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Faculty of Electrical Technology and Engineering

DEVELOPMENT OF LAWNMOWER USING PID CONTROLLER WITH IOT MONITORING SYSTEM

ABDUL HAKIM BIN ARSIL

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

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DEVELOPMENT OF LAWNMOWER USING PID CONTROLLER WITH IOT MONITORING SYSTEM

ABDUL HAKIM BIN ARSIL

A project report submitted
in partial fulfilment of the requirements for the degree of
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DEDICATION

This work is dedicated to:

The sake of Allah, my Creator, and my Master,

My great teacher and messenger, Nabi Muhammad SAW (May Allah bless and grant him), who taught us the purpose of life,

To my beloved mother, Yulni binti Muslim, and father, Arsil bin Muslim, whose unwavering love, constant encouragement, and enduring support have been the bedrock of this journey.

I dedicate this project to all those who worked diligently to assist me in its completion.

ABSTRACT

The development of a lawnmower equipped with a PID (Proportional-Integral-Derivative) controller and an IoT (Internet of Things) monitoring system is presented in this study. Lawncare is a crucial aspect of maintaining a well-groomed outdoor space, and the automation of lawnmowers has gained significant attention due to its potential to improve efficiency and convenience. The proposed lawnmower system incorporates a PID controller, which enables precise control of the mower's movements. The PID controller uses feedback from sensors, such as ultrasonic sensors, to adjust the speed and direction of the lawnmower in real-time. This allows the lawnmower to autonomously navigate through the lawn, ensuring effective coverage and avoiding obstacles. Furthermore, an IoT monitoring system is integrated into the lawnmower design. This system enables remote monitoring of the lawnmower through a mobile application or a web-based interface. Users can access real-time information about the mower's location, and operational parameters. In addition, the IoT monitoring system provides alerts and notifications in case of any anomalies or maintenance needs, enhancing the overall performance of the lawnmower. The development of this lawnmower system involves a combination of hardware and software components. The hardware includes the PID controller, sensors, actuators, and communication modules, while the software encompasses the control algorithms, IoT connectivity, and user interfaces. Extensive testing and validation are performed to ensure the accuracy and reliability of the system under various operating conditions. The results of this study demonstrate the feasibility and effectiveness of the proposed lawnmower system. The PID controller enables precise navigation, ensuring thorough lawn coverage and obstacle avoidance. The IoT monitoring system enhances user convenience and provides valuable insights for effective lawncare management. The development of such a system opens new possibilities for automation in lawncare, improving efficiency and reducing manual effort.

ABSTRAK

Pembangunan pemotong rumput yang dilengkapi dengan pengawal PID (Proporsional-Integral-Derivatif) dan sistem pemantauan IoT (Internet of Things) dipersembahkan dalam kajian ini. Penjagaan halaman adalah aspek penting dalam menjaga ruang luar yang terurus, dan automatasi pemotong rumput telah menarik perhatian besar kerana potensinya untuk meningkatkan kecekapan dan keselesaan. Sistem pemotong rumput yang dicadangkan ini menggabungkan pengawal PID, yang membolehkan kawalan yang tepat terhadap pergerakan pemotong rumput. Pengawal PID menggunakan maklum balas dari sensor, seperti sensor ultrasonik, untuk menyesuaikan kelajuan dan arah pemotong rumput secara langsung. Ini membolehkan pemotong rumput bergerak secara autonomi melalui halaman, memastikan liputan yang berkesan dan mengelakkan halangan. Selain itu, sistem pemantauan IoT diintegrasikan ke dalam reka bentuk pemotong rumput. Sistem ini membolehkan pemantauan jauh pemotong rumput melalui aplikasi mudah alih atau antara muka berasaskan web. Pengguna boleh mengakses maklumat secara langsung mengenai lokasi pemotong rumput dan parameter operasi. Selain itu, sistem pemantauan IoT memberikan amaran dan pemberitahuan dalam kes ketidaknormalan atau keperluan penyelenggaraan, meningkatkan prestasi keseluruhan pemotong rumput. Pembangunan sistem pemotong rumput ini melibatkan kombinasi komponen keras dan perisian. Perangkat keras merangkumi pengawal PID, sensor, aktuator, dan modul komunikasi, manakala perisian mencakupi algoritma kawalan, sambungan IoT, dan antara muka pengguna. Ujian dan pengesahan yang meluas dilakukan untuk memastikan ketepatan dan kebolehpercayaan sistem di bawah pelbagai keadaan operasi. Hasil kajian ini menunjukkan kebolehlaksanaan dan keberkesanan sistem pemotong rumput yang dicadangkan. Pengawal PID membolehkan navigasi yang tepat, memastikan liputan rumput yang menyeluruh dan mengelakkan halangan. Sistem pemantauan IoT meningkatkan keselesaan pengguna dan menyediakan wawasan yang berharga untuk pengurusan penjagaan halaman yang berkesan. Pembangunan sistem seperti ini membuka peluang baru untuk automatasi dalam penjagaan halaman, meningkatkan kecekapan dan mengurangkan usaha manual.

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LIST OF ABBREVIATIONS

V	-	Voltage
IoT	-	Internet of Things
PID	-	Proportional-Integral-Derivative
Ah	-	Ampere hours
m	-	meter
bps	-	Bits per seconds
Rpm	-	Round per minutes
A	-	Ampere
Li-ion	-	Lithium ion
NiMH	-	nickel metal hydride battery
IDE	-	integrated development environment
Kp	-	proportional gain
Kd	-	derivative gain
Ki	-	integral gain
PWM	-	Pulse-width modulation

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CHAPTER 1

INTRODUCTION

1.1 Background

Lawnmowers have been a crucial tool for maintaining lawns and gardens for well over a century. The invention of the lawnmower can be traced back to 1830, when a man named Edwin Budding developed a machine that could cut grass in a uniform manner.[1] Initially, these mowers were manually operated, with the user pushing the mower across the lawn.

In the late 1800s, gasoline-powered mowers were introduced, which allowed for faster and more efficient mowing.[1]Over time, these mowers have become more sophisticated and powerful, with features such as self-propulsion, electric start, and even robotic operation. Today, there are many different types of lawnmowers available, including push mowers, riding mowers, and zero-turn mowers, each with their own unique features and benefits.[3]

The use of PID (proportional-integral-derivative) controllers in lawnmowers has gained attraction in recent years. A PID controller is a feedback control system that adjusts a variable based on the difference between the desired set point and the actual value.[4] In the case of lawnmowers, PID controllers can be used to regulate the speed of the motor based on real-time data from sensors such as height sensors or GPS.[5] When combined with an IoT monitoring system, lawnmowers that utilize PID controllers can provide a highly efficient and customization lawn care experience. Moreover, the integration of an IoT monitoring system allows for remote monitoring and control of the lawnmower's operation providing real-time alerts and notifications in case of theft, malfunction, or other issues.[6] This enables users to set schedules, adjust settings, and receive notifications about the status of the mower in real-time. This system can also provide data on the performance and efficiency of the lawnmower, allowing for improvements to be made in its design and operation.

Lawnmowers have become an essential tool for homeowners and landscapers alike, providing a convenient and efficient way to keep lawns and gardens looking neat and tidy.

1.2 Promoting sustainability.

One significant benefit is the reduced emissions associated with robotic lawn mowers. Unlike traditional gasoline-powered mowers that emit pollutants and greenhouse gases, robotic mowers are typically electrically powered or use rechargeable batteries. This eliminates harmful emissions, improves air quality, and reduces the carbon footprint associated with lawn maintenance.[7]

Another advantage mentioned is the energy efficiency of robotic mowers. These machines are designed to be highly efficient in their operation. They utilize advanced technologies such as artificial intelligence, GPS navigation, and sensors to optimize cutting patterns and adapt to the lawn's needs. This results in reduced energy consumption compared to conventional mowers, further decreasing the environmental impact.[8]

Additionally, robotic mowers offer a quieter operation. Traditional mowers can be noisy and disruptive to the surrounding environment. In contrast, robotic mowers operate at significantly lower noise levels, minimizing noise pollution and creating a more pleasant outdoor experience for both users and their neighbours.

Overall, the summary of the article emphasizes that robotic lawn mowers are better for the environment due to their reduced emissions, energy efficiency, and quiet operation. These sustainable features make robotic mowers a greener choice for lawn maintenance, helping to combat climate change and support environmentally conscious practices.

1.3 Problem Statement

The manual approach of traditional lawnmowers is often time-consuming and labour-intensive, most people are too busy to manually manoeuvre the lawnmower across the lawn, which can be tiring, and traditional lawnmowers require physical effort to push or ride, which can be difficult for people with mobility issues or disabilities, especially for larger lawns.

Besides, the use of traditional lawnmowers can lead to overuse of resources such as water and fuel, which can cause harmful to the environment. Traditional lawnmowers emit harmful gases into the atmosphere, contributing to air pollution and climate change and can be so loud that can be disruptive to neighbor and wildlife.

Based on safety concern, the traditional lawnmower can be dangerous if not used properly and can cause serious injuries to users or bystanders. Furthermore, lack of efficiency of the traditional lawnmowers may leave patches of grass uncut, resulting in an uneven lawn appearance. Based on this fact, a PID controller may be used to develop a lawnmower that can satisfy a certain performance objective.

1.4 Project Objective

There are three objectives aimed to be achieved at the end of the project:

a) To develop and design an autonomous lawnmower by using a Proportional Integral Derivative (PID) controller.

b) To develop the suitable controller and employ IoT monitoring system for data collection.

c) To analyze and evaluate the system performance in term of position and obstacle avoided.

1.5 Scope of Project

The scope of this project are as follows:

a) Implement PID controller to control motor position based on the real-time data obtained from the sensors.

b) IoT monitoring system to facilitate autonomous operation and monitoring of lawn care activities.

c) The experiment is conducted based on the grassy area perimeter up to $25m^2$.

d) Using the Internet of Thing (IoT) application Blynk to get the feedback from the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides background and prior work information on the topics that are relevant to the development of lawnmower using PID controller with IoT monitoring system. This chapter is divided into several part which is history of lawnmower design, autonomous lawnmower system, and the technology that will be use in this project such as IoT monitoring, PID controller and path planning system.

2.2 History Lawnmower design

The first lawnmower is developed in 1830 by Edwin Budding to cutting the grass in sport ground and large garden.[1], [9], [10] Figure 2.1 shown the first lawnmower create, he then patents the product and licensed to the other company to produce the mower.

Figure 2.1 First Lawn Mower Design Created by Budding[1]

In 1985s, the others company start to make they own lawnmower design when the patent was terminated, and the first innovation is chain driver mover that called the Silens Messor by Thomas Green, the name of mower came for function of the mower that work in quieter. There also an innovation where they are using house to drawn lawnmower with the risk to tearing up the grass. It also involves to the lawnmower that is lighter and easier to push but lawn the garden still become the inconvenient task that take a lot of time and energy until 1902. When steam powered engine were commonly used and the introduced of the first internal combustion gasoline powered engine, United State was able to produce gasoline powered mower in 1919 but rarely use due to the economic crisis at those times. In 1920s until 1960s, a lot of developing are happen such as electric powered mower, smaller, lighter weight designs along with more powerful engines also plastic material mower to reduce the weight and cost.

Modern lawn mowing involves various applications with different technologies. The most popular mowers are gasoline-driven, but there are also electric and hybrid options available. Mowers can have mechanical, electrical, hydraulic, or combined deck lifting systems. There are three main types of mowers: walk-behind, riding, and tow-behind. Walk-behind mowers are the simplest and have limited mowing capacity. They can be mechanical, gasoline-powered, or electric. Riding mowers are more complex, with larger engines and higher mowing capacity that can be gasoline-powered or electric. Tow-behind mowers are used for larger areas like fields, and they are towed by tractors or powerful vehicles that are mostly mechanical and utilize the rotation and energy from being pulled to cut grass. Each type of the modern mower has its advantages and recommended usage based on the size and terrain of the lawn.

Figure 2.2 Silens Messor (1959)[1]

Figure 2.3 Engine Powered Mower[1]

2.3 Autonomous Lawnmower System

The advent of autonomous lawn mowers has sparked significant interest in recent years, offering a potential revolution in lawn maintenance. These robotic devices, equipped with advanced technologies such as artificial intelligence and computer vision, can autonomously navigate lawns, detect obstacles, and efficiently mow the grass without human intervention. This literature review aims to provide an overview of the existing research on autonomous lawn mowers, exploring their historical development, technical aspects, and potential for future advancements. By synthesizing the current knowledge, this review aims to contribute to the understanding and advancement of autonomous lawn mower technology.

In the study of [11], the author focuses on the design and implementation of an autonomous lawnmower using Field Programmable Gate Array (FPGA) technology. The study explores the advantages of using FPGA for real-time control of autonomous systems, specifically in the context of lawn maintenance. The author presents their own design for an autonomous lawnmower that uses an FPGA-based control system. The author then explains the advantages of FPGA technology, such as its reconfigurability and high-speed processing capabilities, and how it can be applied to the control system of the lawnmower. The robot follows a path planning technique based on four Global Positioning System (GPS) points set as boundaries to ensure operation within the designated area specified by the user. The autonomous lawn mower operates efficiently and smoothly returns to its designated path after navigating past obstacles. It utilizes 25% of the available pins on the board and 31% of the total Digital Signal Processing (DSP) blocks. The author concludes that the autonomous lawnmower successfully operates without encountering any physical issues during movement. The structure of the lawnmower is user-friendly and cost-effective.

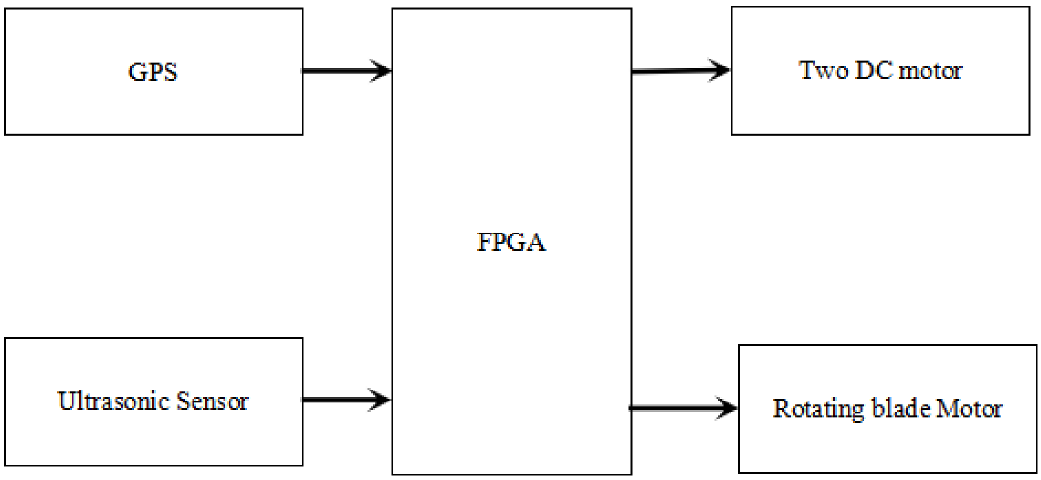

Figure 2.4 block diagram of hardware in [11]

The usage of DSP TMS320F2808 chip was as the control core and Raspberry Pi is used as image recognition and human-machine interface design with the program written to control the motor. [12]DSP TMS320F2808 was used as the environmental interface as shown in Figure 2 that using C language writing program CCS on the platform of F2808 in this development environment.

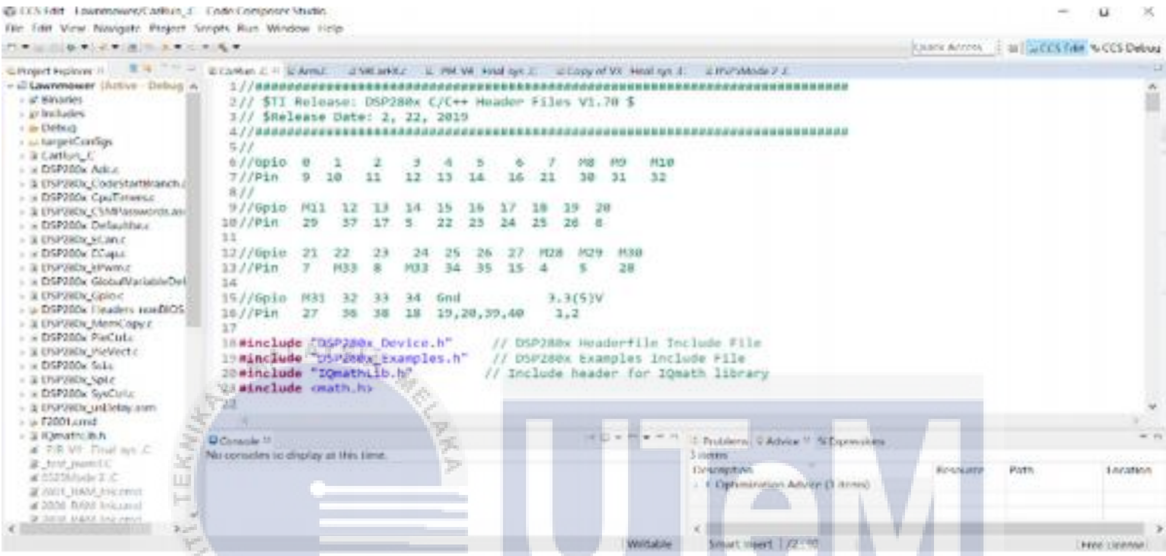

Figure 2.5 Environmental interface of Code Composer Studio (CCS) v6.0.

2.3.1 Control system

In [2], reported in an improved controller for grass cutting application. The authors use a combination of theory and simulation to demonstrate the effectiveness of their approach and begin by discussing the limitations of existing grass cutting controllers and the need for an improved design. They then introduce the theoretical background of the proportional-integral-derivative (PID) algorithm, which is commonly used in industrial control systems. The authors modify the PID algorithm by adding a feedforward control component that compensates for changes in terrain. The authors use simulation to demonstrate the performance of their improved controller. They compare the performance of their controller with that of a conventional PID controller and show that their controller provides more accurate and stable control of the cutting height. The authors also discuss the practical implementation of their improved controller. They describe the hardware and software components required to implement the controller and provide a detailed explanation of the control algorithm.

Autonomous lawn mower in [13] starts moving after analysing are done in acquiring the GPS coordinates until it detects obstacle by using ultrasonic sensor, and the lawnmower will stop to avoid obstacle. The lawnmower is programmed to move forward until it reaches a preset limit boundary defined by GPS coordinates. To ensure precise movement, a proportional-integral-derivative (PID) controller is employed to minimize any error between the two DC motors, ultimately guiding the robot to move in a straight line. If the lawnmower reaches the boundary, it will perform a 360-degree turn and continue mowing the grass in a serpentine pattern. The lawnmower will stop mowing once it reaches the final designated coordinate point. Figure 5 illustrates the control system's process flow for the autonomous lawn mower. The autonomous lawnmower can operate with the design that have been made and encounter no physical problem when moving.

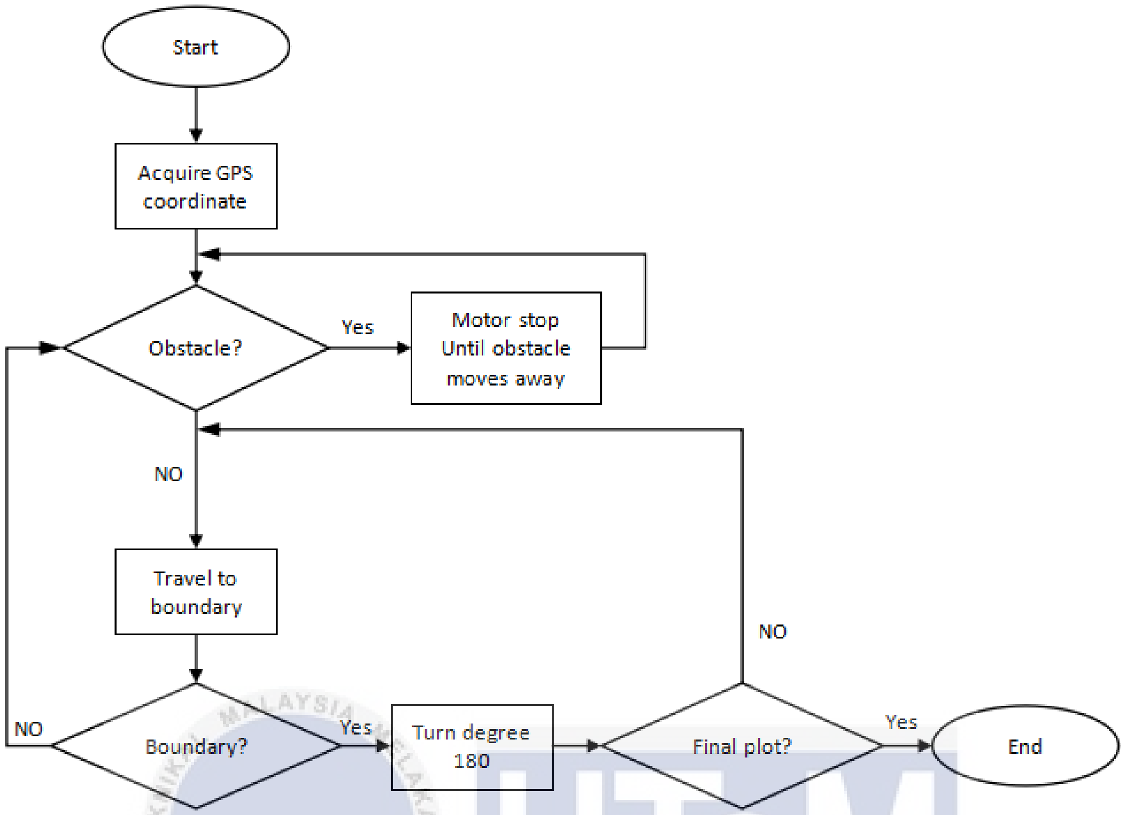

Figure 2.6 Process flow of control system in [13]

An improved controller of machine cutter capable to improve grass cutting process controlled by radio frequency (RF) remotely.[14]The remote control contains a transmitter, while the lawnmower has a receiver. The RF signal is transmitted from the remote control to the lawnmower through an antenna (joystick). RF is a cost-effective and reliable method for long-distance communication. In this project, the transmitter and receiver are programmed to control the lawnmower's movement and blade speed. The circuit includes an H-bridge connection to adjust the lawnmower's manoeuvrability, allowing for slow or fast operation. The author concludes that the smart cutter machine easier to handle since the movement will control by using remote control.

2.3.2 Effect of wedge angle of the cutting blade

The journal in [3] presents a detailed study on the design and fabrication of a smart mower, which is a type of autonomous lawn mower that uses sensors and advanced algorithms to navigate and cut grass. The authors then present their own design for a smart mower. This paper focuses on optimizing the vibration and sound levels of a lawnmower during the grass-cutting process. The project entails defining technical requirements, including customer preferences, cost modelling, product design specifications, concept generation, concept selection, and prototyping. These requirements are essential for building a safe and efficient Smart Mower. The experiment involved analysing vibration and sound levels by varying the wedge angle of the cutting blade from 200 to 900 degrees during simulated grass cutting. The authors test the performance of the smart mower in a simulated environment and demonstrate that it is capable of efficiently navigating and cutting grass in a controlled manner. This study aimed to investigate the relationship between the wedge angle of the blade and the levels of vibration and sound produced during grass cutting. The results indicate a slight increase in vibration and sound as the wedge angle decreases. The cutting process is influenced by various factors, including the design of the cutting assembly, the shape or angle of the cutting edge, operational parameters of the device, and the physical properties of the grass such as strength and structure. The experiment demonstrated that reducing the wedge angle leads to a decrease in vibration and sound levels. However, this change also affects blade sharpness by increasing the reduction of the tip radius and reducing the amount of material available to withstand high compressive forces. The experiment showed that the minimum sound level recorded was 80.32 dB for a wedge angle of 200, while the maximum sound level reached 83.74 dB for a wedge angle of 900, indicating a profound condition.

2.4 IoT Monitoring

The Internet of Thing (IoT) is a game-changing technology that has transformed the way we interact with the world around us. It has redefined how we connect with devices and opened new possibilities for communication and innovation. This literature review aims to provide an overview of the IoT technology by the past researcher.

In [6], The project focuses on developing a monitoring system for mobile robots using IoT technologies. The system integrates sensors, communication modules, and cloud-based platforms to enable real-time monitoring and control of mobile robots. Through IoT connectivity, the system enables continuous monitoring of various robot parameters such as location, battery status, and environmental conditions. The integration of machine learning algorithms further enhances system performance by enabling predictive analytics and adaptive control.[15] By leveraging IoT connectivity, the mobile robot monitoring system can reduce operational costs when the real-time monitoring helps identify potential issues early, preventing costly breakdowns or delays. The reviewed projects open avenues for further research in the field of robotics and logistics. The mobile robot monitoring system based on IoT, showcases the immense potential of combining IoT and machine learning. With its real-time monitoring capabilities, machine learning algorithms, and centralized control, the system can transform operations across various industries.

The study for the monitoring and control system in [16]–[18] presents a deep understanding of IoT and its application in creating an intelligent robot system. This research project delves into the design, analysis, and potential impact of integrating IoT technology into robotics, offering valuable insights into the realm of real-time monitoring and control. By showcasing the successful integration of IoT technology for remote control and real-time data transmission, the research presents a practical framework for developing advanced mobile robot systems. By leveraging IoT protocols, such as Wi-Fi or Bluetooth, the system enables users to monitor and control their electrical devices remotely, regardless of their location. The study emphasizes the importance of data analysis and decision-making algorithms in the IoT-based intelligent robot system. By employing advanced analytical techniques, such as machine learning and artificial intelligence, the system can extract valuable insights from the collected data.[19] These insights enable the robot to make autonomous decisions, adapt to dynamic scenarios, and optimize its operations accordingly. The implications of this work extend to industries seeking autonomous exploration solutions, researchers exploring IoT applications in robotics, and professionals working in surveillance or environmental monitoring sectors. Several wireless architectures have been developed to implement wireless system. Table 2.1 is the comparison between each wireless module.

Table 2.1 Comparison on different wireless specification. [16]

Criteria	Different wireless				
	NodeMCU	**ZigBee**	**802.11(Wi-fi)**	**Bluetooth**	**IR Wireless**
Data Rate	**Max. 300 kbps**	**Max. 250 kbps**	**Max. 54 mbps**	**Max. 25 mbps**	**Max. 4 mbps**
Range (m)	**225 m**	**10-100 m**	**32 m indoor and 95 m outdoor**	**5-30 m**	**10 m**
Frequency of operation (Ghz)	**2.4**	**2.4**	**2.45**	**2.4**	**800-900nm**
Complexity	**Low**	**Low**	**High**	**High**	**Low**
Power consumption	**Very low**	**Very low**	**High**	**Low**	**Low**
Security	**WPA/WPA2**	**128 AES**		**64 & 128 bit encryption**	

2.5 PID Controller

Mobile robots play a crucial role in various fields, including industrial automation, surveillance, and exploration. To ensure accurate and efficient operation, control systems are essential components of mobile robots. This literature review aims to analyse a research paper that focus on different control system methodologies and their results in the context of mobile robotics. The study in [20]explore the performance of Fuzzy-PID and Fuzzy-PI control systems on the speed control of a four-wheeled mobile robot. The author in [21]focuses on designing and developing a digital PID controller using an embedded platform for a DC motor drive system in a mobile robot. The author presents the hardware and software configuration and implements the PID algorithm. The study highlights the effectiveness of the embedded platform in achieving precise control for the mobile robot's DC motor drive system. The author of [22]proposes a discrete optimal tracking control strategy for a two-wheel mobile robot driven by DC motors. The author formulates an optimal control problem and employs a discrete-time optimization algorithm. They conduct experiments, comparing various performance metrics such as speed response, settling time, steady-state error, accuracy, and disturbance rejection.

Table 2.2 show the study comparing Fuzzy-PID and Fuzzy-PI control systems. The study reveals that both systems exhibit excellent speed response and disturbance rejection. However, Fuzzy-PID outperforms Fuzzy-PI in terms of settling time and steady-state error. The authors attribute these differences to the control system parameters and provide explanations for the observed results.

Parameter	Comparison of Control Methods	
	Fuzzy-PID	Fuzzy-PI
Delay Time	0.09 s	0.12 s
Rise Time	1.13 s	0.24 s
Peak Time	-	0.35 s
Steady Time	0.35 s	0.49s
Maximum Overshoot	-	14.26 %

Table 2.2 Result of response performance in [20]

Overall, these studies contribute to the advancement of control methodologies in mobile robotics, addressing challenges such as speed control, trajectory tracking, and control system design. The results and analyses presented in these papers offer valuable information for guiding the development of efficient and reliable control systems for mobile robots. Future research can build upon these findings to further enhance the performance and adaptability of control systems in mobile robotics applications.

2.6 Path Planning System

In the journal[23], the author presents a novel approach that employs the adaptive neuro-fuzzy inference system (ANFIS) to empower robots with adaptive decision-making and navigation capabilities. The primary objective is to optimize path planning strategies by combining the strengths of neural networks and fuzzy logic. The approach involves training an ANFIS model to generate optimal paths for autonomous mobile robots. The model takes inputs such as the robot's current position, goal position, and environmental information. By utilizing fuzzy logic rules, the ANFIS model assesses the environmental characteristics to determine the best path while avoiding obstacles. The training process utilizes a combination of supervised and reinforcement learning, allowing the model to adapt to changing conditions. By leveraging the capabilities of ANFIS, the proposed approach enhances the adaptability, efficiency, and obstacle avoidance capabilities of autonomous mobile robots. The research findings demonstrate the superiority of the ANFIS-based approach over traditional methods. Further exploration and refinement of this approach could significantly contribute to the field of autonomous robotics. Figure 2.7 show the block diagram for the system with the ANFIS controller.

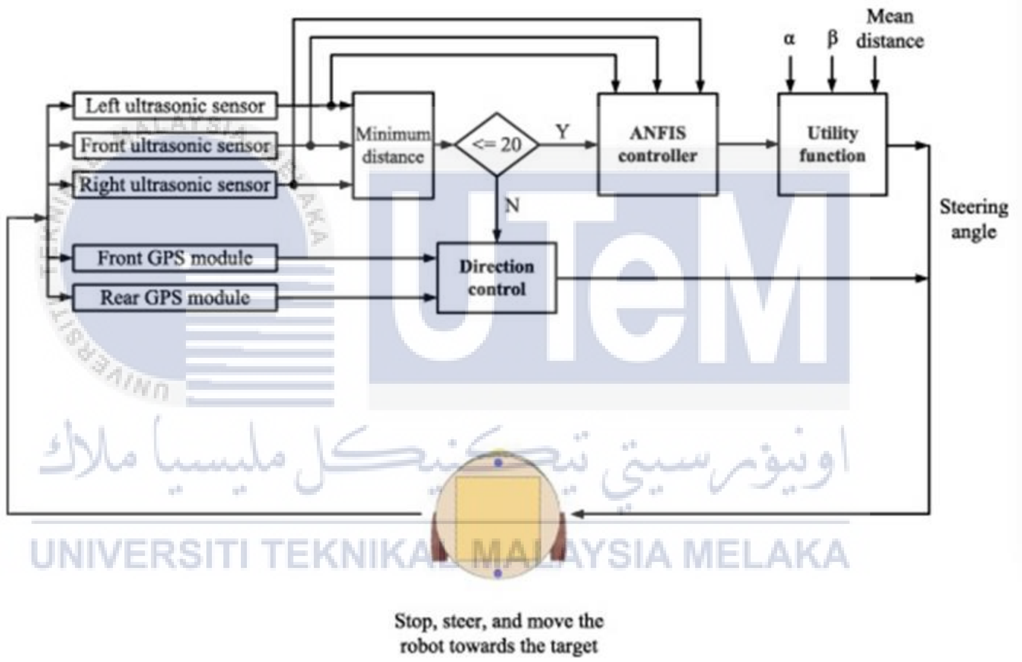

Figure 2.7 A scheme of the system workflow.

2.7 Comparison between previous projects

Past research	Method	Result	Disadvantage
Control system	-integration of the control algorithm is based on nonlinear control theory. [24][25][26]	the control algorithm effectively guides the mower thoroughly.	• not address potential issues related to the robot's performance under various lawn conditions,
	utilization of a PID controller to enhance the machine's performance and efficiency[4][27][28][29]	effectiveness in optimizing energy consumption	
	FPGA technology for real-time responsiveness and efficient processing[11]	high-speed processing and flexibility for algorithm modifications	
	remote monitoring and control of the grasscutter robot through a web or mobile application.[30][31][32]	effectively cuts grass autonomously while being remotely monitored through the IoT platform.	
IoT system	designing and analysing the IoT-based intelligent robot.[15]–[19], [33]	• Successful design and analysis of the IoT-based intelligent robot for real-time monitoring and control. • Monitoring environmental parameters	• The lack of standardized protocols and interoperability among different IoT devices and platforms.

2.8 Summary

After reviewing multiple journal articles related to the design and implementation of autonomous lawnmower robots and IoT-based intelligent robots, the findings reveal several key points. The research studies on autonomous lawnmower robots showcase successful designs and implementations with features such as autonomous navigation, obstacle detection, and efficient grass-cutting capabilities. Solar power is commonly employed to ensure sustainability and prolonged operation. Quantitative data on performance metrics like mowing efficiency, battery life, and obstacle detection validate the effectiveness of these robots.

On the other hand, the integration of IoT technology in robots enables real-time monitoring, control, and remote accessibility. IoT-based intelligent robots showcase features such as data collection, analysis, and decision-making capabilities. Performance metrics, including response time, accuracy, and reliability, demonstrate the effectiveness of IoT-based intelligent robots. They offer advantages such as improved efficiency, enhanced safety, and remote accessibility.

In conclusion, all this review has given some insight on how develop this project on selecting the component, develop the control system and employ the IoT system. Next, the methodology use for this development project will be discuss in the next chapter.

CHAPTER 3

METHODOLOGY

In this chapter, it delves into the methodologies employed to successfully accomplish the project over the course of time. The primary objective of this chapter is to furnish comprehensive information and validation regarding the execution of the project. The project entails the utilization of both hardware and software in the Development of Lawnmower Using PID Controller with IoT Monitoring System.

3.1 Research Workflow

A well-defined research workflow is vital for the systematic and efficient execution of a project, ensuring success and the fulfillment of desired objectives. In the context of Development of Lawnmower Using PID Controller with IoT Monitoring System, establishing a clear research workflow is crucial for organizing and effectively progressing through various project stages. This sub-section offers an overview of the outlined research workflow, outlining the key steps to be undertaken in conducting the project and attaining the desired outcomes.

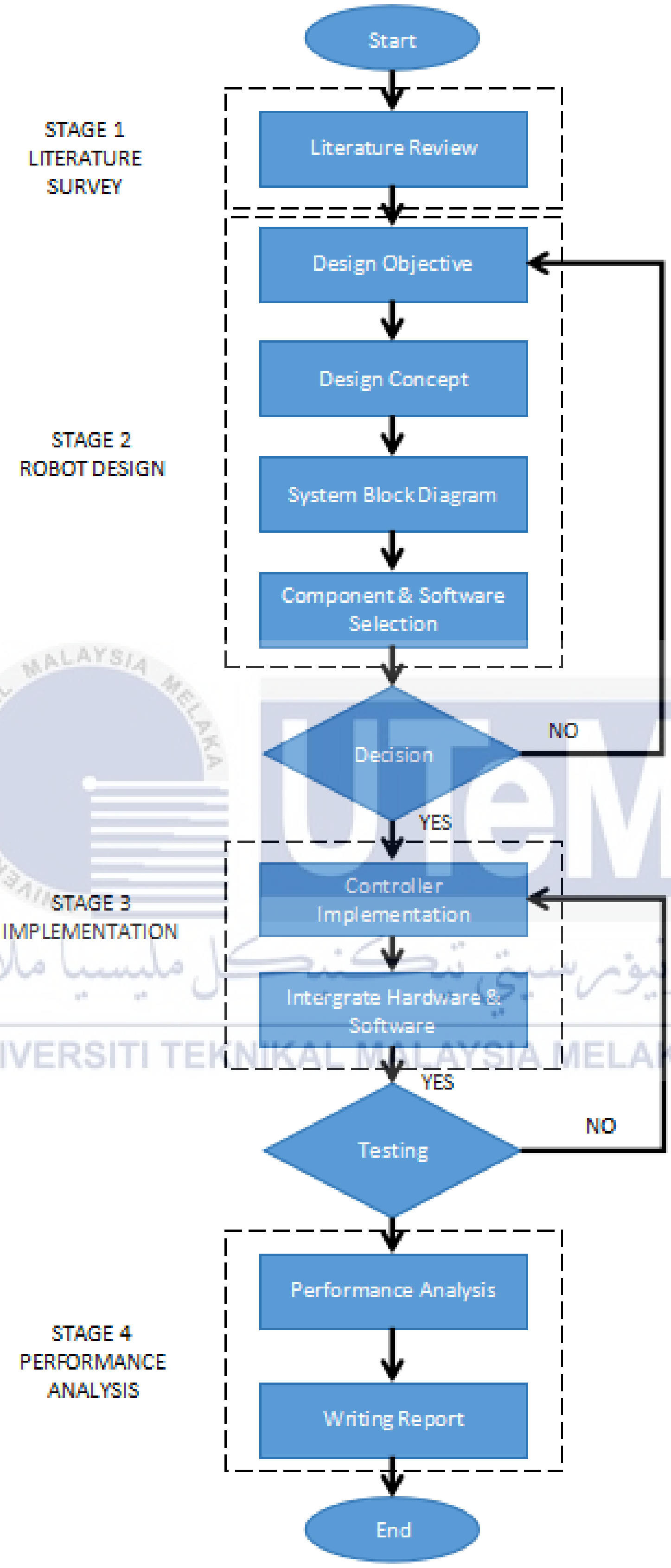

Figure 3.1 Research Workflow

3.1.1 Stage 1: Literature Survey

In the initial stage of developing a lawnmower using a PID controller with an IoT monitoring system, a thorough literature survey is conducted. This involves delving into existing research on PID controllers and their applications in autonomous systems, exploring IoT monitoring systems for outdoor devices, and reviewing literature on the development of autonomous lawnmowers. The goal is to gain a comprehensive understanding of established methodologies, technologies, and challenges in these areas.

3.1.2 Stage 2: Robot Design

Following the literature survey, the second stage focuses on the design aspect of the lawnmower and its associated PID controller system. This involves crafting the physical and electronic components of the lawnmower, considering integration with IoT devices for monitoring and control. Design tasks include specifying PID controller parameters based on the lawnmower's dynamics, creating a chassis and mechanical components, and integrating sensors for environment perception such as obstacle detection. The goal is to create a well-thought-out design that sets the foundation for the subsequent implementation phase.

3.1.3 Stage 3: Implementation

With the design in place, the third stage centres on the actual implementation of the lawnmower system. This involves coding the PID control algorithm for the lawnmower's navigation, developing software for sensor data processing and obstacle avoidance, and integrating communication protocols for IoT devices. The physical components are assembled, and the system is tested to ensure proper functionality. This stage is critical for translating the theoretical design into a tangible, working prototype that can be further refined and optimized.

3.1.4 Stage 4: Performance Analysis

The final stage focuses on evaluating the performance of the developed lawnmower system. Experiments are conducted to assess the responsiveness of the PID controller in maintaining a desired trajectory. The lawnmower's performance is tested across various terrains and conditions, and data from the IoT monitoring system is analysed to identify patterns and potential improvements. Based on the findings, adjustments are made to fine-tune the PID controller parameters and software. This iterative process ensures that the lawnmower system meets the desired performance criteria and is ready for potential real-world applications. This stage further discussion is in the Chapter 4 Result and Discussion topic.

3.2 Design objective

The primary goal of the autonomous lawnmower's design is to develop a system that efficiently and safely maintains lawns without human intervention, maximizing user convenience and minimizing potential risks. The autonomous lawnmower should be designed to operate with high efficiency, includes efficient navigation, minimizing unnecessary travel, and avoiding repetitive patterns. The autonomous lawnmower should be designed for easy maintenance, allowing users to clean, repair, and replace components without excessive effort or technical expertise.

3.3 Design Concept

A rough sketch for the lawnmower is needed to predict the location and size for the component. In figure 3.2, the dimension for this lawnmower is 230mm x 200mm x 100mm (without the casing) where the 100mm wheel is placed at the front of the cassis on both sides. This wheel will be controlled by the gear motor inside the chassis. DC motor and grass blade will be placed at the center of the lawnmower so that when the lawnmower moves it can cut the grass along the way. For stability, a wheel caster is placed at the back of lawnmower so that the lawnmower can turn left and right smoothly. The controller box is the place where the microcontroller, motor driver and the other electrical component are located. Battery is placed at the back of the lawnmower so that it can easily charge or replace if needed.

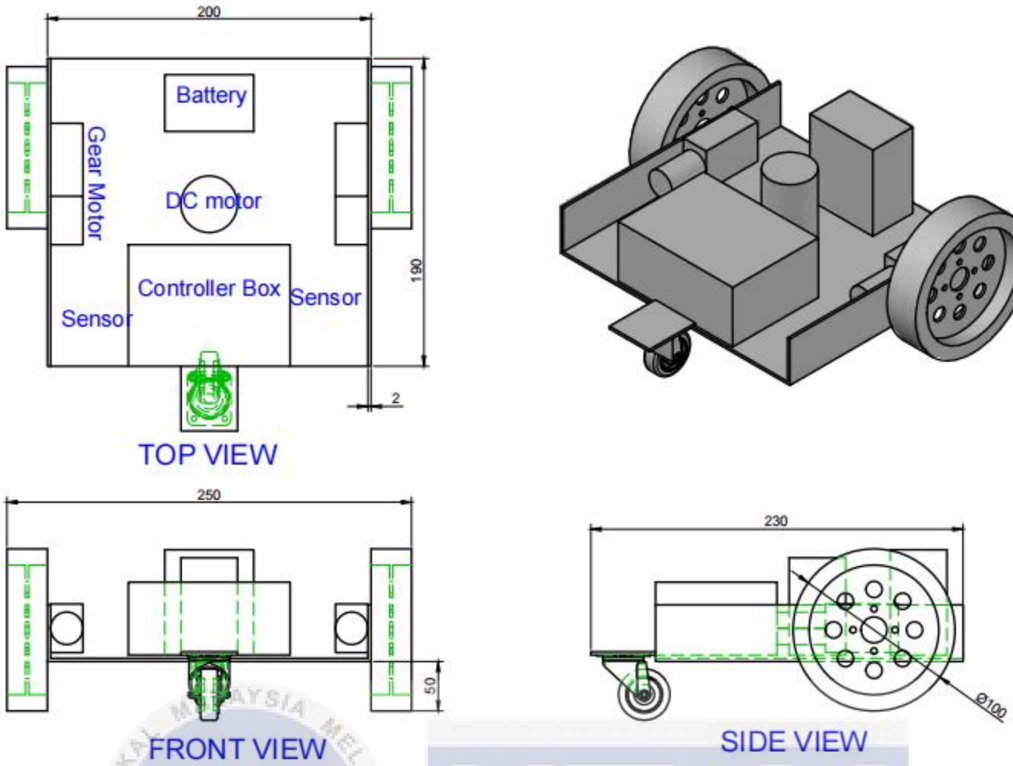

Figure 3.2 Design concept (unit in mm)

3.4 System block diagram

System block diagrams play a crucial role in project development as they provide a visual representation of the system's architecture and its functional components. The block diagram enables a systematic analysis of the system's functionality and performance. By breaking down the system into distinct blocks, each representing a specific function or component, it becomes easier to identify potential bottlenecks, dependencies, or areas that require further attention. The block diagram in figure 3.3 provides a visual representation of the system's major components and their interconnections.

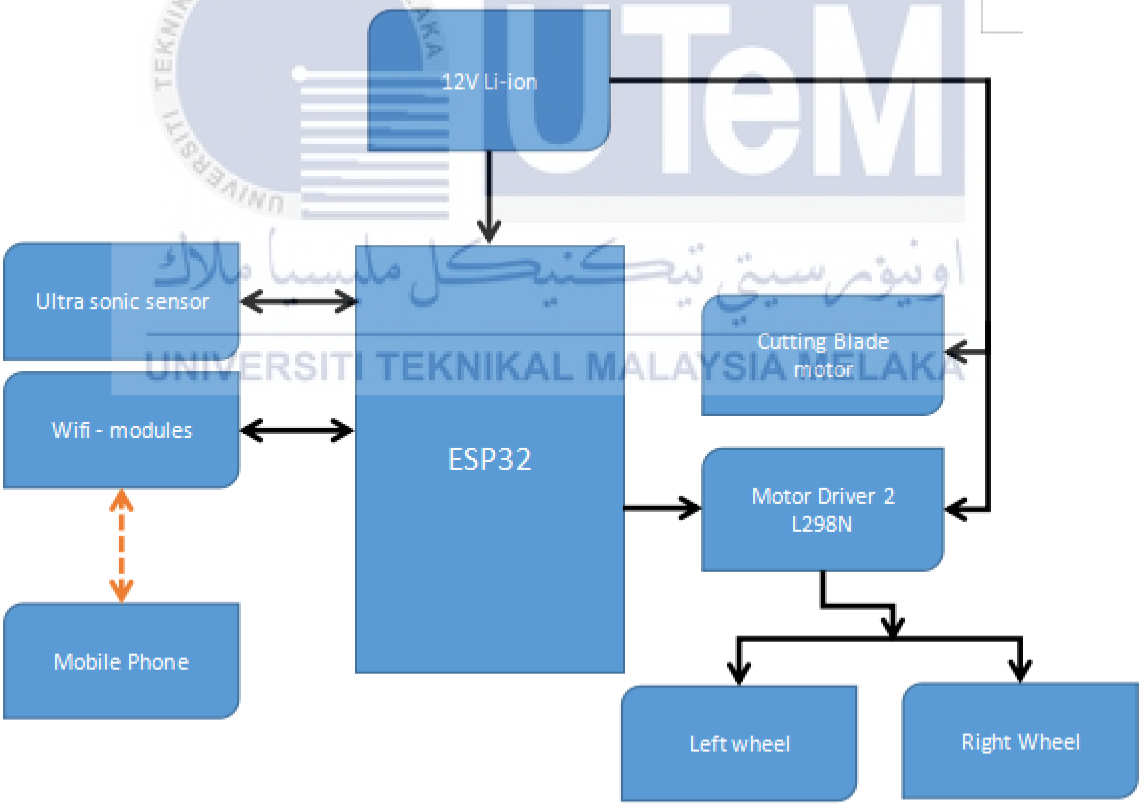

Figure 3.3 System block diagram

3.5 Project Component

In this sub-section, the type of component that is use in this project with the elaborate function. The component is listed based on the study on literature review. Figure 3.4 shows the flow chart of the component study.

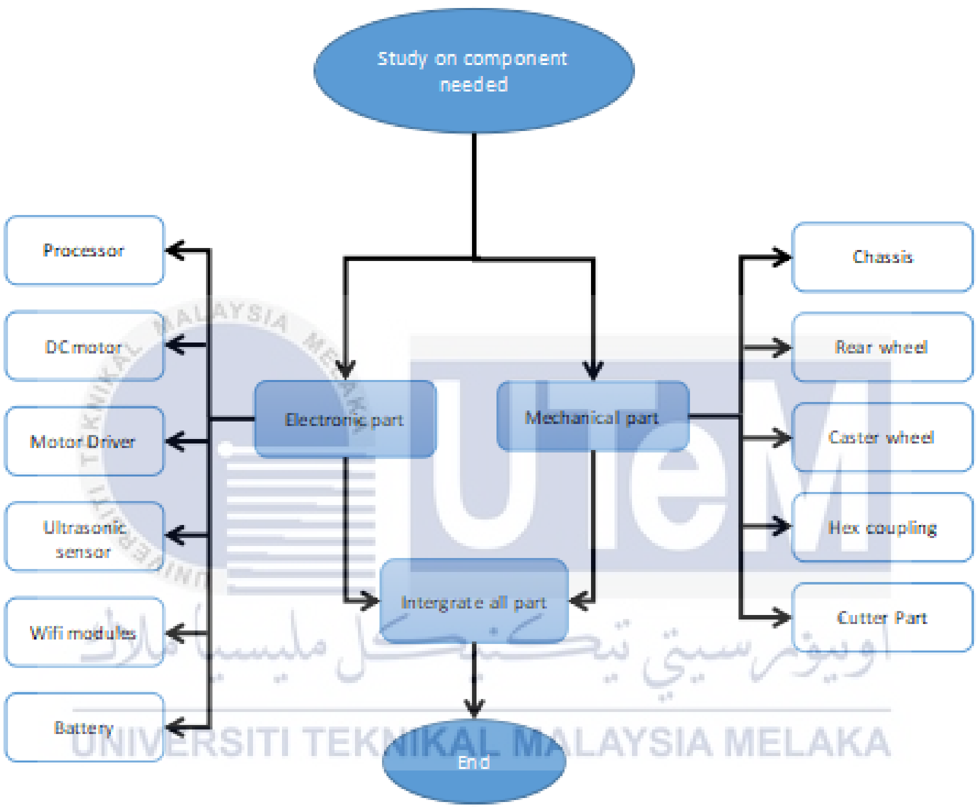

Figure 3.4 Study on component process flow

3.5.1 Electronic Part

Electronic components in a robot can be likened to the brain, heart, and nerves in a human body. The processor functions as the brain, processing data and producing outputs through mapped pins. These outputs are then transmitted via wires, acting like nerves, to drive the actuators and produce physical movement. The resulting motion is like muscles in a body, and what we observe is the robot's physical actions. This analogy helps illustrate how electronic components facilitate the translation of electrical signals into meaningful robotic behaviour.

Robotic systems incorporate a variety of electronic components to enable their functionality and control. These electronic parts play crucial roles in sensing, actuation, communication, computation, and power management. In this part, we can divide the electronic part to processor, driver, and actuator.

a) Processor

This project will use ESP32-WROOM as a processor for this system. Espressif Systems' ESP32-WROOM is a module that combines the ESP32 microcontroller with Wi-Fi and Bluetooth capabilities. The reason for chosen ESP32 microcontroller is that because it has many I/O pin can be use as user interface compared to ESP8266 and also can easily use to connect into IoT platforms. Figure 3.5 Show the ESP32 and all the pinout that use can use.

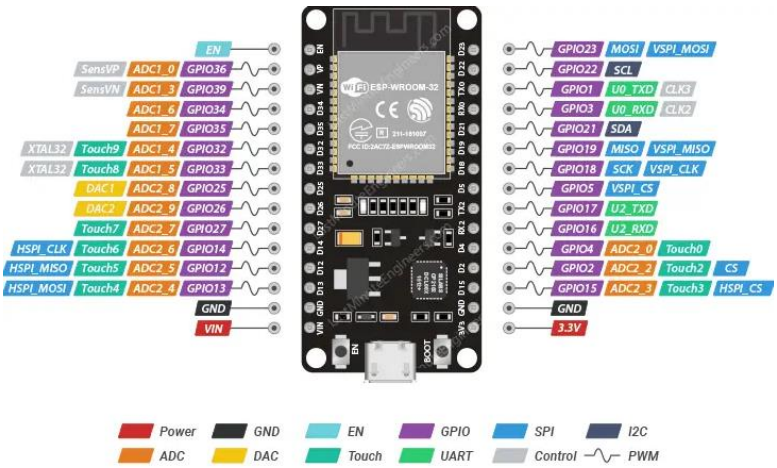

Figure 3.5 ESP 32 pinout

b) DC motor

DC motors are widely used in robotics for providing mechanical motion and actuation. They are versatile, efficient, and offer precise control over speed and direction. DC motors operate based on the principle of electromagnetic induction. They consist of a rotor (the rotating part) and a stator (the stationary part). When an electrical current is passed through the motor's windings, it creates a magnetic field that interacts with the permanent magnets or electromagnets on the rotor, causing it to rotate.

In this project, it uses 2 type of dc motor which is the first on is RS-750 12-24VDC DC MOTOR and 12V worm gear motor.

i. RS-750 12-24VDC DC MOTOR

Figure 3.6 show the motor that is use as grass cutter that will be placed at the bottom centre of the robot.

Figure 3.6 12V DC motor

ii. 12V worm gear motor.

The motor is equipped with a worm gear mechanism, which consists of a threaded shaft (worm) that engages with a gear (worm gear). This mechanism provides a high gear reduction ratio, resulting in increased torque and reduced speed output. This motor will act as the actuator for the robot. Figure 3.7 show the motor that act as the actuator for the robot movement and direction.

Figure 3.7 12V worm gear motor

c) Motor Driver

A motor driver in robotics is an electronic device or module that is used to control and power the motors used in robotic systems. It acts as an interface between the microcontroller or control system and the motors, providing the necessary electrical signals and power to drive the motors effectively. In this project it uses L298N. This driver is a popular motor driver IC (integrated circuit) commonly used in robotics and other motor control applications. Figure 3.8 show the driver that can drive two DC motors or a bipolar stepper motor, providing control over motor speed and direction for the motor.

Figure 3.8 L298N motor driver

d) Ultrasonic Sensor

In this project, ultrasonic sensor will be used as an input for PID controller to measure distance and object detection detecting the presence or absence of an object within a certain range which are commonly used in robotics and automation. Figure 3.9 show how the ultrasonic sensor work.

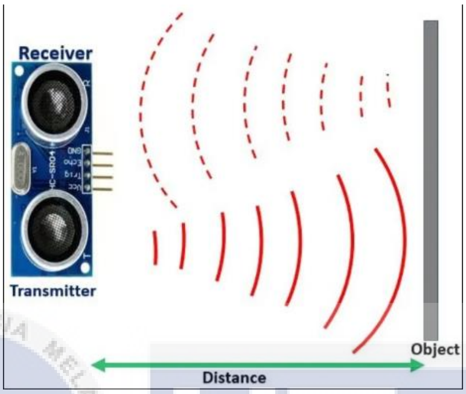

Figure 3.9 Ultrasonic sensor

e) Battery

The battery in the robot system serves as its power source, providing the necessary electrical energy to operate and move the robot. This project will use 12V Li-ion Battery as a supply for the whole system. This is because 12V Li-ion battery in figure 3.10 is more light weight and easy to handle than NiMH cell.

Figure 3.10 12V Lithium 18650 Rechargeable Battery

3.5.2 Mechanical Part

The mechanical component plays a pivotal role in the project, as it is responsible for the physical movement and is driven by an electronic counterpart. The two parts are interconnected, and the absence of either would render the project incomplete as a final product. By examining the mechanical aspect, we can determine the appropriate motor torque required to move the robot based on its weight.

a) Chassis

The base frame that has been chosen for this project is the aluminium plate. The objective was to conceive a straightforward robot chassis that would provide a robust foundation capable of navigating uneven terrain while maintaining a lightweight structure. The chassis in figure 3.11 comprises a 2.0mm thick aluminium plate, with the dimension of 260mm x 210mm.

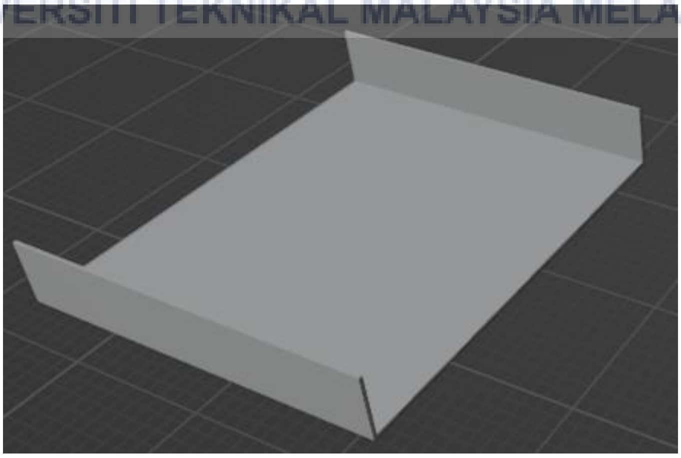

Figure 3.11 Chassis

b) Front Wheel

The front wheel of this robot is the part that will be connected to the gear motor and act as the main part to provide locomotion and enable movement for the robot. The wheel that has been chosen to use is made of rubber material with a weight of not more than 100g per wheel. Figure 3.12 is the Rear wheel that is used with its dimension.

Figure 3.12 130 mm Robot Wheel

c) Caster Wheel

For this project, it uses the caster wheel as the rear wheel for the robot so that the robot will be more stable and easier to move in whatever direction. The caster wheel in figure 3.13 that selected for the robot is in range of 70mm wide and 50mm high.

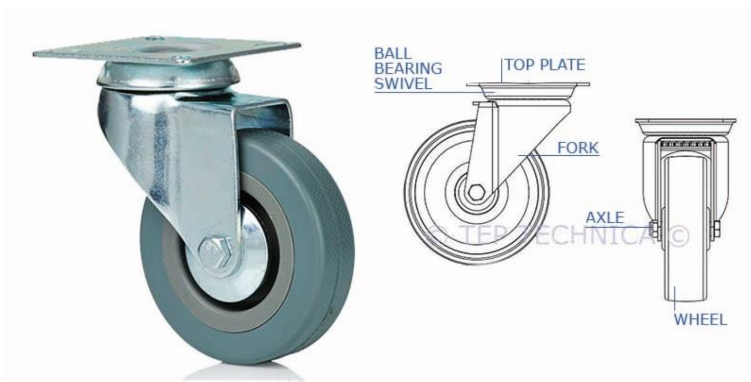

Figure 3.13 Caster Wheel

d) Hex Coupling

A hex coupling is a sort of coupling mechanism used to link a dc motor to a wheel. In this project, the motor uses a hex coupling in figure 3.10 to connect the motor to the wheel. This type of coupling provides additional contact points, which improves stability and lowers the danger of slippage or misalignment and easy to install and remove from the motor, making it convenient for maintenance and replacement.

Figure 3.14 Long Hex coupling

e) Cutter Part

In a lawnmower, the function of the cutter, also known as the cutting mechanism or blade, is to trim or cut the grass at a desired height to maintain a neat and well-manicured lawn. For cutter part, this project uses chuck adapter in figure 3.15, also known as a drill chuck adapter or chuck converter. It is because it provides compatibility between the tool's chuck and the desired accessory such as blade and cable tie.

Figure 3.15 Example of chuck adapter

3.6 Software tools

A software tool is a program or application that aids in the development, management, analysis, or execution of software or digital systems. It is designed to assist users in performing specific tasks more efficiently and effectively. Software tools can be broadly classified into different categories based on their purpose and functionality. For this lawnmower system it will need some software system such as Arduino IDE,

3.6.1 Arduino IDE

Arduino IDE (Integrated Development Environment) is an open-source software tool specifically designed for programming Arduino microcontrollers. Arduino IDE is built on the Processing programming language and uses a simplified version of C/C++ code to program Arduino or any microcontroller boards. In this development, ArduinoIDE is used to compile the coding with the additional ESP32 board module and libraries. Figure 3.16 show the ArduinoIDE interface on windows.

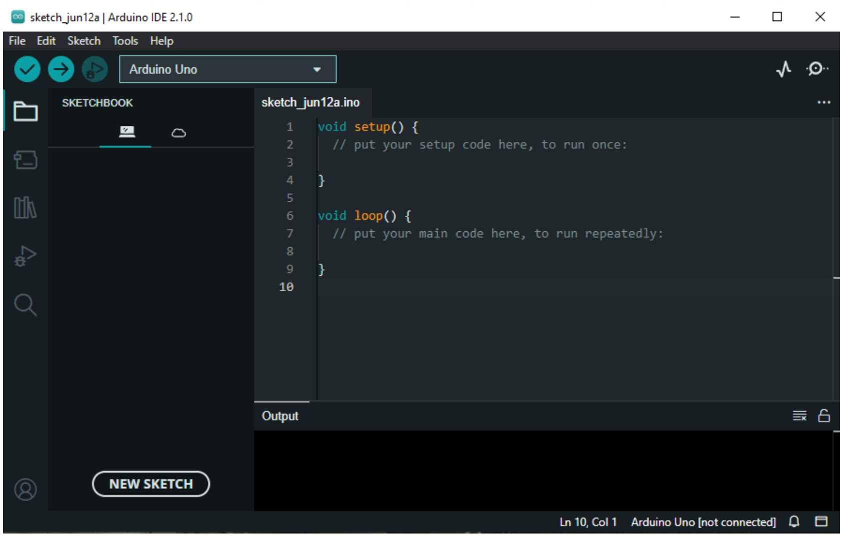

Figure 3.16 Arduino IDE interface.

3.6.2 Blynk

Blynk is a popular IoT (Internet of Things) platform that allows users to easily build, and control connected projects. Blynk also have data visualization, remote control and notifications that will be use in this project and it provides powerful visualization capabilities, allowing users to display sensor data, graphs, and real-time charts in their mobile app interfaces. This helps users monitor and analyse the data generated by their IoT projects in a clear and intuitive manner. It enables users to remotely control their IoT projects from anywhere in the world using their mobile devices. Users can send commands, toggle switches, and receive notifications based on specific events or conditions, enhancing the interactivity and responsiveness of their IoT applications.

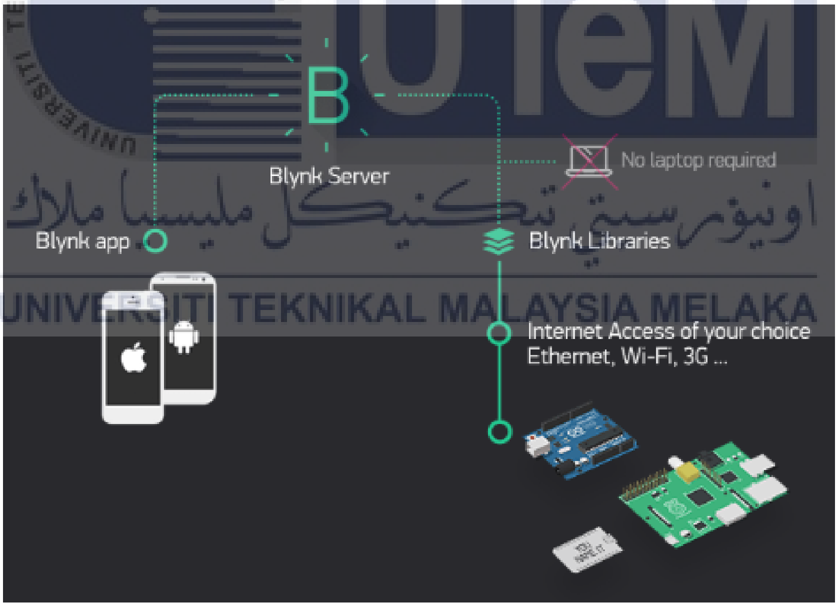

Figure 3.17 Blynk feature

3.6.3 ThingSpeak

ThingSpeak is a MathWorks Internet of Things (IoT) platform meant to simplify data collecting, storage, and analysis from linked devices. Users may input data from sensors or other devices to ThingSpeak servers, where it is organized into channels, using this cloud-based architecture. This project chooses to add ThingSpeak as the IoT interface because of the visualization capabilities that allow users to build charts and graphs for monitoring and analysis. The platform integrates with MATLAB, allowing for more advanced data analysis and modelling using MATLAB scripts. ThingSpeak also has an Application Programming Interface (API) for easy interaction with third-party apps, as well as interoperability with a variety of IoT applications for improved device administration. Figure 3.18 shows the ThingSpeak platform and the only downside of ThingSpeak is that with the license option the user can only update the data for every 15 second and not the real time response.

Figure 3.18 ThingSpeak platform

3.7 PID Controller Implementation

This project utilizes a closed-loop system featuring a PID (Proportional–Integral–Derivative) controller to serves as a tool employed by control engineers within industrial control systems for the regulation of variables such as temperature, flow, pressure, speed, and other parameters. Operating through a feedback mechanism within a control loop like in the Figure 3.19, PID controllers are renowned for their precision and stability, making them highly effective in controlling various process variables. In this system, the output is the PWM value that change the speed of the DC motor.

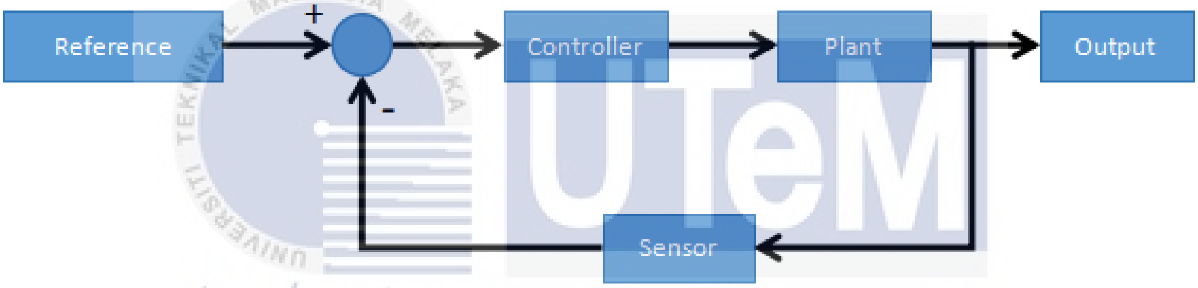

Figure 3.19 Closed-Loop Control System Diagram

In this project, a PID perimeter turning method is employed to identify the most suitable parameters. When tuned optimally and meeting the specified tuning parameters, a PID motor controller effectively minimizes deviation from the set point and promptly responds to disturbances or changes in the set point, all while minimizing overshoot. Despite the availability of controllers with auto-tune capabilities, a fundamental understanding of PID tuning remains essential for achieving optimal performance in motor control applications.

3.7.1 Selection of PID Parameters

The operational principle of a PID controller involves the individual adjustment or 'tuning' of the proportional ("P"), integral ("I"), and derivative ("D") terms. A correction factor is then calculated based on the discrepancy between these values and applied to the input. For this system, if the robot is close to the object or obstacle it will change direction.

Figure 3.20 shows the procedure to choose the suitable PID parameter to design the controller for the system.

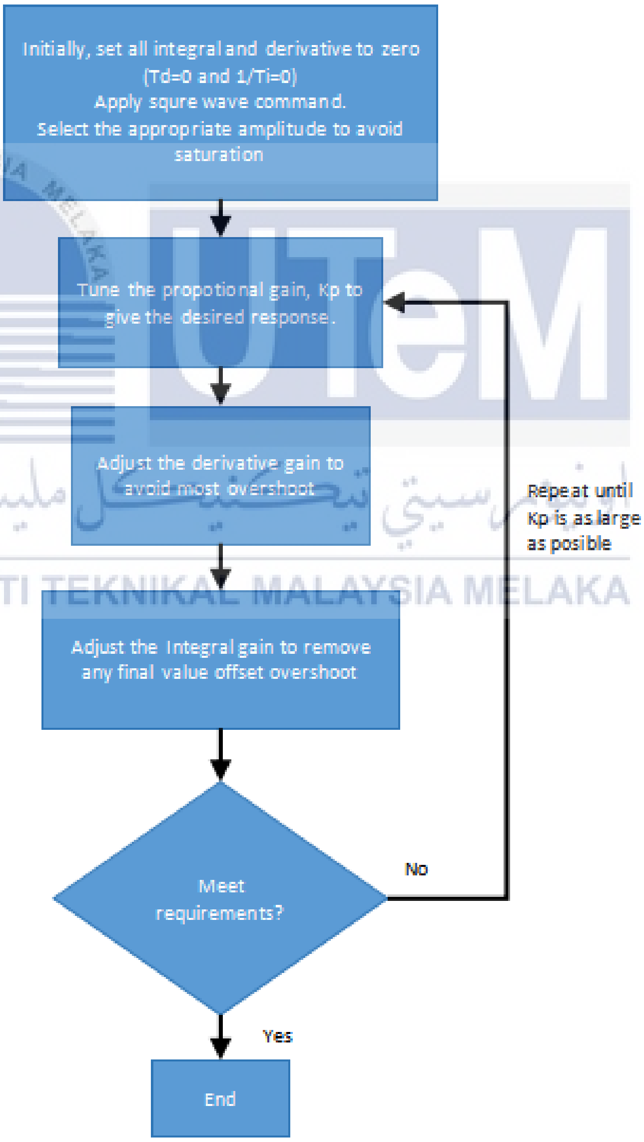

Figure 3.20 PID controller design procedure.

3.8 Integrate Hardware and Software

This section illustrates the process of establishing the connection between hardware and software to achieve the integration of the autonomous lawnmower system.

3.8.1 Circuit design

Circuit design plays a vital role in electronic development projects by selecting components, defining system architecture, ensuring functionality and performance, managing power, enabling signal processing, and facilitating testing and verification. It is a critical step in translating system requirements into practical and functional electronic circuits. Figure 3.21 shown the connection of the component that will used to the esp32 input and output pin.

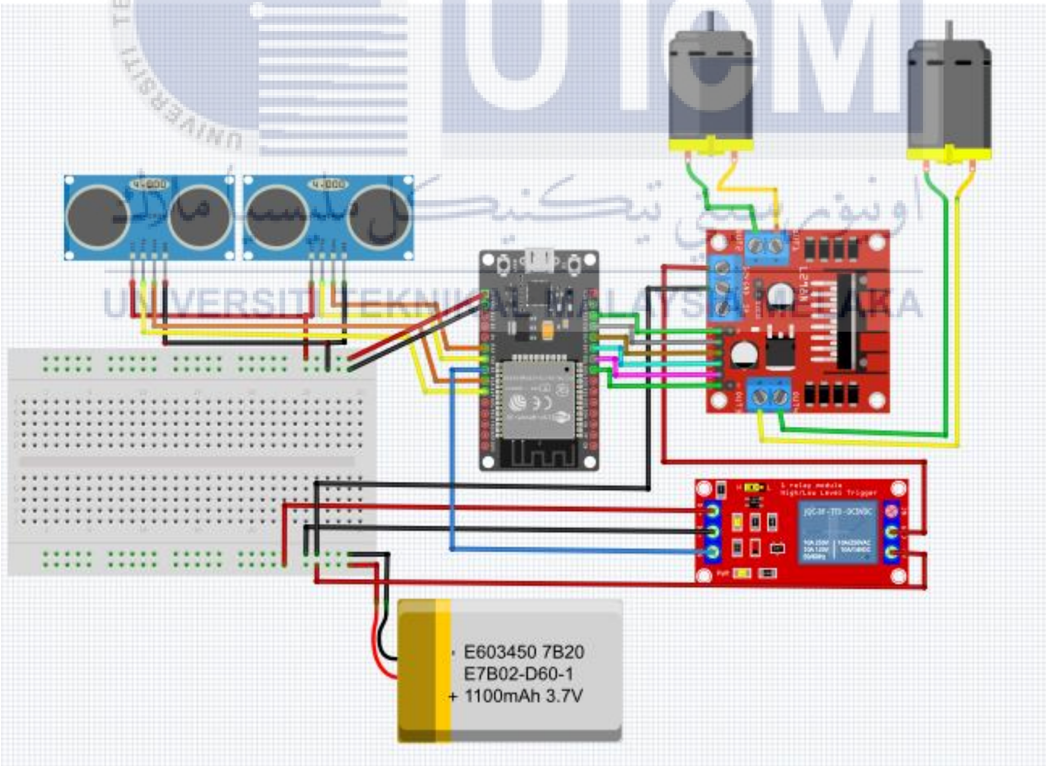

Figure 3.21 Circuit connection

3.8.2 Software Development

In the software development section, it explains about the libraries and algorithms used to complete this project. In this section, it shows how we develop the system for the project and for the Arduino coding it will divide into 2 part which is the controller part and IoT part. Figure 3.22 show the flow chart for the movement of the lawnmower.

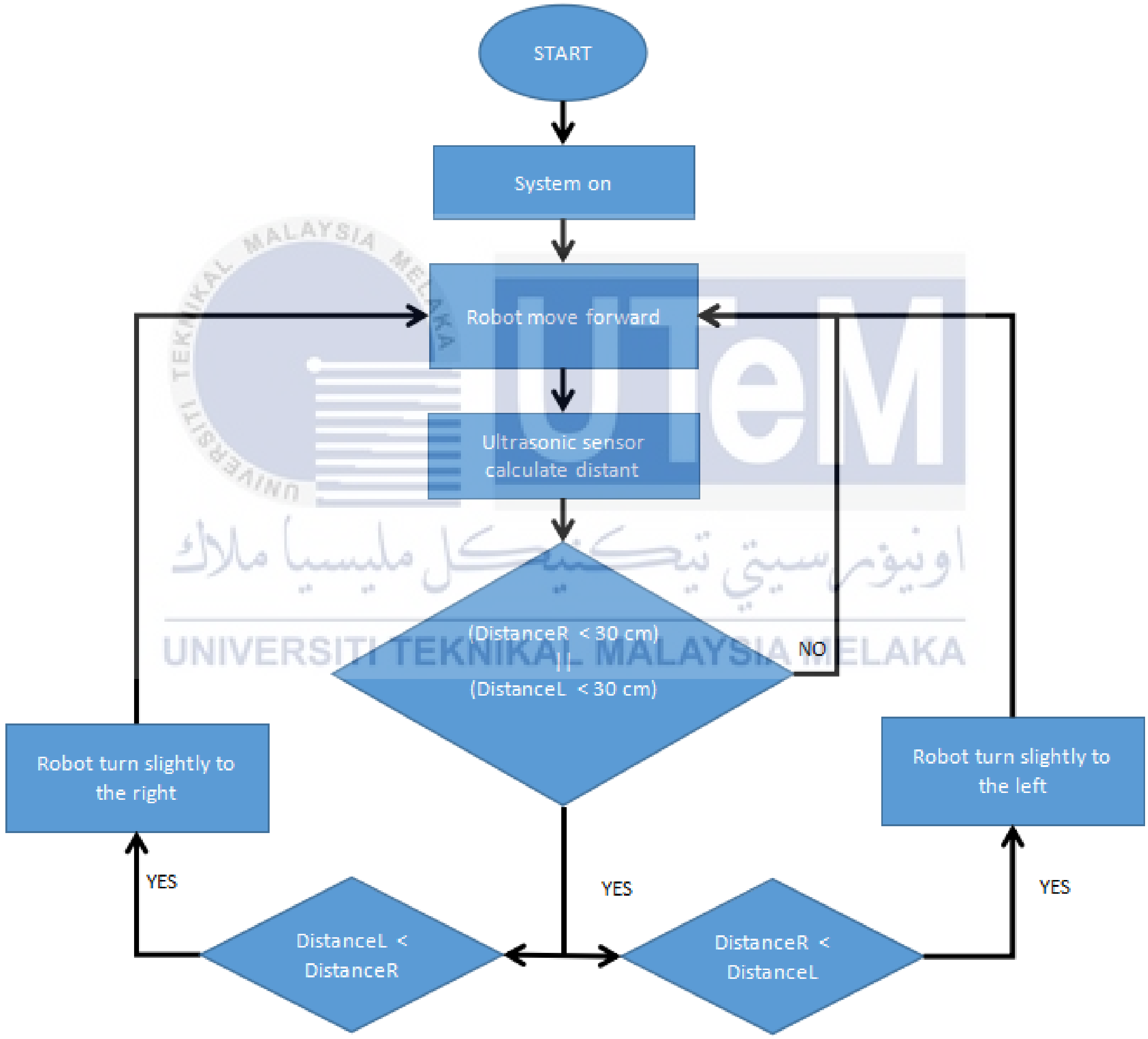

Figure 3.22 Flow chart for the movement

a) Controller Part

Software development in controller part in basically to make the algorithms to make controller for the motor so that in can move according to the system. And as per title name, the controller for the system will be PID controller. Therefore, the coding for the controller will be develop according to the PID perimeter with the ultrasonic sensor as the input and motor speed as the Output.

For PID perimeter, this system will use Arduino PID Library - Version 1.2.3 by David Forrest and Brett Beauregard. Figure 3.23 show the basic coding to implement PID controller into the system.

```
#include <PID_v1_bc.h>

// Define PID parameters
double Kp = 1.0;
double Ki = 0.1;
double Kd = 0.01;

// Define PID input, output, and setpoint variables
double setpoint = 0.0;  // Target value for the controlled variable

// Create PID instance
PID_v1_bc myPID(&input, &output, &setpoint, Kp, Ki, Kd, DIRECT);

void setup() {
  // Initialize  hardware and sensors
  // Set initial values for setpoint, input, and output
  myPID.SetMode(AUTOMATIC);  // Enable the PID controller
}

void loop() {
  // Read sensor input (replace this with your actual sensor reading code)
  input = readSensor();
  // Compute PID output
  myPID.Compute();
  // Apply the PID output to control the lawnmower system (replace this with
your actual motor control code)
  controlLawnmower(output);
}
```

Figure 3.23 Template PID controller

$$\text{Output} = K_P e(t) + K_I \int e(t)\,dt + K_D \frac{d}{dt} e(t)$$

$$\text{Where : } e = \text{Setpoint - Input}$$

Figure 3.24 PID Equation

Figure 3.24 show the calculations that occur when the command "***myPID.Compute()***" is utilized in the code. It takes all the data needed in the command "***myPID(&input, &output, &setpoint, Kp, Ki, Kd, DIRECT)***" and calculated the value for the output in the figure 3.24. In this system, the output is the value of the PWM to control the speed and direction of the motor.

b) IoT Part

In the IoT development part, it used Blynk and ThingSpeak to monitor and control the motor speed based on distance readings. We carefully planned the IoT system's architecture, with Blynk as the platform for real-time user visualization and ThingSpeak for storing and analysing distance-related data. Blynk and ThingSpeak were chosen because they work well together, making integration and data flow efficient.

This IoT for lawnmower utilizes a language ensuring seamless communication between motor control, the distance sensor, and chosen platforms. Performance optimization is achieved through a PID controller adjusting motor speed based on distance data. The Blynk app provides a user-friendly interface for monitoring and control, offering real-time distance data and motor speed control through widgets. ThingSpeak handles data storage and analytics, elucidating the impact of distance variations on motor speed. The lawnmower's software development, centred on Blynk and ThingSpeak integration, showcases effective motor speed monitoring and control based on distance metrics.

To integrate the IoT software into microcontroller we will need to add some coding and library depend on the type of microcontroller that we use. In this project, we use esp32 microcontroller and all additional coding for this software development will be discuss in figure 3.28 below.

```
#define BLYNK_TEMPLATE_ID "*****"
#define BLYNK_TEMPLATE_NAME "LAWNMOWER MONITORING"
#define BLYNK_AUTH_TOKEN "***"
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include "ThingSpeak.h"

#include <PID_v1_bc.h>

BlynkTimer timer;

// Your WiFi credentials.
// Set password to "" for open networks.
char auth[]   = BLYNK_AUTH_TOKEN;
char ssid[]   = "**********";
char pass[]   = "**********";
int keyIndex = 0;           // your network key Index number (needed only for
WEP)
WiFiClient  client;

//Thingspeak
#define SECRET_CH_ID *******
#define SECRET_WRITE_APIKEY "***********"

unsigned long myChannelNumber = SECRET_CH_ID;
const char * myWriteAPIKey = SECRET_WRITE_APIKEY;

void initWiFi() {
  WiFi.begin(ssid, pass);
  Serial.println("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  Blynk.begin(auth, ssid, pass);
```

Blynk user ID

Library for IoT

User Wi-Fi network

ThingSpeak user ID

WiFi connection

```
  //status for success connect
  Serial.println("WiFi CONNECTED");

  Serial.println("");
  Serial.print("Connected to WiFi network with IP Address: ");
  Serial.println(WiFi.localIP());
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

}
void setup() {
  Serial.begin(9600);
  initWiFi();
  initPinMode();

  timer.setInterval(1000L, sendDataToThingSpeak);
}
void loop() {
  Blynk.run();
  timer.run();
  Blynk.virtualWrite(V1, distanceL);  // V1 is the virtual pin for distance
  Blynk.virtualWrite(V3, distanceR);  // V1 is the virtual pin for distance
  Blynk.virtualWrite(V2, Output);    // V2 is the virtual pin for PID output

}
void sendDataToThingSpeak() {

  // set the fields with the values
  ThingSpeak.setField(2, static_cast<float>(Input));
  ThingSpeak.setField(1, static_cast<float>(Output));
  int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
  if (x == 200) {
    Serial.println("Channel update successful.");
  }
  else {
    Serial.println("Problem updating channel. HTTP error code " + String(x));
  }
}
```

Send data to IoT platform.

Figure 3.25   Coding for IoT development

3.8.3 Hardware Preparation

The hardware preparation phase is a foundational element in the development process, laying the groundwork for the successful implementation of any project. The physical components of the system must be carefully arranged, configured, and calibrated at this critical stage. The smooth integration and optimal functioning of the complete system are guaranteed by the careful attention to detail during hardware preparation, regardless of the sensors, actuators, microcontrollers, or other essential components.

This section delves into the specifics of putting the hardware components together and setting them up. The first part is to prepare the cassis or base for the robot. For the cassis, all the components need to be arranged on their position and labelled. It is so, the drill work on the aluminium plate can be done just like in figure 3.29. After done with drill work, all the hardware components can be place at the cassis.

Figure 3.26 Aluminium plate cassis

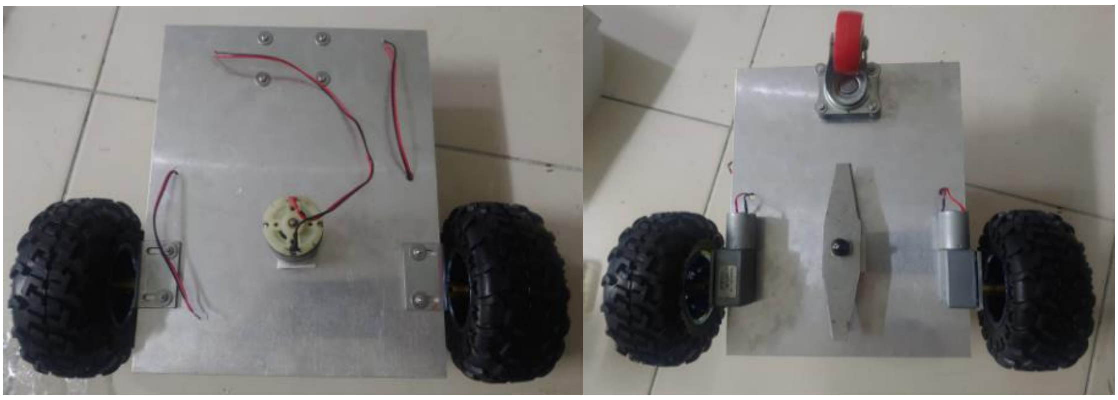

Figure 3.27   Top and bottom view of the cassis

The next part is to design the casing for the lawn mower robot. To design the casing for the robot, it is imperative to meticulously gather essential measurements encompassing its height, length, and width. For the casing, this lawnmower will the ABS plate as the casing material.

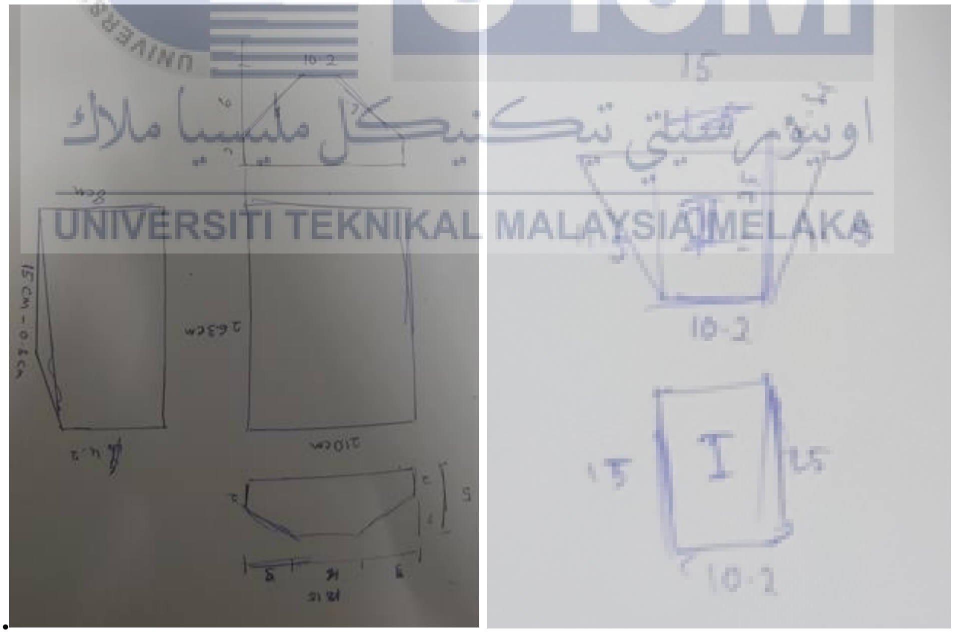

Figure 3.28   Early measurement for the casing

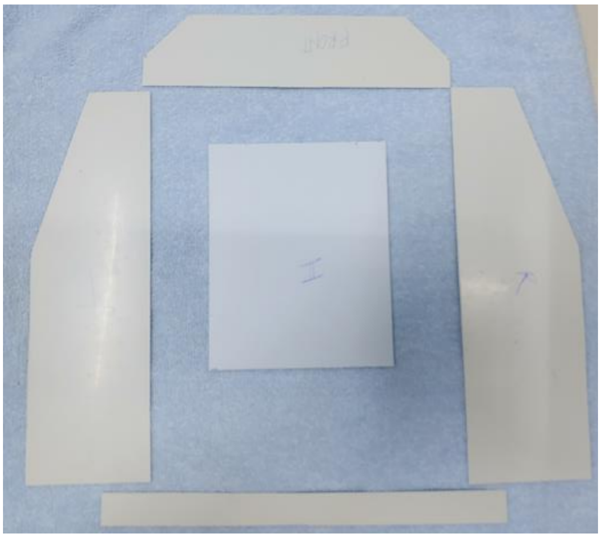

Figure 3.29 Cut the ABS plate into section.

Figure 3.30 Combine all sections.

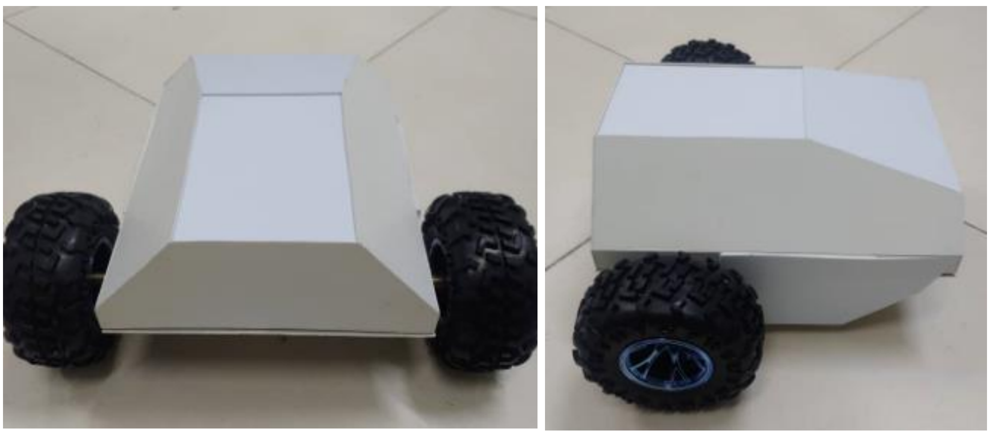

Figure 3.31 Casing testout on cassis.

And lastly is to make the circuit connection on the cassis to finalise and testing the product function.

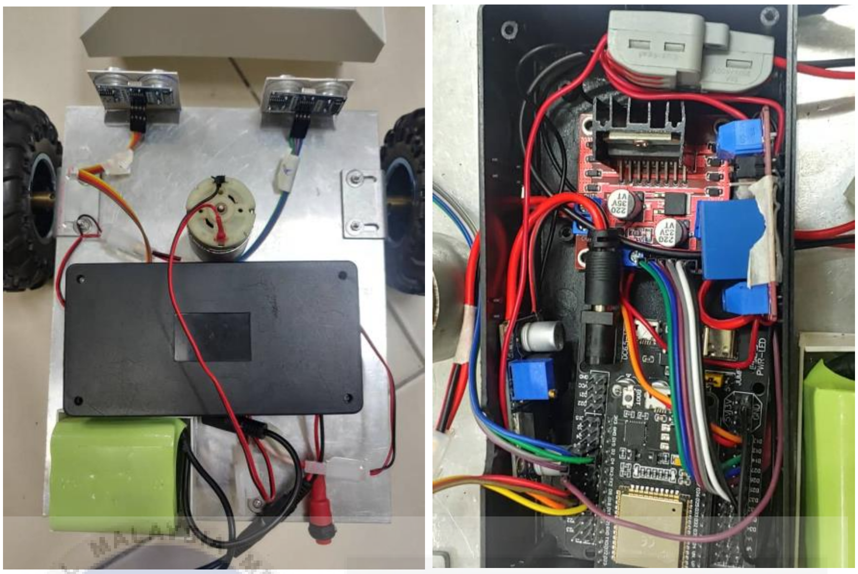

Figure 3.32 Control box connection.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, we look at the performance of the lawn mower, which is now equipped with a PID controller and an IoT monitoring system. The focus is on examining the practical results of this development, which go beyond mere numerical data. The aim is to understand the effectiveness of the lawn mower with its PID system and to evaluate the performance of the lawnmower and added value of the IoT monitoring system.

Aspects such as the responsiveness of the lawn mower to speed changes, its ability to deal with varying conditions and the contribution of the IoT system in providing real-time data will be investigated. The aim of this discussion is to analyse the results, highlight successes and identify areas for improvement.

4.2 PID Controller Tuning

The developed lawnmower system's PID controller's performance turned out to be crucial for preserving exact control over the moving process. The PID algorithm's proportional, integral, and derivative components allowed the controller to respond to setpoint deviations with a high degree of accuracy and consistency.

To get the desired output from the PID controller system, we need to configure the suitable value for PID perimeter. In this development process, some tuning has been done to achieve the desired level of performance and responsiveness in the lawnmower system.

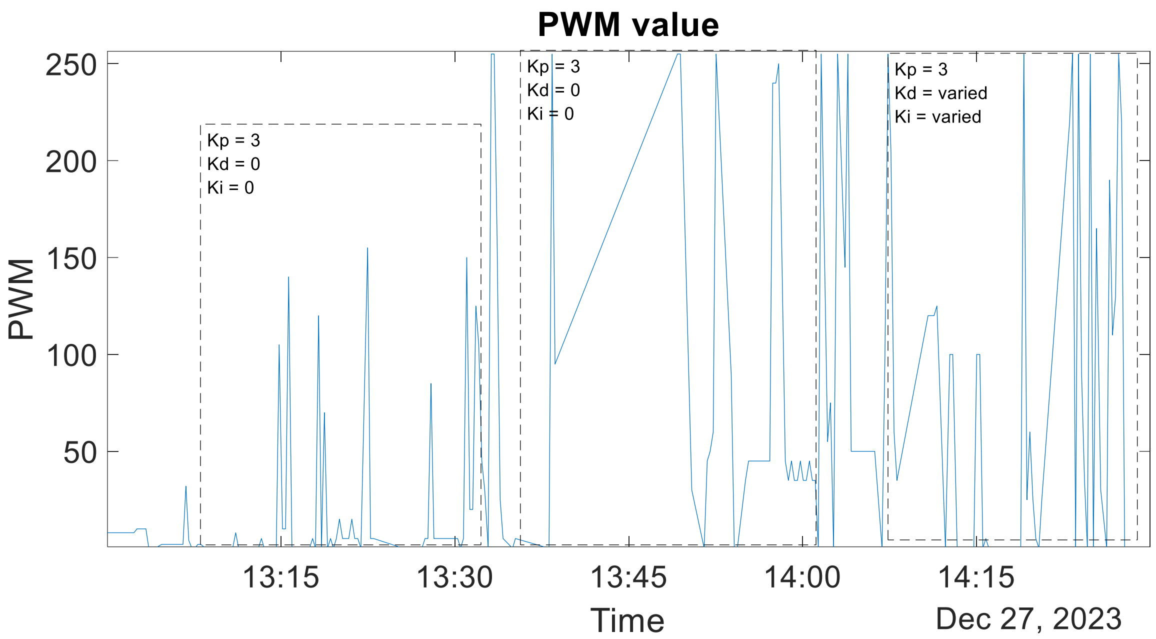

Figure 4.1 Experimental result with different PID perimeter.

To find the suitable perimeter, a series of experiments were conducted, involving the systematic configuration of different values for the proportional gain (Kp), derivative gain (Kd), and integral gain (Ki). In these experiments, the lawnmower's speed response concerning distance was analysed, with the setpoint fixed at 20. Figure 4.1 presents the outcomes obtained under various PID parameter configurations.

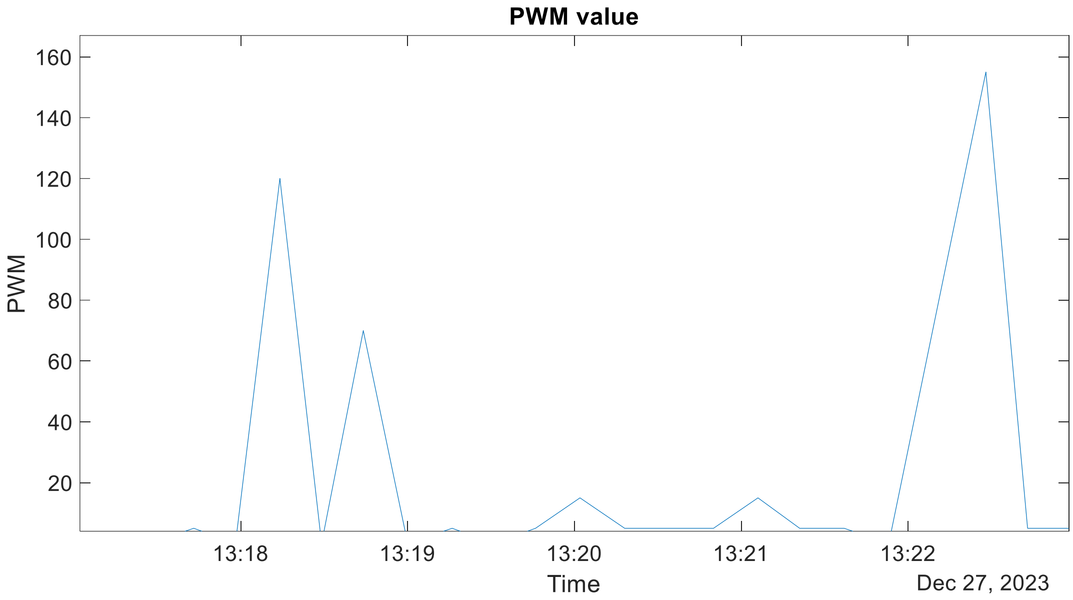

Figure 4.2 Experimental result with different PID perimeter (Kp = 3)

Figure 4.2 shows a PID controller with a Kp set to 3 was employed. Despite this setting, the output value reached only 155, indicating a partial utilization of the maximum available value of 255.

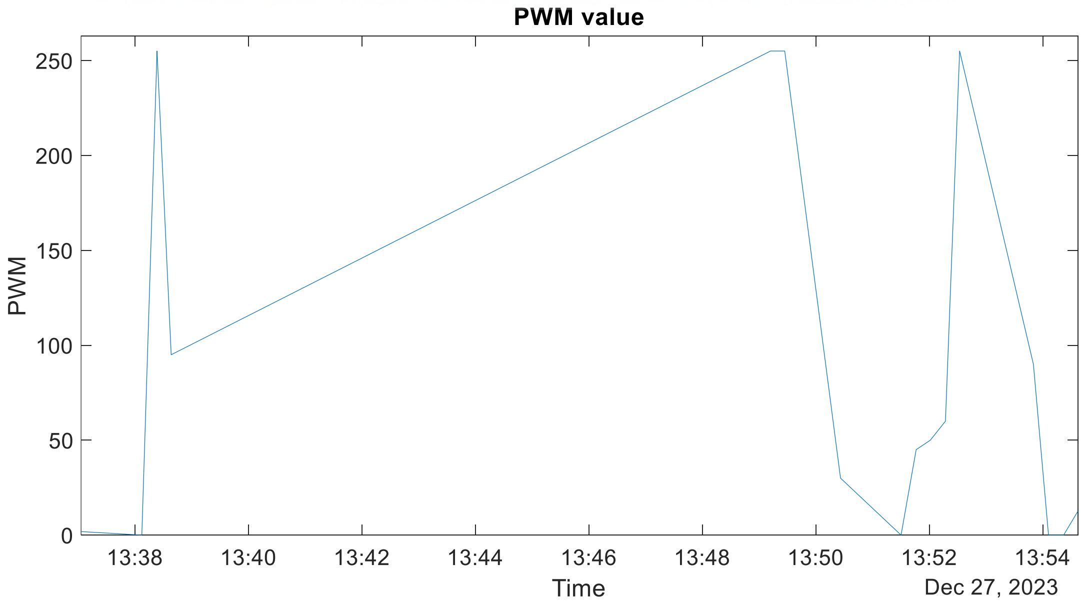

Figure 4.3 Experimental result with different PID perimeter (Kp = 5)

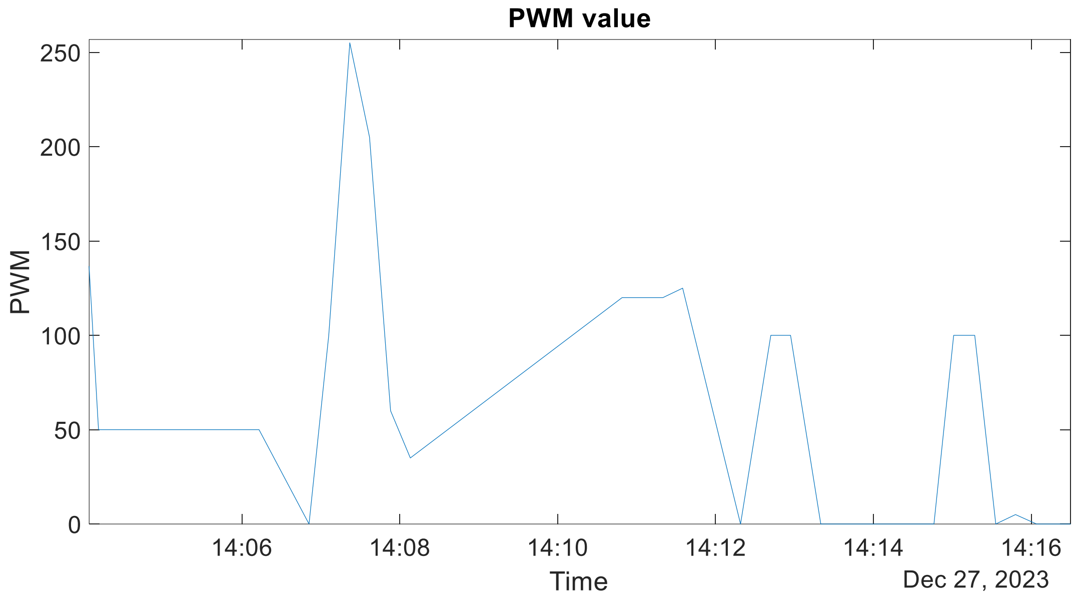

Figure 4.4 Experimental result with different PID perimeter (Kp=5 & Kd,Ki =0.5)

In the figure 4.3, with the Kp adjusted to 5, the PID controller demonstrates an increased response. The speed output successfully reaches the maximum value of 255 when the distance is below the setpoint. Additionally, notable speed adjustments occur as the lawnmower approaches the setpoint, highlighting the impact of the altered Kp value on the system's behaviour. Given these outcomes, it prompts consideration of potential effects when adjusting the Kd and Ki values. The observed from figure 4.4 show the sensitivity to distance changes suggests that fine-tuning Kd and Ki may further optimize the lawnmower's responsiveness and stability in maintaining the desired setpoint.

4.3 Performance Evaluation

The lawnmower's performance evaluation is a comprehensive study that emphasizes two vital areas: movement speed and obstacle detection response. One of the key components of the lawnmower's overall efficiency is its ability to travel quickly and effectively over a variety of terrains. Simultaneously, the assessment extends to the lawnmower's response mechanism when encountering obstacles, ensuring a safe and adaptive operation. By focusing on important components that enhance the lawnmower's usability and functionality, this review seeks to offer a thorough grasp of its capabilities. In this sub-section experiment, the final value of PID perimeter is set to Kp = 9, Kd = 2, and Ki = 1 and the setpoint of 25.

4.3.1 Moving Speed

When evaluating the performance of the lawnmower, particularly its movement speed on the different surface and situation. An experiment has been conducted and all the data from this experiment is to be analyzed and present in this sub-topic.

Table 4.1 presents the results of speed tests conducted physically on the lawnmower across diverse surfaces. The time taken to cover 2 meters is recorded for each surface type, providing insights into the lawnmower's performance and adaptability in different outdoor environments. From the table below we can see there is the difference between the time taken for the lawnmower to move for 2m in the flat surface and grassy surface. Because of the differences in land elevation, the lawnmower takes longer to go across a grassy area than it does on a flat one. Furthermore, the state of the grass itself influences the dynamics of movement, leading to different periods for doing the task of mowing.

Table 4.1 Comparative Analysis of Lawnmower Speed Across Different Surfaces, Measured in Seconds to Cover 2 Meters

No. of test	Time taken for covering 2 Meters (s)		
	Flat Surface	Grassy Surface	
		Wet	Dry
1	9.80	10.75	10.23
2	9.84	11.25	10.55
3	9.71	11.09	10.15
4	9.75	10.95	9.80
5	9.80	11.17	10.26
6	9.84	10.44	9.76
7	9.86	11.15	10.15
8	9.73	10.45	9.85
9	9.88	10.85	10.24
10	9.75	11.15	10.45
Average	9.796	10.925	10.144

4.3.2 Obstacle Detection Response

In the following experiment, the objective is to assess the lawnmower's responsiveness to encounters that occur in its path. This evaluation involves diverse scenarios, including obstacle detection and the presence of individuals or objects passing in front of the lawnmower. The experiment is designed to ascertain the lawnmower's ability to effectively respond to various situations, emphasizing its role in ensuring safety during operation.

Figure 4.2 displays the response data retrieved from the ThingSpeak IoT interface. This graphical representation visually depicts the modulation of PWM values in response to robot detecting and maneuvering around obstacles. It's essential to note that the ThingSpeak platform updates data every 15 seconds. Consequently, the graphs presented in ThingSpeak may exhibit gaps due to the intermittent nature of the data updating process.

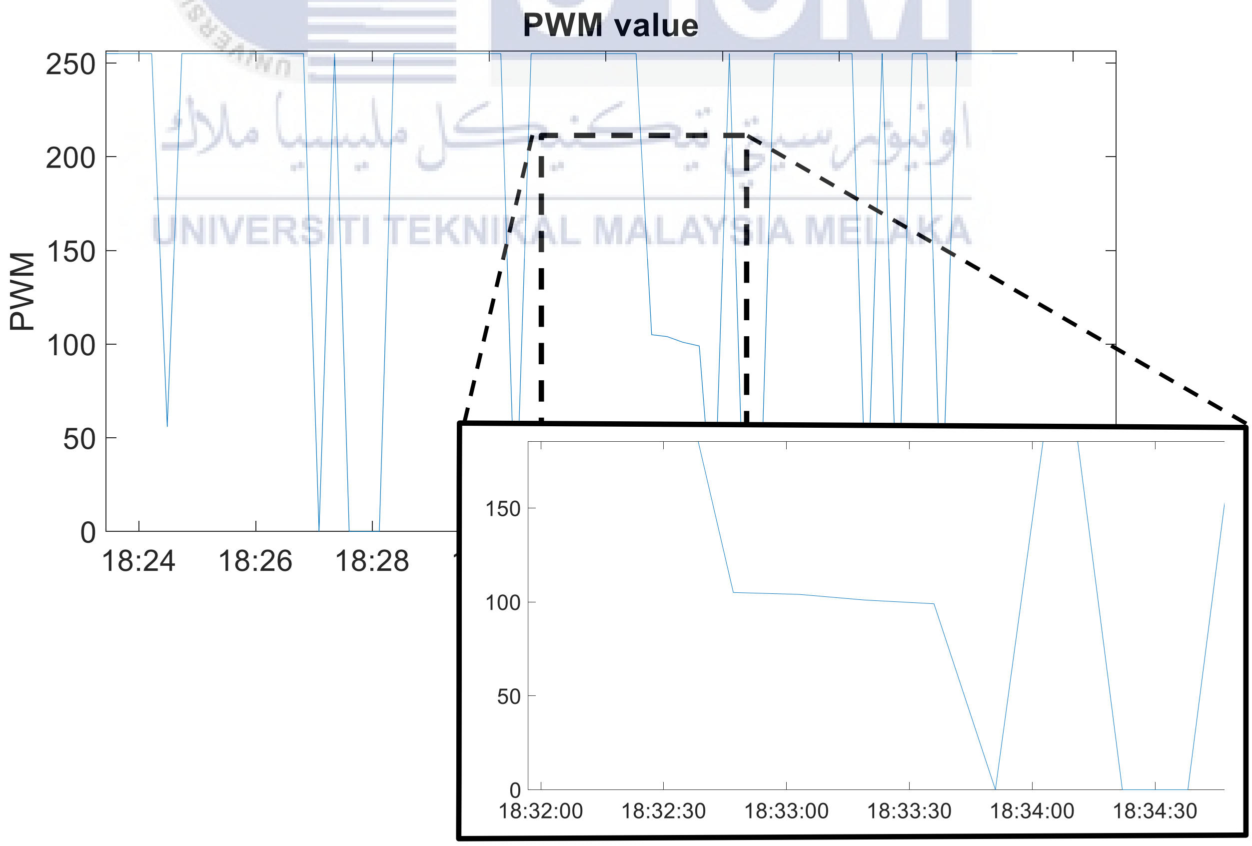

Figure 4.5 Response from the Thingspeak.

Table 4.2 presents some of the outcomes derived from the real-time data in Blynk IoT interface. From the table, we can see the change in the PWM value depend on the distance of the object or obstacles. When the robot detects an object in its path, the PWM (Pulse Width Modulation) value will be reduced, causing the robot to decelerate before altering its direction to evade obstacles. This adjustment is aimed at ensuring the robot slows down when an obstacle is nearby, facilitating obstacle avoidance manoeuvres. Once the object is at a considerable distance, the PWM value is adjusted again to restore the robot to its original speed, allowing it to resume its normal pace when the obstacle is no longer a threat.

Table 4.2 Output response from the distance

	PWM Value	Distance	Action
1	139.3	31	Slow-down
2	104.2	26	
3	152.35	32	
4	0	19	Change direction
5	0	19	
6	255	116	Regular speed
7	255	114	
8	55.4	29	Slow-down
9	70.4	18	
10	10	16	Change direction
11	0	9	
12	0	9	
13	54.9	24	Slow-down
14	96.25	30	
15	124.25	36	

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the development of an autonomous lawnmower focuses on creating a self-operating robotic system capable of navigating and maintaining lawns without human intervention. This objective involves integrating cutting-edge technologies, such as sensors and controller to enable the lawnmower to autonomously detect and avoid obstacles. By achieving this objective, we pave the way for a future where lawn care becomes easier, more efficient, and environmentally friendly.

In essence, the successful completion of this project marks a significant advancement in lawnmower technology, showcasing the potential of integrating intelligent control systems and IoT capabilities. The autonomous lawnmower developed through this project stands as a testament to innovation in the field of lawn care, providing users with a sophisticated and user-friendly solution for maintaining their lawns with precision, efficiency, and enhanced safety.

The accomplished objectives are as follows:

a) Able to develop and design an autonomous lawnmower by using a Proportional Integral Derivative (PID) controller.

b) We successfully developed an appropriate controller and implemented an IoT monitoring system for efficient data collection. Employing an ESP32 as the microcontroller, we integrated a PID controller to regulate movement. Additionally, we utilized both Blynk and

ThingSpeak as IoT monitoring systems, enhancing our capability to collect and manage data effectively.

c) Able to analyse and evaluate the system performance in term of position and obstacle avoided. The accomplished goals encompass the attainment of real-time results facilitated using Blynk applications. This platform offers instantaneous access to data. In contrast, the accomplishment with ThingSpeak revolves around updates occurring at 15-second intervals. Although this platform yields valuable data, its update frequency operates with a slight delay compared to the immediate data acquisition capability of real-time systems like Blynk.

5.2 Potential for Commercialize

The developed autonomous lawnmower, featuring a PID controller and IoT monitoring system, exhibits substantial potential for commercialization owing to its multifaceted advantages. Its core strength lies in the efficiency it brings to lawn maintenance, saving users valuable time and effort through autonomous operation. The user-friendly technology, facilitated by the PID controller and IoT interface platforms like Blynk, ensures accessibility to a broad spectrum of users. Moreover, the lawnmower aligns with the growing emphasis on environmental sustainability by reducing resource overuse, fuel consumption, and emissions. The adaptability of the PID controller allows precise control, catering to various terrains and grass heights for a tailored lawn care experience. Safety features, including obstacle avoidance technology, enhance its appeal. Scalability for larger lawns or commercial applications, coupled with the potential for fleet management systems, positions it as a viable solution for large-scale lawn care. In tandem with the burgeoning demand for smart home technologies and eco-friendly solutions, the autonomous lawnmower taps into market trends. Continuous technological advancements offer avenues for future enhancements, providing a competitive edge over traditional lawnmowers. Strategic partnerships with landscaping companies, smart home technology providers, or IoT platform developers could further amplify its market presence and commercial success.

5.3 Future Work

In considering the promising strides made in the development of the lawnmower using a PID controller with an IoT monitoring system, there exists a compelling avenue for future work to propel this technology even further. As we reflect on the achievements of the current project, it becomes evident that numerous opportunities lie ahead for innovation and refinement. The subsequent exploration of future work aims to delve into advanced realms of technology, artificial intelligence, energy efficiency, and user-centric enhancements to augment the capabilities of the smart lawnmower. This journey into the future endeavors to push the boundaries of autonomy, efficiency, and environmental adaptability, ushering in a new era for intelligent lawn care solutions.

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APPENDICES

Appendix A   Coding for ESP 32 Wroom

```
#define BLYNK_TEMPLATE_ID "TMPL6bC8S8IQU"
#define BLYNK_TEMPLATE_NAME "LAWNMOWER MONITORING"
#define BLYNK_AUTH_TOKEN "K84POjd0wYkaTspVFJW_WcQJe4nIdyff"
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include "ThingSpeak.h"

#include <PID_v1_bc.h>

BlynkTimer timer;

// Your WiFi credentials.
// Set password to "" for open networks.
char auth[]  = BLYNK_AUTH_TOKEN;
char ssid[]  = "KAKI REPORT";
char pass[]  = "0104018299";
int keyIndex = 0;          // your network key Index number (needed only for WEP)
WiFiClient  client;

//Thingspeak
#define SECRET_CH_ID 2374788
#define SECRET_WRITE_APIKEY "UIVC2YQU5JFTO5FH"

unsigned long myChannelNumber = SECRET_CH_ID;
const char * myWriteAPIKey = SECRET_WRITE_APIKEY;

void initWiFi() {
  WiFi.begin(ssid, pass);
  Serial.println("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  Blynk.begin(auth, ssid, pass);

  //status for success connect
  Serial.println("WiFi CONNECTED");
```

```
  Serial.println("");
  Serial.print("Connected to WiFi network with IP Address: ");
  Serial.println(WiFi.localIP());
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

}
//================================================================
=========================
// Motor A
const int PWM_A = 13; //11;    // PWM input for motor A
const int motorA1 = 12; //10;  // L298N input 1
const int motorA2 = 14;// 9;  // L298N input 2

// Motor B
const int PWM_B = 25  ; //6;   // PWM input for motor B
const int motorB1 = 27; // 7;  // L298N input 3
const int motorB2 = 26; //8;  // L298N input 4


// Ultrasonic sensor
const int trigPinR = 16;// A0;  // Trigger pin
const int echoPinR = 17; //A1;  // Echo pin
const int trigPinL = 18;// A0;  // Trigger pin
const int echoPinL = 19; //A1;  // Echo pin

//relay motorSwitch
const int relayPin = 5;
int PWM;

// PID parameters
double Setpoint = 25;   // Desired distance from obstacle
double Input, Output;
double Kp = 9;        // Proportional term
double Ki = 1.0;       // Integral term
double Kd = 2.0;       // Derivative term

PID myPID(&Input, &Output, &Setpoint, Kp, Ki, Kd, DIRECT);

void initPinMode() {
  // Motor pins setup
  pinMode(motorA1, OUTPUT);
  pinMode(motorA2, OUTPUT);
  pinMode(PWM_A, OUTPUT);
  pinMode(motorB1, OUTPUT);
  pinMode(motorB2, OUTPUT);
  pinMode(PWM_B, OUTPUT);

  // Ultrasonic sensor pins setup
  pinMode(trigPinR, OUTPUT);
```

```
  pinMode(echoPinR, INPUT);
  pinMode(trigPinL, OUTPUT);
  pinMode(echoPinL, INPUT);
  pinMode(relayPin, OUTPUT);

  digitalWrite(relayPin, LOW);
}
//=========================================================================================
void setup() {
  Serial.begin(9600);
  initWiFi();
  initPinMode();

  // PID setup
  myPID.SetMode(AUTOMATIC);
  myPID.SetOutputLimits(255, -255);

  timer.setInterval(1000L, sendDataToThingSpeak);
}
//=========================================================================================
void loop() {
  Blynk.run();
  timer.run();

  int distanceR = getDistanceR();
  int distanceL = getDistanceL();
  // Set the input for PID controller
  Input = (distanceR+distanceL)/2; //average of left and right sensor

  // Compute PID output
  myPID.Compute();

  int motorSpeed = abs(Output);
  PWM = 255-motorSpeed;

  // Move forward if there is no obstacle, turn right if there is an obstacle
  if ((distanceR < 30) || (distanceL < 30)){
    if (distanceR >= distanceL){
      // Turn right
      motorControl(255, -255);
      delay (80);
    }else if (distanceL > distanceR){
      // turn left
      motorControl(-255, 255);
      delay (80);
      } else {
      }
```

```
  } else {
    //move forward
    motorControl(PWM, PWM);
    }

  // Print distance and PID output for debugging
  Serial.print("Distance Right: ");
  Serial.print(distanceR);
  Serial.print("cm,   Distance Left: ");
  Serial.print(distanceL);
  Serial.print("cm,   Average distance ");
  Serial.print(Input);
  Serial.print(" cm,   Output: ");
  Serial.println(Output);
   Serial.print(" PWM: ");
  Serial.println(PWM);

  Blynk.virtualWrite(V1, distanceL);  // V1 is the virtual pin for distance
  Blynk.virtualWrite(V3, distanceR);  // V1 is the virtual pin for distance
  Blynk.virtualWrite(V2, PWM);    // V2 is the virtual pin for PID output

  delay(100);

}


 int getDistanceR() {
  digitalWrite(trigPinR, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPinR, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinR, LOW);

  return pulseIn(echoPinR, HIGH) / 58;  // Convert pulse duration to distance in cm
}

 int getDistanceL() {
  digitalWrite(trigPinL, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPinL, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinL, LOW);

  return pulseIn(echoPinL, HIGH) / 58;  // Convert pulse duration to distance in cm
}


void motorControl(int speedA, int speedB) {
  // Motor A control
  if (speedA > 0) {
```

```
    analogWrite(PWM_A, speedA);
    digitalWrite(motorA1, HIGH);
    digitalWrite(motorA2, LOW);
  } else {
    analogWrite(PWM_A, -speedA);
    digitalWrite(motorA1, LOW);
    digitalWrite(motorA2, HIGH);
  }

  // Motor B control
  if (speedB > 0) {
    analogWrite(PWM_B, speedB);
    digitalWrite(motorB1, HIGH);
    digitalWrite(motorB2, LOW);
  } else {
    analogWrite(PWM_B, -speedB);
    digitalWrite(motorB1, LOW);
    digitalWrite(motorB2, HIGH);
  }
}


BLYNK_WRITE(V0) {  // Virtual pin for Blynk switch widget
  int relayState = param.asInt();
  digitalWrite(relayPin, relayState);
}

void sendDataToThingSpeak() {

  // set the fields with the values
  ThingSpeak.setField(2, static_cast<float>(Input));
  ThingSpeak.setField(1, PWM);
  //ThingSpeak.setField(3, motorSpeedRPM);
  // write to the ThingSpeak channel
  int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
  if (x == 200) {
    Serial.println("Channel update successful.");
  }
  else {
    Serial.println("Problem updating channel. HTTP error code " + String(x));
  }
}
```