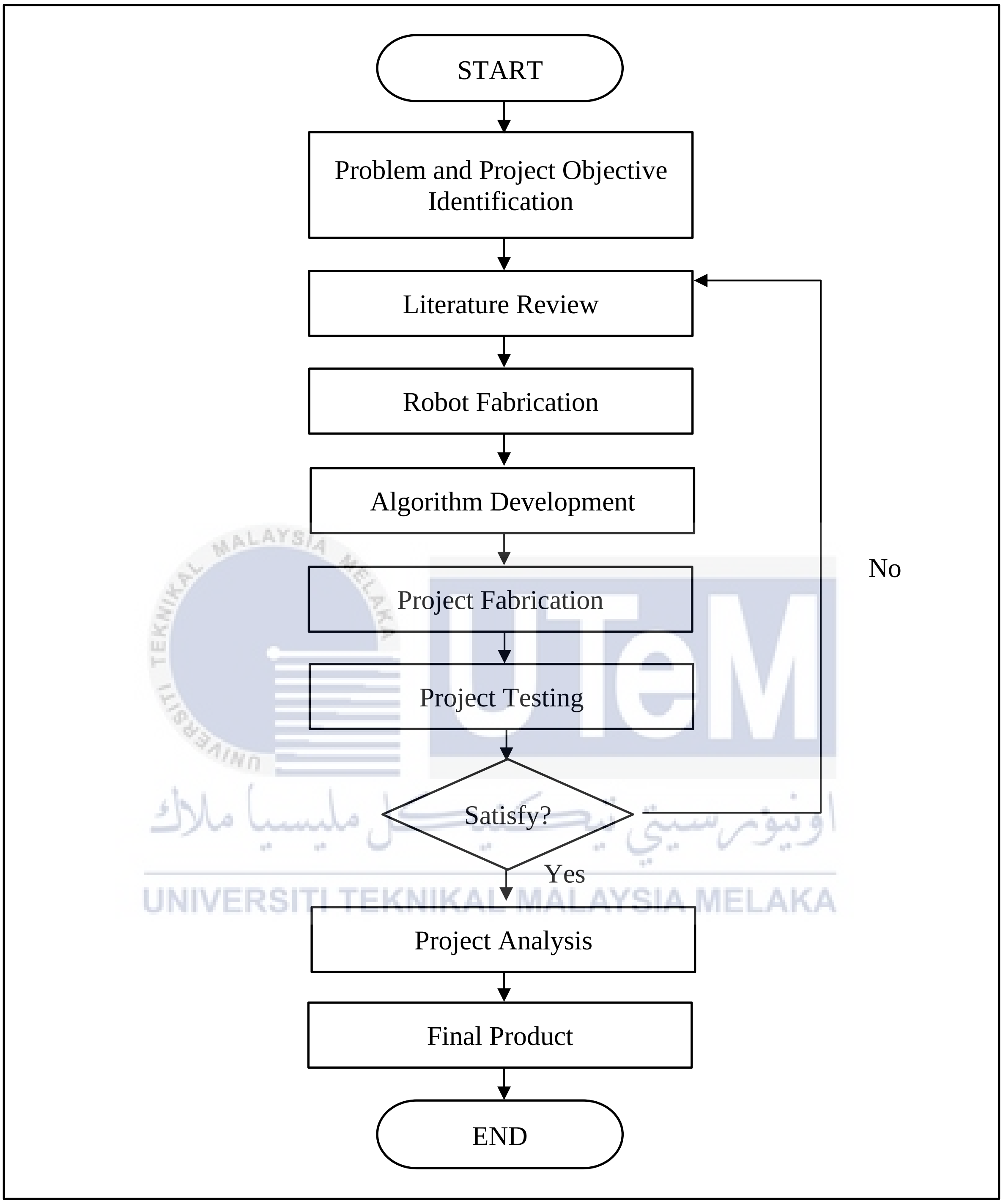

Figure 3.1 Process Planning Flowchart

By following the organized planning at Figure 3.1, the project can be finished within the required time. Prior to design fabrication, the research have been made to make sure the design of the project can carried out more strength before the fabrication process is made. In fabrication, the equipment to use in the project must be selected carefully to avoid huge spending in completion of the final product. Performing a thorough project analysis is the crucial strategic step to pinpoint and optimize the significant advantages that can be identified upon project completion, guarenteeing a well-informed and positive finish to the entire project.

3.4 Engineering Design Fabrication

Design fabrication phase consists of block diagram of the robot, drawing draft, material selection, and project cost.

3.4.1 Block Diagram

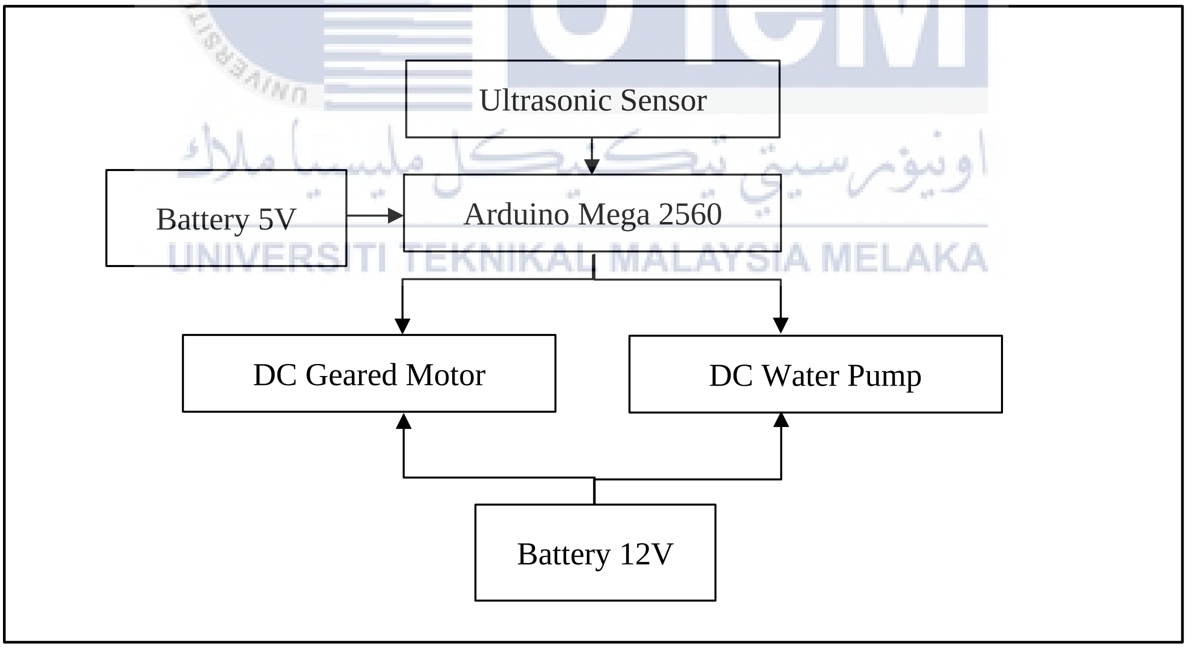

Figure 3.2 Block Diagram

An Arduino Mega 2560 is at the heart of the system, powered by a 5V battery. The Arduino takes input from an ultrasonic sensor. As output, it controls both a DC geared motor and a DC water pump, both powered by a 12V supply.

3.4.2 Drawing Draft

AutoCAD 2023 software have been used to develop mechanical drawing of this robot with the approximately accurate dimension. Mechanical drawing is an important step to provide visual representation of the product to be designed. It ensures that the design intent is precisely translated into the actual product, resulting in successful and effective fabrication.

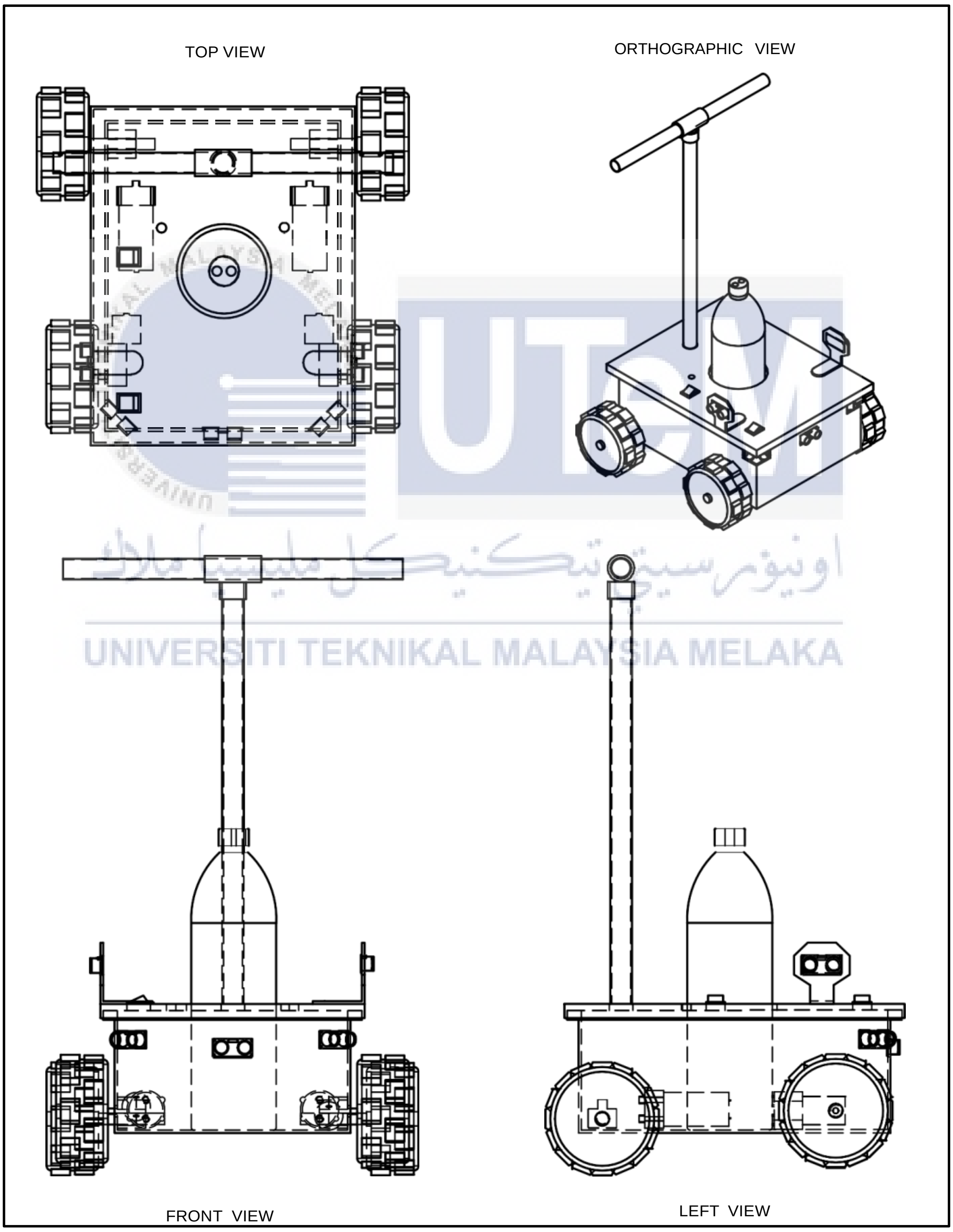

Figure 3.3 Autodesk AutoCAD 2023

3.4.3 Circuit Diagram

Fritzing software have been used to illustrates the wiring and circuit diagram of this robot. Circuit diagrams provide visual representation of electronic components, arrangement, layouts and interconnections. Circuit diagrams play a vital role in the design, analysis, troubleshooting, and maintenance of electronic circuits, whicih are essential tools for effective communication and documentation of electronic systems.

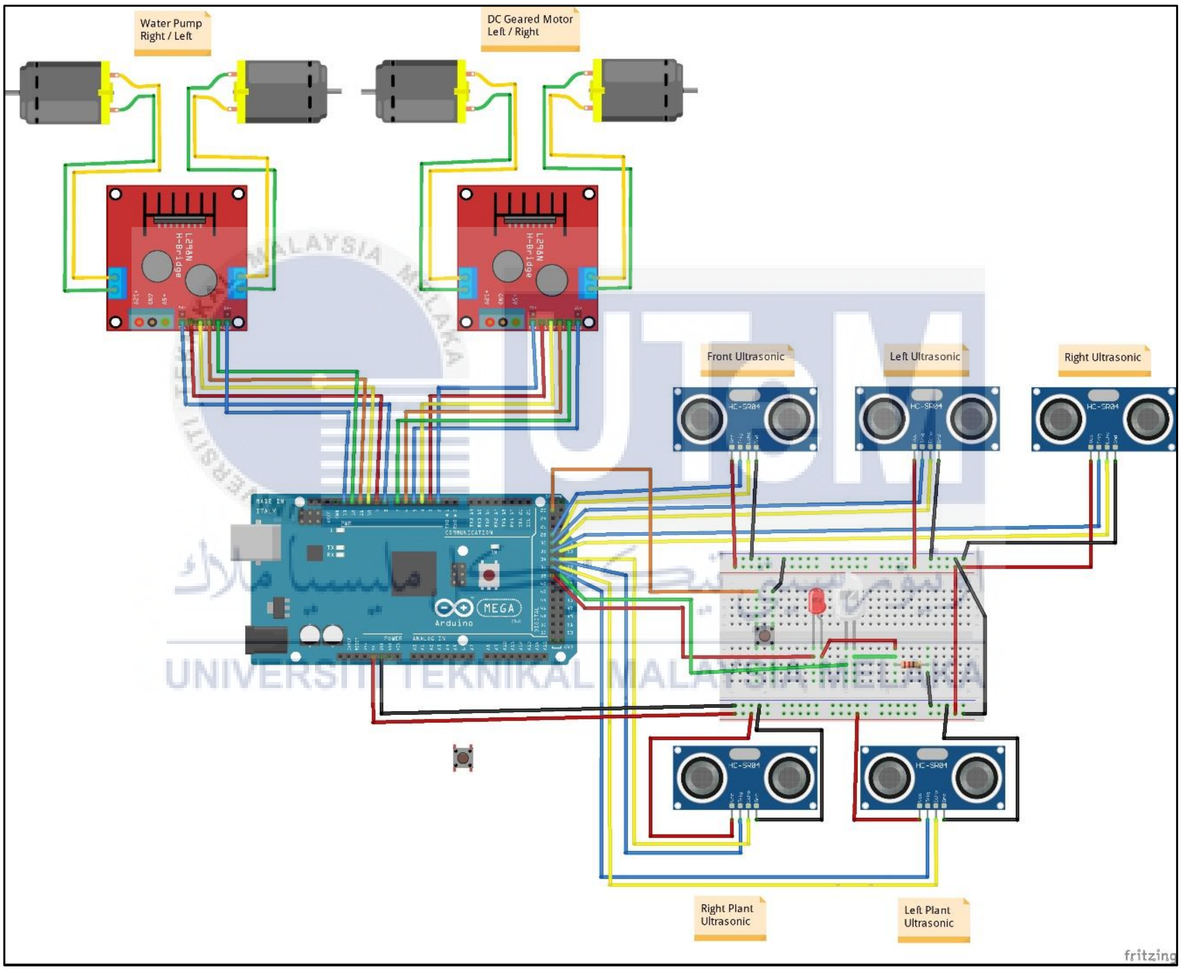

Figure 3.4 Circuit Diagram of Robot Prototype

3.5 List of Material

Table 3.1 Project Cost

No	Material	Cost (RM)	Quantity	Total Cost (RM)
1	Storage Box (Robot Casing)	25.00	1	25.00
2	4x4 Wheels 130mm	20.00	4	80.00
3	Hexagon Coupling for Wheels	6.50	4	26.00
4	Shaft Rod (8mm x 200mm)	8.00	1	8.00
5	Linear Motion Bearing Block 8mm	6.50	2	13.00
6	Shaft Clamp Collar	3.00	2	6.00
7	PVC Pipe	3.00	1	3.00
8	Tank (1.5litre)	1.00	1	1.00
9	8mm Plastic Hose	4.00	1	4.00
10	Elbow Hose Connector	1.50	2	3.00
11	Mist Sprinkler 0.3mm	3.60	2	7.20
12	Arduino Mega 2560 R3	50.90	1	50.90
13	Ultrasonic Sensor	3.20	5	16.00
14	Motor Driver L298N	5.40	2	10.80
15	12V DC Motor Worm Gear with Bracket	42.00	2	84.00
16	12V DC Motor Water Pump	11.90	2	23.80
17	12V Battery	69.00	1	69.00
18	5V Battery with Holder	4.50	2	8.00
			Grand Total	**438.70**

3.6 Equipment Section

3.6.1 Arduino Mega

The Arduino Mega 2560 R3 is a microcontroller board based on the ATmega2560 chip that has significantly more capabilities than standard Arduino boards. It has 54 digital I/O pins, 16 analogue I/O pins, and a larger flash memory, making it suitable for complex projects requiring a greater number of input and output connections. Additional features of the Mega include multiple UARTs (Universal Asynchronous Receiver-Transmitter) and more PWM (Pulse Width Modulation) outputs, which provide greater flexibility for communication and controlling various devices.

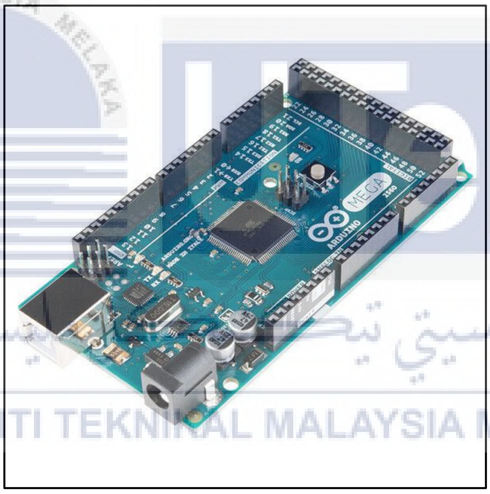

Figure 3.5 Arduino Mega 2560 R3

3.6.2 Water Pump

A pneumatic diaphragm water pump is a type of pump that uses a diaphragm to move water or other fluids and is powered by compressed air or gas. This water pump has been chosen for their ability to handle corrosive, abrasive, or viscous liquids, as well as their suitability for applications in harsh environments. The pneumatic motor supplies the necessary energy to drive the diaphragm, allowing for efficient and dependable pumping operations.

Figure 3.6 R385 DC 12V Pneumatic Diaphragm Water Pump

Table 3.2 Water Pump Specifications

Pump size	69 x 40 x 35 (L x W x H) mm
Recommended tube diameter	6mm
Operating voltage	6 – 12V DC
Operating current	0.5 – 0.7 A
Flow rate	1.5 – 2 L/min
Lifecycle	2500 hours
Capabilities	Pumping heated liquid up to 80 ºC
	Pull water through tube up to 2m
	Pump water vertically up to 2.5m

3.6.3 DC Motor

A worm geared motor is a compact motor that operates at low speeds by using a worm gear mechanism. It transmits power through a worm and worm wheel and has self-locking capabilities. The high-speed rotation of the motor is converted to a slower rotational speed with increased torque at the output shaft. Worm geared motors is used in robot movement because of its durability and offers high torque to carry heavy load. It is powered with 12V power supply.

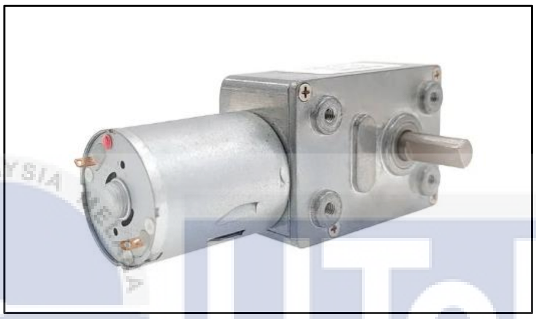

Figure 3.7 DC 12V Worm Geared Motor 4632 (JGY-370)

Table 3.3 Worm Geared Motor Specifications

Rated voltage	12 V DC
Weight	150 g
No load speed	40 RPM
No load current (mA)	60 mA
Loaded torque (kgf.cm)	4.5 kgf.cm
Loaded speed	30 RPM
Loaded current (A)	0.5 A
Stall torque (kg.cm)	9.0 kg.cm
Stall current (A)	1.3 A

3.6.4 L298N Motor Driver

The L298N is a renowned motor driver IC (integrated circuit) that is used to control and drive DC or stepper motors. Its dual H-bridge configuration, voltage/current handling capabilities, and compatibility with microcontrollers make it a wise decision to employ it for this project.

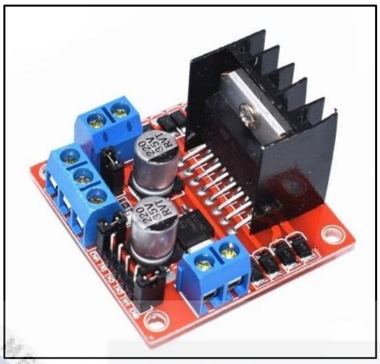

Figure 3.8 L298N Motor Driver

Table 3.4 L298N Motor Driver Specifications

Driver terminal supply	5 – 35 V
Driver peak current	2 A
Control signal input voltage	0 – 5 V
Dimension	5.5 x 4.4 x 2.7 cm
Weight	28 g

3.6.5 Ultrasonic Sensor

The HC-SR04 ultrasonic distance sensor is employed for precise and straightforward distance measurement using ultrasonic sound waves. With a non-contact measurement range spanning from 2cm to 400cm and an impressive accuracy of 0.3cm, the HC-SR04 is known for its reliability. The sensor module is equipped with an ultrasonic transceiver, functioning by initiating the measurement process through a pulse sent to its Trigger pin at a frequency of at least 10kHz. The selection of this sensor is based on its reputation for reliability and versatility, making it a suitable choice for various applications that demand precision in distance measurement.

Figure 3.9 Ultrasonic sensor HC-SR04

Table 3.5 HC-SR04 Specifications

Flexible input voltage	3 – 5.5 V
Operating current	5.3 mA
Sensing tolerance	0.1cm ±
Capabilities	Effective range of 2cm to 450cm (5 V)
	Effective range of 2cm to 400cm (3.3 V)
Effective Angle	< 15 degree
Operating temperature	-20 to 80 ºC

3.7 Programming

For the project development, this prototype requires abundance of coding and algorithm which need to be synced all together to develop a working autonomous robot. The coding has been classified for its action in this subtopic as to arrange the prototype development being carried out systematically.

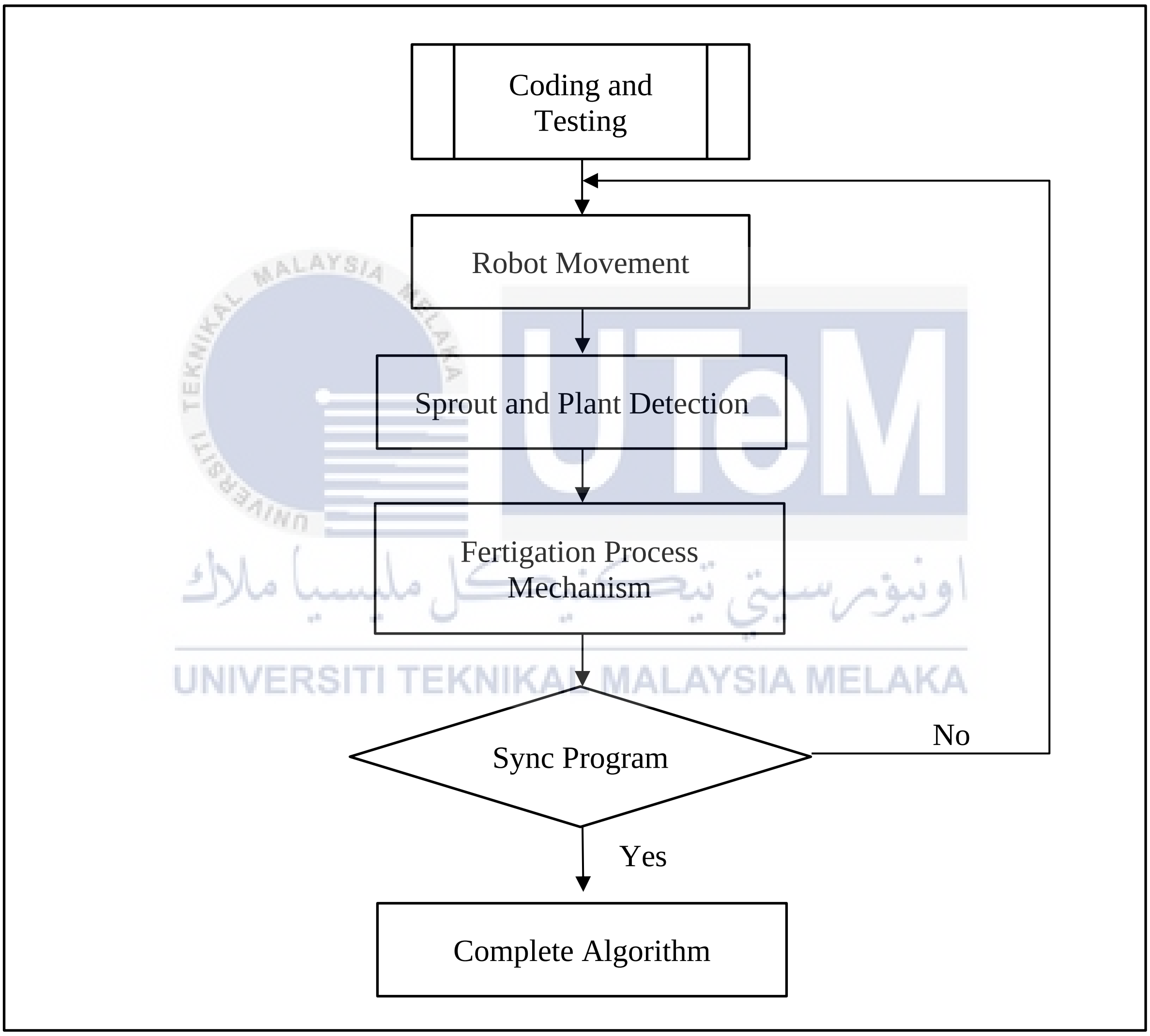

Figure 3.10 Task Flowchart

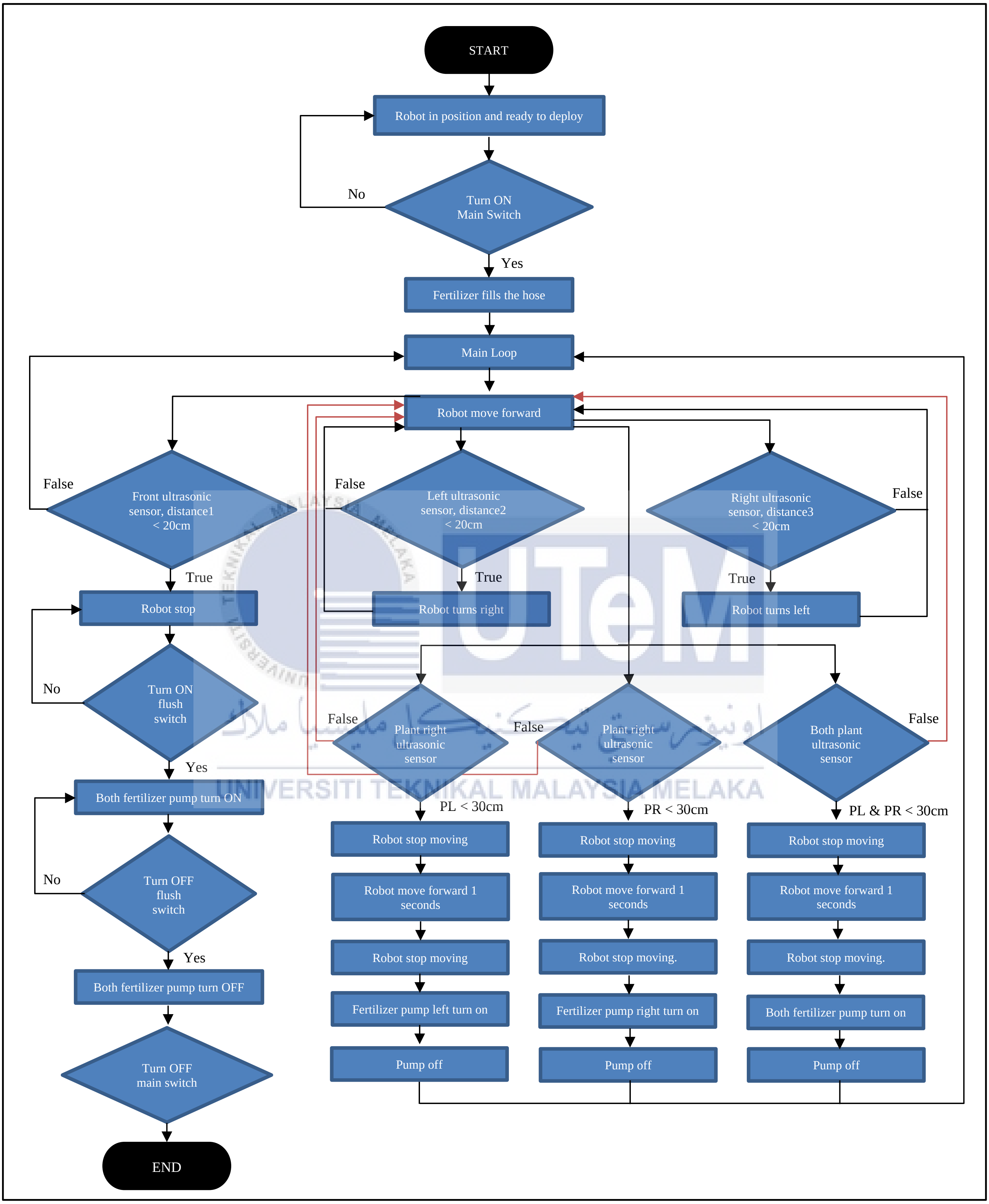

Figure 3.11 Robot Programming Flowchart

Figure 3.5 and 3.6 shows the programming mechanism that will be develop and integrated into the robot system later. By using Arduino as microcontroller, Arduino IDE will be used in order to create and modify the program, so the robot can carried out the task successfully. The Arduino Integrated Development Environment (IDE) stands as a robust and user-friendly software tool designed for the composition, compilation, and uploading of code onto Arduino microcontrollers. This platform significantly streamlines the process of programming Arduino boards, providing a user-friendly interface that facilitates the development of interactive and imaginative electronic projects. By offering a seamless environment for coding, the Arduino IDE contributes to the accessibility and versatility of Arduino-based projects, empowering both beginners and experienced users to bring their electronic creations to life.

Figure 3.12 Arduino IDE

3.8 Parameter Effectiveness

Parameters need to be set to tailor a system or process to specific requirements or conditions. It ensures that robots can carry out their tasks with consistency and effectiveness, which correlates with their successful deployment in a variety of circumstances. The parameters that are important in this section are,,

1. Ultrasonic sensor detection.
2. Obstacle avoidance.
3. Pump energized delay time.
4. Pump starting time for each process.

3.8.1 Ultrasonic sensor detection

The primary objective is to validate the reliability of the sensor's output by comparing it with actual measurements obtained using a measuring tape. This validation process involves employing a formula to calculate the percentage accuracy, a crucial step in gauging the performance of the ultrasonic sensor in real-world scenarios. The ultrasonic sensor will measure the distance initially, then take an actual measurement, and finally, compare the two to determine accuracy. The formula used are,

$$Accuracy\ (\%) = \frac{|Measured\ Distance - Actual\ Distance|}{Measured\ Distance} \times 100$$

3.8.2 Obstacle avoidance

Moving beyond the verification phase, the focus shifts towards leveraging the measured parameter to optimize the robot's movement and navigation within the agricultural environment. The importance of this optimization lies in the prevention of collisions and potential damage to plants and crops. By establishing the best distance parameter for the robot's movement, the prototype can navigate through the cultivated area seamlessly, avoiding obstacles and ensuring the safety of the surrounding plant.

3.8.3 Pump Starting Time

This phase plays a pivotal role in preparing the robot for the precise dispensing of fertilizer to cultivate crops. It is imperative because, in order to effectively spray the plant, the hose must be filled with the liquid fluid. This section specifically concentrates on optimizing the duration of this process, ensuring that the pump is efficiently primed and ready for the full loop cycle of the programmed operation.

3.8.4 Pump Energized Delay Time

The aim for this part was to distinguish variable for pump motor to energize within the time frame so the sufficient amount of fertilizer compound was distributed evenly to the plants crop. Suitable amount of fertilizer are 3 pounds per 100 square feet according to Mike Hultquist in A Guide to Growing Chili Peppers [56]. Assuming each plant in testing area are $20cm^2$, so the required amount of fertilizer is approximately 66 g after conversion which means 66 mL of fertilizer for each plant. Due to constraints, this prototype able to dispense 10g of fertilizer each pump.

To determine the correct volume of fertilizer, the parameter of pump energized delay time have to organized. The method suitable for this parameter is conducting experiment on the volume of fluid out within specified time for water pump to obtained fluid flow rate of each pump. The formula used are,

$$Flow\ rate\ (mL/s) = \frac{Volume\ before - Volume\ After}{Activation\ Time}$$

$$Achieved\ Delay\ Time\ for\ Pump = Desired\ Fertilizer\ Weight\ \times Pump\ Flow\ Rate$$

3.9 Robot Performance

The robot will undergo real-time testing to assess its performance. During this test, the robot will be subjected to various layouts and paths to assess its performance. The goal is to observe how well the robot navigates and operates under different conditions. Various aspects will be observed during this experiment, including,

- plant detection,
- path mapping, and
- spray accuracy.

In each provided layout, the robot will traverse through two distinct paths. The first path involves the robot navigating from one end of the layout, while the second path entails the robot moving from the opposite end. Throughout these movements, the distances between elements within the layout will be meticulously recorded. This data collection aims to gauge the effectiveness of the robot's performance.

The layouts are strategically designed with the inclusion of plants and obstacles to challenge the robot's capabilities. By encountering these elements, the robot is expected to adeptly discern obstacles from plants, showcasing its ability to navigate and respond intelligently in a dynamic environment. The recorded distances will serve as key metrics in evaluating the robot's efficiency and effectiveness in different scenarios, contributing valuable insights into its overall performance.

3.9.1 Layout 1

Figure 3.13 Layout 1

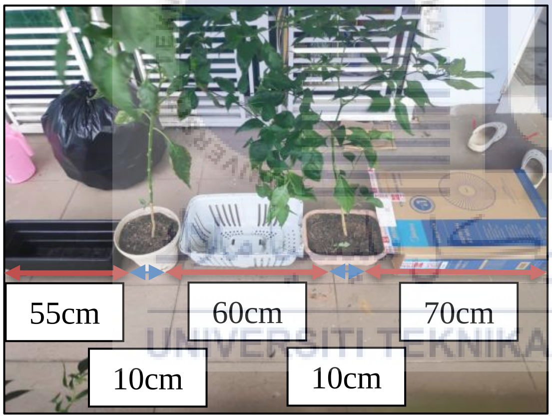

Figure 3.14 Right side object distance

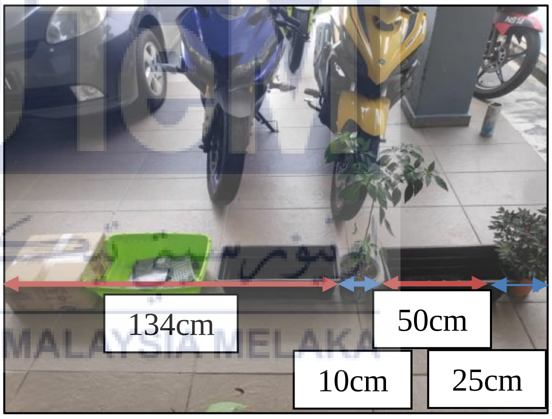

Figure 3.15 Left side object distance

3.9.2 Layout 2

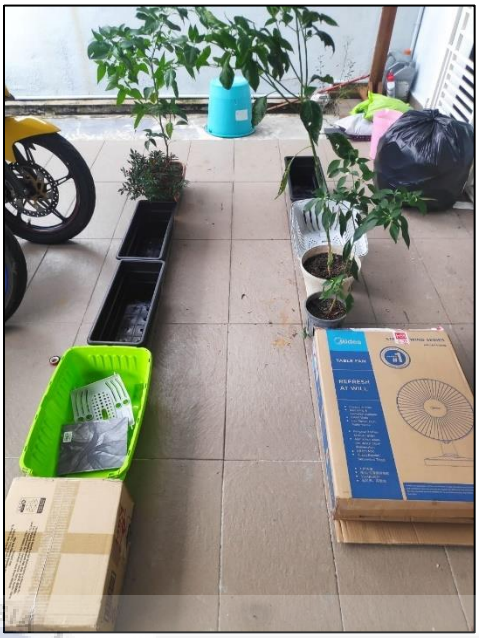

Figure 3.16 Layout 2

Figure 3.17 Right side object distance

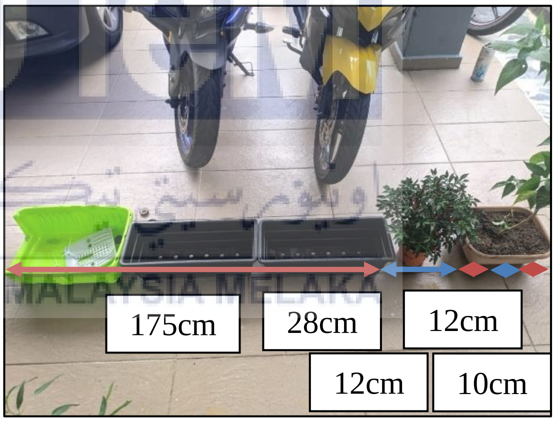

Figure 3.18 Left side object distance

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

At this chapter, the topic will be focused on the premilinary results obtained from the product development and the expected result of the product on its functionality. This chapter will consist of analysis of the robot premilinary design and the robot programming to meet the expected result of robot operation. For the product functioniality, this section will summarize on the robot operation with each program according to the section.

4.2 Final Design

Figure 4.1 Final Prototoype

4.3 Program Algorithm Analysis

This section analyzes the efficiency of the meticulously selected parameters for the robot prototype critically, acknowledging their crucial function as a project-wide success factor. Through a comprehensive examination of the impacts of these variables and performance results, the aim is to clarify the effects on the robot functionality, adaptability to dynamic environments, energy efficiency, safety protocols, and overall task-specific effectiveness.

4.3.1 Ultrasonic Sensor Detection

As an automated robot, this prototype heavily relies on the ultrasonic sensor as a primary input element. In this crucial phase, the reliability of the ultrasonic sensor undergoes meticulous testing to ensure the precision and clear success of the robot in its designated tasks. This evaluation provides an innovative robotic system with outstanding efficiency and dependability.

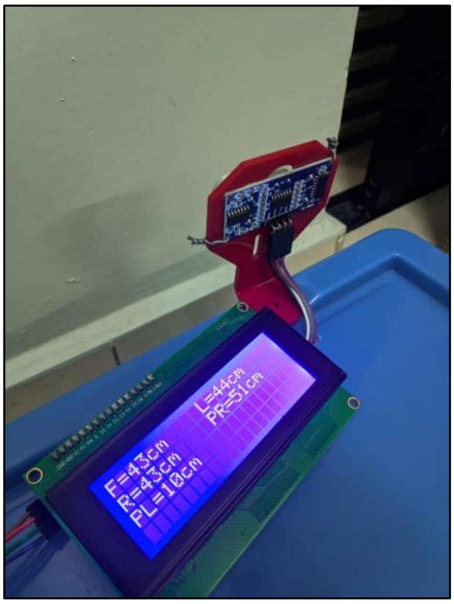

Figure 4.2 Ultrasonic sensor detection

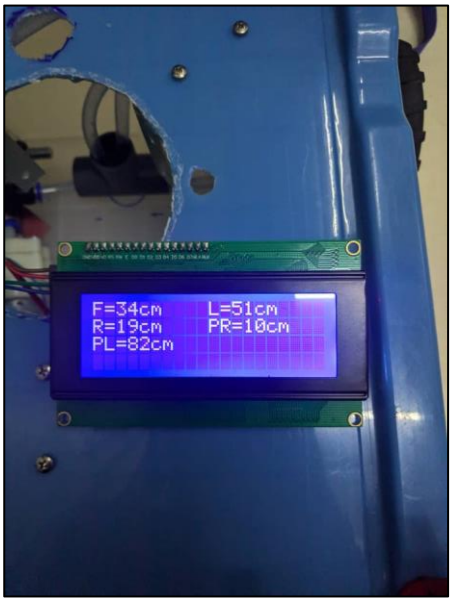

Figure 4.3 Display measurement from ultrasonic sensor

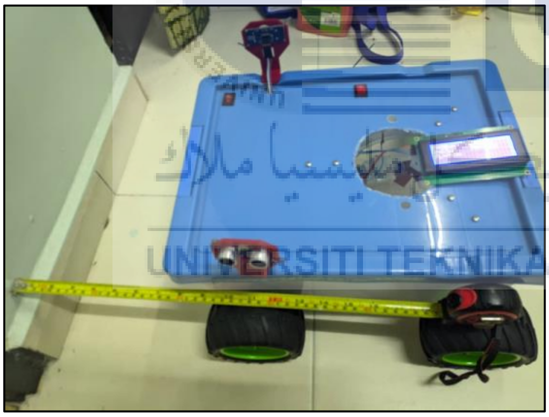

Figure 4.4 Actual measurement procedure

Figure 4.5 Measurement taken

Table 4.1 Ultrasonic Sensor Efficiency

Ultrasonic Sensor	Position	Distance Recorded (cm)	Actual Distance (cm) 1st	2nd	3rd	Average (cm)	Accuracy (%)
1	Forward	10cm	11.4	11.2	11.0	11.2	88.0
		20cm	21.4	21.4	21.3	21.4	93.2
		30cm	31.6	31.1	31.1	31.3	95.8
		40cm	43.4	42.6	42.6	42.9	92.8
		50cm	54.2	54.4	54.0	54.2	91.6
2	Left	10cm	9.8	10.4	10.3	10.2	98.3
		20cm	19.8	20.2	20.1	20.0	99.8
		30cm	31.0	31.1	31.0	31.0	96.6
		40cm	41.2	41.3	41.3	41.3	96.8
		50cm	53.5	53.0	53.3	53.3	93.5
3	Right	10cm	10.8	10.8	10.7	10.8	92.3
		20cm	20.3	20.2	20.3	20.3	98.7
		30cm	30.6	30.4	30.3	30.4	98.6
		40cm	41.4	41.5	41.5	41.5	96.3
		50cm	52.2	52.4	52	52.2	95.6
4	Upper Right	10cm	10.1	10.0	10.0	10.0	99.7
		20cm	20.8	20.6	20.7	20.7	96.5
		30cm	31.1	31	31	31.0	96.6
		40cm	41.4	41.3	41.3	41.3	96.7
		50cm	53.1	53.1	53	53.1	93.9
5	Upper Left	10cm	10.0	10.1	10.2	10.1	99.0
		20cm	21.1	21.1	21.0	21.1	94.7
		30cm	31.5	31.5	31.5	31.5	95.0
		40cm	41.7	41.7	41.7	41.7	95.8
		50cm	52.1	52.0	52.3	52.1	95.7

4.3.2 Obstacle Avoidance

This section is to acknowledge the designation parameter for the distance measurement of the ultrasonic sensor to avoid colliding with the obstacle during robot movement. This is to minimize errors and significantly enhance the robot's adaptability and reliability within its environment. The testing involved three iterations for each distance parameter, and the observation taken by the average performance of the robot movements.

Table 4.2 Obstacle Avoidance Parameter

Ultrasonic sensor parameter (cm)			Right/Left side distance with robot (cm)	Front side distance with robot (cm)	Remarks
Front	Right	Left			
10	10	10	6	4	Robots collide with obstacle.
15	15	15	9	8	Robots slightly collide with obstacle.
20	20	20	11	11	Robot did not collide with obstacle.
25	25	25	16	18	Robot did not collide with obstacle. Slightly stuck in the center.
30	30	30	25	25	Robot did not collide with obstacle. Occasionally stuck in the center.

Based on the obtained results, the optimal configuration for the ultrasonic distance robot parameters has been determined to be set at 20cm. This specific configuration has been identified as crucial for ensuring the smooth and effective functioning of the robot.

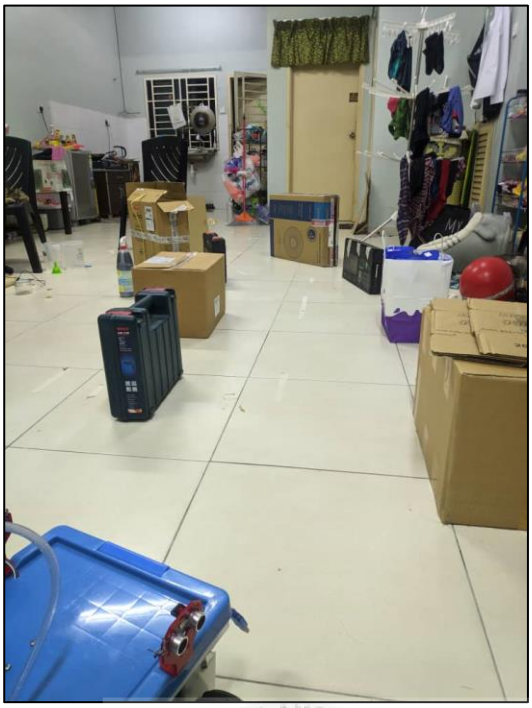

Figure 4.6 Robot movement through obstacle

Figure 4.7 Robot turning testing

Figure 4.8 Side measurement with obstacle

Figure 4.9 Robot stops before collides

4.3.3 Pump Starting Time

In this analysis, the approach involves adjusting the delay time for the initiation of each water pump to allow the hose to fill with the designated fluid, which, in this case, is plain water. The purpose of this experiment is to determine the duration required for the fluid to fully occupy the hose before the system becomes operational in the field.

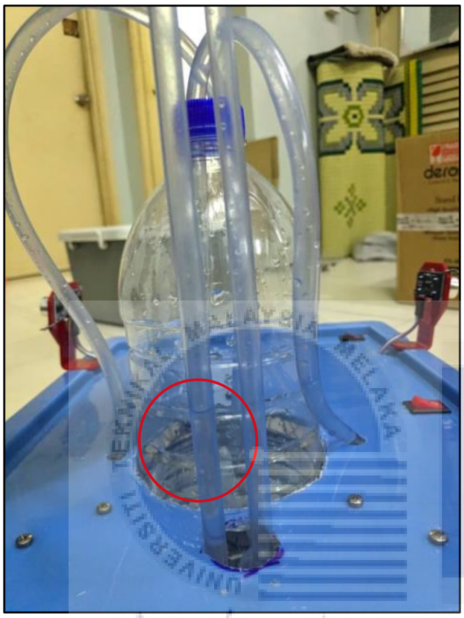

Figure 4.10 Fluid enters slightly inside PR hose

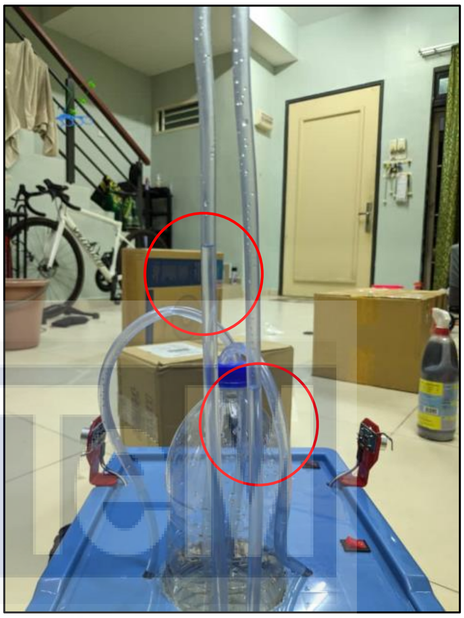

Figure 4.11 Fluid enters half inside both hose

Figure 4.12 Fluid fills PR hose completely

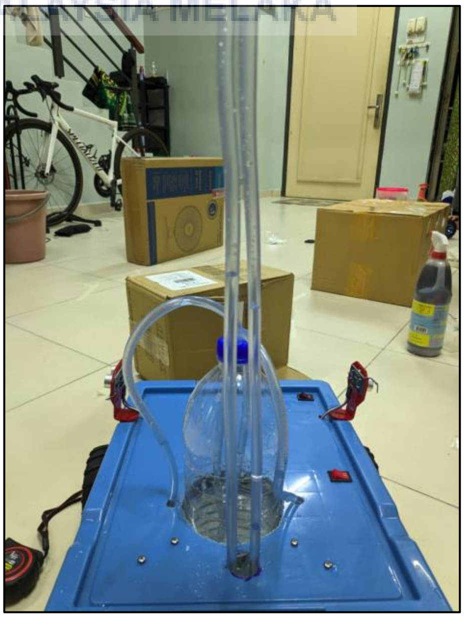

Figure 4.13 Both hose fills completely

The figure above illustrates the methodology employed in conducting the analysis. Upon observation, it is evident that PR (Pump Right) exhibits slightly superior performance compared to PL (Pump Left). The figure also indicates that the hose for PR is positioned on the left, whereas the hose for PL is on the right. This arrangement is specific to the configuration of the line piping in the robot under consideration and is maintained throughout this analysis. The hose positions are fixed during the insertion into the PVC piping line within the completed robot.

Table 4.3 Pump Starting Time Parameter

Water pump	Delay time (s)	Fluid in hose (cm)	Remarks
PR (Right position)	1	0	No water in the hose.
	2	0	No water in the hose.
	3	8	Slightly fills the hose.
	4	29	Fills half the hose's length.
	5	34	Fills half the hose's length.
	6	49	Nearly fills the entire hose.
	6.5	59	Completely fills the hose.
PL (Left position)	1	0	No water in the hose.
	2	0	No water in the hose.
	3	0	No water in the hose.
	4	12	Slightly fills the hose.
	5	29	Fills half the hose's length
	6	35	Fills half the hose's length
	6.5	45	Nearly fills the entire hose
	7	57	Completely fills the hose

Table above shows the results with variation time delay for each of the water pump. Based on this analysis, the optimal timing for the right water pump is determined to be 6.5 seconds, whereas for the left pump, the most effective timing is 7 seconds.

4.3.4 Pump Energized Delay Time

Table 4.4 Pump Delay Time Parameter

Water pump	Pump Activation Time	Volume Before	Volume After	Total Volume Out	Flow rate (mL/s)
PR (Right position)	300 seconds	300mL	110mL	190mL	0.63
PL (Left position)	300 seconds	300mL	200ml	100mL	0.33

Due to constraints, this prototype has the capacity to dispense 10g of fertilizer. Utilizing the known flow rates of both motors, the delay time for each motor can be precisely determined through calculations.

PR activation $= 10 \div 0.63$

$= 15.78$ seconds ≈ 16 seconds

PL activation $= 10 \div 0.33$

`

$= 30.30$ seconds ≈ 31seconds

By using the calculation, the parameter has been configured to satisfy the requirement of 10g fertilizers for each plant.

4.4 Real Time Performance

Experiments have been conducted to verify the outcome of this proposed prototype. Several main focuses have already been set which will determine whether this project is successful or not. The objectives to be found are:

- Path Mapping
- Plant Detection

4.5 Path Mapping

Table 4.5 Path Mapping Analysis

Path	Path 1			Path 2			Path 3			Path 4		
Number of test	1	2	3	1	2	3	1	2	3	1	2	3
Crash Analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The table above shows the results of path mapping. The robot did not crash into the obstacle or plant during the experiment. This proves that robots are successful in path mapping. The figures below show the experiment that have been conduct.

Figure 4.14 Robot path mapping

4.6 Plant Detection

This analysis covers the performance of the robot in plant detection to ensure the robot recognizes the plants. For conducting this analysis, the robot has been put in different path to verify the robot performance.

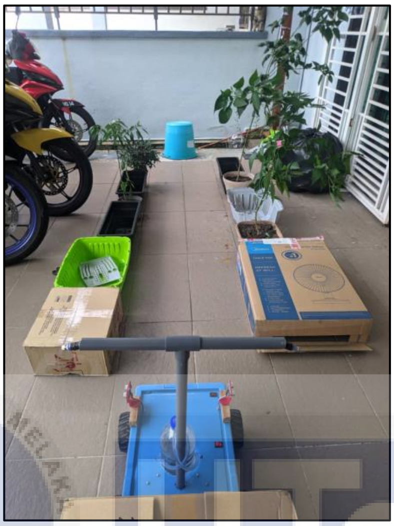

Figure 4.15 Robot testing in path 1

Figure 4.16 Robot sprays to right side

Figure 4.17 Robot sprays to left side

4.6.1 Path 1

Table 4.6 Path 1 Plant Detection

Plant	Number of test		
	1	2	3
1	✗	✗	✗
2	✓	✓	✓
3	✓	✗	✓
4	✓✓	✓✓	✓✓

4.6.2 Path 2

Table 4.7 Path 2 Plant Detection

Plant	Iterations		
	1	2	3
1	✓	✓	✓
2	✓	✓	✓
3	✓	✓	✓
4	✓	✓	✓

4.6.3 Path 3

Table 4.8 Path 3 Plant Detection

Plant	Iterations		
	1	2	3
1	✓	✓	✓
2	✗	✗	✓
3	✓✓	✓✓	✓✓
4	✓	✗	✓

4.6.4 Path 4

Table 4.9 Path 4 Plant Detection

Plant	Iterations		
	1	2	3
1	✓	✗	✓
2	✓	✓	✓
3	✓✓	✗	✓
4	✓	✓	✓

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the development of an autonomous agriculture robot for fertigation using Arduino has been a multifaceted endeavor aimed at achieving specific objectives. The primary goal was to successfully create a prototype of an agriculture robot dedicated to fertigation, employing the Arduino platform. This involved integrating essential components and technologies to facilitate autonomous navigation and control. A crucial aspect of the project focused on designing an algorithm for path mapping to enable the autonomous robot to navigate through agricultural environments efficiently. The algorithm aimed to optimize the robot's movement, ensuring it follows predefined paths for effective fertigation. The final objective centered on assessing the performance of the autonomous robot prototype within the fertigation system. This involved real-time testing scenarios, including plant detection, path mapping execution, and evaluating the accuracy of fertigation processes.

Through systematic development and testing, the project has yielded significant outcomes. The successful creation of the prototype robot demonstrates the feasibility of using Arduino for autonomous agricultural applications. The algorithm designed for path mapping has enhanced the robot's ability to navigate complex layouts, contributing to its overall efficiency. The performance analysis has provided valuable insights into the robot's capabilities, highlighting strengths and areas for potential improvement.

In conclusion, the fabrication of fertigation autonomous robots holds great promise for revolutionizing the agricultural industry. These robots offer precise, efficient, and scalable fertigation capabilities while promoting sustainable farming practices. With ongoing advancements in robotics and sensor technologies, further refinements and enhancements in autonomous fertigation systems are expected, contributing to increased crop yields, reduced resource usage, and a more sustainable future for agriculture. By developing an autonomous robot specifically designed for fertigation tasks, several benefits can be realized.

5.2 Future Works

Based on the project development, there are several task that have to be done in future works so all the objectives of this research can be achieved. Firstly, utilization of more accurate sensor will be useful such as laser sensor. The algorithm for the whole robot programming also need to be revised in order to extend its functionality and capabilities. Then, progressive and details analysis can be done to anticipate the effectiveness of the proposed method compared with the existing method. The results of the robot behaviour and mechanisms also can be analyzed whether its reach the full capabilities and potential. Moreover, improvements need to be carefully implemented so the proposed method can be fabricated beyond the desirable outcomes.

5.3 Potential Commercialization

The autonomous robot, equipped with fertigation capabilities and intelligent navigation, addresses the growing demand for precision agriculture solutions. Commercializing the technology can offer farmers a tool to enhance the efficiency of fertilization processes, optimize resource usage, and increase crop yields. If the project demonstrates cost-effectiveness in comparison to traditional fertigation methods, it becomes an attractive proposition for commercial use. Farmers and agricultural enterprises are continually seeking technologies that improve efficiency while minimizing operational costs. Ensuring that the autonomous robot complies with agricultural regulations and safety standards is crucial for commercialization. Providing a solution that aligns with industry norms instills confidence in potential users. Highlighting the environmental benefits of the autonomous robot, such as reduced resource usage and optimized fertilization, can resonate with consumers who prioritize sustainable and eco-friendly farming practices.

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APPENDICES

Appendix A Arduino Programming

```
//Left motor
const int enableLeftMotor = 2;
const int leftMotorPin1 = 3;
const int leftMotorPin2 = 4;

//Right motor
const int enableRightMotor = 5;
const int rightMotorPin1 = 7;
const int rightMotorPin2 = 6;

//Left motor 2
const int enableLeftMotor2 = 8;
const int leftMotor2Pin1 = 9;
const int leftMotor2Pin2 = 10;

//Right motor 2
const int enableRightMotor2 = 13;
const int rightMotor2Pin1 = 12;
const int rightMotor2Pin2 = 11;

//waterpump right
const int inPumpR = 40;
const int outPumpR = 41;

//waterpump left
const int inPumpL = 42;
const int outPumpL = 43;

const int jarakpokok = 28;
const int jarakobstakle = 20;

//Ultrasonic Front
#define trigPinF 28 //attach pin D3 Arduino to pin Trig of HC-SR04
#define echoPinF 29 // attach pin D2 Arduino to pin Echo of HC-SR04
long duration1, distance1;; // variable for the duration of sound wave travel
 // variable for the distance measurement

//Ultrasonic Left
#define trigPinL 30//attach pin D3 Arduino to pin Trig of HC-SR04
#define echoPinL 31// attach pin D2 Arduino to pin Echo of HC-SR04
long duration2, distance2; // variable for the duration of sound wave travel
 // variable for the distance measurement

//Ultrasonic Right
#define trigPinR 32 //attach pin D3 Arduino to pin Trig of HC-SR04
#define echoPinR 33 // attach pin D2 Arduino to pin Echo of HC-SR04
long duration3, distance3; // variable for the duration of sound wave travel
 // variable for the distance measurement

//Ultrasonic Pump Right
#define trigPumpR 34 //attach pin D3 Arduino to pin Trig of HC-SR04
#define echoPumpR 35 // attach pin D2 Arduino to pin Echo of HC-SR04
long durationPR, distancePR;;

//Ultrasonic Pump Left
#define trigPumpL 36 //attach pin D3 Arduino to pin Trig of HC-SR04
```

```
#define echoPumpL 37 // attach pin D2 Arduino to pin Echo of HC-SR04
long durationPL, distancePL;;

#define LED_merah 38
#define LED_ijo 39

#define flushbutton 22

void setup()
{
  pinMode(enableRightMotor, OUTPUT);
  pinMode(rightMotorPin1, OUTPUT);
  pinMode(rightMotorPin2, OUTPUT);

  pinMode(enableLeftMotor, OUTPUT);
  pinMode(leftMotorPin1, OUTPUT);
  pinMode(leftMotorPin2, OUTPUT);

  pinMode(enableRightMotor2, OUTPUT);
  pinMode(rightMotor2Pin1, OUTPUT);
  pinMode(rightMotor2Pin2, OUTPUT);

  pinMode(enableLeftMotor2, OUTPUT);
  pinMode(leftMotor2Pin1, OUTPUT);
  pinMode(leftMotor2Pin2, OUTPUT);

  pinMode(inPumpR, OUTPUT);
  pinMode(outPumpR, OUTPUT);

  pinMode(inPumpL, OUTPUT);
  pinMode(outPumpL, OUTPUT);

  //ultrasonicFront
  pinMode(trigPinF, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPinF, INPUT); // Sets the echoPin as an INPUT
   //ultrasonicLeft
  pinMode(trigPinL, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPinL, INPUT); // Sets the echoPin as an INPUT
 //ultrasonicRight
  pinMode(trigPinR, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPinR, INPUT); // Sets the echoPin as an INPUT

  pinMode(trigPumpR, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPumpR, INPUT);

  pinMode(trigPumpL, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPumpL, INPUT);

  pinMode(LED_merah, OUTPUT);
  pinMode(LED_ijo, OUTPUT);

  pinMode(flushbutton, INPUT_PULLUP);

  digitalWrite(LED_merah, LOW);
  digitalWrite(LED_ijo, LOW);
```

```
  Serial.begin(9600);
  delay(1000);

//  pumpPR();
//  pumpPL();
//  delay(6500);
//  pumpstop();
//  pumpPL();
//  delay(500);
//  pumpstop();
  delay(1000);

}


void loop()
{
  ultrasonicsenseF();
  ultrasonicsenseL();
  ultrasonicsenseR();
  ultraPumpR();
  ultraPumpL();
  ObstacleAvoidance();

  if (distance1<20){
    stopOperation();
    return;
  }

   if (distancePR < jarakpokok && distancePL < jarakpokok) {
      performTaskAB();
      pumpstop();
      return;
    }

  if (distancePR < jarakpokok){
      ultraPumpL();
      performTaskA();
      pumpstop();
      return;
   }
   if (distancePL < jarakpokok){
      ultraPumpR();
      performTaskB();
      pumpstop();
      return;
   }

}

void performTaskA(){
  motorstop();
  digitalWrite(LED_merah,HIGH);
  delay(1000);
  motormove();
  if(distancePL < jarakpokok){
```

```
      performTaskAB();
      return;
  }
  delay(1000);
  motorstop();
  delay(500);
  pumpPR();
  delay(5000);
  pumpstop();
  delay(500);
  digitalWrite(LED_merah,LOW);
}

void performTaskB(){
  motorstop();
  digitalWrite(LED_ijo,HIGH);
  delay(1000);
  motormove();
   if(distancePR < jarakpokok){
      performTaskAB();
      return;
  }
  delay(1000);
  motorstop();
  delay(500);
  pumpPL();
  delay(5000);
  pumpstop();
  delay(500);
  digitalWrite(LED_ijo,LOW);
}

void performTaskAB(){
  digitalWrite(LED_ijo,HIGH);
  digitalWrite(LED_merah,HIGH);
  delay(500);
  motormove();
  delay(1000);
  motorstop();
  delay(500);
  pumpPR();
  pumpPL();
  delay(5000);
  pumpstop();
  pumpPL();
  delay(5000);
  pumpstop();
  delay(500);
  digitalWrite(LED_merah,LOW);
  digitalWrite(LED_ijo, LOW);
}



void pumpPR(){
  digitalWrite(inPumpR,HIGH);
```

```
  digitalWrite(outPumpR,LOW);
}

void pumpPL(){
  digitalWrite(inPumpL,HIGH);
  digitalWrite(outPumpL,LOW) ;
}

void pumpPRL(){
  digitalWrite(inPumpR,HIGH);
  digitalWrite(outPumpR,LOW);
  digitalWrite(inPumpL,HIGH);
  digitalWrite(outPumpL,LOW) ;
}

void pumpstop(){
  digitalWrite(inPumpR,LOW);
  digitalWrite(outPumpR,LOW);
  digitalWrite(inPumpL,LOW);
  digitalWrite(outPumpL,LOW);
}

void motormove(){
    analogWrite(enableLeftMotor,255);
    digitalWrite(leftMotorPin1,LOW);
    digitalWrite(leftMotorPin2,HIGH);
    analogWrite(enableRightMotor,255);
    digitalWrite(rightMotorPin1,LOW);
    digitalWrite(rightMotorPin2,HIGH);
    analogWrite(enableLeftMotor2,154);
    digitalWrite(leftMotor2Pin1,LOW);
    digitalWrite(leftMotor2Pin2,HIGH) ;
    analogWrite(enableRightMotor2,154);
    digitalWrite(rightMotor2Pin1,LOW);
    digitalWrite(rightMotor2Pin2,HIGH) ;
}

void motorstop(){
    analogWrite(enableLeftMotor,0);
    digitalWrite(leftMotorPin1,LOW);
    digitalWrite(leftMotorPin2,LOW) ;
    analogWrite(enableRightMotor,0);
    digitalWrite(rightMotorPin1,LOW);
    digitalWrite(rightMotorPin2,LOW) ;
    analogWrite(enableLeftMotor2,0);
    digitalWrite(leftMotor2Pin1,LOW);
    digitalWrite(leftMotor2Pin2,LOW) ;
    analogWrite(enableRightMotor2,0);
    digitalWrite(rightMotor2Pin1,LOW);
    digitalWrite(rightMotor2Pin2,LOW) ;
}

void ObstacleAvoidance(){
  if (distance2<jarakobstakle){
    analogWrite(enableLeftMotor,255);
    digitalWrite(leftMotorPin1,HIGH);
```

```
    digitalWrite(leftMotorPin2,LOW) ;
    analogWrite(enableRightMotor,255);
    digitalWrite(rightMotorPin1,LOW);
    digitalWrite(rightMotorPin2,HIGH);

    analogWrite(enableLeftMotor2,200);
    digitalWrite(leftMotor2Pin1,HIGH);
    digitalWrite(leftMotor2Pin2,LOW) ;
    analogWrite(enableRightMotor2,200);
    digitalWrite(rightMotor2Pin1,LOW);
    digitalWrite(rightMotor2Pin2,HIGH) ;

    delay(500);
  }
  else if (distance3<jarakobstakle){
    analogWrite(enableLeftMotor,255);
    digitalWrite(leftMotorPin1,LOW);
    digitalWrite(leftMotorPin2,HIGH) ;
    analogWrite(enableRightMotor,255);
    digitalWrite(rightMotorPin1,HIGH);
    digitalWrite(rightMotorPin2,LOW) ;

    analogWrite(enableLeftMotor,200);
    digitalWrite(leftMotor2Pin1,LOW);
    digitalWrite(leftMotor2Pin2,HIGH) ;
    analogWrite(enableRightMotor2,200);
    digitalWrite(rightMotor2Pin1,HIGH);
    digitalWrite(rightMotor2Pin2,LOW) ;

    delay(500);
  }
  else{
      motormove();
  }
}

void ultrasonicsenseF() {
  digitalWrite(trigPinF, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPinF, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinF, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration1 = pulseIn(echoPinF, HIGH);
  // Calculating the distance
  distance1 =(duration1/2) / 29.1; // Speed of sound wave divided by 2 (go and back)
}

void ultrasonicsenseL() {
  digitalWrite(trigPinL, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPinL, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinL, LOW);
```

```
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration2 = pulseIn(echoPinL, HIGH);
  // Calculating the distance
  distance2 = (duration2/2) / 29.1; // Speed of sound wave divided by 2 (go and back)
}

void ultrasonicsenseR() {
  digitalWrite(trigPinR, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPinR, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinR, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration3 = pulseIn(echoPinR, HIGH);
  // Calculating the distance
  distance3 = (duration3/2) / 29.1; // Speed of sound wave divided by 2 (go and back)
}

void ultraPumpR() {
  digitalWrite(trigPumpR, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPumpR, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPumpR, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  durationPR = pulseIn(echoPumpR, HIGH);
  // Calculating the distance
  distancePR =(durationPR/2) / 29.1; // Speed of sound wave divided by 2 (go and back)
}

void ultraPumpL() {
  digitalWrite(trigPumpL, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPumpL, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPumpL, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  durationPL = pulseIn(echoPumpL, HIGH);
  // Calculating the distance
  distancePL =(durationPL/2) / 29.1; // Speed of sound wave divided by 2 (go and back)
}

void stopOperation() {
  motorstop();
  Serial.println("Emergency stop button pressed. Halting all operations.");
  while (distance1<30) {
    ultrasonicsenseF();
    int buttonValue = digitalRead(flushbutton);
    if (buttonValue == LOW){
        // If button pushed, turn LED on
        pumpPRL();
    }
    else{

      pumpstop();
    }

    // Wait until the switch is released before continuing
  }
  Serial.println("Emergency stop button released. Resuming operations.");
  pumpstop();
}
```

Appendix B BDP 2 Gantt Chart

TITLE : DEVELOPMENT OF AN AUTONOMOUS AGRICULTURE ROBOT FOR FERTIGATION USING ARDUINO
NAME : IRHAM MUKHLIS BIN ROSMAN **MATRIC NUMBER** : B082010252
SUPERVISOR : TS MADIHA BINTI ZAHARI

Week / Activity	1 9-13/10	2 16-20/10	3 23-27/10	4 30/10-3/11	5 6-10/11	6 13-17/11	7 20-24/11	8 4-8/12	9 11-15/12	10 18-22/12	11 25-29/12	12 1-5/1	13 8-12/1	14 15-19/1
Material Gathering														
Project Fabrication														
Coding and Testing														
Parameter Analyzation														
Project Testing														
Project Documentation														
Presentation														

Plan

Actual