STEERING CONTROL FOR A CAR USING FUZZY LOGIC CONTROLLER

NUR AMIN B. ABDUL WAHID

This report submitted in partial fulfillment of the requirement for the award of
Bachelor of Electronic Engineering (Industrial Electronics) with Honors

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

April 2009

" I hereby declare that this report is the result of my own work except for quotes as cited in the references"

Signature :……

Author :……..……..

Date :…...…….

" I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award and quality of Bachelor of Electronic Engineering (Industrial Electronic) With Honors."

Signature :……

Supervisor's name :……..……..

Date :….....…….

ACKNOWLEDGMENT

I am deeply indebted to many people who directly or indirectly, are responsible to finish this project and most grateful to En. Ahmad Sadikin Muhd Isira ,my supervisor for this subject on his guidance and constructive criticism of my research through this project. I also thank to all the lecturer and staff in FKEKK that help me completing this project and kindness to support in completing this paper in time.

I am also truly grateful to my entire classmate that helps me indirectly by giving the information, idea and proper guidance especially for technical aspect in this project. Those kindness and support will be not forgotten as the time coming. May God bless all of us and give us opportunity to meet in another time afterwards. I also thank to my family on their support and understanding on this project and help me through the project with morale and financial support. Without them the process to complete this project will be more stressful and tough.

Lastly to all individual or person that I have not mentioned here that has helped me indirectly or directly in completing this project. Thank you for all the support, kindness and inspiration given to me to face all the challenge that I faced during the critical phase of the project. Without all that support I doubly I to complete this project in the time gave. Nothing in this world that I can give to repay all the contribution that gives to me during this time.

ABSTRACT

This project is about steering aid system called steering control is evaluated by simulating different driving condition with existing of disturbance. A vehicle model, implemented in Matlab /Simulink, is used to form a total system and to compare the two systems: a conventional vehicle and a controlled vehicle. Simulations are made for a constant speed and a specific changeable road adhesion coefficient. The control system takes the yaw rate as input and derives a steering angle contribution to be added to the drivers command. The motivation for this work is to understand and characterize the response of a vehicle with a complementary steering system. Specific driving events are considered for the simulations such as a wind force disturbance and a severe double lane change. The response of the controlled vehicle is similar to the response of the conventional vehicle for nominal driving, but the steering aid system reduces the effect of wind force disturbances. Improved stability is obtained for the vehicle during slippery road driving and the controller used in this project use fuzzy logic controller which is recently used for the dynamic system.

ABSTRAK

Projek ini adalah mengenai satu sistem yang membantu pemanduan dinilai berdasarakan simulasi dalam keadaan pemanduan yang berbeza dengan kehadiran gangguan luaran. Menggunakan perisian MATLAB/ SIMULINK ,matematik model yang menggambarkan sistem ini di aplikasikan untuk melihat perbezaan antara dua sistem iaitu sistem moden dan sistem konvensional. Simulasi dibuat pada kelajuan tertentu dan pemalar keadaan jalan yang berbeza. Sistem ini mengambil output daripada kadar pusingan tayar dan mengukur sebanyak mana tindak balas yang diperlukan untuk ditambah pada kemasukan dari pada pemandu. Motivasi dalam menyiapkan projek ini adalah untuk memahami dan mengkriteriakan respon kereta dibandingkan dengan sistem yang lama. Gangguan luaran yang digunakan dalam simulasi adalah gangguan angin kencang dan perubahan laluan kereta dengan melihat tindak balas daripada pemandu.Respon daripada pengawal adalah lebih kurang sama dalam keadaan biasa jika dibandingkan dengan sistem konvensional tetapi sistem ini membantu mengurangkan kesan gangguan. Kestabilan kereta ini ditingkatkan dalam keadaan yang licin dan merbahaya dengan menggunakan pengawal *Fuzzy* yang mana sistem ini agak baru diperkenalkan dalam sistem dinamik.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVATION

DOF -	Degree of freedom
Yaw rate -	The angle of the tire to the horizontal plane
Vehicle sideslip angle -	Lateral velocity divided with longitudinal velocity.
Cornering stiffness -	The change in lateral force per unit slip angle change in he linear range.
Roll -	The rotation of the vehicle about its longitudinal axis.
Bounce -	Vehicle motion perpendicular to the ground.
Pitch -	The rotation of the vehicle about its lateral axis.
SBW -	Electrical steering that replaces the mechanical steering control.
Settling time-	The time needed for a system to achieve steady state region.
Percentage Overshoots-	Percentage of the oscillation before it become stable.
Simulink-	Computer software that used to built Mathematical model and simulation of the system

CHAPTER I

INTRODUCTION

1.1 Introduction

Recently the research in steering control is expanding rapidly with researches from all over the world with the different controller strategies. The main reason for this is to improve safety and handling for the car steering to make sure that the driving experience is safe. There is a lot of analysis in the dynamic system of the steering and the controller strategy, however it is still difficult to value the improvements. In this project one solution is implemented and analyzed which is using single track model mathematical model and fuzzy logic controller strategy.

A steering control system is a complementary system for a front-steered vehicle that adds or subtracts a component to the steering signal performed by the driver. The steering signal from the driver is an angular movement on the steering wheel. The resulting steering angle is thus composed by the component performed by the driver and the component contributed by the steering system. Thus the input of the system came from the front wheel angle of the driver. There are many types of control strategy can be done to attenuate the final output whether using conventional controller such as PID or new controller strategy as fuzzy logic control. In this project fuzzy controller is used to control the system. The assignment for the project is to implement a steering aid system to help the driver.

1.2 Objective

In order to measure the outcome of the project the goals are stated below:

1. To characterize the differences of the response between the controlled and the uncontrolled system
2. To establish whether the system is considered to act within driver reaction time.
3. To have a system with steady state rejection or attenuation of input disturbances.
4. To have a system with steady state rejection or attenuation of input disturbances and enhance the stability using the fuzzy logic controller

1.3 Problem Statement

Road is known as the largest transportation system in the any country. Many dangerous situations and expected event may occur on the roads because the driver cannot act fast enough at the beginning of skidding or rollover. Young and inexperienced driver have high tendency to over react on the unexpected condition during driving. Those reaction may occur an accident to the driver cause by instability of the car that controlled by the driver. The survey done by International safety committee found that 40% of the accident occur from the lost of control by the driver during extreme condition.

The condition of the road is the major factor that will influence the car especially for the tire. If the road condition is slippery and wet, it may increase the accident risk due to lack of the tire friction and it may cause the driver to lost control of the car and the steering system become unstable. The disturbance may come from wind gust disturbance and double lane change that need for controller to assist the driver to overcome those disturbances. The controller design must be able to overcome the instability within driver reaction time and reduce the time for system to achieve steady state condition.

1.4 Scope of work

This project is focusing on the car steering system and using the single track model [1] as the mathematical model to represent the dynamic system of the steering which lumping the front and rear tire into one side only. The other side of the car acts as the passive side. The driving condition is under two (2) conditions which are nominal condition and limit condition. At nominal condition the road adhesion $\mu = 1$ with velocity (v) = 20m/s and for the limit driving condition the road adhesion $\mu = 0.3$ and 1 with velocity (v) = 20 and 40m/s respectively. The input parameter of the car denoted by the front steering angle δf and the disturbance which is wind gust and double lane change. Output that will be analyzed and control is the sideslip angle (β) and its Yaw rate(r) [see appendix B]. As for the result of the project it will be shown clearly in MATLAB/SIMULINK by showing the comparison between control and uncontrollable system. In order to control the stability and to reject unwanted steady state error the fuzzy logic controller strategy used in this project.

1.5 Methodology

To complete the research there are certain procedure and method is used in order to make sure the project is running smoothly. The study of the literature review is firstly done, mostly using the IEEE database as the main source to find the paper and journal regarding to the related field of this project. The book on the controller including modern strategy controller book is also as the main source of the literature review as to find the appropriate mathematical model that going to be used. In order to simulate the final result of the system the study on the MATLAB/SIMULINK software has to be done as the preparation and the familiarization to the workspace used on the simulation result and construction of the system. The mathematical model used in the project is the single track model. This mathematical model is very useful as to represent the dynamic system. After implementing the mathematical model to the MATLAB/SIMULINK the simulation of uncontrollable system can be observed and analyzed and then the controller is designed to enhance the stability and to reject the undesired steady state error.

1.6 Research Methodology

The method of this research is to collect the data from the internet mostly on the IEEE database on research paper that have been lunch to collect data and as the literature study of the project and to built the mathematical model of the control system. Also this project must be able to understand and then must be able to use the MATLAB as the programming software to build the schematic diagram using SIMULINK and to build the simulation.

To build up the mathematical model it is need to understand the mechanical structure of the car system and its parameters hence to convert it to functional block diagram. The fuzzy logic strategy that used in this project as the controller can be achieve if the fundamental process is known that to be applied in the controller design. Then the mathematical model is build to implement to the controller design. The comparison on the fuzzy logic will done to make sure the controller is done well. The simulation using the MATLAB and the output verification will show the final result that can be achieve that will make sure the controller is functioning.

Figure 1.1 Flow chart of research methodology

1.6.1 Literature study

The literature study is the first step that had been applied most of the research in any field of study. The literature study is the important step to make sure the information of the research is very accurate and related study on the project with different strategy. The study is based on the related journal and paper published on the engineering database and related book to the field. The table below shows few of the literature study in this project. The literature review is including the study on the controller used and the parameters value that will use in the simulation.

Name	Title of project	Description
Nor Maniha Ghanil, Yahaya Md. Sam' and Adizul Ahmad	Active steering using Sliding mode	• A single track car model is used in the study approach • Sliding mode compare with LQR and pole placement • Disturbance : Wind Gust & Split Braking
Jurgen Arkerman and Dirk Ordenthal	Damping of vehicle roll dynamic by gain scheduling active steering	• To reduce the rollover risk of vehicle under extreme road surface • By applying the dynamic system of mass spring of the car
Jurgen Ackerman, Wolfgang seinel	Linear and nonlinear design for robust automatic steering	• Using linear and nonlinear controller • Feedback of lateral displacement and yaw rate • Using reference line and sensor
R. karbalaei, A Ghafari,R Kazemi	A new strategy to integrate the Active steering using Fuzzy logic	• Using fuzzy logic controller to control the active steering • Integrate with Yaw dynamic-moment control(DYC

Table 1.1 Table of literature review in this project

The paper by Nor Maniha Ghani,Yahya Md Sam' and Adizul Ahmad to propose a new control method in active steering for vehicle stability using Sliding Mode Control technique. A single track car model is used in the study and the performance of the system using SMC technique will be compared to the pole placement and LQR techniques. Different road friction coefficients and various disturbances will be observed as the varying parameters to see the robustness and effectiveness of the proposed control. Performance of each case and its ability to attenuate disturbances in term of yaw rate as well as side slip angle will be simulated.

For Jurgen Ackerman with his paper about damping of vehicle roll dynamic by gain scheduling active steering is about Active steering is applied to robustly reduce the rollover risk of vehicles with an elevated center of gravity. An actuator sets an auxiliary steering angle which is mechanical added to the steering angle commanded by the driver. The control law presented is based on feedback of the roll rate and the roll acceleration. The controller gain are scheduled with the speed and the vehicle's CG height the controller gains are found by the parameter spec approach and constrained optimization in frequency domain. Robust reduction of transient rollover risk is show by evaluation of the sensitivity function at various operating points. Simulation of a double lane change maneuver illustrates the benefit in time domain.

Meanwhile R. karbalaei, A Ghafari,R Kazemi in his paper stated An integrated vehicle dynamics control system is developed in this paper by a combination of active front steering (AFS) and direct yaw-moment control (DYC) based on fuzzy logic control. The control system has a hierarchical structure consisting of two layers. A fuzzy logic controller is used in the upper layer (yaw rate controller) to keep the yaw rate in its desired value. The yaw rate error and its rate of change are applied to the upper controlling layer as inputs, where the direct yaw moment control signal and the Steering angle correction of the front wheels are the outputs. In the lower layer (fuzzy integrator), a fuzzy logic controller is designed based on the working region of the lateral tire forces. Depending on the directions of the lateral forces at the front wheels, a switching function is activated to adjust the scaling factor of the fuzzy logic controller.

1.6.2 Mastering MATLAB/SIMULINK software

Since the result is based on the simulation to analyze and observe the output, the aid of the simulation must be master to make sure the output is correct output and thus can be controlled. The MATLAB is one of the popular software used by researches to simulate the mathematical model since the software is very accurate to the real system and it can represent almost any real system. In this project the SIMULINK with state-space representation is used as the aid to simulate the mathematical model.

1.6.3 Draw functional block diagram

The dynamic system will convert to the functional block diagram that describes the component part of the system and show their interconnection. It indicates the output the input and the state equation used in the dynamic system. If the system is the electrical system, the schematic diagram can be computed to simplify the analyzing process.

1.6.4 Develop Mathematical model

To determine the mathematical model the physics law is used including Kirchoff's Law and Newton's Law. This physics law led to mathematical relationship between the input and output of dynamic system. One of the models is Linear, Time-invariant and differential equation. Many system can be represented by this equation which related to output c(t) and input r(t). In this project the state-space has been used as the representation of the system. One of the advantage of state-space is they can also used for the system that cannot be described by linear differential equation, Further the state-space method are used to model systems for simulation on the digital computer.

1.6.5 Analysis and design controller

The next phases of the process, following establishing the mathematical model is analysis and design the controller. In this phase the researcher analyzed the system to see if the response specification and performance requirement can be met by simple adjustment of system parameters. If it cannot met the specification needed the controller will be designed to meet the specification and requirement. Test input signals are used which require analyzing the performance under various conditions. This analysis method usually observed from the output graph produces by the output and the tuning process needed if the final value is not meeting the requirement value. MATLAB simulation gives the easier way to analyzed by capability to change the parameters value easily in M-File editor.

1.6.6 Evaluation and verification

Lastly the evaluation will be performed by referring to the related study on the system and comparing to the simulation result using the MATLAB. If the result doesn't match the desired value previous phases will be repeated until the desired value is achieved. The verification on the final value can be done by referring to other journal or paper that similar to the project.

CHAPTER II

LITERITURE REVIEW

2.1 Background

Active Steering is a steering aid system integrated in cars. Firstly we see different system with different control strategy on the market. The idea is to improve safety and comfort by improved stability and handling. Although the regulations demand a mechanical connection between the steering wheel and the steering rack, actuators are used to influence the mechanical system.

This chapter will describe some of the technical solutions of the steering systems used today. The Solutions used by BMW (Active Steering) and General Motors (Quadrasteer) will be considered. Articles on Active Steering will been studied. The survey focus has been on the automatic control area and on the steer-by-wire development.

Active steering is the idea of an integrated steering support system for cars. The system has to behave like the steering on conventional cars but with additional functionality such as disturbance rejection due to, for example, μ-split (split adhesion coefficient between wheels), wind gusts or decreased road adhesion conditions. Several existing systems are conceptual and not intended for the market, but for example BMW has a semi-mechanical system installed on the five hundred and thirty cars [2].

The two systems explained below are two different examples on how to change the conventional steering of a car. The most important reason for changing the steering characteristics of a car is to improve safety and comfort. The following sections will describe a specific theoretical solution for a steering system.

2.2 Active steering concept

Figure 2.1 Conventional steering control block diagram

From the block diagram in Figure 2.1 above shows the conventional system of the car steering which is the output of vehicle receives the input directly from the driver command. If the driver cannot control the condition of the steering the car will be unstable thus causing an accident. This shown that conventional system responds to the driver command without any feedback input.

Figure 2.2 Active steering system control block diagram

Shown on the Figure 2.2 where the controller block is placed after the driver command that gives the feedback to the car steering. The controller received the input from the output system and responds by giving appropriate action to the steer angle [6].

2.3 BMW-Active Steering

The system that BMW uses has a speed dependent variable steering ratio and also the ability to adjust for disturbances during driver reaction time [10]. This is achieved with a planetary gear with two inputs and one output and a fast transmission of information (100 Hz) from different sensors. The planetary gear is able to add or