Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF MOBILE ROBOT FOR FLOOR LEVEL INSPECTION

RAIHANAH BINTI AZAMAN

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

2021

DEVELOPMENT OF MOBILE ROBOT FOR FLOOR LEVEL INSPECTION

RAIHANAH BINTI AZAMAN

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

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled "(Development of Mobile Robot for Floor Level Inspection)" 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.

Signature :

Student Name : RAIHANAH BINTI AZAMAN

Date : 15/2/2022

APPROVAL

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.

Signature :

Supervisor Name : EN AMINNURASHID BIN NOORDIN

Date : 15/2/2022

Signature :

Co-Supervisor Name (if any) :

Date :

DEDICATION

To my beloved mother,Lokmas Binti Ahmad, and father,Azaman Bin Abd Ghani,

ABSTRACT

This project is a specialization of the design and development of mobile robots for floor level inspection. The project uses a smartphone app created with the MIT App Inventor app. In addition, the project focuses on the performance of robots during movement. Among the hardware available on this car such as Arduino UNO, Motor Driver L298N, Bluetooth Module HC-05, Motor DC and MPU6050. The main objective of developing and designing this robotic car was to create a vehicle capable of measuring floor inclination. In addition, the project can be used to control and monitor the movement of robotic cars via smartphones. In fact, the project is capable of automating medium to manual inspection processes to robotic applications. According to the experiments that have been conducted, this robot car has gone through 15 tiles with varying angles. This robot car also went through the floor in the FTK Lobby and the house. Typically, these robotic systems are used before or after the construction process. Through the results of the study findings show that the use of robotic systems allows more accurate monitoring than manual assessment. Finally, with this project, the opportunity to assist the workforce in the mission of measuring the slope of the floor can be overcome in addition to saving time.

ABSTRAK

Projek ini merupakan pengkhususan reka bentuk dan pembangunan robot mudah alih bagi pemeriksaan aras lantai. Projek ini menggunakan aplikasi telefon pintar yang dibuat dengan aplikasi MIT App Inventor. Selain itu, projek ini memberi tumpuan kepada prestasi robot semasa pergerakan. Antara perkakasan yang terdapat pada mobil ini seperti Arduino UNO, Motor Driver L298N, Modul Bluetooth HC-05, Motor DC dan MPU6050. Objektif utama membangunkan dan merekabentuk mobil robot ini adalah untuk mencipta kenderaan yang mampu mengukur kecondongan lantai. Selain itu, projek ini boleh digunakan untuk mengawal dan memantau pergerakan mobil robot melalui telefon pintar. Malahan juga, projek ini berkebolehan untuk medium automasi kepada proses pemeriksaan manual kepada aplikasi robotik. Mengikut uji kaji yang telah dijalankan, mobil robot ini telah melalui 15 jubin dengan sudut yang berbeza-beza. Mobil robot ini juga melalui lantai di Lobi FTK dan rumah. Kebiasaanya, sistem robotik ini digunakan sebelum atau selepas proses pembinaan. Melalui hasil dapatan kajian menunjukkan bahawa penggunaan sistem robotik membolehkan pemantauan yang lebih tepat daripada penilaian manual. Akhir sekali, dengan adanya projek ini, peluang untuk membantu tenaga pekerja dalam misi mengukur kecodongan lantai dapat diatasi selain dapat menjimatkan masa

.ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Ts. Aminnurashid Bin Noordin.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) and parents for the financial support through advice which enables me to accomplish the project. Not forgetting my fellow colleague, Tan Kim Loong for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents, and family members for their love and prayer during the period of my study. An honourable mention also goes to friends for all the motivation and understanding. And to my friend, Akmal Zakwan thanks for share the idea of Soliwork.

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

δ	-	Voltage angle
°	-	Angle
x	-	Value of roll
y	-	Value of pitch
	-	
	-	
	-	
	-	

LIST OF ABBREVIATIONS

V	-	Voltage
CIDB	-	Construction Industry Development Board
	-	
	-	
	-	
	-	
	-	
	-	

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is undergoing rapid development in this world. This rapid development and construction are being carried out by grade A contractors. Before being sold, housing estates, commercial buildings, and offices must maintain their quality. The local government international corporation, the Construction Industry Standards Board (CIDB), is fully responsible for measuring and evaluating the quality of building construction work by the Construction Industry Standards.

The Construction Industry Standards include a floor level inspection as one of the evaluation criteria. The CIDB officer typically performs the measurements manually, using tools like a spirit level. Since it being done manually, many disadvantages such as parallax error, instrument error, spend more time to measure and tired may occurs due to human behavior factor.

Therefore, with advanced in technologies, this manual assessment can be replaced by robotic system to speed-up the assessment processing time and cover most numbers of buildings to be inspect instead of randomly chosen by developer or CIDB itself.

This project aims to develop a mobile robot capable of performing floor level inspections as one of the assessment criteria in CIBD's Construction Industry Standards. The concept for this project is illustrated in Figure 1, where the comparison system flow. The mobile robot is controlled by MIT App Inventor.

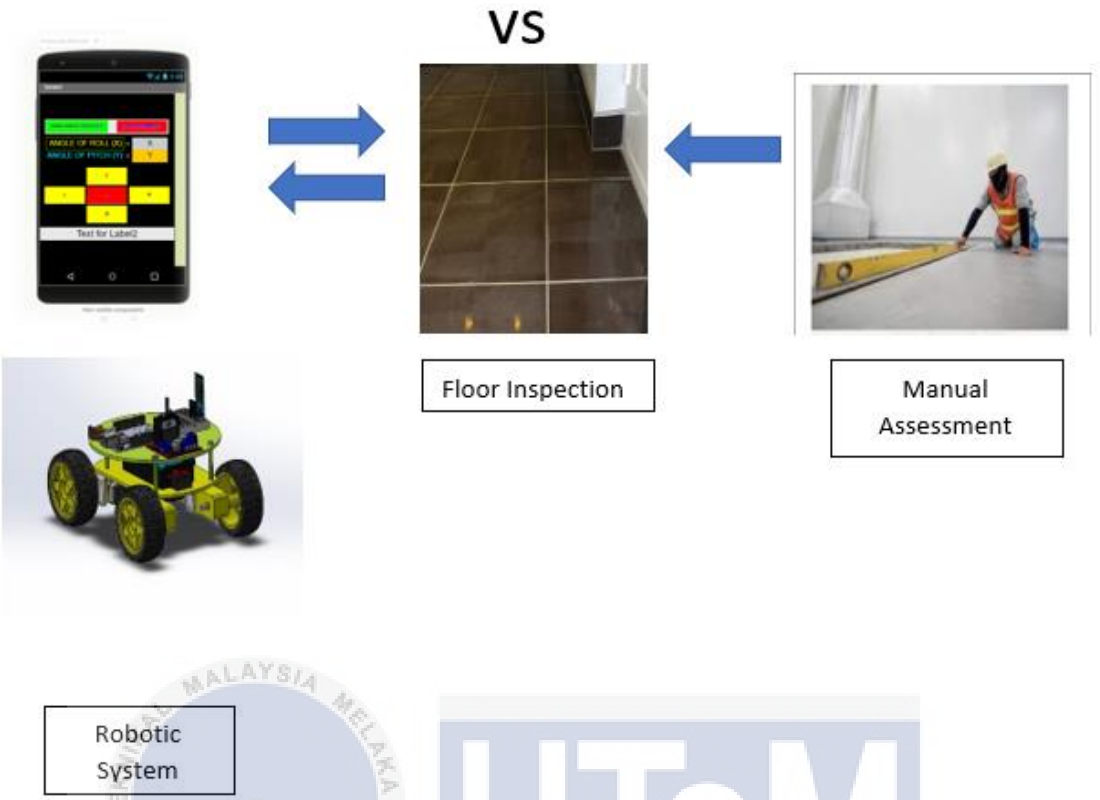


Figure 1: The comparison system flow

1.2 Problem Statement

Many important elements must be emphasized by CIDB in the construction of new buildings before they are sold to developers. Floor level inspection is one of the things that must be emphasized. Floor level inspections are typically detected manually by CIDB officers. They use a spirit level as their measuring tool.

They used their full energy for floor level inspection. This procedure must be carried out under meticulous conditions. They must bend down to determine whether the water balance is upright or not. The manual inspector may get tired after some time and the inspection accuracy may decrease over time. The state of angle roll and angle pitch cannot be read by the instrument manual. This procedure is also time-consuming and tiresome.

Other than that, there are two types of error when doing floor level inspection manually. First, systematic error caused by surveying equipment, observation method and certain environmental factors. For examples of systematic errors such as using not applying curvature and using an incorrect prism offset such as retractable angle mirror and spirit level. Secondly, manual measurement level surface can cause random error. Random error not directly to the condition of observation. Not All floor surface level checked and recorded.

Considering this time-consuming, tiresome, and uninteresting procedure, and motivated by a large market demand for robot construction. As a result, the Mobile Robot for Floor Level Inspection was created to prevent this from happening again. In today's technology, the design of a mobile robot for level inspection can make it easier for CIDB officers to inspect than manual instruments.

1.3 Project Objective

The objectives of this project are as follows:

a) To design a mobile robot for floor level inspection.

b) To control and monitor the motion of the robot for floor level inspection.

c) To automate process from manual inspection using tools to using robotics application.

1.4 Scope of Project

By narrowing the needs for this project, a few guidelines are proposed to ensure that this project will achieve its objectives. The scopes covered for this project are:

i. To design four wheels mobile robot for floor level inspection.

ii. The size robots about 150mm x 135mm.

iii. Using MPU6050 as sensor for floor level measurement.

iv. Using Arduino UNO as microcontroller board.

v. The communication between robot and smart phone using Bluetooth.

vi. Controlling the motion of mobile robot using smartphone.

viii. Monitor and display the leveling floor level inspection by smartphone.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss about the articles related to this project. It consists of the product developed prior to this project by institution. The purpose of this chapter is to provide enough study-related information before going into depth in the next few chapters.

2.2 Building Assessment

Construction Industry Development Board (CIDB) is organization that responsible to measure and evaluate the workmanship quality of building construction based on Construction Industry Standard (CIS 7: 2006). Based on (Construction Industry Development Board of Malaysia, 2019a), objective CIDB is to benchmark the quality of workmanship of the construction industry. Besides, this objective also to establish a standard quality assessment system on quality of workmanship of construction work. Ten percent from total house in Malaysia will be checked by CIDB. CIDB officer measure floor level surface in building such as residential house manually using tapping rod, L square, steel wedge, steel rule, retractable angle mirror, spirit level, measuring tape and hard cover casing. In this building assessment, not just inclination, but hollowness, cracks, and alignments are included.

2.2.1 Hollowness problem

According to (Lesley, 2020), there are many causes that may the floor hollowness. The characteristics that may cause hollow when the concrete substrate not prepare properly due to concrete surface too dense and not absorb moisture well. Next, the tiles not properly cleaned before application. Other factors that contribute to debonding are excessive floor deflection. Hollowness problem in building assessment occurs when tile is installed over a less dense substrate. On the other hand, (Yan et al., 2019) state that the hollowness problems can be seen under wall or floor tiles because not doing work properly. If the surface and tile are wrong adhesives not doing properly wrong adhesives which can possibly cause a broken tile because it is not stressed uniformly. Hollowness defects can be found by distinguishing the sound difference produced by and without a tile.

(Rectification, 2017) state that there was so many hollowness that effect building assessment such as squeaking sound on wood floor. This possible can cause types of sub floor installed. Besides, the floor slab with thinner adhesive. Next, insufficient bonding for the planks with sub floor. Figure 2.1 shows the differential of type which can make hollowness.

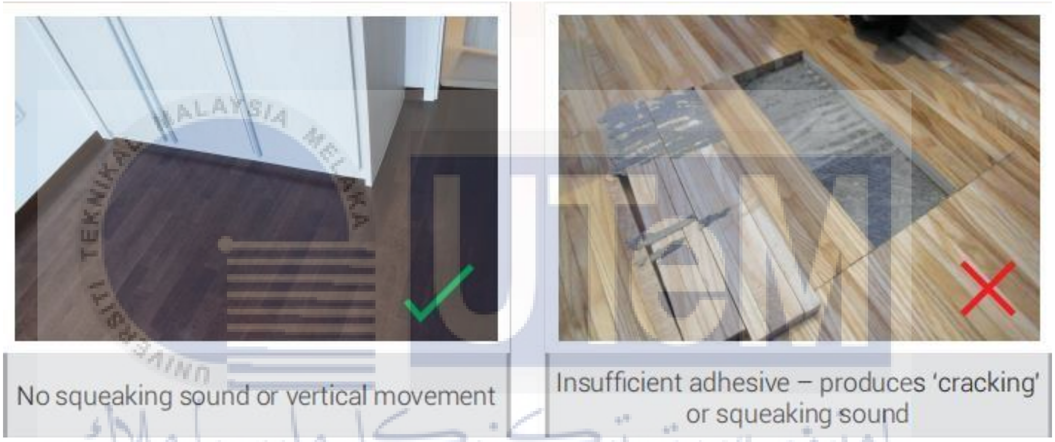


Figure 2.1: The differential of type which can make hollowness.

In manual assessment, equipment used for to detect hollowness is metal rod. The process to detect the hollowness with take a metal rod then put it on the floor and bring it moving. When the floor is hollow, a hollow sounding tone produce depend on the tile assembly configuration. Building Construction Assessment (BCA, 2018) states that the hollow sound can occur when tapped with hard object. The hollowness not applicable for exposed Mass Engineered Timber (MET) elements and ceramic laid in this reference. Figure 2.2 shows the metal rod used to detect the hollowness of the floor.

Figure 2.2: The metal rod used to detect the hollowness of floor

According to (John Brown, 2017), the idea of recommendations of non-hollowness. The recommendations that need to prevent hollowness from happening again are follow the flooring and adhesive manufactures' installation specifications and limitations. When bad adhesive is used to install wood flooring, the entire installations would be negatively impacted. Next, using the proper flooring trowel when applying the recommend adhesive is very important. Installers' comprehensive understanding of trowel requirements is highly recommended by adhesive manufacturers. Insufficient adhesive application may cause substandard adhesion. Besides, injection repair kits are available and allow an installer to inject additional adhesive under the flooring. Next, another recommendation is used the thermal camera. The thermal camera is used for the short time after heating the environment to capture a thermal picture. Due to the hollow defect temperature in tile, it is recommended to extract the hollow functions (Yan et al., 2019).

2.2.2 Allignment problem

According to (Yan et al., 2019), stated about defect alignment problems. It occurs when two walls in right angles (angle of right is a 90° angle) which is consistent with the problem of the alignment. The traditional evaluation of the alignment of the walls is performed by checking the distance of one side of a set square from the other wall by closely touching the second wall. In this research state when assessment process, measurement errors are imported into action because the inspectors have a very difficult task in maintaining the set square horizontally accurately. In this study, the new robotic system proposes a methodology of assessment which can give the angle between two. In this article, the manual assessment use set square.

These finds also supported by (Wiki, 2017) and (Rectification, 2017). According to (Wiki, 2017), poor alignment can produce when misalignment at the beginning of tile installations. This is because poor planning can lead to crooked tiles, small cut tiles in plain view. The excessive cuts for fitting and overall unprofessional appearance. On the other hand, (Rectification, 2017) stated the alignment may cause uneven sub floor. The characteristics of alignment is about more than 3mm per 1.2m. Figure 2.3: the different type floor of alignment

Figure 2.3: The different type floor of alignment

Alignment is an arrangement in a straight line (Thetahaurus, 2020). While, the definition in (Collin, 2021) state that a something is its position relation to something else in correct position. Besides that, the manual method instrument use screwdriver, screw level to get the measurement.

The recommendation precautions to avoid the alignment is ensure sub floor is in alignment condition (Rectification, 2017). Then, do necessary rectification if uneven and apply self levelling compound for direct installation or play wood to blends the planks more consistency. According to (Building and Construction Authority, 2018), the recommendations to avoid alignment problem is check tiles which have adequate characteristics. The characteristics are the length, width and thickness, straightness, rectangular and surface flatness. The surface quality has to make sure the quality to match the design of expectation.

2.2.3 Crack problem

According to (Eldarrat, 2021), cracks are one kind of universal problem of concrete construction. Crack problem can affect the function of building artistic and destroy the wall's integrity. On the other hand, Rectification (2017) mention that crack and damages caused by poor unit control of human and insufficient protection on the floor. Next, the research from (Building and Construction Authority, 2018) states that chipping and scratches are examples of the crack problem. The possible cause of the crack and damages is because poor handling, poor cutting which directly impacts the damage by other trades after laying if unprotected. Figure 2.4 show the different type of damage floor.

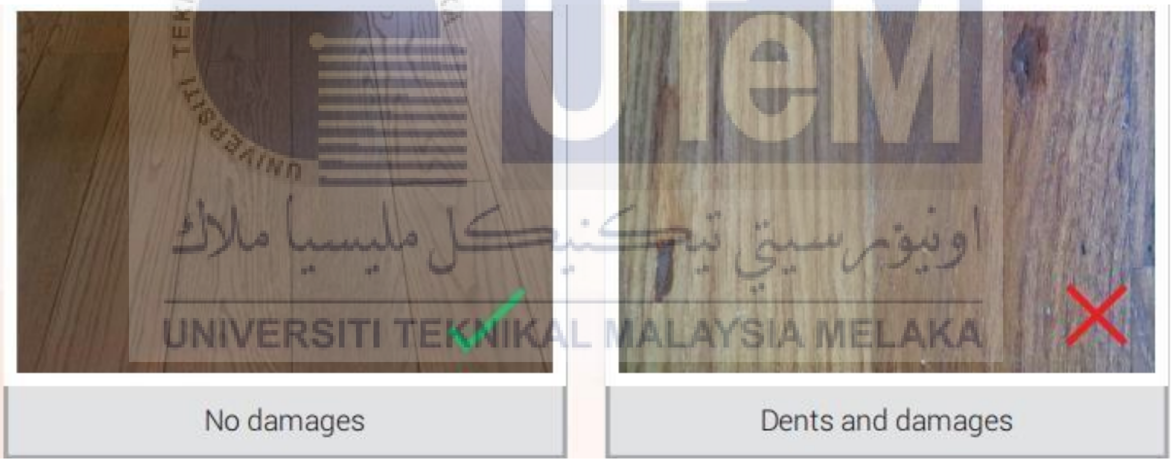


Figure 2.4: The different type of damage floor

Crack is complete or incomplete separation of concrete into two or more parts produced by breaking and fracturing. There are six common types of cracks in concrete (Caroline, 2021) The types of cracks are plastic shrinkage concrete cracks, expansion concrete cracks, heaving concrete cracks, settling concrete cracks, concrete cracks caused by overloading the slab and concrete cracks caused by premature drying.

The recommendation to avoid the crack problem not occur again with ensure proper protection during tile the floor. Besides, make sure to use proper tools during the process to do (Building and Construction Authority, 2018). Besides, Rectification (2017) also mention that the recommendation that we should take to avoid crack. First, control access to restrict workers entering unit. Next, plan sequence of work in order to minimize damage on flooring. Then, provide the cardboard corrugated sheet or suitable protection to protect flooring after engineering wood flooring is installed. According to (Eldarrat, 2021), make a concrete surface at a low temperature is one alternative to avoid crack problem. This is because a high temperature in (700°C to 900°C) can cause surface cracking. Lastly, Yan et al., (2019) mention that Black-Hat method can extract crack-related. This method can rendudant features.

2.2.4 Inclination problem

According to (Chen et al., 2020), causes that bring inclination floor such as poor drainage, deficiency during construction, age of house, house settlement, house settlement initial and continuing, foundation problem and damage to or deterioration of floor sill, girder or joints. Besides, (Magorzata,2017) stated factors cause inclination classified into three groups which are subsoil properties, foundation, and anthropogenic. Next, the inclined building can affect structure with critical height to width ratio. Intensive underground mining exploration also reason inclination of building.

According to (Trenchless,2018), the inclination is the degree or angle of slope that wellbore. The angle which made by the line with x-axis measured counterclockwise from positive direction of that axis. Next, (Construction Industry Development Board of Malaysia, 2019), stated that manual assessment use spirit level for measurement. According to (Youliang Wang, 2019), it is important to measure the inclination of building to detect the perpendicularity of the building.

The recommendation to avoid inclination problem is loading grown and drainage system (Magorzata,2017). Loading ground is method that consists in loading ground on the higher side of structure. The soil layers are recompressed. One of the treatments is applied to level the Tower of Pisa. Next, drainage system is reduction of water which can decrease volume to induce subsidence and lower the part of inclined buildings. Table 2.1 shows the comparison of the building assessments

Table 2.1: The comparison of the building assessment

No.	Author	Building Assessment	Method/ Precaution/Benefit
1.	Lesley Goddin,2020	• Hollowness problem	• concrete substrate can properly due to concrete surface too dense and not absorb moisture
2.	BCA, 2018	• Hollowness problem	• applicable for exposed MET elements and ceramic laid directly on MET elements
3.	Building and Construction Authority, 2018	• Hollowness problem	• Air not entrapped in setting bed • Not waterproofing membrane separation installed between a slab and bedding material.
4.	Yan et al., 2019	• Hollowness Problem	• surface and tile adhesive doing properly
5.	Rectification, 2017	• Hollowness Problem	• Must squeaking sound or vertical movement. • Sufficient adhesive

6.	Yan et al., 2019	• Alignment problem	• checking the distance of one side of a set square from the other wall by closely touching the second wall
7.	Rectification, 2017	• Alignment problem	• Evenness must less than 3mm
8.	Building and Construction Authority, 2018	• Alignment Problem	• can focus on academic performance, student satisfaction and student experience
9.	Building and Construction Authority, 2018	• Alignment problem	• check the tiles used have adequate characteristics. • The surface quality has to make sure the quality to match the design of expectation.
10.	Yan et al., 2019	• Crack Problem	• The NDE robotic system technologies focus mainly on four types of defects such as cracks, delamination, a reinforced elastic module
11.	Building and Construction Authority, 2018	• Crack problem	• ensure proper protection during tile the floor make sure to use proper tools during the process to do.

12.	Chen et al., 2020	• inclination problem	• avoid inclination problem such as poor drainage, deficiency during construction, age of house, house settlement, house settlement initial and continuing, foundation problem and damage to or deterioration of floor sill, girder or joints.
13.	Magorzata,2017	• Inclination Problem	• The inclination of load-bearing walls should be ignored. • the problem can be addressed in terms of serviceability limit states.
14.	Building and Construction Authority, 2018)	• Inclination Problem	• any loose materials mut removed with high pressure cleaner

2.3 Mobile Robot Design

According to researches done by (Yan et al., 2019), the development of a quality inspection robot which can scan the entire room autonomously by cameras and laser scanners. In order to develop a dispenser mechanism to expand the thermal camera and color camera range, two motors are used. The two motors rotate slowly, so that images are not blurred or squeezed. The number of motor vehicles used on the North and Newfoundland lines will be reduced by 400 mm as a result of this engine. The two switches are turned on to reduce the linearity of this mountain range. Furthermore, two cameras move simultaneously because mounted on the same mechanism. At both the back and the front section, the trolley and the mobile robot are connected. The entire system is driven by a differentially driven AXON mobile robot and an industrial PC MXE-5400 is chosen to integrate all the hardware and mechanisms with a fourth generation i7 four-core processor, a 257GB SATA-III SSD, a 16GB memory and Ubuntu operating system. In order to simultaneously locate the robot and construct a 2D ambient map, a HOKUYO URG 04LX laser scanner installed on the top of the mobile robot's long rod is used. In order to avoid obstacles to movement, multiple sonar sensors installed in the rod center. Figure 2.1 shows the design of mobile robot assessment postconstruction.

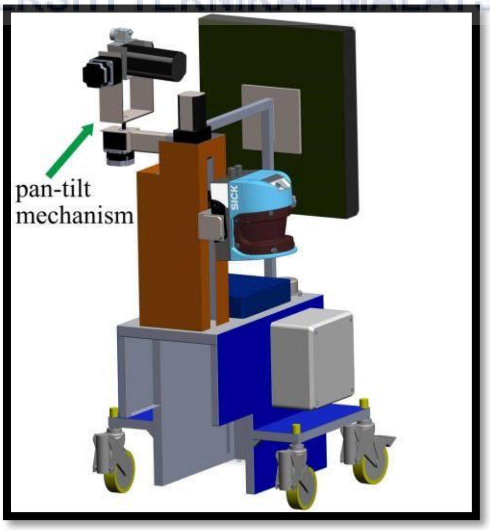


Figure 2.5: Four wheeled mobile robot

According to (Klančar et al., 2017) stated wheel mobile robot can operate in unconstrained environments, need external sensing to determine position and need external sensing to avoid obstacles. Any information a robot collected to learn and map the surroundings. All sensor such as need degree of certainty and uncertainty reduced by multiple measurements. Figure 2.2 shows the design of wheel mobile robot.

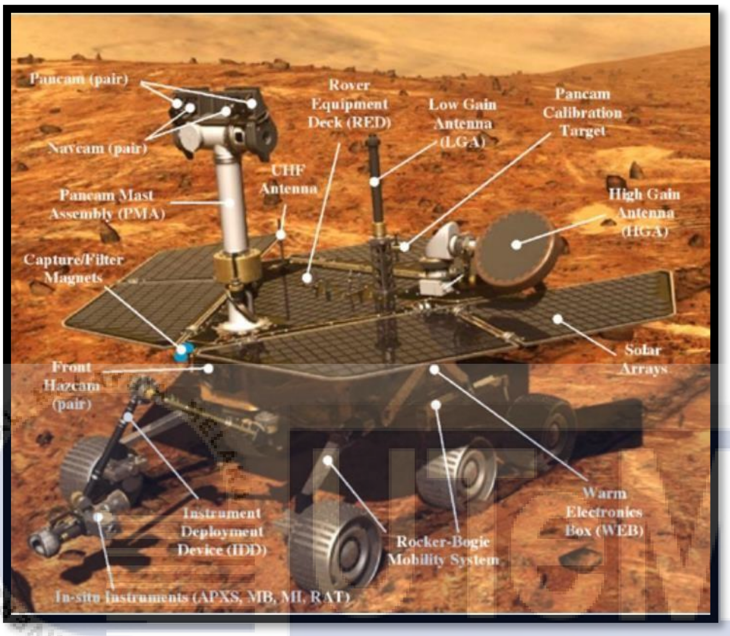


Figure 2.6: Wheel Mobile Robot

According to (Ali & En, 2018), their idea in mobile robot also can restricted environment. In this Figure 2.3 show the wheeled mobile robot is non holonomic which has one castor wheel and two differential wheels. The body structure is about 30x30mm and 40x40 of alluminium profile. consists of two loops, outer loop and inner loop. PD controller used in this system.

Figure 2.7: The wheeled mobile robot.

Next, the research from (Andrej, 2017) stated that SLAM robot can mapping and localization. SLAM is process which robot can build a map and compute its location. SLAM stands for Simultaneous Localization and Mapping. This article shows the mobile robot can convergence for linear case, applied successfully in large scale environment and reduce computational complexity.

Furthermore, the mobile design also from (Kung, 2018) state that design of agile two wheels robot is use artificial/intelligence algorithms for robotic system. The architecture including description of machine vision module (MVM). The modelling feedback is balance and the microcontroller has hardware signal processing.

According to (Yunardi et al., 2021), Indonesian wheeled robot is one of the mobile designs that able predetermined task such as catch the ball. This mobile robot used holonomic omnidirectional to navigating the omnidirectional movement. It has three omnidirectional wheels and DC motor for the movement of robot. DC motors controlled by EMS 30A H Bridge as a driver and Arduino Mega 2560 as the main microcontroller.

Apart from that, (Jiménez et al., 2020) stated that design modelling and control of Two Wheeled Auto Balancing Robot (TWABR). It was designed to stabilize the equilibrium point. A classic PID (Proportional Integral Derivate) controller and optimal controller LQR (Linear Quadratic Controller) by Matlab. Figure 2.4 shows the design of TWABR.

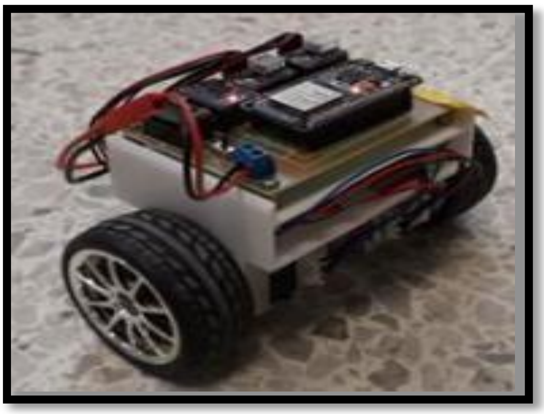


Figure 2.8: The TWABR were designed.

The design of self-balancing based on concept of "Inverted Pendulum" used gyro and tilt for their sensors (Mudeng et al., 2020). It is because to detect a balancing angle. In this reference also state that feedback control method balancing position error. The design of this robot also occupied with PID controller.

In addition, the reference from (Asafa et al., 2018) state the design of vacuum robot include in mobile robot. In this project, this vacuum contains wheel, cleaning and control system which can achieve efficient cleaning. Next, it was designed reverse and forward for movement pf robot.

According to (Luo et al., 2018) state that systematic approach for synthesizing of mechanical structures. Besides, this robot also used concept of modular design of isomorphic and non-isomorphic. The structure contains four types of mechanism which consists five types of suspensions.

Table 2.2: The comparison of mobile robot design

No.	Author (s)	Techniques/Components used	Advantages	Disadvantages
1	Rui Jun Yan, 2018	• Mobile robot with 4 wheels (pan tilt mechanism) • Components that used in this project is thermal camera, color camera, laser scanner, AXON mobile robot.	• Can detect and measure the inclinometer, hollowness, crack and alignment problem easily.	• All the components expensive to buy.
2	Klančar et al., 2017	• Wheel Mobile robot which has thermometer, potention meter, accelerometer, optical encoder and gyroscope sensor.	• Can change use batteries • Perform specific measurements	• Has little effect on systematic errors. • Require more sensor
3	Ali & En, 2018	• This wheel mobile robot consists of two loops, outer loop and inner loop. PD controller	• Able to make dynamic system stable and robust	• Big error occurs between the reference path and actual path. • System easily robust.

		mechanical dynamics equation.	• Performance faster without high overshoot	
4	Mudeng et al., 2020	• This project describes the implementation of self-balance robot, operated by DC motor with the installation HCSR04 and Arduino microcontroller.	• Better accuracy the value of probability.	• Most difficult system to control in the field of control engineering.
5	Kung, 2018	• This agile two wheels Robot has RC servo motor, infrared object and distance detector, camera and also machine vision module.	• Can communicate with robot via Ling Rage (LoRa)	• The Bluetooth not sufficient to continuous video. Because the user in real time only got 4 second for 14 samples

6	Asafa et al., 2018	• This vacuum cleaner robot designed in disk shape. The robot has front castor wheels and two rear wheels. It • also 28.8V DC battery (for two • hours fully charge Also use ultrasonic sensor and Arduino mega2560	• Better cleaning pattern.	• Require large manpower for proper function.
7	Luo et al., 2018	• The wheel mobile robot set with four types of mechanism, the concept of isomorphic and non-isomorphic with type of rigid	• robot also use concept of modular design of isomorphic and non-isomorphic	• Low level-control system.

8	Andrej, 2017	• This wheel mobile robot consists of 2 castor wheels, a sensor	• Good pose estimate to build map	• Probabilistics method • Mid eight (the stone age of robotics)
9	Yunardi et al., 2021	• Used holonomic omnidirectional to navigating the omnidirectional movement. • It has three omnidirectional wheels and DC motor for the movement of robot	• Efficient movement • Able to control the ball well Not • easily overturned.	• Heavy • Expensive Difficult in process controlling.
10	Jiménez et al., 2020	• The TWABR system consists of Lagrange	• Low cost	• The TWABR system linearized with highly unstable dynamics

CHAPTER 3

METHODOLOGY

3.1 Introduction

To make sure this project is carried out successfully, there are many processes to do to form mobile robot for floor level inspection. This project was broken down into four stages which are milestone 1 (literature review), milestone 2 (designing), milestone 3 (stimulating) and milestone 4 (assembling and testing). Figure 3.1 shows the flowchart of this project.

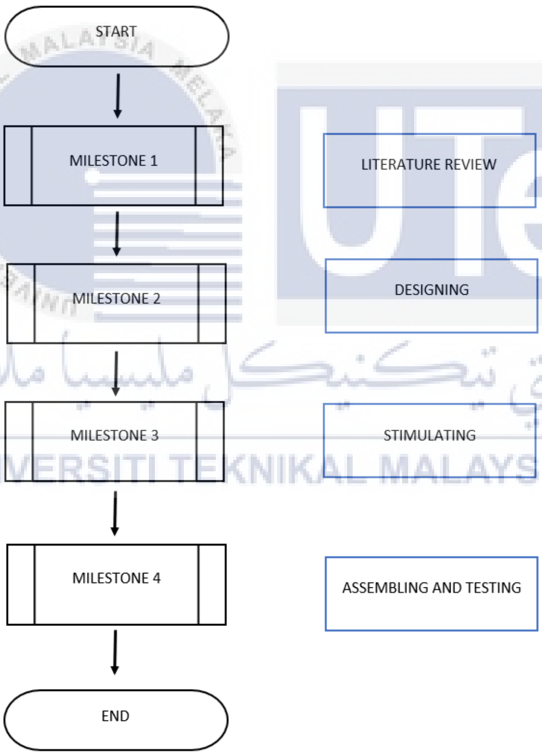


Figure 3.1: Methodology flowchart

3.2 Methodology

This project presents a mobile robot for floor level inspection. Development of mobile robot for floor level inspection used MPU6050 as inclinometer, Arduino UNO and HC-05 Bluetooth Module as microcontroller, driver module H-bridge with 4 DC motor as movement of robot and MIT App Inventor as control robot.

3.3 First Milestone

First, the project objectives were discussed with the supervisor. The literature review for this project was completed after all of the objectives were determined. The goal of a literature review is to gain idea from previous research done by researchers or institutions. The previous research was used to gather ideas and information about the component used, problem solving, and the analysis method. Then, the scopes which will cover the objectives were listed and get the approving from the supervisor. The flow chart of literature review as shown in Figure 3.2.

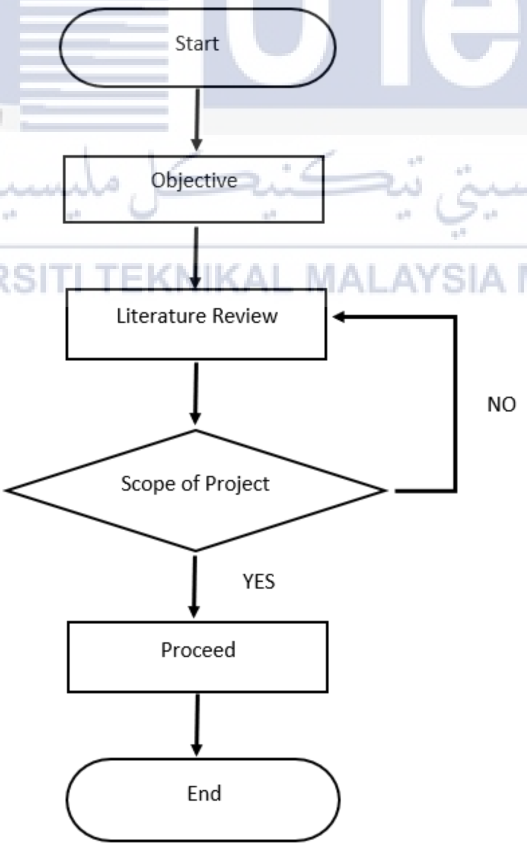


Figure 3.2: Literature review flow chart

3.4 Second milestone

3.4.1 Design of mobile robot

In designing a mobile robot for floor level inspection, there are several specifications that need to be taken into account such as material type used and the size of mobile robot. It is made up of acrylic robot chassis which is sturdy and durable. The acrylic robot can effectively protect the mobile robot from being worn. Besides, a mobile robot with four wheels is also designed to carry IMU, batteries, H Bridge Driver Module and HC-05 Bluetooth Module. Such a design also function to make connections to mobile robot. The size of robot is 210mm while the thickness about 3mm. The figure 3.3 shows the 3D model design for the whole mobile robot in CAD Solid Work. The figure 3.4 shows the design of Mobile Robot For Floor Level Inspection.

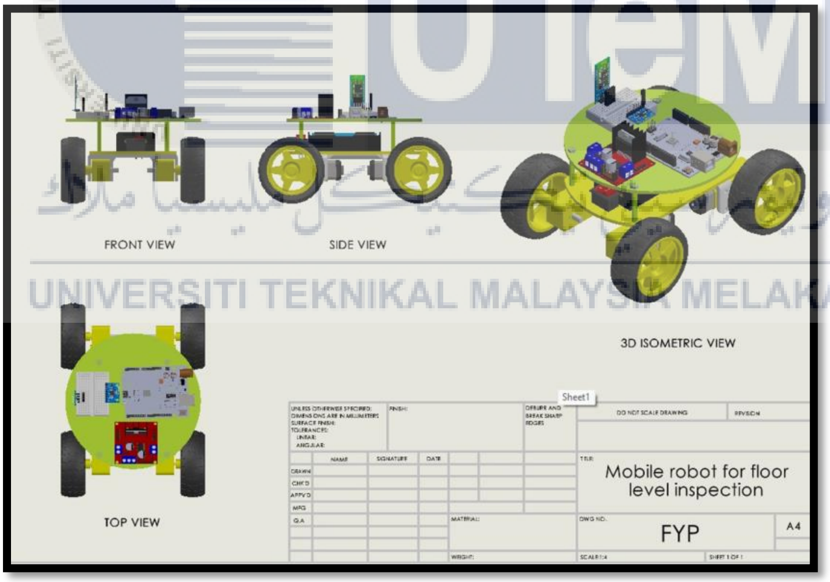


Figure 3.3: 3D model design for the whole mobile robot in CAD Solid Work

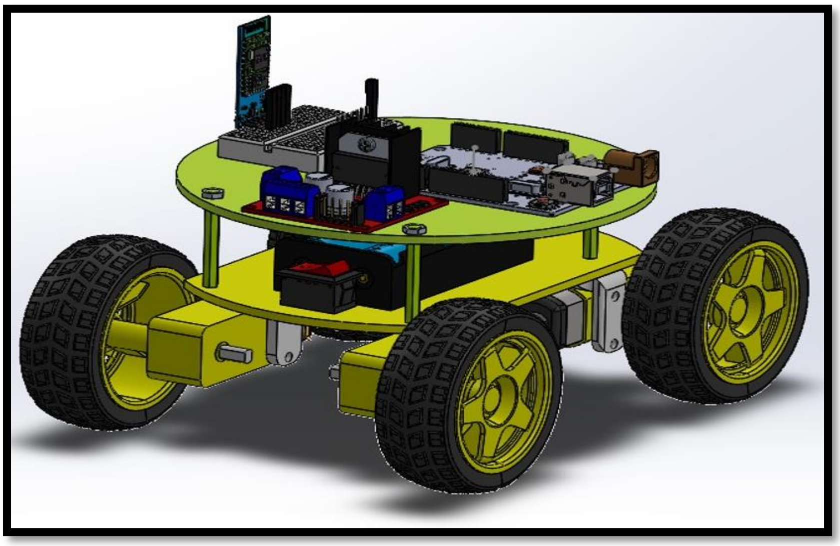


Figure 3.4: Design of Mobile Robot for Floor Level Inspection

3.4.2 Selection of components

3.4.2.1 Arduino UNO

Figure 3.5: Arduino UNO

Arduino Uno is an ATmega328P-based microcontroller board (datasheet). It contains 14 digital pins, 6 of them PVM inputs, 6 analog inputs, a ceramically powered 16MHz (CSTCE16M0V53-R0), USB, power jack, ICSP header and the reset button. The CSTCE16M0V53-R0. It consists of microcontrollers, which can be connected to a computer using a USB cable or powered to start with an AC-to-DC adapter or battery.

3.4.2.2 MPU6050

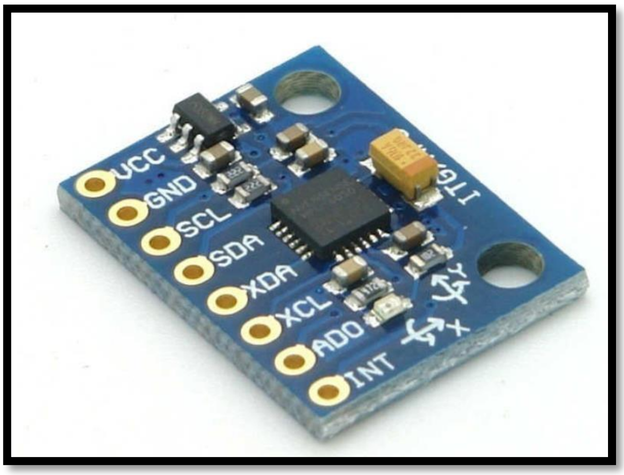


Figure 3.6: MPU6050

The Motion Tracking Device MPU6050 is a complete 6-axis sensor module. It combines 3-axis accelerometer and 3-axis gyroscope which digital movement processor in a single package. MPU6050 uses a standard 12C- Bus for data transmission I2C bus for data transmission. It is connected to other sensor devices such as 3-axis magnetometer and pressure sensor to correct for this effect. This combination of sensors such as accelerometers or magnetometers to correct for this 'Inertial Measurement Units'. The MPU6050 is a 3-axis Mechanical System (MEMS) technology gyroscope. This is used as shown in the figure below to detect rotational velocity on the X, Y, Z axis.

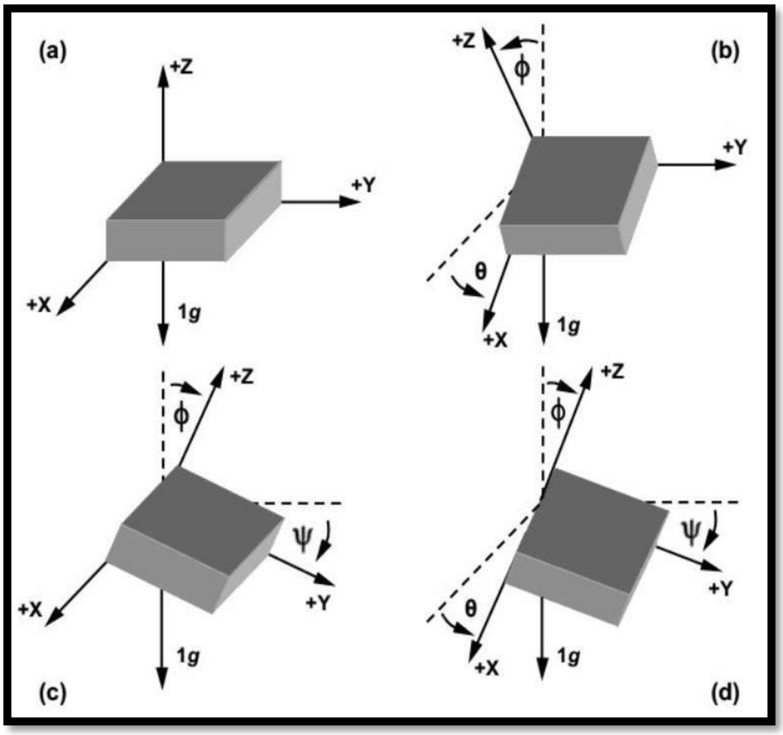


Figure 3.7: The accelerated axis distracts the moving weight

The accelerated axis distracts the moving weight. This moving plate (mass) displacement unbalances the differing condenser, resulting in the capability of the sensor. The output amplitude is commensurate with the speed. ADC 16-bit for digital output. Measured in unit g (force of gravity). DMP Database (Digital Motion Processor) used for calculating motion processing algorithms is the embedded Digital Motion Processor (DMP). Data from the gyroscope, accelerometer, and other 3rd party sensors are collected.

3.4.2.3 HC-05 Bluetooth Module

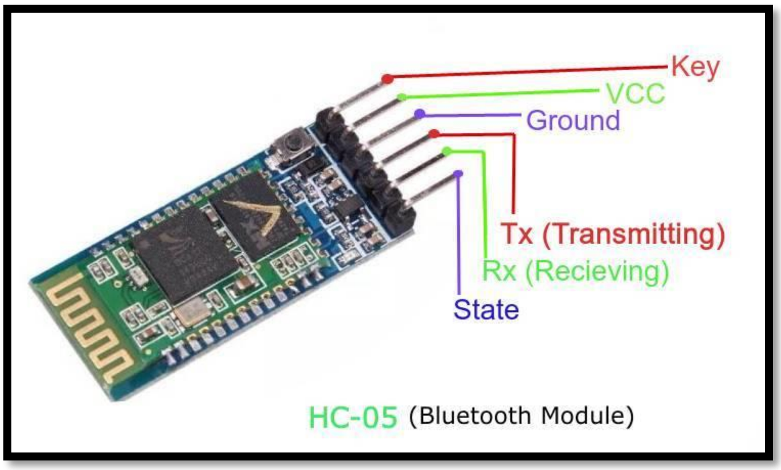


Figure 3.8: HC-05 Bluetooth Module

The HC-05 is a Bluetooth module that can communicate in both directions which is full-duplex. It is compatible with the vast majority of microcontrollers. It employs the Serial Port Protocol (SSP). The module communicates at a baud rate of 9600 using a USART (Universal Synchronous/Asynchronous Receiver/Transmitter), but it also supports other baud rates. As a result, we can connect this module to any microcontroller that supports USART. The HC-05 has two modes of operation.

3.4.2.4 DC Motor

Figure 3.9: The DC motor

Rotary electrical motors are machines that convert direct current electrical energy into mechanical energy. The most common types rely on magnetic field forces to operate. Almost all types of DC motors have an internal mechanism, either electromechanical or electronic, that allows the current direction in a portion of the motor to be changed on a regular basis. DC motor could be powered by existing direct-current lighting power distribution system. DC motors were the first type of motor that was widely used. The speed of a direct current motor can be varied over a wide range by changing the strength of current in its field windings or by varying the supply voltage.

3.4.2.5 L298N Driver Module

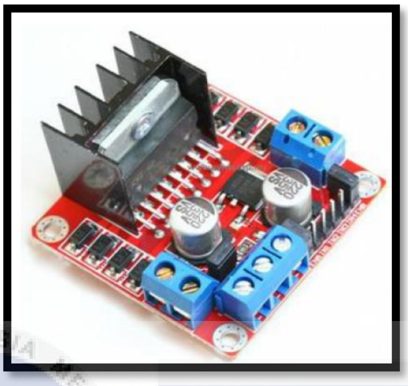


Figure 3.10: L298N Dual H-Bridge Driver Module

The L298 Dual H-Bridge Motor Driver Integrated Circuit serves as the foundation for this dual bidirectional motor driver. The circuit will allow you to control two motors of up to 2A each in both directions easily and independently. It is well suited for robotic applications and can be connected to a microcontroller requiring only a few control lines per motor It can also be linked to simple manual switches. TTL logic gates, relays, and so on. This board has power LED indicators, an on-board +5V regulator, and diodes for protection.

3.5 Third milestone

This part discusses about the simulation of mobile robot for floor level inspection. In this part, the mobile robot was coding by using Arduino software. Figure 3.11 shows the coding Arduino program. Figure 3.12 shows the connection of Arduino UNO with MPU6050 and Bluetooth HC-06 using fritzing software.

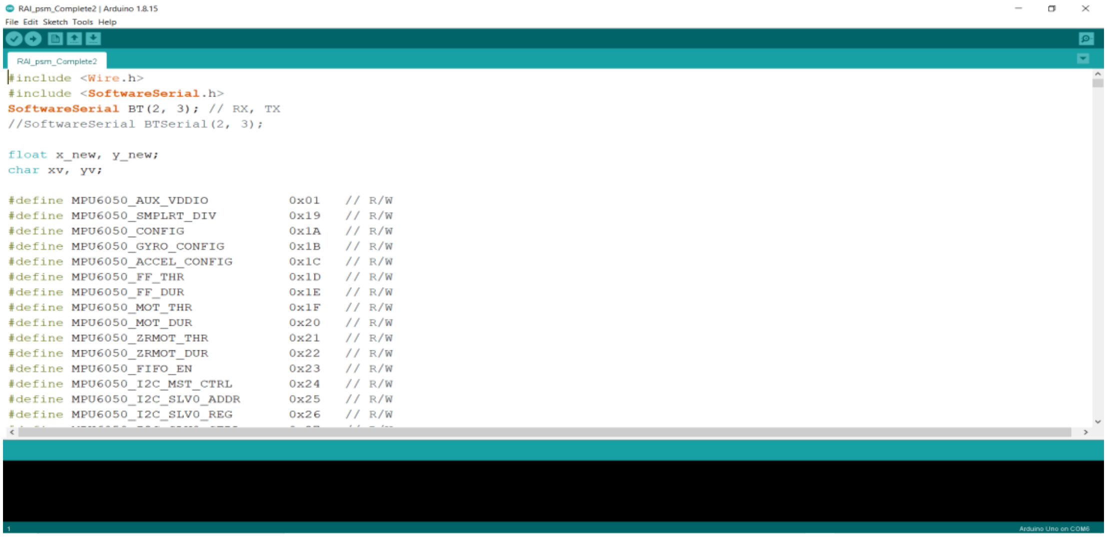


Figure 3.10: The coding of Arduino program.

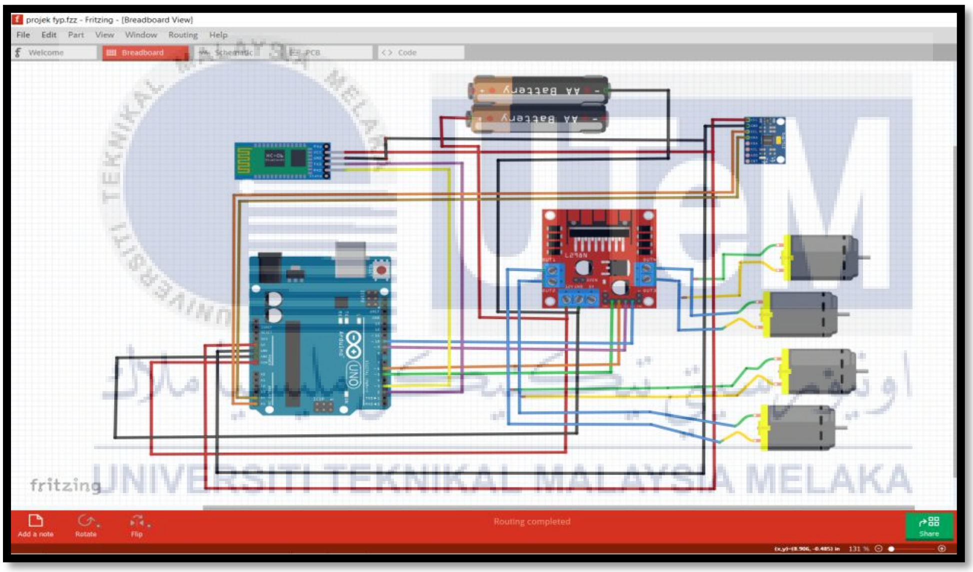


Figure 3.11: The connection of Arduino UNO with MPU6050, Bluetooth HC-05, Driver module H-Bridge L298N and 4 DC Motor.

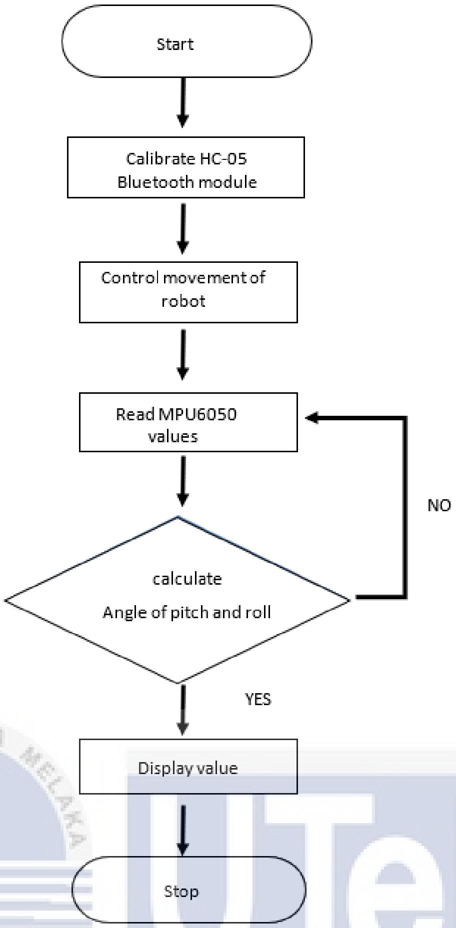


Figure 3.12: The flowchart of overall program

3.6 Fourth milestone

In the part explain about the process of implementation components and testing analysis. The process begins with the testing of the component functionality and analysis of the data.

3.6.1 Integration of the components and hardware to robot

After the process of installing electrical components on the mobile robot is completed, then create an application to monitor and control the movement of the mobile robot and monitor the angle of pitch and yaw. The application used is MIT App Inventor. This application needs to create blocks and designs according to the characteristics of this project. When the application for the mobile robot is completed, the electronic components and batteries will be integrated inside the mobile robot. Figure 3.13 clearly shows the procedure of implementation. Figure 3.14 shows the block in the MIT App Inventor and figure 3.15 shows the designer in MIT App inventor.

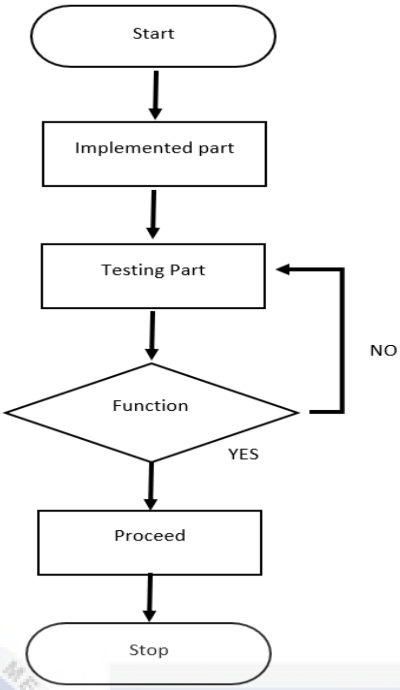


Figure 3.13: Implementation of components flowchart

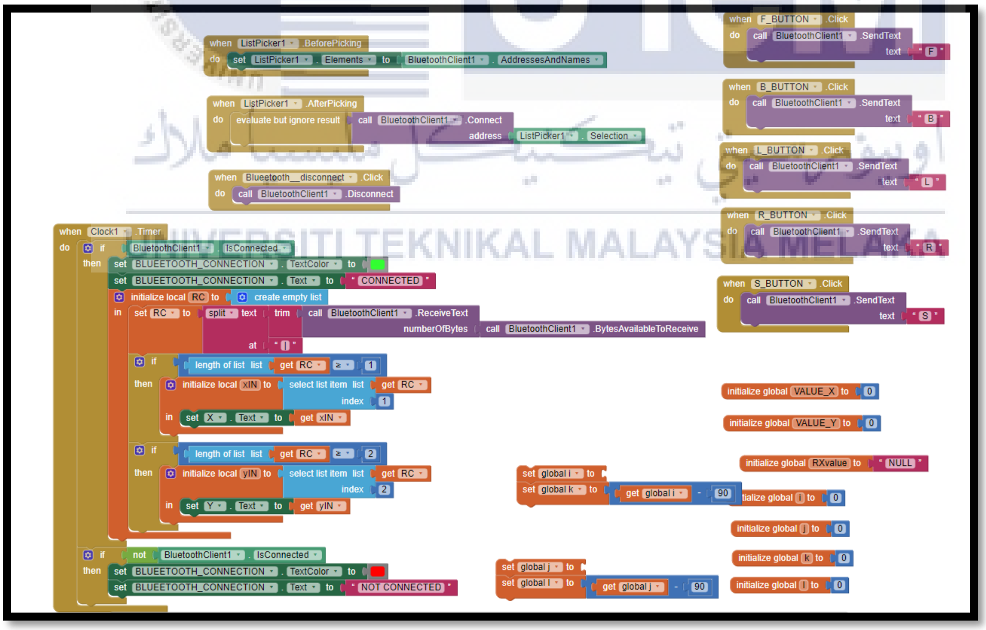


Figure3.14: The block in the MIT APP Inventor

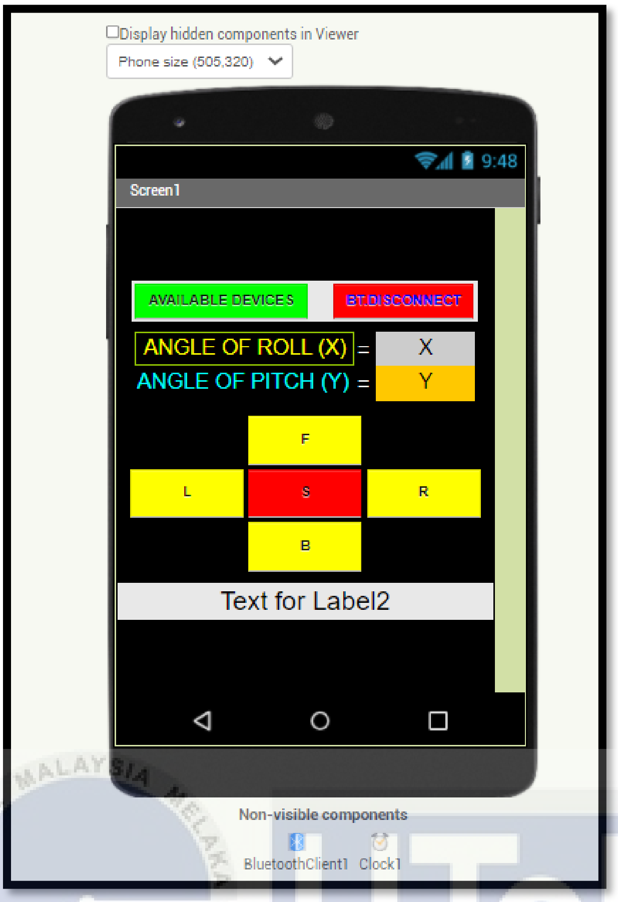


Figure 3.15: The designer in MIT App Inventor.

3.6.2 Integration of the components and hardware to robot

The purpose of testing and analysis is to verify the data of roll angle and pitch angle traversed by the mobile robot are obtained. This experiment shows for testing the movement of a robot that passes through 15 tiles that located at Lobby FTK and house. The data for recording the roll angle and pitch of each tile is shown in Figure 3.16. Figure 3.16 shows The movement of mobile robot at Lobby FTK whereas Figure 3.18 shows the roll (x) and pitch (y) directions on the sensor IMU MPU6050 installation.

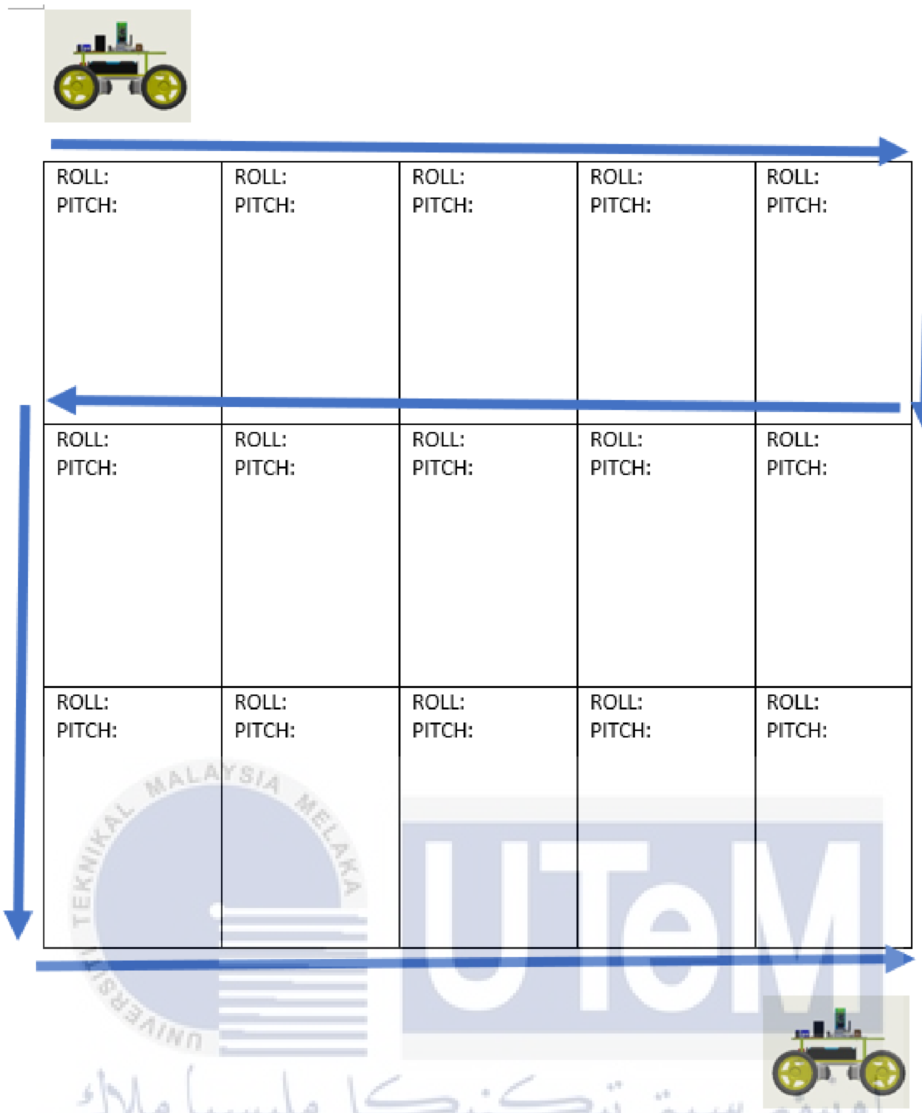


Figure 3.16: The movement of mobile robot to get the data each tile

Figure3.17 : The movement of mobile robot at Lobby FTK

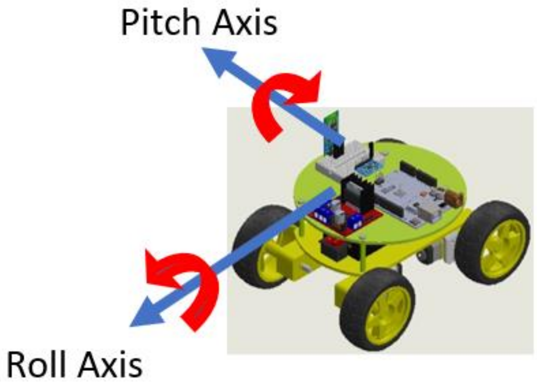


Figure 3.18: The directions of roll (x) and pitch (y) on the sensor IMU MPU6050 installation.

3.6.3 The uses of complementary filter

The accelerometer and gyroscope data are both susceptible to systematic errors. The accelerometer provides long-term accurate data but is noisy in the short term. In the short term, the gyroscope provides accurate data about changing orientation, but the necessary integration causes the results to drift over longer time scales. By dividing the accelerometer data from Krodal' s code by a factor of 16384, the data is converted into multiples of g (9.8 m/s2). However, because the conversion to angles uses acceleration vector component ratios, this factor divides out. It is important to note that as long as gravity is the only force acting on the sensor, the accelerometer results provide accurate orientation angles. However, when we move and rotate the sensor, we apply forces to it, causing the measurements to fluctuate. As a result, accelerometer data is typically noisy, with brief but significant perturbations. When these are averaged out, the accelerometer produces accurate results over timescales longer than the perturbations.

The gyroscope sensor measures angular velocity (the rate of change in orientation angle), not angular orientation. To compute the orientation, we must first initialize the sensor position with a known value (possibly from the accelerometer), and then measure the angular velocity () around the X, Y, and Z axes at known intervals (t). After that, t = angle change. The original angle plus this change will be the new orientation angle. The issue with this method is that we are integrating – adding up many small computed intervals – to determine orientation. Adding up increments of t again and again will result in small systematic errors becoming magnified over time. This is the cause of gyroscopic drift, and the gyroscope data will become increasingly inaccurate over long timescales.

The solution to these issues is to combine the accelerometer and gyroscope data so that the errors cancel out. The standard method for combining these two inputs is through the use of a Kalman Filter, which is a fairly complex methodology. Fortunately, a Complementary Filter is a simpler approximation for combining these two data types.

Filtered Angle = $\alpha \times$ (Gyroscope Angle) + $(1 - \alpha) \times$ (Accelerometer Angle) (1)

$\alpha = \tau / (\tau + \Delta t)$ and (Gyroscope Angle) = (Last Measured Filtered Angle) + $\omega \times \Delta t$ (2)

Δt = sampling rate, τ = time constant greater than timescale of typical accelerometer noise (3)

3.7 Summary

To conclude, the methodology used to develop a mobile robot for the floor level inspection was explained. The flow of the system was further explained by the use of a flow chart. An extensive and complete description of all of the hardware part used in this project has been explained.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The development of mobile robot for floor level inspection is discussed in this chapter, along with the decisions and analysis that ended up going into it. The goal is to demonstrate that the objectives are being implemented correctly. Strengths and weaknesses can be discovered throughout the analysis.

4.2 The performance of the mobile robot

After the development of the mobile robot is completed, the robot's performance to perform the movement is investigated and tested. Then, identify the roll angle and pitch angle on each floor tiles was observed.

Before starting the movement, the roll angle and pitch on the smartphone were observed. This can be seen through figure 4.1 the angle of roll and angle of pitch at 0° was observed. Figure in 4.2 shows the result on the serial monitor which proves the mobile robot at 0°and has no inclination. The result from serial monitor state when connect USB with mobile robot.

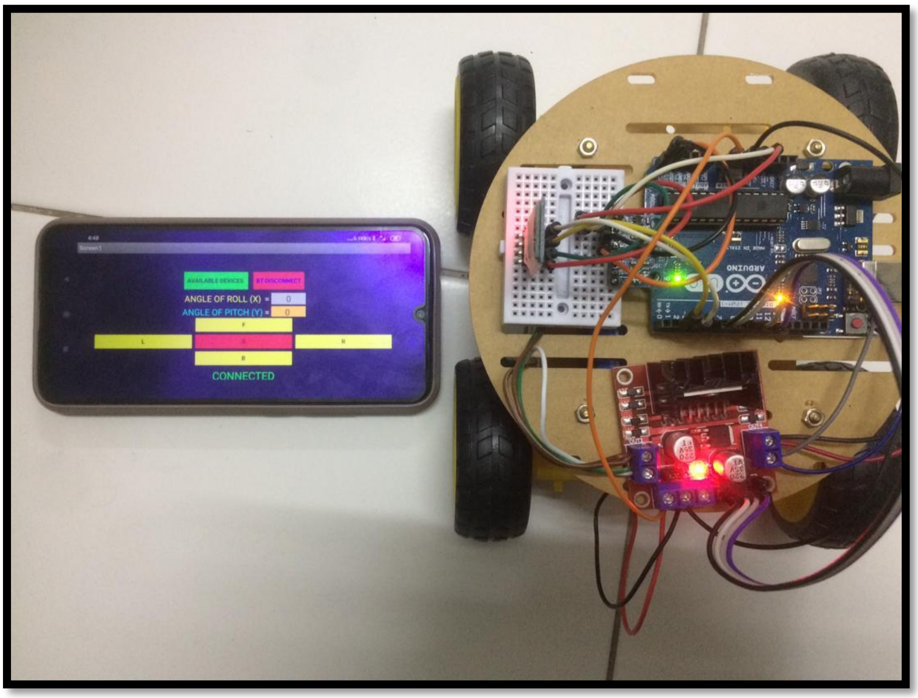


Figure 4.1: The angle of roll and pitch at 0°

Figure 4.2: The result of angle of roll and pitch about 0° in serial monitor.

The angle of roll and pitch is 0°, as shown in figure 4.2. The results show that the surface is flat and has no inclination.

4.2.1 The angle of roll and pitch

Based on the observations in this experiment, this robot can also find the roll angle and pitch angle in addition to locomotion performance. Figure 4.3 shows a mobile robot get the angle of roll and pitch through 15 slightly sloping tiles in the lobby of the Faculty of Engineering Technology. Figure 4.4 shows a mobile robot get the angle of roll and pitch through 15 tiles same level at house.

Figure 4.3: The mobile robot get the angle of roll and pitch through 15 slightly sloping tiles in the lobby of the Faculty of Engineering Technology.

Figure 4.4: shows a mobile robot get the angle of roll and pitch through 15 same level tiles at the house

Figure 4.3 shows a mobile robot went through 15 slightly sloping tiles in the lobby of the Faculty of Engineering Technology. This mobile robot works to measure the roll angle and pitch angle on the floor. This step is made inside the building. Each tile has an area of 25cm x 25cm. The mobile robot moves from one tile to another in the direction shown. Every tile reading was recorded. On the first and second tiles, the readings of the angle to roll and the pitch angle are 0 °. From the result, the angle of roll and angle of pitch has no inclination and in flat condition. On the third, fourth and fifth tiles, the angle reading for the roll is -2 ° and the pitch angle is 0 °. In general the third, fourth and fifth tiles have a uniform inclination, These findings show that the tiles have a tendency compared to the first and second tiles. This is because the floors on the third, fourth and fifth tiles are not flat. The robot will then proceed to the tiles six, seven, and eight. The sixth, seventh, and eighth tiles have been observed to have a consistent pattern. The angles of the roll and pitch tiles are identical to those of the third, fourth, and fifth tiles. The sixth, seventh, and eighth tiles have the angle reading for the roll is -2 ° and the pitch angle is 0 °. After that, the robot goes through the ninth and tenth tiles. Based on the observation, the floor condition is even. Therefore, the angles on the roll and pitch have 0°. The robot will then proceed to the tiles eleven and twelve. Based on the observation, the floor condition is even same as tile nine and tenth. Therefore, the angles on the roll and pitch have 0°. Tiles 11 and 12 are the next stop for the robot. Tiles nine and ten appear to be in the same condition as the rest of the floor. Because of this, the roll and pitch angles are both 0°. Final tiles are 13, 14, and 15, which are completed by the robot. The roll angle is -2° and the pitch angle is 0° after passing through the tile. Tiles 13 ,14 and 15 have a consistent pattern, according to my observations. Tiles 13 , 14 and 15 have a slightly different tendency compared to the 12th and 13th tiles.

Figure 4.4 shows a mobile robot through 15 tile which have same level at house. This mobile robot works to measure the roll angle and pitch angle on the floor surface. This step is made inside the building. Each tile has an area of 15cm x 15cm.Every tiles were recorded. From the result, the angle roll and pitch from one to fifteenth tiles were at 0 °. This result prove that the floor tile has no inclination and at the flat state.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The project has successfully carried out and achieved its objective. The mobile robot can perform locomotion and find the roll and pitch angle. The locomotion of a mobile robot is manually controlled using an android based smartphone that communicates using Bluetooth.

To develop a mobile robot capable of performing locomotion performances, a lot of considerations should be taken into account, including the material chosen, the structure of the components arrangement, electronic and electrical parts, and the mechanism chosen. Those can have a considerable impact on the overall robot performance.

The design of the mobile robot must be simulated using simulation software like SolidWorks to avoid any mistakes and save some money while constructing this project. The next step is to research the components that plan to purchase and the issues during the simulation that can be addressed before the actual prototype is built. Time spent on this project can be cut in half if this step is included.

5.2 Recommendation

On the other hand, the mobile robot produced in this research has a ton of potential in the future. Even though it is controlled by hand, the robot's movements must be closely observed by those in control. The robot can be connected with a cIn the future, GPS is also recommended in this project. A battery initially powered the mobile robot. There are worries that it may be impossible to identify the robot once the power runs out and it has gone further. As a result, It is easy to track it down anywhere with the GPS. After using GPS, it is easier to inspect mobile robots at tar road.

In the future, the robot could be linked to a camera for more precise work. This research's mobile robot holds a lot of promise for the future. There must be constant monitoring of the robot's movement even though it is operated manually. In the future, the robot could be linked to a camera for more precise work. When a camera is attached, the robot's movements will be observed and controlled by a human operator.

5.3 Project Potential

This mobile robot can be used for construction in the long term because it can move freely. When the construction industry is at a low point, robotic systems can fill in the gaps more extraordinary. Constructing a property has its share of challenges, including those related to the economics of the contractor and workplace culture. This mobile robot can replace human energy.

For developing a robot like this, Malaysia needs engineers with a wide range of specialities who can collaborate effectively. The rest of the time, our country is not ready for this kind of technology and therefore can't develop this kind of project. We've already established that this robot has much potential to support construction workers in completing their assigned work.

REFERENCES

Ali, M. A. H., & En, C. Y. (2018). Control of wheeled mobile robot in restricted environment. *IOP Conference Series: Materials Science and Engineering*, *319*(1). https://doi.org/10.1088/1757-899X/319/1/012057

Allasia, P., Godone, D., Giordan, D., Guenzi, D., & Lollino, G. (2020). Advances on measuring deep-seated ground deformations using robotized inclinometer system. *Sensors (Switzerland)*, *20*(13), 1–20. https://doi.org/10.3390/s20133769

Asafa, T. B., Afonja, T. M., Olaniyan, E. A., & Alade, H. O. (2018). Development of a vacuum cleaner robot. *Alexandria Engineering Journal*, *57*(4), 2911–2920. https://doi.org/10.1016/j.aej.2018.07.005

BCA. (2018). *BCA Construction Quality Assessment System CONQUAS overview*. *April*. https://www.bca.gov.sg/Professionals/IQUAS/conquas_abt.html

Building and Construction Authority. (2018). *Ceramic Tiling*. https://www.bca.gov.sg/Professionals/IQUAS/tile.html caroline. (2021). *types of crack*. Concrete Supply Co. https://concretesupplyco.com/6concrete-cracks/

Chen, Y., Xiong, C., Ma, T., Zeng, W., & Wang, J. (2020). Research on Floor Response Spectrum of Shielded Building Structure under Seismic Loading. *IOP Conference Series: Earth and Environmental Science*, *446*(2). https://doi.org/10.1088/17551315/446/2/022001 collin. (2021). *definition of allignment*. Collin. https://www.collinsdictionary.com/dictionary/english/alignment

Construction Industry Development Board of Malaysia. (2019a). *Construction Industry Standard - Guidelines on Construction Works at Night (CIS 14:2019)*. *45*.

Construction Industry Development Board of Malaysia. (2019b). *Construction Industry Standard - Guidelines on Prevention of Fall at Construction Site (CIS 15:2019)*.

Eldarrat, H. (2021). *Variability in Crack Patterns and Compressive Strength of Concrete due to Elevated Temperature*. *January*, 0–7.

Hoang, M. L., & Pietrosanto, A. (2021). A New Technique on Vibration Optimization of Industrial Inclinometer for MEMS Accelerometer without Sensor Fusion. *IEEE Access*, 20295–20304. https://doi.org/10.1109/ACCESS.2021.3054825

Jiménez, F. R. L., Ruge, I. A. R., & Jiménez, A. F. L. (2020). Modeling and control of a two wheeled auto-balancing robot: A didactic platform for control engineering education. *Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology*, 1–12. https://doi.org/10.18687/LACCEI2020.1.1.556

john brown. (2017). *avoid hollow spot*. Floor Covering News. https://www.fcnews.net/2016/07/installments-avoiding-hollow-spots-in-hardwoodflooring/

Klančar, G., Zdešar, A., Blažič, S., & Škrjanc, I. (2017). Introduction to Mobile Robotics.

Wheeled Mobile Robotics, 1–11. https://doi.org/10.1016/b978-0-12-804204-5.00001-9

Kumbar, K. A., & Guruprasad, K. N. (2020). *ARDUINO INCLINOMETER USING MPU6050*. *June*, 187–195.

Kung, F. (2018). Design of agile two-wheeled robot with machine vision. *Proceeding of 2017 International Conference on Robotics, Automation and Sciences, ICORAS 2017*, *2018-March*(February), 1–5. https://doi.org/10.1109/ICORAS.2017.8308055

Lesley Godding. (2020). *the cause make floor hollow*. Linked In.

Luo, Z., Shang, J., Wei, G., & Ren, L. (2018). Module-based structure design of wheeled mobile robot. *Mechanical Sciences*, *9*(1), 103–121. https://doi.org/10.5194/ms-9-103-2018

Mudeng, V., Hassanah, B., Priyanto, Y. T. K., & Saputra, O. (2020). Design and Simulation of Two-Wheeled Balancing Mobile Robot with PID Controller. *International Journal of Sustainable Transportation Technology*, *3*(1), 12–19. https://doi.org/10.31427/ijstt.2020.3.1.3

Pei, H., Jing, J., & Zhang, S. (2020). Experimental study on a new FBG-based and TerfenolD inclinometer for slope displacement monitoring. *Measurement: Journal of the International Measurement Confederation*, *151*, 1–28. https://doi.org/10.1016/j.measurement.2019.107172

Rectification, P. (n.d.). *8. Common Defects and Rectification 8.1*. 36–41.

thetahaurus. (2020). *definition of allignment*. https://www.dictionary.com/browse/alignment

Wiki, R. (2017). *FLOOR TILE DEFECT*. WIKI. https://renopedia.fandom.com/wiki/Floor_Tile_Defects

Yan, R. J., Kayacan, E., Chen, I. M., Tiong, L. K., & Wu, J. (2019). QuicaBot: Quality Inspection and Assessment Robot. *IEEE Transactions on Automation Science and Engineering*, *16*(2), 506–517. https://doi.org/10.1109/TASE.2018.2829927

Youliang Wang. (2019). *Comparative Analysis of Total Station Measuring Inclination and Settlement*. Science Publishing Group. http://sciencepublishinggroup.net/journal/paperinfo?journalid=229&doi=10.11648/j.ajce.20190702.12

Yunardi, R. T., Arifianto, D., Bachtiar, F., & Prananingrum, J. I. (2021). Holonomic Implementation of Three Wheels Omnidirectional Mobile Robot using DC Motors. *Journal of Robotics and Control (JRC)*, *2*(2). https://doi.org/10.18196/jrc.2254

yundle. (2020). *definition of hollow*. Yundle Lnc.

Ali, M. A. H., & En, C. Y. (2018). Control of wheeled mobile robot in restricted environment. *IOP Conference Series: Materials Science and Engineering*, *319*(1). https://doi.org/10.1088/1757-899X/319/1/012057

Allasia, P., Godone, D., Giordan, D., Guenzi, D., & Lollino, G. (2020). Advances on measuring deep-seated ground deformations using robotized inclinometer system. *Sensors (Switzerland)*, *20*(13), 1–20. https://doi.org/10.3390/s20133769

Asafa, T. B., Afonja, T. M., Olaniyan, E. A., & Alade, H. O. (2018). Development of a vacuum cleaner robot. *Alexandria Engineering Journal*, *57*(4), 2911–2920. https://doi.org/10.1016/j.aej.2018.07.005

BCA. (2018). *BCA Construction Quality Assessment System CONQUAS overview*. *April*. https://www.bca.gov.sg/Professionals/IQUAS/conquas_abt.html

Building and Construction Authority. (2018). *Ceramic Tiling*. https://www.bca.gov.sg/Professionals/IQUAS/tile.html

caroline. (2021). *types of crack*. Concrete Supply Co. https://concretesupplyco.com/6concrete-cracks/

Chen, Y., Xiong, C., Ma, T., Zeng, W., & Wang, J. (2020). Research on Floor Response Spectrum of Shielded Building Structure under Seismic Loading. *IOP Conference Series: Earth and Environmental Science*, *446*(2). https://doi.org/10.1088/17551315/446/2/022001

collin. (2021). *definition of allignment*. Collin. https://www.collinsdictionary.com/dictionary/english/alignment

Construction Industry Development Board of Malaysia. (2019a). *Construction Industry Standard - Guidelines on Construction Works at Night (CIS 14:2019)*. *45*.

Construction Industry Development Board of Malaysia. (2019b). *Construction Industry Standard - Guidelines on Prevention of Fall at Construction Site (CIS 15:2019)*.

Eldarrat, H. (2021). *Variability in Crack Patterns and Compressive Strength of Concrete due to Elevated Temperature*. *January*, 0–7.

Hoang, M. L., & Pietrosanto, A. (2021). A New Technique on Vibration Optimization of Industrial Inclinometer for MEMS Accelerometer without Sensor Fusion. *IEEE Access*, 20295–20304. https://doi.org/10.1109/ACCESS.2021.3054825

Jiménez, F. R. L., Ruge, I. A. R., & Jiménez, A. F. L. (2020). Modeling and control of a two wheeled auto-balancing robot: A didactic platform for control engineering education. *Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology*, 1–12. https://doi.org/10.18687/LACCEI2020.1.1.556

john brown. (2017). *avoid hollow spot*. Floor Covering News. https://www.fcnews.net/2016/07/installments-avoiding-hollow-spots-in-hardwoodflooring/

Klančar, G., Zdešar, A., Blažič, S., & Škrjanc, I. (2017). Introduction to Mobile Robotics. *Wheeled Mobile Robotics*, 1–11. https://doi.org/10.1016/b978-0-12-804204-5.00001-9

Kumbar, K. A., & Guruprasad, K. N. (2020). *ARDUINO INCLINOMETER USING MPU6050*. *June*, 187–195.

Kung, F. (2018). Design of agile two-wheeled robot with machine vision. *Proceeding of 2017 International Conference on Robotics, Automation and Sciences, ICORAS 2017*, *2018-March*(February), 1–5. https://doi.org/10.1109/ICORAS.2017.8308055

Lesley Godding. (2020). *the cause make floor hollow*. Linked In.

Luo, Z., Shang, J., Wei, G., & Ren, L. (2018). Module-based structure design of wheeled mobile robot. *Mechanical Sciences, 9*(1), 103–121. https://doi.org/10.5194/ms-9-1032018

Mudeng, V., Hassanah, B., Priyanto, Y. T. K., & Saputra, O. (2020). Design and Simulation of Two-Wheeled Balancing Mobile Robot with PID Controller. *International Journal of Sustainable Transportation Technology, 3*(1), 12–19. https://doi.org/10.31427/ijstt.2020.3.1.3

Pei, H., Jing, J., & Zhang, S. (2020). Experimental study on a new FBG-based and TerfenolD inclinometer for slope displacement monitoring. *Measurement: Journal of the International Measurement Confederation, 151*, 1–28. https://doi.org/10.1016/j.measurement.2019.107172

Rectification, P. (n.d.). *8. Common Defects and Rectification 8.1*. 36–41.

thetahaurus. (2020). *definition of allignment*. https://www.dictionary.com/browse/alignment

Wiki, R. (2017). *FLOOR TILE DEFECT*. WIKI.

https://renopedia.fandom.com/wiki/Floor_Tile_Defects

Yan, R. J., Kayacan, E., Chen, I. M., Tiong, L. K., & Wu, J. (2019). QuicaBot: Quality Inspection and Assessment Robot. *IEEE Transactions on Automation Science and Engineering*, *16*(2), 506–517. https://doi.org/10.1109/TASE.2018.2829927

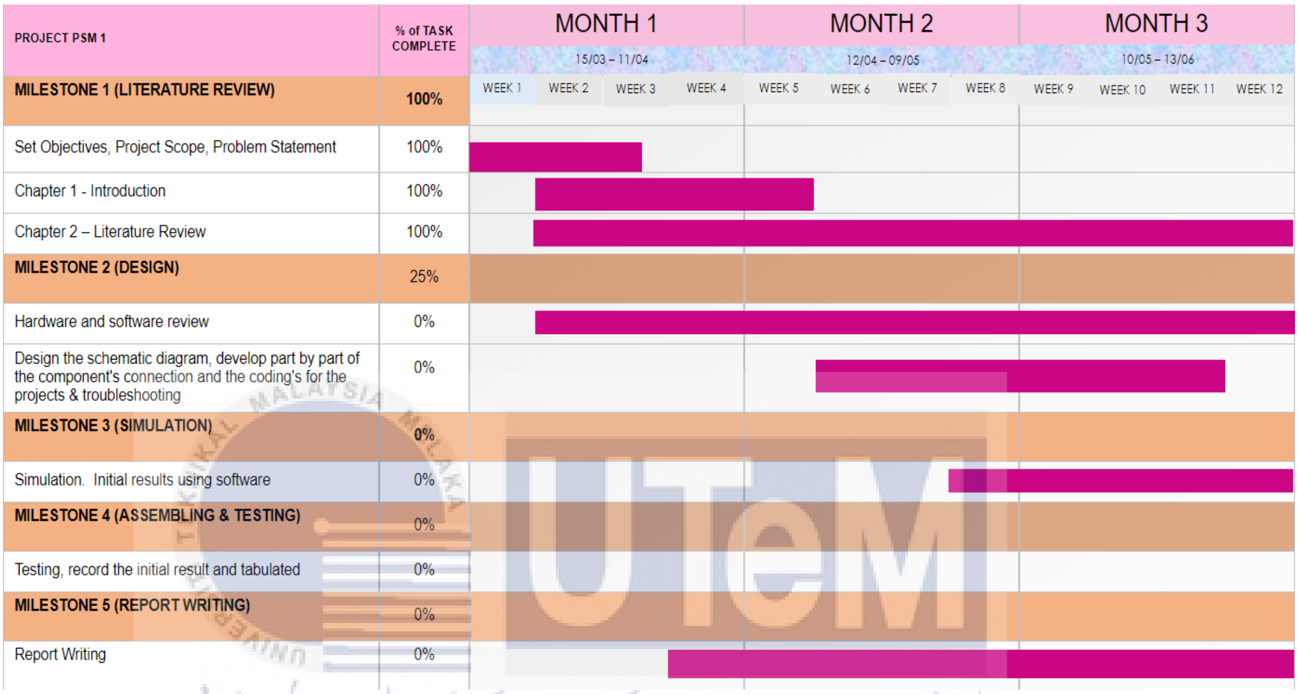
Youliang Wang. (2019). *Comparative Analysis of Total Station Measuring Inclination and Settlement*. Science Publishing Group. http://sciencepublishinggroup.net/journal/paperinfo?journalid=229&doi=10.11648/j.ajce.20190702.12

Yunardi, R. T., Arifianto, D., Bachtiar, F., & Prananingrum, J. I. (2021). Holonomic Implementation of Three Wheels Omnidirectional Mobile Robot using DC Motors. *Journal of Robotics and Control (JRC)*, *2*(2). https://doi.org/10.18196/jrc.2254

yundle. (2020). *definition of hollow*. Yundle Lnc.

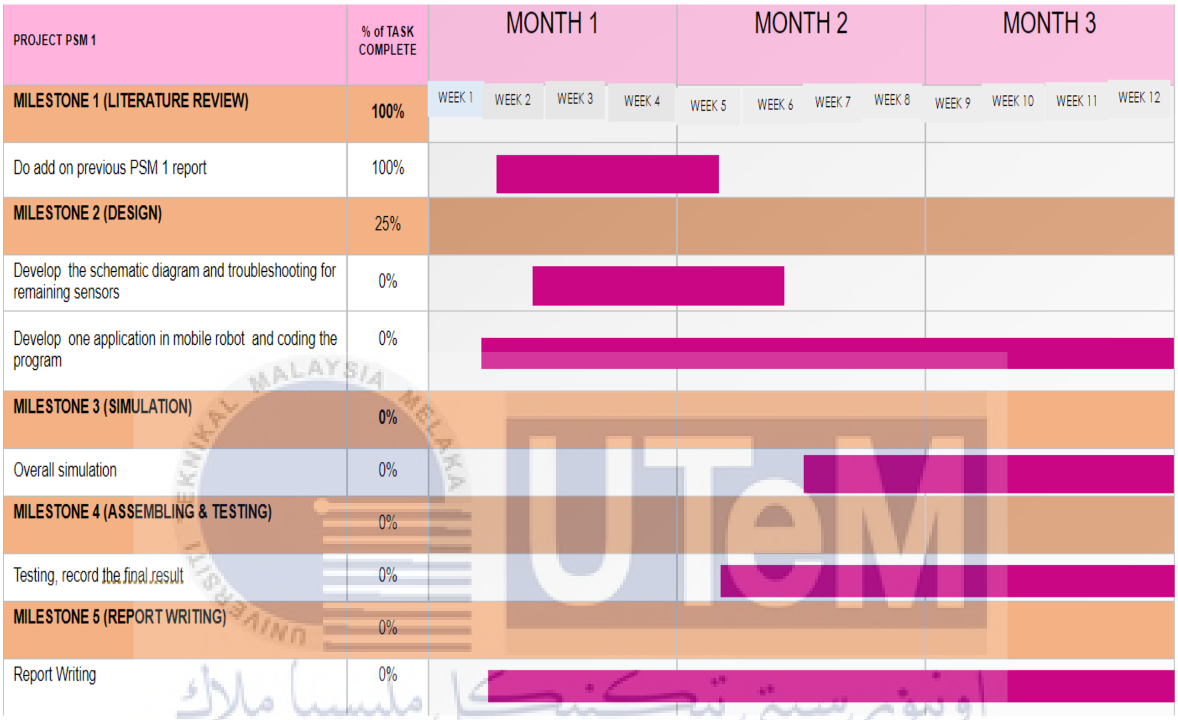
APPENDICES

Appendix A Gantt chart PSM 1



APPENDICES

Appendix B Gantt chart PSM 2



APPENDICES