STEERING CONTROL FOR A CAR USING BACKSTEPPING CONTROL STRATEGY

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

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Dedicated to my beloved parents, family and fellow friends, who had strongly encouraged and supported me in my entire journey of learning…

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ABSTRACT

This project is to design an active steering controller for the car steering. The controller built is based on the backstepping control technique which is a state feedback system. The steering control is commonly known as the active steering in the automotive industry. An active steering is capable of controlling and correcting the vehicle's trajectory when the system is subjected to an external interference. In most crosswind cases, the vehicle may not be able to travel in a straight line. The crosswind causes the vehicle to change its trajectory and becomes unstable. For such case, the active steering can help realign the vehicle's steering thus allowing the vehicle to travel in its intended path safely.

ABSTRAK

Projek ini adalah untuk merekabentuk satu sistem kawalan untuk sistem stering kereta. Alat kawalan tersebut direkabentuk berasaskan teknik *backstepping,* iaitu merupakan salah satu bentuk sistem suap balik. Alat kawalan stering kereta lebih dikenali sebagai stering aktif dalam industry automotif. Stering aktif ini berkebolehan untuk mengawal dan membetulkan halatuju kereta tersebut apabila sistem kenderaan mengesan berlakunya perubahan halatuju tanpa perubahan sudut stering. Kebanyakan kes angin lintang, kereta biasanya tidak dapat bergerak dalam garisan lurus. Angin lintang ini akan menyebabkan kereta itu mengubah halatuju dan menjadi kurang stabil. Dalam keadaan ini, stering aktif ini boleh membetulkan stering kereta dan seterusnya membolehkan kereta tersebut bergerak dalam halatuju yang diinginkan dengan selamat.

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LIST OF ABBREVIATION

IEEE	-	Institute of Electrical and Electronics Engineers
LQR	-	Linear Quadratic Regulator
DOF	-	Degree Of Freedom
SBW	-	Steer by Wire
MP	-	Momentary Pole
CG	-	Center of Gravity
m	-	Mass of Vehicle
v	-	Velocity of Vehicle
β	-	Sideslip of Body
ψ	-	Yaw Angle
r	-	Yaw Rate
F_{yF}	-	Front Axle Lateral Force in Chassis Coordinate
F_{yR}	-	Rear Axle Lateral Force in Chassis Coordinate
F_x	-	Retarding Force
J	-	Moment of Inertia
l_F	-	Length between Front Axle to the Center of Gravity
l_R	-	Length between Rear Axle to the Center of Gravity
M_{zD}	-	Disturbance Torque
β_F	-	Sideslip Angle at Front Axle
β_R	-	Sideslip Angle at Rear Axle
α_F	-	Front Tire Sideslip Angle

α_R	-	Rear Tire Sideslip Angle
δ_F	-	Front Steering Angle
δ_R	-	Rear Steering Angle
F_{ytF}	-	Lateral Force in Front Tire Coordinate
F_{ytR}	-	Lateral Force in Rear Tire Coordinate
μ	-	Adhesion Coefficient
C_F	-	Front Tire Cornering Stiffness
C_R	-	Rear Tire Cornering Stiffness
Co	-	Controllability
km/h	-	Kilometers per Hour
m/s		Meters per Second

CHAPTER I

INTRODUCTION

1.1 Introduction of the Project

Losing control of a car at high speeds is a common problem. These accidents occur because of the driver's failure to understand the many situations that could result in loss of control. They have failed to understand the limit of their vehicle. A city car which is small is not designed to be driven at highway speeds while tires with poor grip increase the chances of losing control. Such problems are due to the driver's negligence to do proper maintenance. A new driver would not even be able to fully control the car, let alone to understand the hidden dangers of disturbances.

A well maintained vehicle can also lose control due to external factors. The external disturbance that causes a car to lose control includes but not limited to crosswind and unstable braking torque. These factors cannot be visible but the driver can feel its effects. Although many controllers are being installed on a vehicle such as antilock brake system, traction control, dynamic stability control and active steering, these system is still unable to defy extreme forces such a full thrust from a Boeing 747 that is about to take off. Such systems are only aimed to improve the drivability of a vehicle during difficult driving situations such as poor road adhesion and crosswinds.

1.2 Objectives

The objective of this project is being defined as below:

i. To identify the method of producing a mathematical model of a car steering.
ii. To identify and simulate the disturbance signal
iii. To identify the effects of disturbance towards the vehicle's sideslip angle and yaw.
iv. To identify the requirements of the backstepping controller's requirement and its implementation.
v. To design a steering control system for a car using the backstepping control strategy.

1.3 Problem Statement

Driving a car at high speed requires a lot of concentration a vehicle can easily lose control due to multiple disturbances. The most common problems are the existence of crosswinds. These crosswinds can easily throw a vehicle off balance, resulting in the vehicle to veer off course. The driver will have to counter steer in order to maintain the correct path, else the vehicle may crash. Counter steering is not an easy task as too much will result in a spin, and too little may not be enough to correct the path. Even high speed braking is dangerous as the brakes applied are not necessarily same as there are different amount of forces acting. This will result in the vehicle to move sideways. Therefore, a controller is required to be implemented to reduce these disturbances to make driving a safer task. Many controllers are implemented such as antilock brake system and traction control. It is believed that adding a steering control or active steering can further enhance the safety level. It must be taken into consideration that the controllers implemented on the car are only to improve the vehicles handling and it does not defy the law of physics.

1.4 Scope

The scope of this project is to focus on the method of developing the vehicle's mathematical model especially that of the steering system. The mathematical model will then be transferred into Simulink in MATLAB for simulation. The graphs relating to the yaw and sideslip are then generated by adding a simulated disturbance. On the second part of the project, the focus will be on developing a back stepping controller and will then be integrated into the mathematical model to improve vehicle stability. This project will only focus on simulation and does not involve any hardware.

1.5 Outline of Methodology

Literature reviews are conducted to further understand the development of steering control. The project will simply focus on the construction of the mathematical model of a vehicle steering. From there, a state feedback strategy controller is designed and attached to the vehicle steering which is known as the active steering. This project will not involve any hardware building as is only a simulation. Majority of this information are referred to the book titled Robust Control: The Parameter Space Approach [1].

The project was started of with the literature review. In order to understand the basics of the steering system, a literature review has to be made on the steering system and the many systems involved in building the state space model that is required to be simulated in the Simulink of MATLAB. MATLAB is a very powerful simulation tool. While it was being taught in the syllabus, refreshment is required as it has been quite some time ago since it was last applied. The MATLAB has many other multiple tools under Simulink and the multiple commands that can be very useful in the simulation process. Therefore a clear understanding is required in order to fully utilize the software. Additional assistance can easily be found under its help file.

Having to understand the basics, some research was done on active steering through multiple sources including the IEEE's journals. From these journals, much information can be gathered to further understand the problems and solutions applied to the same concept of active steering. The journals can only give a simple overview of the research done as most information still requires the readers to further their research by referring their respective references books. This is to ensure that the readers can fully understand the entire system more clearly.

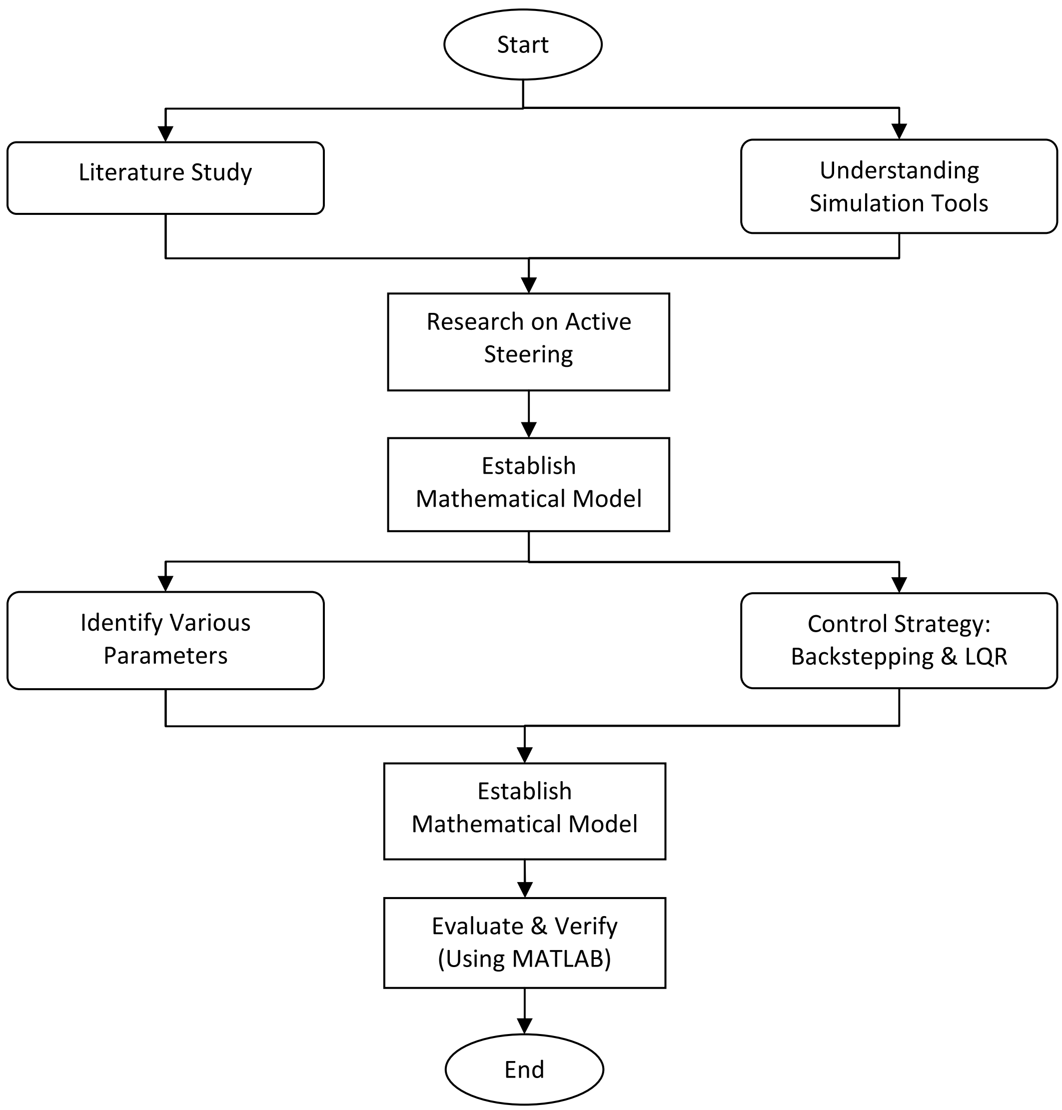

Figure 1.1: The methodology flow of the process.

Chapter 2 of the project is to identify the nature of the project which is a simulation type only. After completing the literature study, a research on the current Active Steering technology and its many research which can be found in the IEEE's website. By doing so, we are able to identify the method used to simulate the system.

In chapter 3, by referring to the references, a standard mathematical modeling for a car steering is established. The modeling is only limited to three degree of freedom which is sufficient to represent the vehicle's steering characteristics. The vehicle simulation is verified by comparison with the references.

In chapter 4, the type of controller to be implemented is chosen. The backstepping controller is capable of controlling multiple types of condition at one moment, thus improving system efficiency. The design and implementation of the backstepping controller is studied carefully and executed. The mathematical model is combined with the backstepping controller which results in the active steering. The controller is verified by adding the Linear Quadratic Regulator (LQR).

Chapter 5 consists of the simulation and results. The simulation is executed with many types of variables being used as to show the performance of the controller at different types of conditions. By matching the pattern of the controllers and the uncontrolled model, it proves that the results are correct and that the simulation is in line with other types of simulation for vehicle steering.

Chapter 6 is about the discussion and future recommendation. The discussion is for the results generated. The future recommendation for this project is also discussed here as this project can be further develop to complete a vehicle simulation.

Finally in chapter 7, the conclusion for this report is noted here. The initial objectives are reviewed in order to obtain the success level of this project.