DESIGN AND DEVELOPMENT OF A CONTROL SYSTEM FOR A 4 WHEEL SKID STEERING MOBILE ROBOT

This report submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons)

by

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2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DESIGN AND DEVELOPMENT OF A CONTROL SYSTEM FOR A 4 WHEEL SKID STEERING MOBILE ROBOT**

SESI PENGAJIAN: **2018/19 Semester 1**

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Broadbase) (Hons.). The members of the supervisory committee are as follow:

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ABSTRAK

Robot mudah alih 4 roda panduan gelinciran mempunyai empat roda dimana setiap dua roda dikawal oleh satu motor untuk setiap sisi. Arah pandu robot mudah alih panduan gelinciran ditentukan dengan mengawal kelajuan setiap motor pada setiap sisi. Robot mudah alih cenderung untuk menghala ke kanan apabila kelajuan motor kanan leih rendah berbanding motor kiri dan begitu juga sebaliknya. Robot akan bergerak dalam garisan lurus apabila kelajuan untuk kedua-dua sisi motor adalah sama. Tujuan kajian ini adalah untuk membangunkan system kawalan tertutup PID untuk mengawal pusingan motor. Sistem kawalan dibangunkan dengan menggunakan Matlab/Simulink dengan bantual set blok Mplab yang telah diisi di dalam Matlab. Setiap motor dikawal oleh pemandu motor MD10C dimana setiap pemandu motor disambung pada papan SKds40A. DsPIC30F4011 adalah PIC yang digunakan dalam projek ini. Litar dibekalkan kuasa oleh dua set bateri 12V yang disambung secara selari. Signal PWM digunakan untuk mengawal putaran motor termasuk kelajuan. Pada akhir kajian, graf darjah putaran melawan masa dinantikan. Tindakbalas keluaran motor diperlihat untuk mengenalpasti parameter kp, ki, dan kd. Pengawalan robot adalah melalui hubungan tanpa wayar antara pengawal dan computer riba dengan bantuan peranti XBEE.

ABSTRACT

4-wheel skid steering mobile robot consists of 4 wheel where each two wheels is controlled by a single motor for each side. The direction of the skid steering mobile robot is determined by controlling the speed for each side of the motor. The mobile robot tends to move to the right if the speed of the right motor is lesser than the left motor and vice versa. The mobile robot will travel in a straight line if the same speed is applied to both side of the motor. The goal of this research is to develop a PID closed loop control system to control the rotation of the motor. The control system is developed by using Matlab/Simulink with the help of Mplab block set toolbox installed in the Matlab. Each motor is controlled by single motor driver MD10C where each motor driver is connected to the single microcontroller board SKds40A DsPIC30F4011 is the PIC used in this project. The circuit is powered by 2 set of 12V batteries connected parallel. PWM signal is used to control the rotation of the motor as well as speed. At the end of the research, graph of Angle of rotation vs time is expected. Output response of the motor is observed to determine the best parameter of kp, ki, and kd. As soon the parameter is determined, the control system is embedded to the mobile robot. The control of the robot is through wireless connection between controller and laptop with the help of XBEE device.

DEDICATION

Dedicated to my mother, family and everyone who involved in this project.

Thank you for giving me moral support, money, cooperation, understanding and encouragement

ACKNOWLEDGEMENT

First I would like to give all the praise to Allah, the most gracious, the most merciful, that I manage to complete this final year without any difficulty. I would like to extend my thanks to all individual who involved in this project for the kind support and help.

I would like to express my gratitude to my respected supervisor, Dr. Shariman Bin Abdullah for the guidance and constant supervision throughout the project until the project is completely finish.

I would like to extend my gratitude to my family members for their moral support during the completion of this project especially to my mother, Sarimah Binti Yahyer for always remind me not to give up and my father, Roslan Bin Md Noor whom always there to give financial support and thanks to all my family members.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you.

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LIST OF ABBREVIATIONS

AC	-	Alternate Current
A/D	-	Alternate/Direct
AHRS	-	Attitude and Heading Reference System
ASOC	-	Active Split Offset Caster
CAN	-	Controller Area Network
CCC	-	Cross-coupled Control
CCD	-	Charge Coupled Device
COM	-	Component Object Model
CPU	-	Central Processing Unit
DC	-	Direct Current
EEPROM	-	Electrically Erasable Programmable Read-only Memory
FVFO	-	Fuzzy Vector Field Orientation
G	-	Center Mass
GNSS	-	Global Navigation Satellite System
I/O	-	Input/Output
LCD	-	Light Crystal Display
LED	-	Light Emitting Diode
ICR	-	Instantaneous Center of Rotation
IMU	-	Inertial Measurement Units

IR	-	Infrared
MATLAB	-	Matrix Laboratory
MCM	-	Motor Controller Module
MCU	-	Microcontroller Unit
MPU	-	Microprocessor Unit
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PIC	-	Peripheral Interface Controller
PID	-	Proportional Integral Derivative
PPM	-	Pulse Position Modulation
PWM	-	Pulse Width Modulation
PVDF	-	Polyvinylidene Fluoride
RAM	-	Random Access Memory
RC	-	Remote Control
RF	-	Radio Frequency
RGB	-	Red Green Blue
ROS	-	Robot Operation Process
SSV	-	Skid-steered Vehicle
UGV	-	Unmanned Guided Vehicle
USB	-	Universal Serial Bus

CHAPTER 1

INTRODUCTION

1.1 Chapter 1 Overview

This chapter provides an overview of the research of "Design and Development of a Control System for a 4 Wheel Skid Steering Mobile Robot". Topic discussed on this chapter includes the background of research, problem statement, objective of research, and scope of the research. Generally, the research background is briefs about the main idea of this research. Problem statement expresses the difficulty faced during the completion of the research. Basically objective highlights the main procedure to achieve the goals of the research. Lastly, the scope of research briefs about the limitations as well as focuses in the research.

1.2 Research Background

Generally, this research is about developing a control system to control the speed of the motor of a skid-steering mobile robot. The movement of this type of skid-steering robot is controlled by two motors. Each motor is responsible to control two wheels at front and rear side for each left and right side of the mobile robot. A belt is used to connect the front and rear wheel so that the velocity of front rear will be the same. The movement of a skid-steering mobile robot is determined by controlling the speed of motor of each left and right motor. The motor will travel in a straight line motion when the speed of left and right side shares the same magnitude. The turning of the mobile robot is controlled by computing a difference value of velocity between left and right side. The mobile robot tends to turn to right when the right velocity is lower compare to the left velocity and vice versa.

Generally, the movement of the skid-steering mobile robot is determined by the location of the Instantaneous Center of Rotation (ICR). ICR is a point located around the mobile robot during its movement. The ICR point is a point where it experiences zero velocity. The distance of the ICR to the center mass (G) of the vehicle depends on the velocity of left and right wheel. Bigger difference of velocity between the two sides will result in a shorter distance of ICR and vice versa. The mobile robot will travel in a straight path when ICR of each side shares the same distance to the center mass of the mobile robot due to the same magnitude of velocity of each side. However, the line connected the ICR and G is not perpendicular to the direction of each wheel. This leads to skidding.

Normally system identification is performed to obtain equations that summarised the operation of the mobile robot. The equation is determined by using a kinematic modelling and dynamic modelling. The kinematic modelling calculates the exact parameters of the mobile robot without considering the disturbance while dynamic modelling calculates the parameters by considering the disturbance. The kinematic modelling and dynamic modelling is just a calculation to estimate the movement of the robot. It can be concluded that these approach will not produce accurate outcomes. Thus, system identification is not discussed in this research.

Since there is no system identification, the block diagram is constructed in MATLAB/Simulink software. A control system is to be developed in order to automate the movement of the motor thus moves the mobile robot. A control system divided by two types which is closed loop and open loop. Basically, in an open loop system the process is performed to produce outputs based on the set point or input without taking any account the disturbance that affect the system. Even an open loop system is easy to construct, the output produced is affected by errors which is the difference between input and output. Unlike open loop, closed loop system has a system feedback. The purpose of the feedback is to measure the output and compare to the input. The difference is then sent back to system to be corrected so that the output matches the input. Normally, sensor is used to provide a system feedback to the system. Encoders are attached to each of the motor in order record the rotation information such as angular velocity.

A closed loop system with a Proportional-Integral-Derivative (PID) controller is constructed to automate the motion of the skid-steering robot with the help of encoders attached at each motors to provide a system feedback so that motion of each side left and right of the wheel can be controlled based on the desired input. The movement of the mobile robot is simulated in ADAMS software before control system is embedded in the microcontroller.

1.3 Problem Statement

Control of a skid-steering mobile robot is challenging due to its steering mechanism. It is difficult to control the motor speed for both sides even for a straight line motion. Besides, the turning of the mobile robot is by means of skidding or slippage. Estimation is required to predict the motion of the robot. Mostly, the motion of a skid-steering mobile robot is predicted by using a kinematic modelling and dynamic modelling. However, these modelling can only be used to estimate the motion without considering the real disturbance.

Since there are two motors used to control each side of the mobile robot, driving system is required to link the front and rear wheel mechanically. Gearing system connects the front and rear wheel by means of gears. Often contact between the gears cause frictions. Frequent occurrence will cause the gear to wear thus lower its efficiency. Chain system mechanically links the front and rear wheel by using a chain and sprockets. Friction occurs at the surface contact between the chain and the sprocket leads to wear just like gearing system.

A control system needed to be developed to automate the movement of the mobile robot. An open-loop control system is easy to construct however the system only produce the output based on the computed set point. Most of the time, the output produced does not match with the system input due to the disturbance.

1.4 Objectives

The objectives are as follows:

(a) To develop a control system to control the motor rotation of a skid steering mobile robot.
(b) To simulate and analyse the developed control system in MATLAB/Simulink.
(c) To implement the control system to the skid steering mobile robot.

1.5 Scope of the Research

The research will cover about the design and development of a control system to control the speed of the motor used in a skid-steering robot. The study only focused on a skid-steering which only have particular mechanism. The skid-steering robot used is driven by using two DC servomotors where a single motor drive each side left and right side of the robot. The robot consists of four wheels. The front and the rear wheel for each side are mechanically coupled with means of belt. Besides, the microcontroller used is SKds40A and MP10A motor driver. The communication between PC and the microcontroller is by using Zigbee. The controller in this research is limited to Proportional-Integral-Derivative (PID). Block diagram will be developed in MATLAB/Simulink software.

1.6 Summary

In order to complete this research, information and knowledge about related works done by previous researches is obtained by reading papers. Literature review in chapter 2 comprised of information covers on the definition of the skid-steering robot, the Instantaneous Center of Rotation (ICR) which determine the movement of the mobile robot especially during turning, the mechanism of skid-steering robot, hardware and integration of the hardware, software as well as control system. The information is then analysed and the best method is selected to further this research. The method is presented in a flowchart in chapter 3. Each activity in the flowchart is explained.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter 2 Overview

Generally, this chapter is mainly about the idea and theory based on the various researches that have been done by several previous researches. Related information of previous studies is extracted as references and discussion based on their research about skid-steering robot. Relevant information about the idea of the skid-steering robot is discussed within this chapter.

2.2 Skid-steering Robot

(Dogru and Marques 2017) mentioned that skid-steered vehicles are driven by controlling the rotational speed of both left and right wheels. The automobile intends to move in a straight path when both left and right wheel possess a same velocity. The encoders may obtain the displacement precisely as there is no skidding when the vehicle travels in a straight line. The benefit of skid-steering vehicle is that if one wheel either left or right skids, the vehicle will still move in a straight line as the other wheel of the same side will not skid thus, the encoder mounted on motor for that side will still recording accurate displacements. The vehicle is said to circulate around a zero velocity point which also called instantaneous centre of rotation (ICR) when wheel of either side decrease in velocity. As the line linking the ICR to the wheel is not perpendicular to the wheels, skid occurs. The relationship between rotation of wheels and the robot is important in determining an accurate dead reckoning and enhance performance of controller.

Skid-steering robot commonly used as outdoor mobile robots. They are well suited for applications that require the vehicle to move along on a complex earth terrain such as farm machinery, military applications, and mining because of its modest and firm mechanical built, instant reaction, high manoeuvrability and mobility. There is no steering mechanism to drive and change the direction of the robot and thus, the robot is controlled by setting the velocity of left and right velocity to be different as mentioned by (Elshazly et al. 2015).

Skid-steering robot is differs from wheeled vehicles as reported by (Alhelou, Dib, and Albitar 2015). Various tracked configuration for steering have been introduced such as articulated steering, curved track steering and skid-steering. A skid-steering vehicle consists of two rear wheels which drive the robot and a frontal wheel which is connected by a chain. The norm of skid-steering is rely on the controlling the velocity of both side of wheel exactly like differential wheeled vehicles.

(Mandow et al. 2007) mentioned that skid-steering robot is steered by controlling the velocity of left and right wheel same as controlling the differential drive wheeled robot. However, since the wheels of the robot lies on the longitudinal axis of the robot, turning of the robot require slippage of the wheel. Wheeled skid-steering grants two advantages over alternative wheel configuration as it is simplicity and robust in term of mechanical. Besides, it gives greater manoeuvrability.

According to (Fitton n.d.), the hybrid vehicle used is driven by a wide rubber tracks on each side. Each track is controlled separately in order to obtain maximum speed in a straight path. However, a straight path cannot be achieved when there are different torques are applied between each track even both track share the same magnitude in term of speed. The vehicle will travel in curved path and thus skid occurs. The vehicle spins at a fix axis whenever the tracks drive with the same speed but different direction.

The tracked vehicles have a simple mechanical structure and high flexibility yet it is difficult to steer it. Skid steering involves the dynamic of the vehicle, wheels and characteristic of the terrain. The movement of the robot cannot be predicted due to the skidding (Petrov et al. 2000).

Skid-steered vehicle (SSV) consists of a body driven by a four wheels (Caldwell and Murphey 2010). The movement of the vehicle depends on the force applied to the