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PROJECT REPORT

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Mobile Robot Navigation System: Line Following Robot by using PID algorithm

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Bachelor of Mechatronics Engineering

2014/ 2015

"I hereby declare read through this report entitle "Mobile Robot Navigation System: Line Following Robot by using PID algorithm" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

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MOBILE ROBOT NAVIGATION SYSTEM: LINE FOLLOWING ROBOT BY USING PID ALGORITHM

LING SING YIP

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014/2015

I declare that this report entitle "Mobile Robot Navigation System: Line Following Robot by using PID Algorithm" is the result of my own research except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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Date : 26.6.2015

To my beloved mother and father

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ABSTRACT

According to the World Health Ranking 2011, it has ranked Malaysia as the top 20 countries with the most death causes of road accidents. Hence, autonomous navigation robot is to compromise and reduce the car accident. Conventional line following robot has slow response and the robot would not be able to follow the line smoothly and sometimes robot tends to move out from the track. This report will present a line following robot by using PID algorithm to track a line. The objective of this paper is to design a high speed and autonomous mobile robot that follows a line accurately by using PID algorithm. In this case, PID algorithm is used to reduce wobbling motion and rectify the error if it leaves the line. This particular robot is an autonomous robot which is able to follow a black line drawn on a white surface while maintaining a smooth tracking motion. Two experimental tests were proposed to achieve the objective of the project. Experiment 1 was conducted to test the performance of line following robot while moving at the high speed while experiment 2 to test the sensitivity of sensor which will impact the accuracy performance of the robot. Result from first experiment shown that the PID controller much faster and accuracy compares to P controller which only taken 10s to complete the track compared to P controller needed 14.11s. For accuracy test, the average error detected by PID controller is -0.7333 while for P controller is -1.0556. By implementing of PID controller closer to the desired value (zero) compare to P controller. Lastly, for experiment 2, it shows that the distance between the surface and sensor will affect the performance in term of accuracy of the sensor. The result shows that the sensor needs to locate 0.6cm from the surface to obtain optimum output.

ABSTRAK

Menurut kajian World Health Ranking tahun 2011, Malaysia telah diiktirafkan sebagai Negara berada dalam kedudukan 20 teratas berdasarkan kemalangan maut berlaku di jalan raya. Oleh hal yang demikian, robot berasaskan konsep navigasi tanpa kawalan manusia wajarnya dicipta untuk mengurangkan kadar kemalangan jalan raya. Kertas kerja ini akan membentangkan tentang robot pengikut garisan dengan menggunakan sistem kawalan PID algoritma. Objektif kertas kerja ini adalah untuk menghasilkan robot pengikut garisan yang berkelajuan tinggi dan tepat ketika mengikut garisan dengan menggukan sistem kawalan PID algoritma. Sistem kawalan PID algoritma digunakan untuk mengurangkan kegoyangan ketika bergerak dan memperbetulkan gerakan jika ianya terkeluar dari garisan. Robot ini merupakan robot yang pintar kerana mampu bergerak mengikuti garis hitam yang dilukis pada permukaan putih serta dapat mengawal pergerakan dengan lancar. Terdapat 2 eksperimen yang di jalankan untuk mencapai objektif kertas kerja ini. Eksperimen yang pertama adalah unutk menguji prestasi robot pengikut garisan ketika bergerak dalam kelajuan tinggi, manakala eksperimen kedua adalah untuk menguji kepekaan sensor yang mempengaruhi ketepatan pergerakan robot. Hasil kajian dari eksperimen pertama menunjukkan bahawa kawalan PID lebih pantas dan tepat berbanding kawalan P dengan mengambil masa 10 saat untuk melengkapkan satu pusingan berbandingkan kawalan P mengambil masa 14.11 saat. Untuk ujian ketepatan, purata ralat yang dikesan menggunakan kawalan PID ialah -0.7333 manakala untuk kawalan P ialah -1.0556. Dengan melaksanakan kawalan PID pada sistem, ia akan menghampiri nilai yang dikendendaki (zero) berbanding dengan kawalan P. Eksperimen terakhir menunjukkan bahawa jarak antara permukaan landasan dan sensor akan mempengaruhi prestasi iaitu kepekaan sensor tersebut. Hasil kajian menunjukkan sensor tersebut mestilah berada di atas paras 0.6cm daripada permukaan landasan untuk memperoleh output yang optimum.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

The World Health Ranking 2011 has ranked that Malaysia are the top 20 countries with the most death cause by road accident. Road traffic accidents have been identified top cause of death in Malaysia after heart disease, stroke and pneumonia. Based on report by the Department of Road Safety Malaysia, there were increments of 21 percent in the number of vehicles involved in car accidents from year 2005 until 2009. [19]

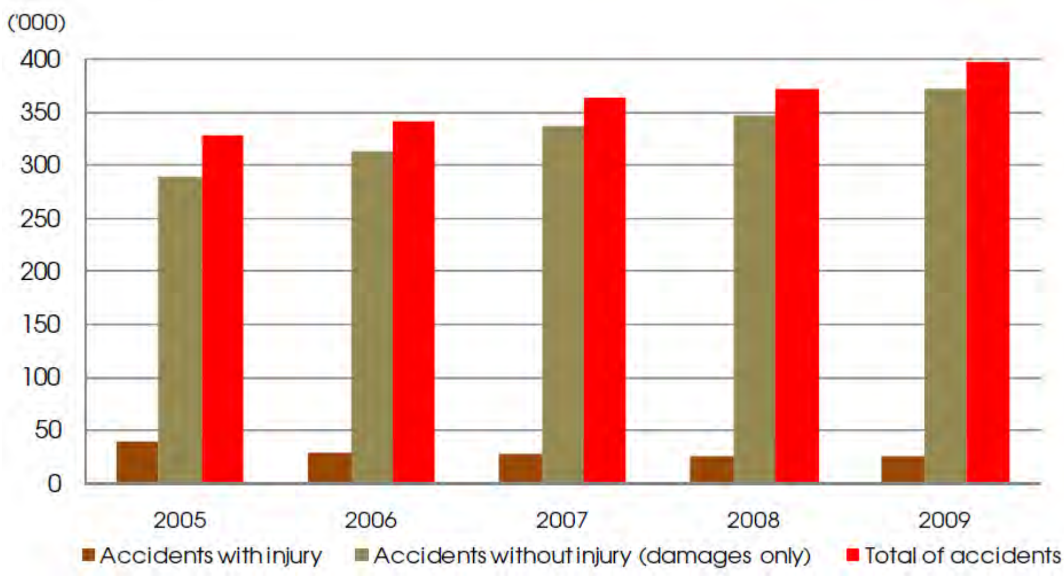

Figure 1.1: Number of accidents, Malaysia, 2005-2009 [1]

The figure 1.1 shows that the number of vehicles involved in accidents has increased in year 2009 (705,623) compared to 2005 (581,082), overall an increase of 21.4 per cent[1]. Almost all categories of vehicles showed an increment in vehicle accidents led by cars & taxis, followed by motorcycles & bicycles, trucks, vans & four wheel drives, buses and others.

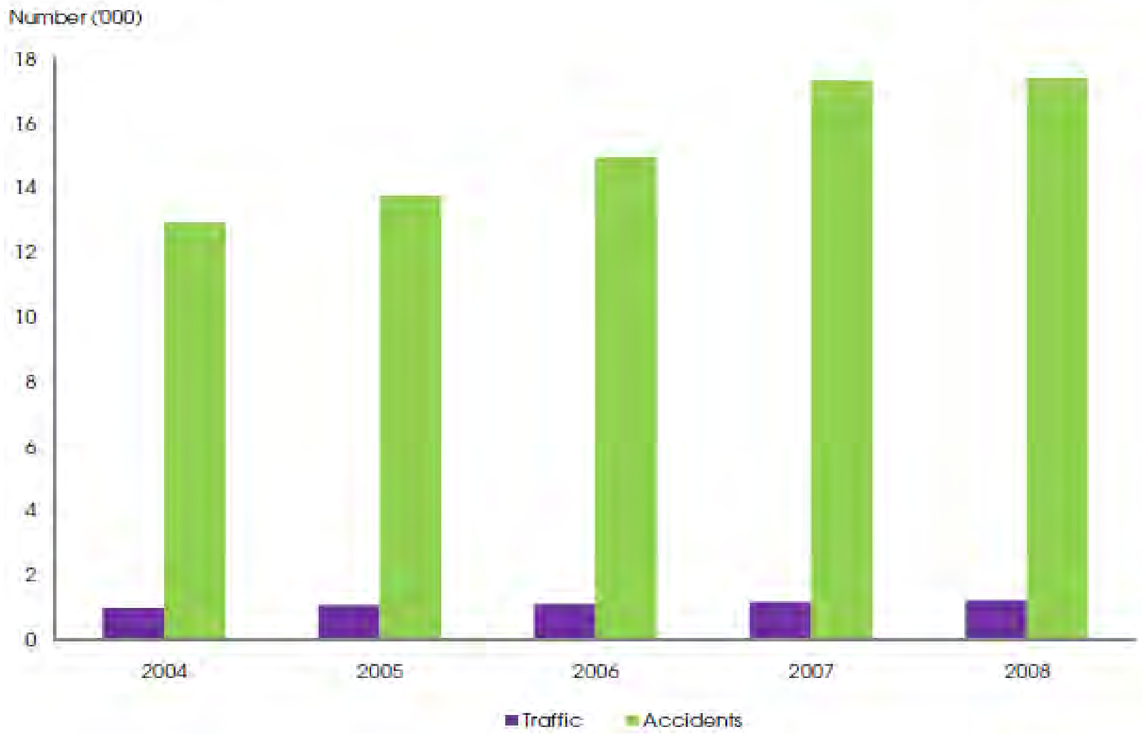

Figure1.2: Number of traffic and highway accidents, Malaysia, 2004-2008 [1]

Highways provide an alternative route to most of the road users. Other than providing a convenient travel option, users may also shorten the travelling time. Until year 2008, there were 24 highways fully-operating in Malaysia. Overall, the traffic volumes have increased to 1,232.6 million in 2008 compared to 1,001.2 million in 2004, an increase of 23.1 per cent. Increased traffic volumes indirectly contributed to the increased number of accidents on the highways. There were a total of 17,369 highway accidents recorded in 2008 compared to 12,949 in 2004, an increase of 34.1 per cent [1].

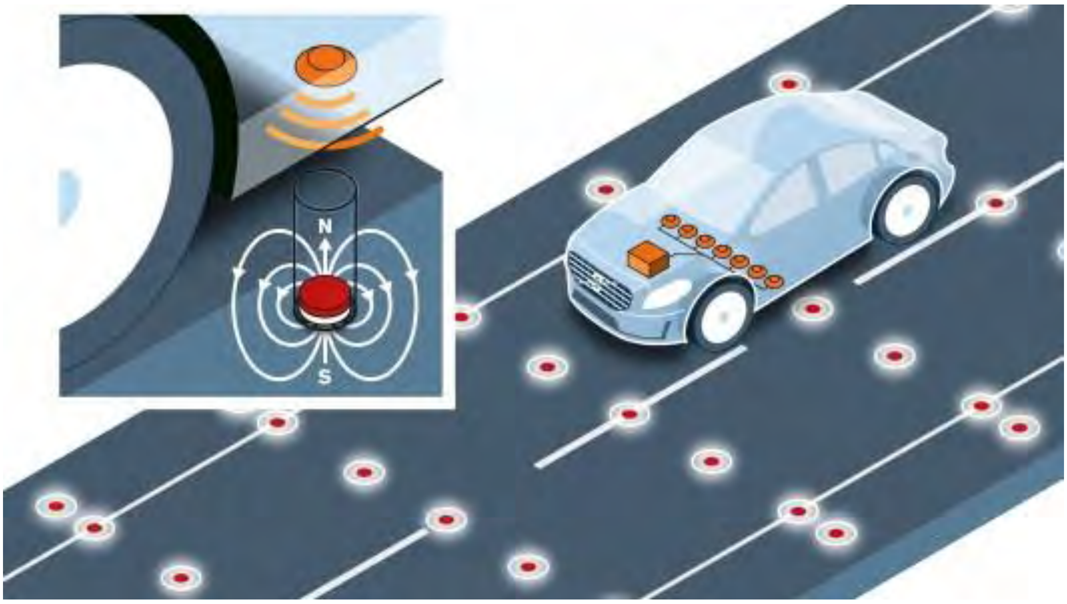

Figure 1.3: Volvo self-driving line following car by use of magnets

Source: https://www.media.volvocars.com/global/en-gb/media/pressreleases/140760/photos

Autonomous navigation robot is to compromise and reduce the car accident. The line following robot is under the category of autonomous navigation robot which can detect visible like detect a line or it can appear invisible like a magnetic field. Line following robot has been a dream of mankind a long time ago. Car manufacturing company, Volvo work on autonomous vehicle with a research project on line following that that use of magnets to keep self-driving cars on the road. Volvo Company pledging to have self-driving autos on 2017 [14]. Incorporating magnet-based positioning in preventive safety systems could help prevent run-off road accidents. Magnets could facilitate accuracy of winter road maintenance, which in turn could prevent damage to snow-covered objects, such as barriers and signs, near the road edge. Upon the researches made, the rate of car accident will be dramatically reduced and the dream of mankind shall be realized in near future. Autonomous car navigation will be a boon to the society. In this project, using the same principle like Volvo Company by replacing the line on the group or track. PID controller will be designed for line following robot to track line.

1.2 Problem Statement

Classical or the line following robot without PID controller has slow response and the robot will not be able to follow the line smoothly and sometimes robots tends to move out from the line. If there is maximum speed beyond which cannot use this classical algorithm, otherwise the robot will overshoot from the line. This problem also will cause the motion of the robot to wobble and its path similar a zigzag pattern, it is wasting valuable time and power supply. Although the mobile robot can follow the line track, its motion and overshoot problem while following in maximum speed needs to be improved. The line following robot faced difficulties to obtain stable and precise navigation. When the speed of the line following robot increases, the robot would not be able to navigate effectively and follow a line precisely. The robot also would not be able to take a sharp turn and tend to move out from the track. These operating problems due to some constraints, slow responses of sensor, time delay and other disturbances. In order to overcome the problem, a better controller is needed to make the robot follow the line accurately, smoothly and without leaving the track of course. The robot will gradually go steer in this project, PID controller is used to improve the motion which forms an effective closed loop system. In developing a PID controller for a line following robot, there are a few requirements which needed to be considered in order to complete the project. Therefore, implementation of PID controller would be able to overcome the problem and increase the performances of the line following robot.

1.3 Project Objective

There are few objectives that need to achieve by end of the project. The objectives of this project are:

i. To design and develop a PID controller for line following robot that able follows a line in high speed and accurately to reduce wobbling motion (oscillation) and be able to rectify the error if it leaves the line.

ii. To test the speed and accuracy of the robot movement by judging its forward motion and overcoming a curvy track turn.

1.4 Scope of projects

i. This project covered the design and develop a PID algorithm controller for a line following robot.
ii. Arduino UNO is selected as microcontroller of the line following robot.
iii. Proportional, integral and derivative controller as a control system of the line following robot.
iv. The speed of the robot is verified by using the PWM module from minimum speed to maximum speed.
v. In this project, the proving of the design method is done by doing lab experiments.
vi. The mobile robot use in this project was small in size, the dimension of the mobile robot was 120mm width and 130mm long.
vii. The mobile robot use 5 sets of IR sensor to communicate with the system.

1.5 Report Outline

This report is about the line following robot by using PID algorithm. In this report, the chapter 1 will cover about the motivation for designing a line following robot by using PID algorithm. The objective and scope of the design will also be stated in this chapter. The theory and basic principle and the review of previous related work of the line following robot by using a PID algorithm will be covered in chapter 2 of the report. This report will also list out the methods and techniques used in this design and fully explained in chapter 3. The preliminary result and the conclusion will be covered in chapter 4 and chapter 5 in this report.

CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

A Line follower is a machine that can follow a path. The path can be visible like black tape on a white surface (or vice-versa) or it can appear invisible like a magnetic field [2]. The essential method to build a line follower is sensing a line and manoeuvring the robot to stay on course, while constantly tuning its error (wrong moves) using feedback mechanism and forms a simple yet effective closed loop system. Line following robot is mobile robot that widely used in different are, especially in industry field. These robots function as material carrier to deliver the product from one place to another where the conveyor and rail not possible. Apart from line following capabilities, this robot should also capability to navigate. Sensor positioning also plays an importance role in optimizing robot navigation performance. Over the past, there are many method for controller has been develop to increase the performances of the robot in term of navigation such as PID controller, PI controller, neutral network and fuzzy logic.

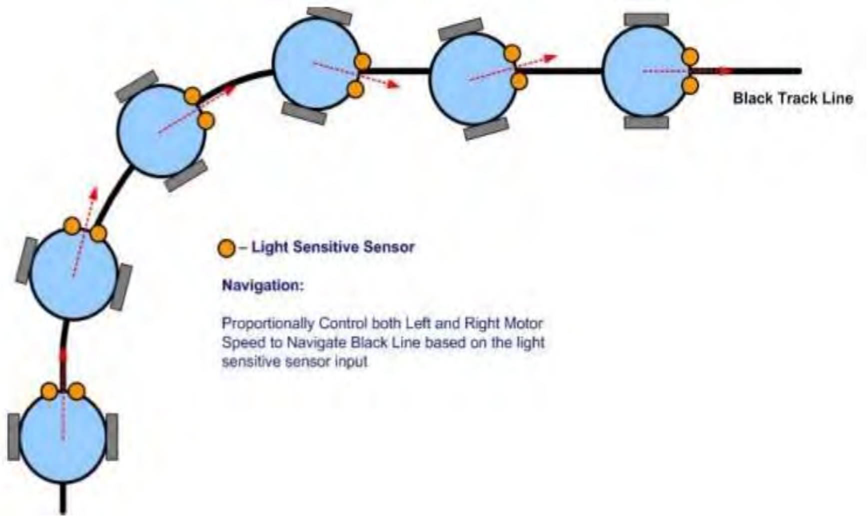

Figure 2.1: Line tracking navigation principle on the line follower robot

Source: http://www.ermicro.com/blog/wp-content/uploads/2011/01/op-amp_lfr_01.jpg

2.1.1 History of PID Controller

PID controllers date to 1890s governor design. PID controllers were subsequently developed in automatic ship steering. Elmer Sperry is the person develops the PID type controller in 1911. However, the first published theoretical analysis of a PID controller was done by Russian-American engineer Nicolas Minorsky, in Minorsky in year 1922. In early history, PID controller implemented as a mechanical device. These mechanical controllers use a lever, spring and a mass and were often energized by compressed air [2].

2.2 Theoretical Background of PID algorithm

A proportional-integral-derivative controller (PID controller) is a generic feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs [3].

The PID algorithm accounts the following three things are existing error, the time where the system stay away from the mean position and the possible of overshooting the mean position.

The PID controller calculation algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted by terms P, I, and D. Simply put, these values can be interpreted in terms of time. P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of changing.

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). The final form of PID algorithm is:

$$u(t) = MV(t) = Kpe(t) + Ki \int_0^t e(\tau)d\tau + Kd \frac{d}{dt}e(t) \quad (2.1)$$

Kp : Proportional gain, a tuning parameter

Ki : Integral gain, a tuning parameter

Kd : Derivative gain, a tuning parameter

e : Error $= SP - PV$

t : Time or instantaneous time (the present)

τ : Variable of integration; takes on values from time 0 to the present t.

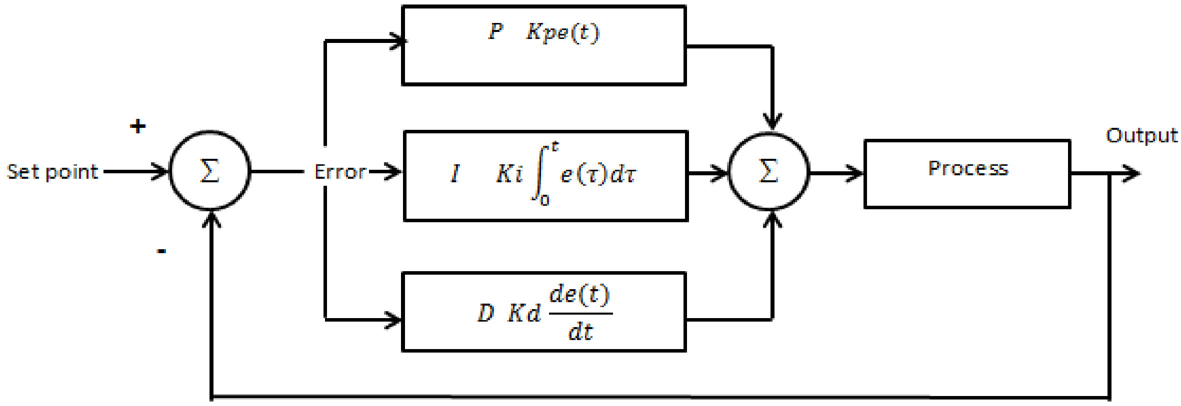

Figure 2.2: A block diagram of a PID controller in a feedback loop

2.2.1 Proportional term

The proportional term produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain constant [3].

The proportional term given:

$$Pout = Kp\, e(t) \qquad (2.2)$$

2.2.2 Integral term

The integral term is proportional to both the magnitude and duration of the error. The integral in PID controller is the sum of the instantaneous error and give the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain K_i and added to the controller output [3].

The integral term given:

$$I\,out = Ki \int_0^t e(\tau)d\tau \qquad (2.3)$$

2.2.3 Derivative term

The derivative of the process error is calculated by determining the slope of the error over time and multiplying the rate of change by the derivative gain Kd. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain, Kd [3].

The derivative term given:

$$Dout = Kd\frac{d}{dt}e(t) \qquad (2.4)$$