# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DEVELOPMENT OF AUTONOMOUS ROBOT FOR FLATNESS INSPECTION SYSTEM

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours.

by

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## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours. The member of the supervisory is as follow:

……

Mr SHAHRIZAL BIN SAAT

# ABSTRAK

Kadang-kala, jalan lebuh raya yang tidak mempunyai sudut kerataan yang tepat menyebabkan pengumpulan lopak air semasa hujan. Pengumpulan lopak air ini mengurangkan geseran tayar di jalan raya dan mungkin menyebabkan kenderaan tergelincir di jalan, akhirnya menyebabkan kes-kes kemalangan maut di jalan raya. Selain itu, pihak pengurusan jalan raya juga tidak dapat mengukur kedataran jalan raya dengan tepat. Dengan ini, projek tersebut bertujuan untuk mencipta sebuah robot automatik yang boleh mengukur kedataran jalan raya supaya pihak pengurusan jalan raya boleh menyediakan pemantauan yang lebih baik dan pengurusan di jalan raya.

Sistem tersebut dapat mengetahui lokasi dan kedataran jalan raya. Sistem yang digunakan dalam projek ini adalah melalui mikropengawal PIC18F4550 yang dapat mengawal seluruh sistem semasa dalam operasi. Sistem tersebut beroperasi dengan menggunakan pengesan IMU yang dapat mengukur kuasa tertentu dan kadar sudut robot tersebut. Dalam pengesan IMU tersebut, ia menggunakan gabungan pecutan dan giroskop. Input untuk sistem ini adalah jarak dan kedataran jalan raya manakala output maklumat dari sistem ini akan dipaparkan dalam komputer dengan "grafik User Interface"(GUI) melalui perisian Visual Studio 2015 (VS).

Dengan maklumat yang dikumpul, ia mewakili sudut cerun di jalan dan menunjukkan lokasi yang tepat pada setiap tempat yang mempunyai kedataran yang berbeza. Dengan ini, pihak pengurusan jalan raya dapat menjalankan pengurusan yang lebih baik terhadap jalan raya.

# ABSTRACT

Along the road of highway, some of the location have improper flatness causing accumulation of puddles during raining time. The interaction between the road and the vehicle is affected by these puddles which decrease the efficiency of the vehicle tyres friction on the road, in particularly severe cases, even determine the loss control of vehicle skidding, therefore compromising the driver's and passenger's safety. Sometimes, road management team is not able to measure the flatness of the road accurately. Hence, this project purposely to design and fabricate intelligent mobile robot for flatness inspection of the road to provide better monitoring and management on the road.

The designed system is able to find out the location and the flatness of the road. This project developed the system using PIC 18F4550, the PIC microcontroller controlling the entire program system developed. The system equipped with IMU sensor that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes. The input to this system would be distance and flatness of the road. While the output from this system would be the collected data and information which displayed in the computer with Graphical User Interface(GUI) develop using Visual Studio 2015.

With the result collected, it represented the current slope angle of the road and shows which location flatness is under standard, hence management team could carry out their management on the location.

# DEDICATION

This report dedicated to:
my beloved supervisor;
my beloved parents.

# ACKNOWLEDGEMENT

I would like to thank Mr Shahrizal Bin Saat as my supervisor for his guidance on completing this project. I would also like to thank all my friends that support me during working on this project.

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# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

| | | |
|---|---|---|
| IMU | - | Inertial Measurement Unit |
| GUI | - | Graphical Use Interface |
| VS | - | Visual Studio |
| I2C | - | Inter-Integrated Circuit |
| RPS | - | revolutions per second |
| PIC | - | Peripheral Interface Controller |
| MCU | - | Microcontroller |
| UART | - | Universal Asynchronous Receiver/Transmitter |
| I2C | - | Inter-integrated Circuit |
| ADC | - | Analog to Digital Convertor |
| GPS | - | Global Positioning System |
| DOF | - | Degree of Freedom |
| SSD | - | Selecting the Sensor Data |
| HHM | - | hidden Markov model |
| EMG | - | electromyography |
| HRI | - | human robot interaction |
| CMOS | - | Complementary Metal Oxide Silicon |
| DLL | - | Dynamic link library |
| LCD | - | Liquid crystal display |
| LED | - | Light emitted diode |
| G-forces | - | Gravitational force |
| DC | - | Direct Current |
| et al | - | and others |

# CHAPTER 1
## INTRODUCTION

This chapter provides an overview of the road flatness measurement issues. The problem background and problem statement describe the details of this project later in this chapter. This is followed by research objectives and scopes of study which involves the design and development of an autonomous robot for flatness inspection system.

## 1.1 Background

Along the road of highway, some of the location have improper flatness causing accumulation of puddles during raining time. The interaction between the road and the vehicle is affected by these puddles which decrease the efficiency of the vehicle tyres friction on the road, in particularly severe cases, even determine the loss control of vehicle skidding, therefore compromising the driver's and passenger's safety. Sometimes, road management team is not able to measure the flatness of the road accurately. Hence, this project purposely to design and fabricate intelligent mobile robot for flatness inspection of the road to provide better monitoring and management on the road. The designed system is able to find out the location and the flatness of the road which will later be proposed after this.

Figure 1.1. Accumulation of puddles on highway road during rain time.

## 1.2 Problem Statement

Sometimes, improper flatness of the road causes some serious problem like accumulation of puddles during raining time. The interaction between the road and the vehicle is affected by these puddles which decrease the efficiency of the vehicle tyres friction on the road and may causes accident due to loss control of skidding vehicle. This project investigate the design criteria required for road flatness inspection and measure the slope angle of the road surface along the highway. It is necessary for the road management team to carry out monitoring and maintenance on the road to measure the flatness of the road accurately. Beside issues of flatness, an exact location of road which have to be fixed also an important factor for them. The problem can be improved by introducing an intelligent mobile robot for flatness inspection to measure which location flatness is under standard, hence maintenance can be carry out by the management team.

## 1.3 Objective of The Study

The aim of this project is to measure the flatness of the road with an intelligent mobile robot for flatness inspection. The intelligent mobile robot will be able to carry out flatness measurement of the road automatically. The distance and location which is under standard will be recorded, so road management team can carry out maintenance more easy. The data and information received will be processed and displayed in computer with Graphical User Interface(GUI) which can be references and records for the road management team. With intelligent mobile robot carry out road monitoring job, it can ease the road management team to save more human resources and time. With the intelligent mobile robot for flatness inspection, it not just able to reduce possibility accident at improper flatness road surface area but also reduce the human resources and time.

## 1.4 Scope of The Study

An Inertial Measurement Unit(IMU) is used to collect angular velocity and linear acceleration data which is sent to the main processor. Inside IMU housing contains two separate sensors which is accelerometer and angular rate sensor triad. Both sensor will generate three analog signals output describing the accelerations and angular rate along each of its axes. MPU 6050 triple axis accelerometer and gyro breakout board is used to collect the data on the moving robot. The information from the sensor is then returned to the main processor via a I2C communications interface.

A Rotary Encoder is used to translate linear motion in to digital signal. It is used to determine the speed, distance and position of the robot while carry out measurement. The information will then be send though the center processing unit to the computer.

Visual C# language is used to describe the information of flatness and distance to user. It provided a way for interaction between user and the Visual Studio(VS).

## 1.5 Summary

In this project, there are five chapter in this project to describe and clarify the flow for this project. In first chapter, it includes the background information and objective of this project, relevant solution and method to solve the problem. In chapter two, literature review included the fundamental theory of the material and element used in this project. It also includes the review on the previous work from journal article, book and other sources. Comparison between previous work and current project will give better overview on knowing the method used in previous work and advantages of this method. In chapter 3, methodology describe the flow of the project and method used to accomplish the target output. In chapter 4 cover the actual results get from this project and discussion on finding. Lastly, chapter five will conclude overall result from this project.

# CHAPTER 2
## LITERATURE REVIEW

This chapter summaries prior works related to design an autonomous robot for flatness inspection system. It will cover the background and details of flatness inspection system. It also summarizes the usability of hardware and software that will going to be utilize to this project. Beside that this chapter will summarizes and discuss the past related research of flatness inspection system.

## 2.1 Introduction

Not all the highway road has the same flatness, and sometimes improper flatness can cause problem to road user. One of the major problem is accumulation of puddles during raining time. This puddles endanger the user where it decreased the fiction efficiency between the road and the vehicle tyres. Which will determine the loss control of vehicle skidding on the wet surface. As technologies evolved and instrument such as flatness measurement sensor, positioning devices etc. become affordable and well-known, an autonomous robot for flatness measurement inspection system is not no more a complicated project.

To solve the existing problem, an accurate flatness measurement inspection system is needed. With the autonomous robot that can carry out measurement inspection system on the road, this can ease the workload of the road management team. Hence more human resource and time can be reduced.

Yayan Prima Nugraha, Dwi Hanto, et al (2015) proposed a flatness measurement system that consisting of multiple sensors to determine whether railroads are flat [1]. The measurement system provided information about translational and rotational shifts from original position and angle in particular locations. The magnitudes of the shifts are obtained from IMU sensor that consist of accelerometer, magnetometer, gyroscope, air pressure and GPS. However, some sensor like magnetometer, air pressure and GPS are not necessary for my project that measure flatness of road.

Wahyudi, Ngatelan, et al (2015) proposed a multi-sensor IMU sensor to measure the angular rate and acceleration in three axes of the land vehicle navigation control system [2]. A sensor with high sensitivity has a short range of measurement, so to optimize the sensitivities of all sensors, a multi-sensor system will be applied in wide range of motion. This project proposed idea of optimize the sensitivity of all sensor is very useful as a reference to improve the accuracy of the data.

Ruben Usamentiaga, Julio Molleda, et al (2015) proposed a flatness measurement system using two laser stripes to remove the effects of vibrations [3]. The method used to measure the flatness is by projection of laser stripes on the steel strip. The lengths of the laser stripes on the strips fibers will be extract and further process and compute to flatness. The advantage of this method is easy to maintain, low-cost components and provide accurate results. The main drawback of this method is only measure the flatness of moving object.

Seong-Og Shin, Donghan Kim, et al (2014) proposed a project for controlling mobile robot using IMU and EMG Sensor-Based Gesture Recognition [4]. The proposed system can control the mobile robot by recognizing every gesture from the user. The body gesture is recognized using IMU sensor, where different direction of force acceleration and orientation recognized as different gesture. Although the project focus on Sensor-Based gesture recognition system, but it used mostly the theory of IMU sensor for collecting data from change of acceleration and orientation of the moving object.

Korrakot Surakul, Sucha Smanchat, et al (2016) proposed a project that used to detect accident by using device consists of inertial measurement unit (IMU) and also a 3G cellular module [5]. In this accident detection project, the IMU and odometry will be used to detect accident and the data of accident coordinate will be send out through cellular network to shown the location on map. This method is useful for flatness measurement with using of IMU sensor module to detect the orientation of the object itself.

Nana O. Abankwa, Steven J. Jhonston, et al (2015) proposed a project of measurement system on the vessel's motion by using inertial measurement unit (IMU) [6]. The data collected will be send through wireless method to the Raspberry Pi, this method is useful as a references to flatness measurement project. Besides, the method of transfer data over wireless method is useful and can be reference in the oncoming project.

Kovacheva, M, E. Stoimenov, P. Yakimov, et al (2014) proposed a research to study the basic characteristics and behaviour of the incremental encoders [7]. In this research, a digital circuit is design to generate the output signal from incremental encoder, the simulation allows to study the basic characteristics and behaviour of the incremental encoders. This research study the behavior and also the output waveform of the encoder gives references to this flatness measurement project as encoder is used to measurement displacement.

Arinata Fatchun Iimiawan, Dito Wijanarka, et al (2014) proposed a speed measurement for incremental rotary encoder using multi stage moving average method [8]. Classical theoretical algorithms which include frequency counting and period counting algorithm can reduce measurement error and increase the measurement accuracy for rotary incremental encoder is very useful for application in speed and displacement measurement.

Wang, Yu-Duo, and Li Bo, et al (2013) proposed a research to study the tools that are useful in handling mathematical operations and design user interface for developer [9]. Visual Studio IDE offers some function in Visual Basic that can handle complicated mathematics operations in scientific research and application design. This research is useful in this flatness measurement project, the method to handle the mathematical data for graph processing and tools to design user interface is one of the references in this project.

Sven Amann, Sebastian Proksch, Sarah Nadi, et al (2016) proposed a research on the Integrated Development Environments (IDEs) in order to understand how it is useful to the developers [10]. In this research, it is important to study how much time is developer spend on Visual Studio IDE and it assistance tools with code executions. This research is useful as the developer tools that been used can be references when choosing the tools to create graphical user interface (GUI) in this flatness measurement project.

## 2.2 Introduction of Inertial Measurement Unit (IMU) Sensor

Based on the journal article appear in 2015 International Conference on Automation, Cognitive Science, Optics, Micro Electronic- Mechanical System, and Information Technology (ICACOMIT), an Inertial Measurement Unit(IMU) is one of the unit in the electronic module that will collects both acceleration data and angular velocity which will then sent to the main processor [1]. Inside the electronic module of IMU, it actually contains of two sensors which are accelerometer and gyroscopes.

An accelerometer is very useful for sensing the vibration or orientation of an object. The acceleration measurement can be divided into two type which is static and dynamic acceleration. A static forces of acceleration is due to the gravitational pull of freefall object which measure in meters per second squared (m/$s^2$) or in G-forces (g). At any surface on the earth, an accelerometer at rest will indicate approximately 1 g upwards, because acceleration acting in upwards direction is relative to the local inertial frame. In outer space, an accelerometer will read only zero during any type of free fall. An analog accelerometer will produce a continuous voltage proportional to acceleration. While dynamic forces of acceleration are measured based on movement and vibration of the object itself. Accelerometer generates three analog signals along three axes x, y, z among it six's surface. The force can act in direction x+ or x- which means forward and backwards, with the same conditions goes for axes y and axes z. Hence it will be able to measure acceleration among all six surface.

A gyroscope is very useful to measure or maintain orientation. Unlike the accelerometer, a gyroscope will not be affected by gravitational force. Due to not affected by any linear acceleration based on vibration, a gyroscope is able to maintain its level of effectiveness and measure the rate of rotation around a particular axis. Gyroscope is used to sense rotation and measure angular velocity of the object itself. The measurement unit of angular velocity are degrees per second ($°/s$) or revolutions per second (RPS). Typically, a triple axis gyroscope can measure rotation around three axes which are x, y, z. But limitations of gyroscope are it often used on objects that are not spinning at a very high speed. Figure 2.1 shows IMU sensor measure angular