LINE FOLLOWER ROBOT WITH PROPORTIONAL, INTEGRAL AND DERIVATIVE CONTROLLER

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Bachelor of Mechatronics Engineering

June 2012

"I hereby declare that I have read through this report entitle " Line Follower Robot with Proportional, Integral and Derivative Controller" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics with Honours"

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A report submitted in partial fulfilment of the requirement for the degree of Mechatronics Engineering

Faculty of Electrical Engineering

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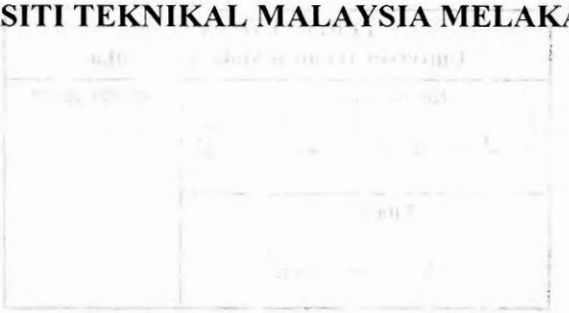

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I declare that this report entitle "Line Follower Robot with Proportional, Integral and Derivative controller" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Line following robot had been used in many applications such as moving materials around a manufacturing facility or warehouse. Line following robot is designed for a mobile robot to detect and follow the line. The line or track is a black line on the white surface and it will be detected by sensors. The project objectives are to design high speed line following robot in term of hardware and software that could take a curvy track turn without leaving the line or track and would be able to correct the error itself if leave the line or track. The project also design and implement proportional, integral and differential control as the error component in the line follower robot. For this project, the robot would have a high speed movement and be able to take a sharp turn without leaving the track or path. If the robot leaves the track or path, the robot would be able to find the way to be back on the right track again. In other word, the robot would be navigate efficiently, make less error and be able to correct the error itself. In order to have effective and smooth navigation, the robot had been implemented with PID controller. From analysis, the line follower robot that had been designed was able to detect and follow the line in higher speed. By using different speed, the line follower robot able to move forward, turn right and left and able to correct the error itself. For future research, the auto tuning for proportional, integral and derivative constant can be developed.

ABSTRAK

Robot pengikut garisan telah digunakan di dalam banyak aplikasi seperti memindahkan barang di sekitar kemudahan pembuatan dan gudang. Robot pengikut garisan direka bagi robot kenderaan untuk mengesan dan mengikut garisan. Garisan atau litar adalah garisan hitam di atas permukaaan putih dan akan dikesan mengunakan penderia. Tujuan projek adalah untuk mereka robot pengikut garisan berkelajuan tinggi yang merangkumi perkakasan dan perisian yang boleh mengambil selekoh tajam tanpa meninggalkan garisan atau litar dan boleh membetulkan kesalahan dengan sendiri jika robot meniggalkan garisan atau litar. Projek ini juga akan mereka dan melaksanakan kawalan berkadar, kamiran dan pembezaan sebagai komponen ralat di dalam robot mengikut garisan. Untuk projek ini, robot akan mempunyai kelajuan tinggi dan boleh mengambil selekoh tajam tanpa meninggalkan garisan atau litar. Jika robot meninggalkan garisan atau litar, robot akan mencari jalan untuk kembali ke atas garisan atau litar. Di dalam erti kata yang lain, robot akan mengemudi dengan berkesan, membuat kesalahan yang kurang dan boleh membetulkan kesalahan dengan sendiri. Bagi mendapatkan pergerakan yang berkesan dan lancar, robot telah dilaksanakan dengan kawalan berkadar, kamiran dan pembezaan. Daripada analisis, robot pengikut garisan yang telah direka boleh mengesan dan mengikut garisan dalam kelajuan yang tinggi. Dengan mengunakan kelajuan yang tinggi, robot mengikut garisan boleh bergerak lurus, membelok ke kiri dan ke kanan, dan boleh membetulkan kesalahan dengan sendiri. Untuk kajian di masa hadapan, pembetulan automatik untuk pemalar bagi berkadar, kamiran dan pembezaan boleh dibangunkan.

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
DC	Direct Current
I	Integral
IR	Infrared
Kd	Derivative Constant
Ki	Integral Constant
Kp	Proportional Constant
LED	Light Emitting Diode
LMS	Least Mean Square
P	Proportional
PI	Proportional, Integral
PD	Proportional and Derivative
PIC	Programmable Integrated Circuit
PID	Proportional, Integral and Derivative
PWM	Pulse Width Modulation
RPM	Revolution per Minute

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Project Background

Line follower robot is mobile robot and has been widely used in different area. The usages of mobile robot are to transport material form one place to another place. Other than that, mobile robot also has been used in military as bomb defusing. However, the development of line follower robot has faced some difficulties mostly to obtain stable and precise navigation. When the speed of line follower is increased, the robot would not be able to navigate effectively or follow the line precisely. This is due to the slow response from the sensors, unstable wheels and other disturbances. These problems would be affecting to the performances of the robot.

The line follower robot consists of several parts which are sensors, actuators, processor, driver, actuators, chassis and body structure. Infrared sensors used to detect the black lines which are installed under the robot. Then, the data from sensors will be transmitting as inputs to the microcontroller. The microcontroller acted as a brain and decided a proper command based on the inputs from the sensors. The outputs from microcontroller will be sending to the motor driver. The motor driver received the signal from microcontroller and acted as a switch. The motor driver will control the movement of the motor which are motor rotate forward, backward or stop. The implementation of PID controller in the line follower robot is due to increase the performances of the line follower robot in term of navigation. The PID controller calculated the error that produced when the robot followed the line. The error calculated based on the data from the sensors reading. In other word, the PID controller calculated the required control response based on the value from sensors and gave a command to the motor driver so that the robot can navigate effectively.

This project would be able to solve the navigating problems when designing line follower robot. The robot would be able to follow the line effectively although the speed is increase.

1.2 Problem Statement

Nowadays, mobile robot has been widely used in different areas such as industries, warehouse, hospitals and nuclear waste facilities. The increase of applications in mobile robot has created a massive development in designing mobile robot. The massive development of mobile robot is due to capability of the robot which has higher accuracy, less dangerous and more durability compare to the human usage. However, the development of mobile robot has faced some difficulties mostly in order to design mobile robot that would have precise and stable navigation system. Precise and stable navigation system will increase the performances of the mobile robot. Therefore, a line follower robot which has precise and stable navigation system is developing.

When the speed of the line following robot is increase, the robot would not be able to detect or follow the line or track smoothly. The robot also would not be able to take a sharp turn and tends to move out of the track. When the robot moves out of the track, it would not be able to find the track or path again. In other word, the robot would not be able to navigate efficiently. These problems occur due to the operating problems such as actuator constrains, time delay and other disturbances. Therefore, the implementation of the PID controller would be able to overcome the time delay caused by slow response of the sensors and other operating problems and increase the performances of the line follower robot.

1.3 Objectives

The objectives of this project are:

1. To design high speed line following robot in terms of hardware and software that could take a curvy track turn without leaving the line and would be able to correct the error itself if leave the line or track.

2. To test the effectiveness of the robot navigation based on the accuracy of robot movement which are moving forward, turning left and right by using different speed.

1.3 Project Scope

The focus of this project is to design high speed line following robot that could take a curvy turn without leaving the track or line would be able to correct the error itself if leave the line or track. So, the project will covers scopes as follow:

1. This project covered the development of hardware and software parts for the line follower robot.
2. The line follower robot used two motored wheels which are placed at the back and a castor wheel which placed at the front for the steering mechanism.
3. PIC 16F877A selected as microcontroller of the line follower robot.
4. Infrared red sensors used to detect the black line.
5. The robot would have two DC geared motor with wheeled.
6. Proportional, integrals and derivative controller as a control system of the line follower robot.
7. MikroC used as a compiler to develop C language and Proteus 7 used to design the schematics diagram of the circuit.
8. The algorithm of the line follower robot is designed based on the line or track that is predetermined.
9. The speed of the robot will be verified using PWM module from minimum speed to maximum speed.

2.0 LITERATURE REVIEW

2.1 Introduction

Nowadays, the application of mobile robot had been highly demanded in different areas such as industries, hospitals, warehouses and nuclear waste facilities [3]. The development of mobile robot has faces large difficulties mostly in navigation. Over the past, there are many methods for controller that has been developed to increase the performances of the robot in terms of navigation such PID controller, fuzzy logic and neural network.

Generally, line follower robot is mobile robot that is designed to detect and follow the line. The path or track is usually predetermined by user and the robot needs to complete the path or track until the finish line. The path or track is basically physical white line on the floor or as complex path marking schemes for example embedded line, magnetic markers and laser guide markers [2]. The basic operations of line follower robot are as follow:

1. The line follower robot will sense or detect the line position with optical sensors and the optical sensors are usually placed at the front end of the robot.
2. The robot will have steering mechanism in order for the robot to move straight, turn left or turn right.
3. The speed of the robot will be controlled according to the lane condition. It means that for curvy lane, the speed of the robot is decrease in order to obtain smooth turn.

2.2 Literature Review on the Previous Study

Research paper by Ardiyanto I focused on how to implement PID controller in low cost mobile robot [1]. In this paper, the method for PID algorithm is using LMS (Least Mean Square). By using LMS (Least Mean Square), there are only one constant that being adjusted that is proportional constant (Kp). For the experiments part, the experiment is conducted based on the tasks given to the robot, which are goal seeking test and wall following test. Each task is testing by using different speed of the robot and each speed is testing for 10 times. Then, for each speed, the behavior of the robot in completing the task given is observed. As conclusion, the mobile robot manages to complete the task given although it uses maximum speed.

The most difficulties in designing line follower robot are to design the line follower robot that can navigate effectively [2]. The navigation of line follower robot usually are effected by the physicals kinematics constraints which are motor and sensor response, position and the turning radius of the robot. In recent years, the designers have faced problems to design a line follower robot that can navigate perfectly. In order to improve the navigation reliability of the differential drive for line follower robot, line sensor configuration is implemented [2]. For electronic components, the robot use VEXTA 15W DC Motor with motor driver card. As mention in this paper, the motor driver card is use because of the ability to control the basic movement, speed feedback and speed control. For master controller, PIC 16F877A has been use due to the reasonable price and easy to obtain. For the sensing method, the line follower robot use ultra-bright LED combined with a light dependent resistor due to the low cost. In order to overcome different light conditions, a new breed tune-able sensor method is used. The controlling strategy that used in this paper is two controllers which are master controller and slave controller. Therefore, the computational burden of the master controller will be reduced. According to this paper, the suitable sensor array design is to use single line sensor array because is use less sensor and still can navigate effectively.

The research paper by Bajestani S.E focused in all the technical aspect in constructing and testing a line follower robot [3]. The robot that has been built is using 16 infrared ON2170 sensors and the sensors array is design in arc of a circle. The purpose of this sensors array design is to perform a smooth turning for the robot [3]. Other than that, the robot also use

comparator because the sensors output is in analog. For the body part, the robot use plaxy glass which are inexpensive. The robot also use strip glue on the tires in order to increase the friction between the wheels and the floor. This method will prevent the robot to slide away when the robot moving forward or turning left and right.

The research paper by Lee S.C focused on how to implement embedded system and control strategy by constructing a line follower robot [4]. The first approach that is introduced in this paper is on how to calibrate the sensors. The calibration process is important due to the different characteristic in sensors. Besides that, researcher also uses quadratic interpolation technique to detect the line position for line follower robot. In order to implement PID controller, SIMULINK behavior model simulation is used. In this simulation, the inputs are the voltage commands for the dc gear motor while the outputs are the plenary coordinates and orientation of the line follower robot [4]. The simulation shown the PD controller is better than P controller. However, the simulation does not implement I controller because the result by using PD controller is not affected due to the small value of the steady state error. For microcontroller, the line follower use dsPIC30F4011. The line following robot manage to win the national racing contest in 2007.

The research paper by Pakdakman M focused on the technical issues and problems in designing line follower robot which is known as TABAR [5]. TABAR use Infrared Ray sensors as a sensing method. The main problems when using Infrared Ray sensors are the effect of the ambient light and the distance between the sensor and the ground. In order to solve this problem, the sensors need to be shielded from the ambient light and the distance between sensors and the ground must be less that 10mm. For the chassis and body part, the TABAR robot use aluminum due to have a light weight and strong robot. From this paper, in order to design high speed line follower robot must use high speed motor and high sensitivity sensors circuit.

The research paper by Saidon M.S focused on the proportional controller method for differential steering control for mobile robot [6]. Generally, the implementation of proportional controller is to control the speed of both wheels when the mobile robot is moving forward, turning right and turning left. In this paper, the kinematic model is use as a mobile robot controller. In order to get a better tuning, the experiment is conducted to find the suitable value for the proportional gain. The experiment is conducted by using

different value of Kcr (right wheel) and Kcl (left wheel) and the speed for each wheel are compared. From the experiment, the best value for proportional parameter is 0.07, 0.08 and 0.09. The movement of mobile robot is also affected by unequal diameter wheel, misalignment and slippage. However, the performances of robot can be improved by using other controller methods that are PI and PID controller.

2.3 Discussion

In this section, the part that needed to be considered in designing line follower robot based on the literature review that has been done is discussed briefly. The parts divided into microcontroller, actuators, sensors, steering mechanism, and motor driver.

The first part is microcontroller. In this project, PIC16F877A is used as a microcontroller which acted as the main brain for the robot. The selection of microcontroller based on the operating speed, numbers of inputs and outputs and cost per unit. The operating speed for PIC16F877A is 20MHz which will produce a faster execution for the program. For numbers of inputs and output, PIC16F877A is available in 5 ports which will fulfill the requirement of my project. The cost per unit for PIC16F877A is reasonable which is about RM 21.00 and it is easy to obtain in the market.

In this project, 2 DC gear motor will be used as an actuators. The selection of motor is based on the robot function, power, speed and precision. The reason of using DC geared motor because it has greater power compared to the other motor. The speed of the DC geared motor will not change if the robot moving towards downhill or uphill due to usage of gear. The speed of DC motor is proportional to the supply voltage which means the speed of the motor is controlled by decrease the value of the supply voltage. For example, if the supply voltage is reduced from 6V to 3V, the motor will run half from its speed. The cost for DC geared motor is reasonable and easily obtains in the market.

The next part is the selection of sensors. The robot used infrared sensors to detect the line. The sensors consists a clear IR LED which acted as transmitter and a black phototransistor that acted as receiver. The selection of sensors is depending on the response time,

sensitivity and cost. The reflectance configuration used as a sensing method for the IR sensors. Clear IR LED transmitted the beam to the white surface. Then, the beam will be reflected back to the receiver. The selection of this sensor is because it has good response time. However, the sensitivity of the sensor is not quite good because it can only sense between two contrasting color. But, it is suitable for this project because the path or track only consist two colors which is black line on the white surface. The sensitivity also can be increased by varying the value of the resistors in the sensors circuit. The problems with using this type of sensor are the presences of the ambient light that will affect the sensor reading. This problem can be solved by using a shield that can protect the sensors from ambient light. The cost for these sensors is also reasonable and easy to obtain.

For steering mechanism, the robot used two wheel differentials drive that will be placed at back of the robot and a castor that will be placed in the front of the robot. The used of this steering mechanism is because it is easy to control compare to the other steering mechanism. By using differential drive, the navigation of the robot can be controlled based on the movement needed. For example, if the robot wants to move forward, the both wheels will rotate forward and if the robot wants to turn right, the left wheel will rotate forward while the right wheel will rotate backward.

In order to control and supply power to the motor, the robot need motor driver. The motor driver will receive the signal from microcontroller and will act as the switch for the motor. L298N is used as a motor driver. This motor driver can be used to control both motor. This driver consists of H-bridge. By using this driver, the movement of the motor can be controlled which are to move forward, turn right and turn left.

The data from sensors will be in analog. Therefore, the analog signals need to be converted into digital signal. Due to that, LM324 is used as a as a converter. Although the PIC16F877A has featured for ADC converter, the using of comparator is actually will make the algorithm for programming become easier and less complicated. The comparator is work by comparing sensors circuit voltage with potentiometer circuit voltage and the output is decide whether the digital signal is high or low.

PID controller is used as a control method for the robot. Although there are other control methods, for example fuzzy logic, neural network, the selection of PID controller is due to the less complexity comparing to the other control method. From the literature review that has been done, the PID controller also give better achievement compare to the other

controller. Furthermore, PID controller has been widely used in industrial as a control method. However, this method has weakness which is the constant parameter is hard to tune.

2.4 Theoretical Review

In this section, the theoretical that are needed to complete this project will be discussed briefly. This is due to have better understanding before the project is started.

2.4.1 PIC Microcontroller

PIC microcontrollers (Programmable Interface Controllers) are integrated circuit that can be programmed to perform several tasks or functions. The project used PIC16F877A as a microcontroller. PIC16F877A consists of 40 pins. For input and output ports, it contains five ports which are Port A, B, C, D and E. The operating frequency for PIC16F877A is 20MHz and also has flash memory that can be reprogrammed more than 1000 times. The PIC16F877A also provided with some features for example timer, ADC and comparators. The PIC16F877A need 5V as a voltage supply. Figure 2.1 shows the entire available pin for PIC16F877A.