UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE DEVELOPMENT OF DIRECTIONAL CONTROL AND WHEEL SYNCHRONIZATION OF VEHICLE STEERING BY WIRE (VSBW) SYSTEM BY IMPLEMENTING FUZZY PID CONTROLLER (FPC)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electrical Engineering Technology (Industrial Automation & Robotics) (Hons.)

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 Degree of Electrical Technology Engineering (Industrial Automation & Robotics) with Honours. The member of the supervisory and co-supervisor is as follow:

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(En. Mohd Zaidi Bin Mohd Tumari)

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(En. Muhammad Syahrani Bin Johal)

ABSTRAK

Teknologi kemudi kenderaan dengan sistem berwayar (*VSBW*) yang terkini telah memberikan peningkatan yang ketara dari segi keselamatan kenderaan, kestabilan, keselesaan dan pergerakan. Pembuangan aci yang menghubungkan kemudi ke bahagian tayar hadapan telah menimbulkan masalah kepada kawalan kemudi khususnya dari segi kawalan arah dan keseragaman tayar kenderaan. Oleh itu, satu sistem kawalan *Fuzzy PID* dihasilkan bagi membantu mengawal kemudi dan tayar hadapan ini. *Fuzzy PID* ini lebih bersifat kepada pengabungan diantara sistem kawalan *PID* dan sistem kawalan *Fuzzy Logic* dimana kedua-dua sistem kawalan ini digabungkan di dalam satu sistem kawalan. Sistem kawalan *Fuzzy PID* akan mengawal sudut stereng dan sudut roda hadapan. Sistem kawalan *Fuzzy logic* akan mengawal sudut stereng dan sistem kawalan *PID* akan mengawal sudut tayar depan. Sistem kawalan *Fuzzy PID* ini menggunakan ralat pada tayar untuk menjana sudut kepada stereng yang dikawal. Sistem kawalan *Fuzzy Logic* ini di tala dengan mengunakan kaedah manual talaan manual dan kaedah pembelajaran. Untuk pengawal *PID* pula, kaedah Ziegler Nichols telah digunakan bagi membuat talaan pada sistem kawalan. Terdapat dua bahagian utama dalam proses membangunkan sistem kawalan *VSBW* ini, iaitu bahagian simulasi yang menggunakan perisian Matlab / Simulink dan bahagian perkakasan yang menggunakan LabVIEW. Modeling bagi kemudi dan tayar hadapan akan digunakan untuk melakukan simulasi dalam perisian Matlab / Simulink. Sistem kemudi sebenar dan tayar hadapan akan digunakan untuk mengambil data sebenar. Prestasi sistem kawalan ini akan diperiksa dari segi keupayaan mengikut input masukan, keseragaman tayar dan masa tindak balas. Akhir sekali keputusan sistem kawalan ini dibentangkan dan dibincangkan.

ABSTRACT

The newest technology of vehicle steering by wire (VSBW) system has made a significant improvement in vehicle safety dynamics, stability, comfort and maneuverability. The complete elimination of shaft that connect the steering wheel and the front wheel practically give problem to steering control specially in terms of directional control and wheel synchronization of the vehicle. The development of the VSBW Fuzzy PID control scheme that help to control the steering wheel and the front wheel. This Fuzzy PID is more like a hybrid type of controller that is PID controller and Fuzzy Logic controller are combine in one control scheme. The Fuzzy PID controller will control the steering angle and front wheel angle. The Fuzzy Logic controller will control the steering wheel angle where else the PID controller will control the front wheel angle. The Fuzzy PID controller used wheel tracking error to generate controlled steering angle. The learning method and manual tuning method is used to tuning the Fuzzy logic membership function. For PID controller, Ziegler Nichols method of tuning is being choose for these type of controller. There are two main parts in developing VSBW control scheme that is simulation section using Matlab/Simulink software and hardware section using Labview. The modelling of steering wheel and front wheel will be used to simulate in the Matlab/Simulink software. Actual steering with rack and pinion will be used for real-time experiment. The performance of control schemes is examined in term of input tracking capability, wheel synchronization and time response specifications. Finally, the result of the control schemes is presented and discussed.

DEDICATION

Special dedication to all my family, lecturer, close friend and to those who give their encouragement, support and praying for my success throughout my journey as a student.

ACKNOWLEDGEMENT

Firstly, I would like to praise to ALLAH that give me strength and patience to complete my PSM that is to develop Vehicle Steering by Wire (VSBW) control system. Secondly, I would like to thanked my PSM supervisor MR. MOHD ZAIDI BIN MOHD TUMARI and MR. MUHAMMAD SHAHRANI BIN JOHAL who help me a lot from the start of this project until it finished. Then I would like to thanked my parent, brothers, sister, close friend and classmate that always pray for my success. I also would like to thanked to other lecturers that help contribute ideas when a problem a rise. Lastly I would like to say thank you to Nur Azmina Izzati binti Ab Rahim for supporting me and give me inspiration throughout this project. Thank you again and
may ALLAH give HIS blessing and kindness to all of you.

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CHAPTER 1
INTRODUCTION

1.0 Background

The conventional way steering method for vehicle is the mechanical connection between the steering wheel and the front wheels. This mechanical contains many components such as steering shaft, column, gear reduction mechanism, etc. Nowadays, vehicle steer by wire (VBSW) system has been one of interesting research because of its major features that is to remove as many mechanical components as possible. The VSBW system is expected to give more advantages than the conventional steering method such as simplicity of control, low cost, etc. The conventional method of steering and the VSBW system is shown in Figure 1 [1].

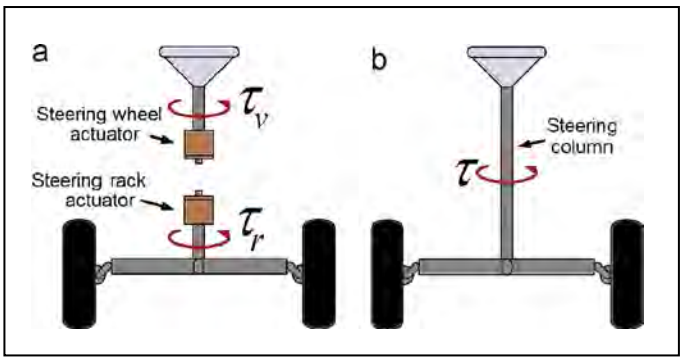

Figure 1.1: (a) VSBW (b)Conventional Steering System

1.1 Problem Statement

VSBW system expected not only implement same function as conventional mechanical coupling steering system, but it expected to provide advanced steering function. The front wheel needs to follow the input from the driver precisely. But in the real situation, the vehicle SBW system is faced many disturbances such as uneven condition of the road and parameter uncertainties of the system. Therefore, a more robust control system for VSBW system need to be develop.

1.2 Objective

The objectives of this project are:

i. To design the Fuzzy PID control schemes for controlling the direction and synchronization of the front wheel in vehicle SBW system.

ii. To develop complete simulation and experimental verification for VSBW system.

iii. To analyze the performances of the control schemes in terms of wheel directional and synchronization control, time response specifications and robustness to parameter uncertainty.

1.3 Project Scope

This project will focus on designing a vehicle steering by wire (VSBW) system and implement Fuzzy PID controller on the system. The mathematical modelling for vehicle steering by wire(VSBW) were derived using modeling of mechanical system method. Then it will be simulated using MATLAB. The Fuzzy PID controller parameters were determined using fuzzy rules and Ziegler Nichols method. In order to test the performance of the controller the hardware for the VSBW system was developed. This hardware were included the steering wheel system, front wheel

system and interface between hardware and software. MYRIO and LABVIEW software is used for the interface between hardware and software.

1.4 Thesis Outlines

There are five chapters in this thesis. The first chapter is an introduction to the thesis. The second chapter is literature review, which basically a review on others work or projects that are related to this project. The third chapter is about what method is used and been implement to complete this project. The fourth chapter will discuss the result. Lastly chapter five will conclude the project and discuss the recommendation.

Chapter 1: In chapter 1, currently brief about general ideas of the project which are introduction, problem statement, target of the project, scope of project, project significant and thesis outlines.

Chapter 2: This chapter is about literature review which is to study and compare the work or journal that related with the project. This is important in order to obtain some knowledge about the project.

Chapter 3: Chapter 3, will be discuss about methodology, which is consists flowchart of whole project and the description of component that will used to solve the problem statement.

Chapter 4: Chapter 4, will be discuss about the result of the project that have been done in order to achieve the objective.

Chapter 5: Chapter 5, will discuss about conclusion and recommendation for this project.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction Literature Review

This chapter will discuss about all related information and study about project to achieve the project aims. This chapter involves research and find the information about the concept of VSBW system that has been done and related to this project.

2.1 Related Work

There are some of journals that are talk about vehicle steer by wire system(VSBW) and the method they used for the system. These journals are used as a reference to complete this project.

2.1.1 PID controller with feedforward variable steering ratio

S. Fahami, et al.(2012), have purpose a method to control a vehicle steering by wire system using PID controller and purpose a new type controller that is feed forward variable steering controller. It purposely to help to controlled the error in front wheel tire when the driver turned the steering and also to give steering feeling to driver when driving vehicle with VSBW system. The control structure or block diagram of the VSBW system diagram is shown in Figure 2.1. There are reasons variable steering ratio and feed forward has been chosen it is because it makes the driver use less force on the steering wheel but give the same angle that the driver need to make the front tire to turn. By mean it take less rotation of steering wheel to turn the font tire.

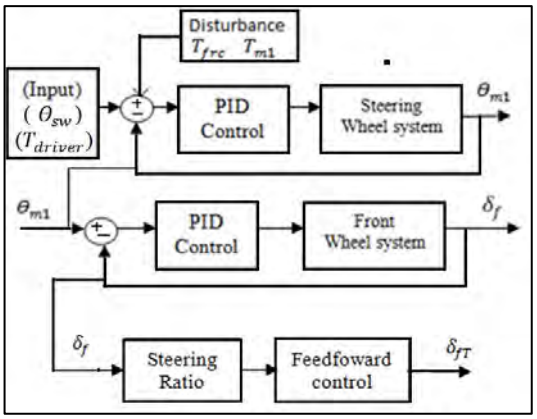

Figure 2.1: Block diagram of VSBW with steering ratio and feedforward controller

2.1.2 Virtual sensing to estimate vehicle yaw rate by only measuring the articulation angle and vehicle speed.

N. Daher, M. Ivantysynova. (2014), have purpose a method virtual sensing to estimate vehicle yaw rate by only measuring the articulation angle and vehicle speed. This type of controller is purpose for the use of more heavy vehicle with high power combustion. The system consists of two sub module that is mechanical module and hydraulic module. Figure 2.2 show the sub module used for this type of VSBW controller. The input for this controller is the hydraulic model. It gives the input system required flow rate to make a linear motion to steering that will be converted to vehicle articulation. For the project the author use three types of sensor that is speed sensor that are used to measure the vehicle true speed. Secondly yaw rate angle sensor, that are used to compare the actual measured response with virtual output. Lastly the author use angle sensor to compare the angle of the rear sub frame with the angle of front sub frame.

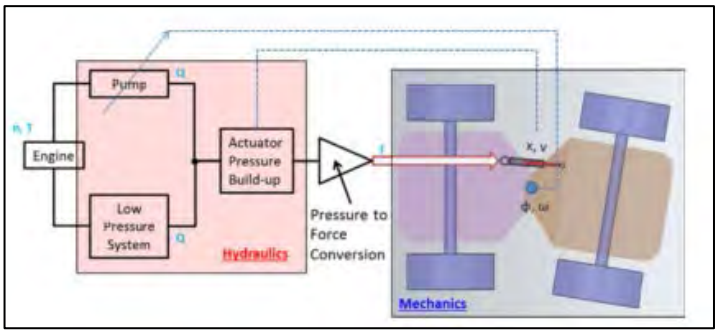

Figure 2.2: Block diagram of steering system

2.1.3 Adaptive on-line parameter identification model reference control (MRC) strategy.

A. Emre Cetin, et al. (2012), method that have been purpose is to uses the external force or torque that is measured as an input reference. From the external force, the output of the system is calculated while the real system is properly controlled to find the system output. The Block diagram of the system is shown in Figure 2.3. Other than that, the adaptive on-line parameter used the output error, equation error and the modified recursive to evaluate the unknown parameter then properly controlled the output system.

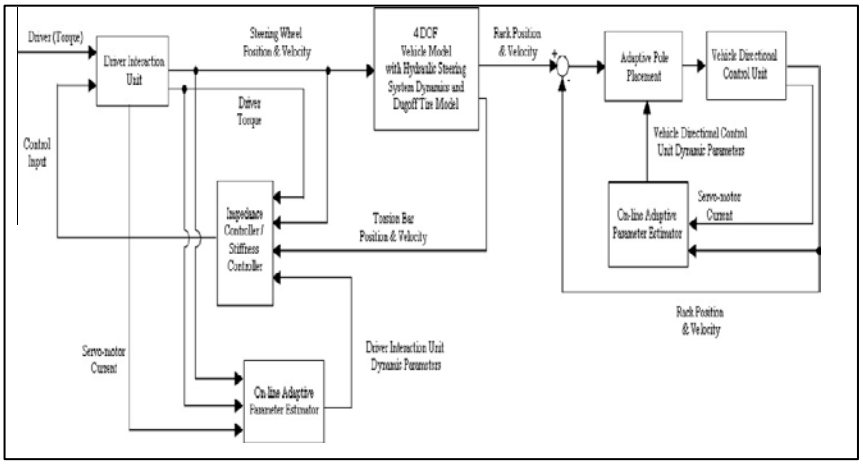

Figure 2.3 Block diagram for control(MRC) strategy

2.1.4 Robust sensor fault detection and isolation based on sliding mode observer.

S.Dhari, et al.(2012), suggest a method that use robust sliding mode observer(H∞) with parametric uncertainties and sensor fault that is based on linear matrix inequalities(LMIs). This method is to improve the previous method that use model based fault detection and isolation, the model based fault detection and isolation method have been proved that in present of disturbance in the parameter will cause the result to be imprecise. Compare to model based fault detection sliding mode observer is more robust and are known for its insensitive nature to an unknown disturbance. Therefore, the sliding mode observer including H∞ performance is design to actively estimate the error of the sensor. To make the design is asymptotically stable an acceptable LMI optimization is calculated.

2.1.5 Bilateral control of vehicle steer by wire system with variable gear ratio

Z. Peng. (2013), has presented a new type of VSBW system that will take the deliberation of the variable gear-ratio. The new control system consists of two controls circle, the first circle is upper control circle and another circle is lower control circle. The control design is shown in Figure 2.4. According to B. Nguyen and J. Ryu. (2009), this variable gear ratio is able to decrease the driver effort and increase the safety for movement of the vehicle because it increases the sensitivity of the drive when turning the steering wheel.

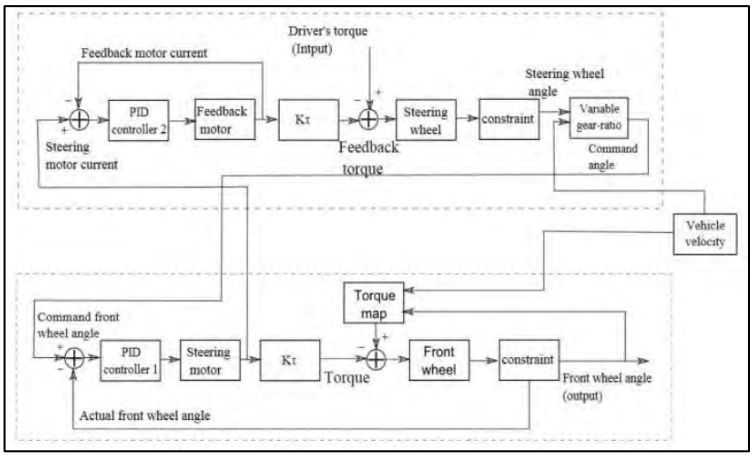

Figure 2.4: Block diagram for upper control circle and lower control circle

2.1.6 Handling safety improvement for Steer-By-Wire Vehicle Using Fuzzy Controller

N. Elmi, et al. (2011), has proposed a novel controller to improve vehicle handling safety. The novel controller used Fuzzy PID controller with Fuzzy compensator to actively control both front wheel and steering wheel independently. The Fuzzy PID controller used dynamic of nonlinear 8Dof model for simulation purpose. To get the desired yaw rate, the controller is designed base on the steady state steering on the circular path. Then it used feedback for yaw rate angle error and its time derivative side slip angle, lateral acceleration and roll angle to improve its handling safety and roll stability. The control design is shown in Figure 2.5

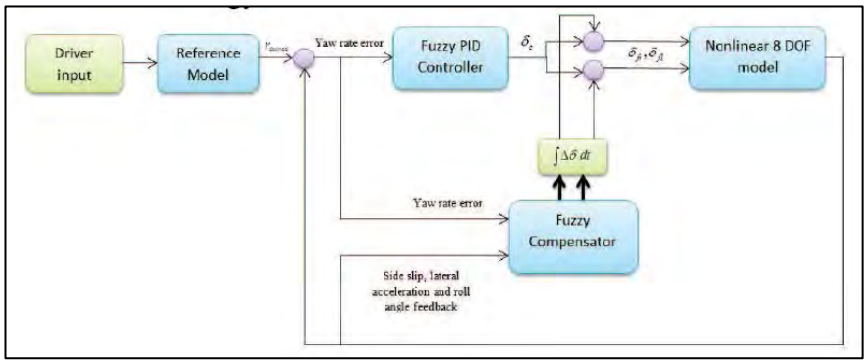

Figure 2.5 controller design that composed of Fuzzy PID controller with Fuzzy Compensator

2.1.7 Incremental Fuzzy Expert PID control

S.G Tzafestas, et al. (1990). Has presented an intelligent PID control that based on Fuzzy Logic application. Them assumes that the parameters of controller are set using conventional method of tuning that is Ziegler-Nichols and Kalman. Then by using appropriate fuzzy matrix that is same with Macvicar-Wheelan matrix, they determine the small changes on these values when the system is operated. This method improved the performance and steady behaviour of the closed-loop system for analog and digital.

CHAPTER 3
METHODOLOGY

3.0 Introduction

In this section the methods used to develop vehicle steering by wire (VSBW) system will be described. The method for developing the Fuzzy PID control(FPC) schemes will also be described in this chapter. These methods explained in this chapter are important in order to make sure that the flow of this project will progress without difficulties.

This chapter also will be explaining the software, hardware and experimental development that are used for this project. There are two softwares that are used for this project which are MATLAB and LABVIEW. Therefore, the overall details of method above will be describing in this chapter.

3.1 Project Flow

Flow chart is one of important step in order to smooth the project flow. These flow chart will help the process to complete this project step by step. Figure 3.1 shows the flow from start to end on how this project is to be completed.