UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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AUTONOMOUS ROBOT FOR FLATNESS INSPECTION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Engineering Technology (Industrial Electronic) (Hons)

by

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FACULTY OF ENGINEERING TECHNOLOGY
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **AUTONOMOUS ROBOT FOR FLATNESS INSPECTION**

SESI PENGAJIAN: **2015/16 SEMESTER 1**

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I hereby, declared this report entitled “Autonomous Robot for Flatness Inspection” is the results of my own research except as cited in references.

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Name **: Jamil bin Ab Hamid**

Date **: 18/12/2015**

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 Engineering Technology (Industrial Electronics) (Hons.). The member of the supervisory is as follow:

....

(Shahrizal bin Saat)

ABSTRAK

Projek Sarjana Muda (PSM) ini menunjukkan cara bagaimana untuk memeriksa kerataan di persekitaran permukaan seperti jalan raya dan permukaan lantai bangunan. Terdapat banyak cara untuk memeriksa kerataan, misalnya dengan menggunakan kaedah lama iaitu pengukur rata menggunakan buih. Teknik ini digunakan secara meluas kerana kos rendah, tetapi data yang diperolehi tidak tepat dan sukar untuk dijadualkan. Projek ini menggunakan robot autonomi yang menggunakan komponen elektronik dikenali sebagai Unit Pengukuran Inersia (IMU). Komponen ini akan bertindak balas dengan perubahan gerakan dan ia akan memberi nilai untuk paksi x, y dan z untuk roll, pitch dan yaw. Robot ini dicipta dengan pengesan infra merah yang berfungsi untuk mengelak halangan, namun ia perlu digunakan pada tempat di mana tidak ada halangan yang banyak kerana pengesan ini hanya boleh mengesan halangan pada hadapan robot sahaja dan statik menyebabakn pergerakan akan menjadi terhad. Hasil dari IMU akan dipaparkan pada antaramuka pengguna grafik dan ianya akan diplotkan dalam LabVIEW dalam bentuk carta masa sebenar. Analisis kaedah yang berbeza untuk penapis IMU untuk memproses dan memerhati tindak balas output akan dilaksanakan. Langkah untuk mengkonfigurasi semua proses yang akan ditunjukkan dalam laporan ini dan keputusan eksperimen juga akan diterangkan dalam laporan ini

ABSTRACT

This final year project (FYP) report shows how to inspect the flatness of surroundings surface like road and building surface. There are many ways to inspect for the flatness, for the example by using old school method that is balance measurement. This technique is widely used because of the low cost, but the data is not accurate and hard to tabulate. This project is using an autonomous robot that has been attached an electronic component called Inertial Measurement Unit (IMU). This component will react with the changes of motion and it will give a value for the axis x,y and z that is for roll, pitch and yaw. This robot is created with obstacle avoidance sensor that is infrared sensor, it should be use at a place where has less obstacle, because the sensor can only detect obstacle at the front of the robot and static then it will limit the movement of the robot. The result from the IMU will be display at Graphical user interface that is LabVIEW in form of real time chart. The analysis of different method for IMU filters to process and observe the output response will be implement. Step to configure all the process will be shown in this report and result of the experiment will also be explained in this report.

DEDICATION

Specially dedicated to my beloved parents,
Ab Hamid bin Muhammad and Rohimah bt Senik
To my siblings,
To all my course mates,
4BETE 2015/2016

Thank you for keep supporting me until i completed the bachelor degree project
I am very appreciate all of your support and help.
Thank you for all memories.

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Firstly i would like to forward my utmost gratitude to my supervisor, En Shahrizal bin Saat because have guide me to complete my PSM (Projek Sarjana Muda). Special thanks to my co supervisor En. Farees Ezwan and my Friend Ibrahim bin Abu Bakar who has also guide and gave many information to perform my project.

I would like to give my appreciation to all lab mangement, especially technicians who give cooperation for me to complete my project by manage the time to use the lab machines.

Lastly I would like to thanks to all person who involve directly and indirectly during the project research. I hope that my report will be source for other student and can help them understand the guideline how to complete the PSM in the future.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURE

CHAPTER 1

INTRODUCTION

1.1 Background

The purpose of this project is to improvise current technique for flatness inspection technology that are important in building and road construction. This project is used to inspect a flatness in a place or spot. Using the IMU sensor, the slope of the travelling road is estimated and that is utilized to estimate the planar distance from the origin which is a very important factor for the localization of the mobile robot on the provided map, while the travel distance is being measured by the encoders,the absolute motion of the mobile robot is recorded based upon the encoder data which is compensated for the slope angle which is measured by the IMU (Inertial Measurement Unit) sensor. This IMU is a combination of two sensors that is gyroscope and accelerometer. This combination of two sensors will give a smooth and accurate values of the changes of angle made by the mobile robot.

1.2 Problem Statement

This PSM project is built to improve the exists flatness inspection technique . These are the problem for the exists technique:

a. Robotic for tunnel inspection and condition of tunnel is currently been used but the technology is using a wired robot need a human guide.
b. Concrete Laser Filtering (CLF) is used to make sure the surface is flat but due to high cost and need a big space, it caused a low demand from user.
c. A highway road is always faced with flood due to uneven road. A regular inspection used manpower and manual tools to inspect the flatness of the road.

1.3 Objective

a. To create a autonomous robot for flatness inspection.
b. Plot the real time chart for observation purpose.
c. Analyze the data through GUI

1.4 Scope

This research work includes the combination several elements and aspects such as hardware, electronic and software. In this project, the mobile robot will be operated within a fixed environment where there are no moving objects around the robot. There will be no sensor used to detect the existence of obstacles or changes of its environment. Therefore, no obstacles avoidance will be performed.. Below are the scopes of this project :

i. Design and construct the hardware and mechanism of autonomous robot.
ii. Design and construct the circuits that control all the peripherals of the Autonomous robot, which include IMU circuit, LCD display and DC Brushless motor driver. Microcontroller from Microchip PIC18F family will be used as main controller for the system.

iii. Implementation of different method for IMU filters to process and observe the output response at Graphical User Interface (GUI).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarizes and discusses all the reviews of some similar project that conducted out prior doing this project. Literature review provides information such as theories, techniques and design applied in projects of related topic.

2.2 Gyroscope Based Navigation for mobile Robot

The first nonholomic differential mobile robot in Universiti Teknologi Malaysia (UTM) was developed by (Ng Xiao Qin.2011.) based on gyroscope model.

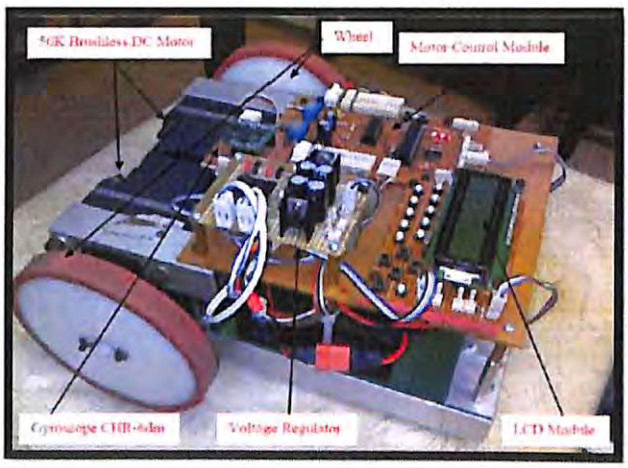

Figure 2.1: Gyroscope-based nagivation mobile robots

In this project, a differential base movement was specifically designed for the mobile robot. The angles of IMU along with gyroscope have been used as the feedbacks sensor for this mobile robot. The robot was actuated by two units of Vexta Brushless DC motors and Microchip PIC33FJ128MC202 as a main controller and motor control module. The goals of this project are to achieve a simple path and to examine the positional mobile robot navigation.

The control algorithm that applied to robot is only using PD control. However, there still exist a significant error of gyroscope reading and the actual path. Gyroscope value also provided unstable reading due to different power supply. It is suggested that PID control system Kalman filter or Butterworh low pass filter will overcome these drawbacks.

2.3 TWO WHEELED SELF BALANCING ROBOT

(Calvin Chan Lit Yong.2010.) from Universiti Teknologi Malaysia (UTM) has developed two wheeled self balancing robot. This two wheeled robot is using inertial measurement unit (IMU) together with kalman filter to combine both accelerometer and gyroscope measurement in order to estimate and obtain the tilt angle of the robot. This two wheeled self balancing robot has the ability to balance itself using IMU.

According to many researcher, conventional three or four-wheeled mobile robot are common, as they offer static stability without the help of external forces. These robots maximize their platform stability by lowering their center of gravity. If the robot's center gravity is too high, or the robot's motion changes too rapidly, the robot can fail and tip over. A robot must be tall enoug to be able to interact with people and human environment at a reasonable height and also capable of making its way around without bumping into things. In this case conventional multi-wheeled mobile robots have certain limitation in achieving these requirements.

Two-wheeled balancing robot, on the other hand has several advantages for this case. This robot generally statically unstable, but dynamically stable which allow it to have a considerable resistance against external impulse forces. The inverted pendulum concept used to balance this robot defies conventional multi-wheel robot's control theory

Figure 2.2 Balancing robot with a bottle of water on top

2.4 Filtering Algorithm Research on MEMS Gyroscope Data

(Liu.2010.) has investigated on the filtering algorithm on MEMS gyroscope data in. There are two ways that are recommended on this work which were Butterworth low pass filter with the help of PSD estimate method and Kalman Filter. Design Butterworth filter according to PSD estimate which can achieve very high spectrum resolution, so implement PSD estimate of gyroscope"s output data through Yule Walker method. Yule Walker method is based on the AR model of stationary stochastic process. The results show that the sine composition included in original data disappear after filtering and the plain part between -60dB/Hz and -70dB/Hz before filtering also become the plain part between -80dB/Hz and -100dB/Hz after filtering. Kalman filter adopts statement equation to describe the dynamic change discipline of estimated variable, whose dynamic statistical information is decided by source white noise and statement equation. Through the analysis to a great number of groups of data, it shows that the IMU output drift data is erratic and in most case not mean stationary, but variance stationary. The final equations that are obtained from the experiment are

$$X_{k}/k-1 = X_{k-1} \tag{2.1}$$

$$P_{k}/(k-1)=P_{k-1+Q} \tag{2.2}$$

$$K_{k}= \mathrm{P_k/k} - 1(\mathrm{P_k/k} - 1 + \mathrm{R})-1 \tag{2.3}$$

$$X_{k}=X_{k}/k-1+K_{k}\ (Zk-X_{k}/k-1\ ) \tag{2.4}$$

$$Pk=(\ 1-k\ )P_{k}/k-1\ (1-K)k\ +K_{k}RK_{k} \tag{2.5}$$

where,

$X_{kk}-1$ is one step prediction of state X_{k};

$P_{kk}-1$ is one step prediction of mean square error Pk;

K_{k} is the filter gain;

X_{k} is state estimate;

P_{k} is mean square error estimate.

Let say initial values X0 and P0 are set, the state estimate $X_{k}(k=1,2,.)$ of k moment through

Kalman filter filtering equation can be easily obtained.

Table 2.1 The mean and variance of the data before filtering and after Butterworth filter

filtering.

	Mean	Variance
Before filtering	0.2615	0.0034
After filtering	0.2615	1.6894×10^{-4}

Table 2.2 The mean and variance of the data before filtering and after Kalman filter filtering.

	Mean	Variance
Before filtering	0.2615	0.0034
After filtering	0.2615	1.3918×10^{-4}

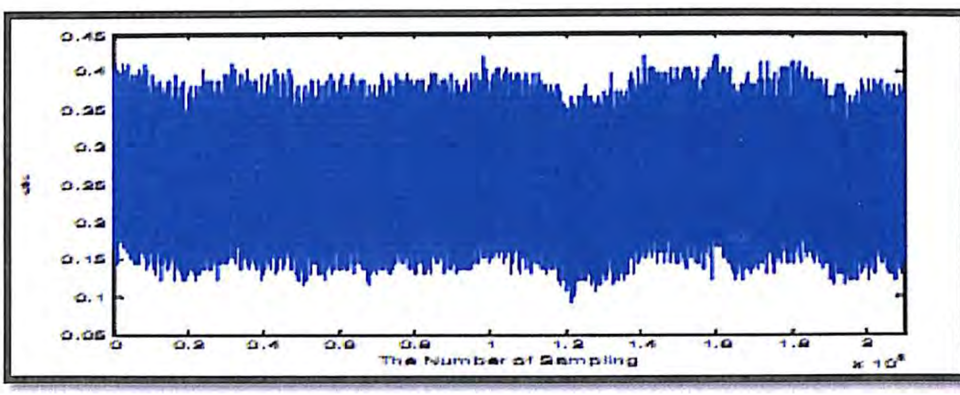

Figure 2.3 The sampling data of Y-axis gyroscope

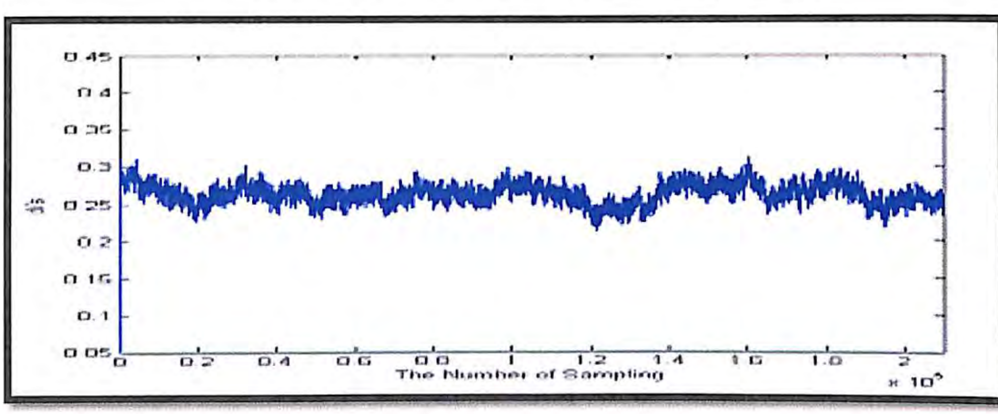

Figure 2.4 The filtered data after Butterworth filter filtering

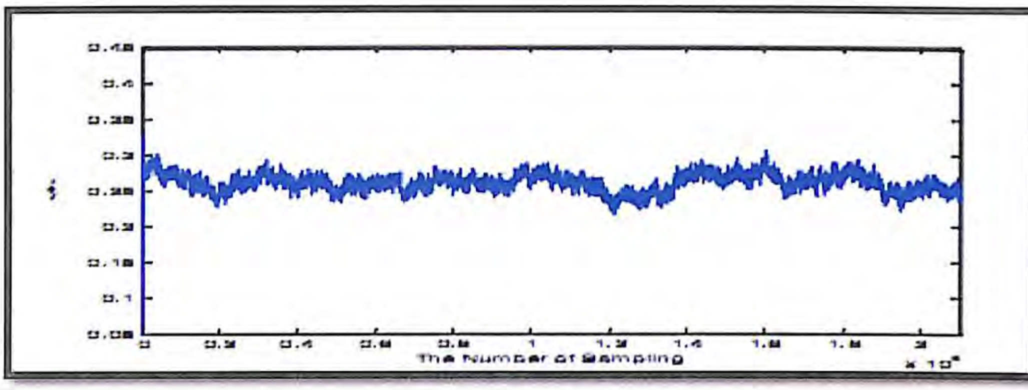

Figure 2.5 The filtered data after Kalman filter filtering

Based on observation, Kalman filter more suitable filter rather than Butterworth Low pass filter. As the result of the mean and variance shown in Table 2.1 and Table 2.2 the data through Butterworth filter is $1.6894e{-}4$and that through Kalman filter is $1.391e{-}4$. From the Figure 2.4, Figure 2.5, and Figure 2.6 show the sampling data and filtered data.

2.5 Improvement of Travel Distance at the Outdoor Environment by using IMU and Encoder

(Kyoung-hwan,Beom-seok Seo,Keon-woo Jeong and Jang-myung Lee.2010.) from Pusan National University has make a research for improvement of travel distance at outdoor environment by using IMU and encoder.A new algorithm is been proposed for improving estimation accuracy of travel distance of a mobile robot at the outdoor environment by estimating the slanted angle of road. When a mobile is robot moving on the flat surface, the travel distance can be estimated by the encoder values directly even though it includes some error caused by the slippage and the disturbances. However, when the mobile robot is moving on irregular topography, the real travel distance of the mobile robot become less than the distance provided by the encoder.

Using the gyroscope sensor, the slope of the travelling road is estimated and that is utilized to estimate the planar distance from the origin which is a very important factor for the localization of the mobile robot on the provided map, while the travel distance is measured by the encoder. The absolute motion of the mobile robot is recorded based upon the encoder data which is compensated for the slope angle which is measured by the IMU sensor.

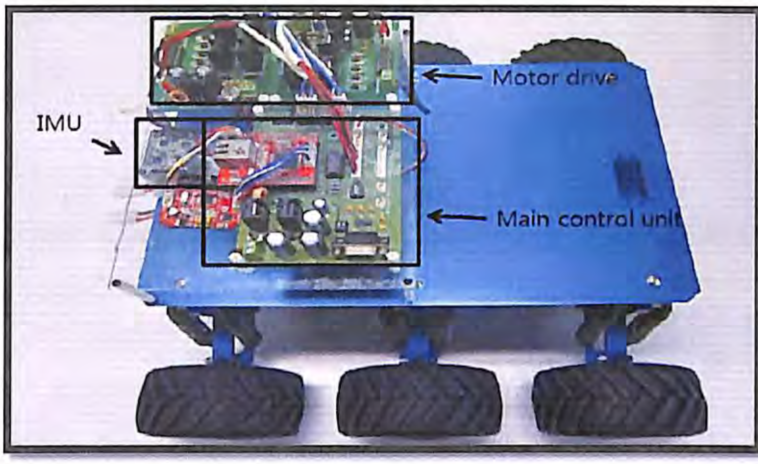

Figure 2.6 Overall composition form of mobile robot

$$\omega s = \frac{1}{n}\sum_{i}^{n} = 1\ \omega g, i \qquad (2.6)$$

where

ωs - static bias drift

n - total number of samples(n = 100 for a 10-second sample with the RD2100)

However, this simple method does not correct the errors due to the non-linearity in the

scale factor and temperature.

As mentioned above, the basic idea is to rotate the gyro at a known input rate w, and compare this value with the measurement output of the gyro, ωg . The difference ε between both values is the error introduced by the gyro because of the non-linearity in the scale factor.

$$\varepsilon = \omega g - \omega \qquad (2.7)$$