ACTIVE CAR STEERING USING SLIDING MODE CONTROLLER

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Faculty of Electronic and Computer Engineering
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Thank to God because me strength to finish my Bachelor's Project in a good implementation.

I would like to acknowledge the generous support of Universiti Teknikal Malaysia Melaka (UTeM) in providing chance to study here and also to implement this project.

Special thanks to Mr. Ahmad Sadhiqin Bin Mohd Isira as my supervisor that have given a lot of guides to me along this project implementation.

I would like to acknowledge to all my friends that have given a moral support and some opinion in implementing this project.

Lastly, I would like to thank all my friends that have contributed in completing this report.

For Beloved Mom and Dad

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ABSTRACT

This project is to build Active Car Steering using Sliding Mode controller by using MATLAB and Simulink for the simulation. Active steering is used to control the yaw rate and side slip angle of vehicles. Active steering can reduce unstable that caused by the cross-wind and braking torque. The active steering is efficient because it will react to information from the yaw rate sensor to modify the steering angle of the front wheel to stabilize the vehicle if the driver experiences a skid or slide because of poor road conditions. Besides that, the active steering can operate in different situation of the road such as dry road with μ=1, wet road with μ=0.5, and icy road with μ=0.15. To satisfy this project, the MATLAB and Simulink are used to do simulation of the system without and within controller.

ABSTRAK

Projek ini adalah untuk mencipta pengawal untuk stering kereta aktif yang dipanggil 'Sliding Mode' dengan menggunakan MATLAB dan juga Simulink. Stering kereta aktif digunakan untuk mengawal 'yaw rate' dan 'side slip angle' kereta. Aktif stering berkesan kerana ia bertindak balas dengan maklumat dari sensor 'yaw rate' untuk mengubah sudut stering roda hadapan untuk menstabilkan kereta sekiranya kereta mengalami gelinciran disebabkan keadaan jalan raya yang tidak baik. Active stering dapat beroperasi pada keadaan jalan raya yang berlainan. Nilai pembolehubah bagi jalan raya yang kering ialah μ=1, jalan raya yang basah ialah μ=0.5 dan jalan raya yang bersalji ialah μ=0.15. MATLAB dan juga Simulink digunakan dalam simulasi sistem tanpa pengawal dan dengan pengawal.

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β	-	Side Slip Angle
r	-	Yaw Rate
δ_F	-	Front Angle
δ_R	-	Rear Angle
MzD	-	Disturbance
m	-	Mass of the car body
J	-	Moment of inertia for the car body
v	-	Velocity of the car
c_R	-	Cornering stiffness of the rear axle
c_F	-	Cornering stiffness of the front axle
ℓ_R	-	Wheelbase of the rear axle
ℓ_F	-	Wheelbase of the front axle

CHAPTER 1

INTRODUCTION

1.1 Introduction

Sliding mode control has been greatly investigated in active steering system. The car will become unstable because of the disturbance injection torque caused by braking forces and side wind. The car will be in under-control while disturbance exist. This situation may cause an accident [8].

There are so many methods that have been used to control the active steering system such as robust decoupling of car dynamics with arbitrary mass distribution, H∞ control approach, model reference adaptive control and fuzzy control [8].

A steering system is one of the major automotive subsystems required for operation of the car (see figure 1.1). It provides the driver control of the path of the car over the ground. Steering functions by rotating the plane of the front wheels in the desired direction of the turn. The angle between the front wheel plane and the longitudinal axis of the car is known as the steering angle. This angle is proportional to the rotation angle of the steering wheel [2].

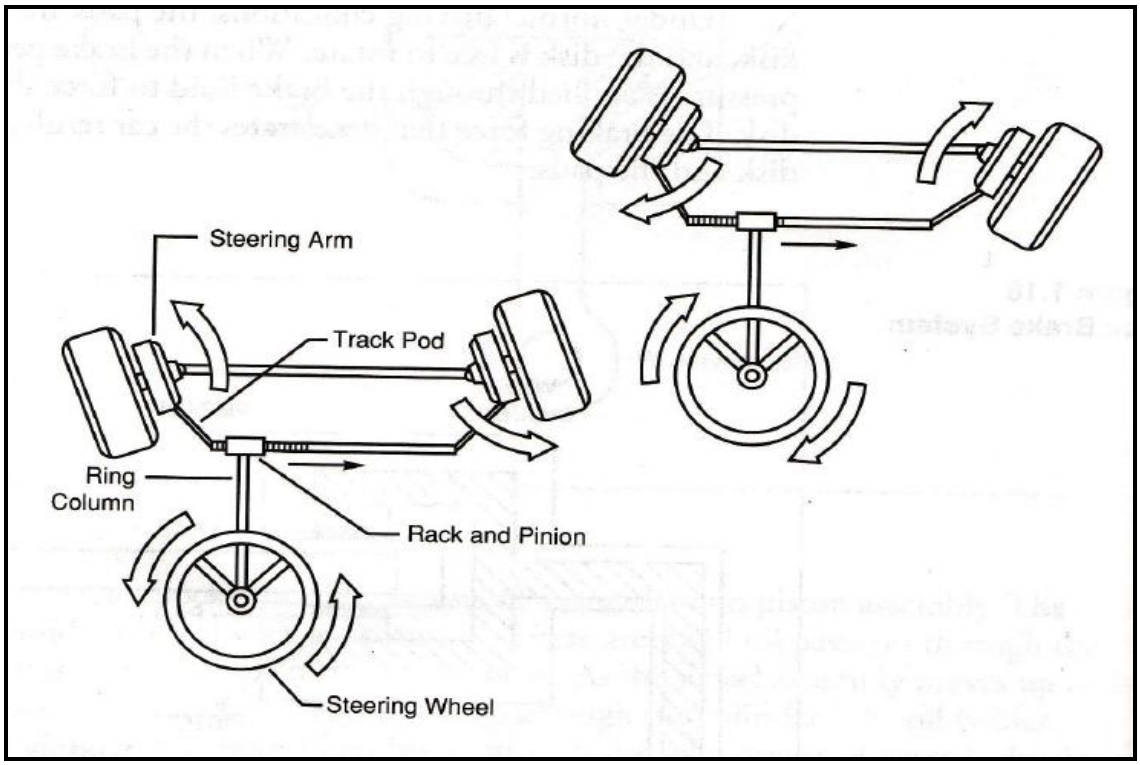

Figure 1.1 One type of steering mechanism

The term ‘sliding mode control’ first appeared in the context of variable-structure systems [4]. Due to its order reduction property and its low sensitivity to disturbances and plant parameter variations, sliding mode control is an efficient tool to control complex high-order dynamic plants operating under uncertainty conditions which are common for many processes of modern technology [4]. Sliding mode called when the control as a function of the system state switches at high (theoretically infinite) frequency [4]. The motion of the sliding mode system while confined to the switching line or a surface is referred to as sliding. A sliding mode will exists if the vicinity of the switching surfaces the state velocity vectors are directed toward the surface [5]. A variable structure system is a dynamical system whose structure changes in accordance with the current value of its state [5]. A sliding mode controller is implemented to this project to control the steering while injecting by external disturbance that can caused unstable of the car.

This project aim is to design sliding mode controller that can detect the external disturbances and reduce unstable because of the disturbance injection torque caused by

crosswind and braking torque using linear single-track model system. At the same time this system can improve road handling and avoid skidding.

Single-track model is obtained by lumping the two front wheels into one wheel in the center line of the car; the same is done with the two rear wheels.

Active steering is an efficient means to influence a vehicle's yaw and roll dynamics [7]. In this project, three situations of road are considered which are dry, wet and icy that have different road friction coefficient. Two disturbances which are crosswind and braking torque will be observed to see the robustness and effectiveness of the proposed control. This project involved simulation by using MATLAB.

1.2 Objectives

The main objectives of this project are:

i. To reduce unstable of the disturbance injection torque caused by braking forces and side wind.
ii. To improve road handling and avoid skidding.

This project will capable to reduce the effect of external disturbance to yaw rate and side slip angle of the car using sliding mode controller. After implement the sliding mode controller, the car can be improved in it road handling and avoid skidding. The other aim of this project is to gain knowledge about car steering, sharpen the skill in using MATLAB and learn on how to manage a project within predetermined time.

1.3 Problem Statement

The vehicles are becoming unstable because of the torque disturbance caused by braking and side wind forces. The tire of the car may lose grip when water exists on the road, side wind caused by larger or speeding vehicles and loose gravel on the road.
Most of the cars are facing the situation.

1.4 Scope of work

There are 4 scopes of work involve in this project. There are find suitable mathematical model for the controller design, identify various parameter for disturbance (input), design controller and do simulation of the system using MATLAB and Simulink.

1.4.1 Mathematical Modeling

The mathematical model obtained is the non-linear single-track model. It will be linearized to get a linear system. Then it will be transferred to the state-space form. The block diagram will be constructed based on the state-space form.

1.4.2 Find parameter of disturbance

There are two disturbances that used in this project. Those disturbances are cross-wind and braking torque. The disturbances act as the input to the system.

1.4.3` Design Controller

Identify the controller that will be implemented to this project which is 'Active Car Steering'. Design Sliding Mode Controller to achieve the objectives.

1.4.4 Do simulation using MATLAB and Simulink.

Simulate the constructed block diagram using Simulink and recheck controllability using MATLAB.

1.5 Methodology

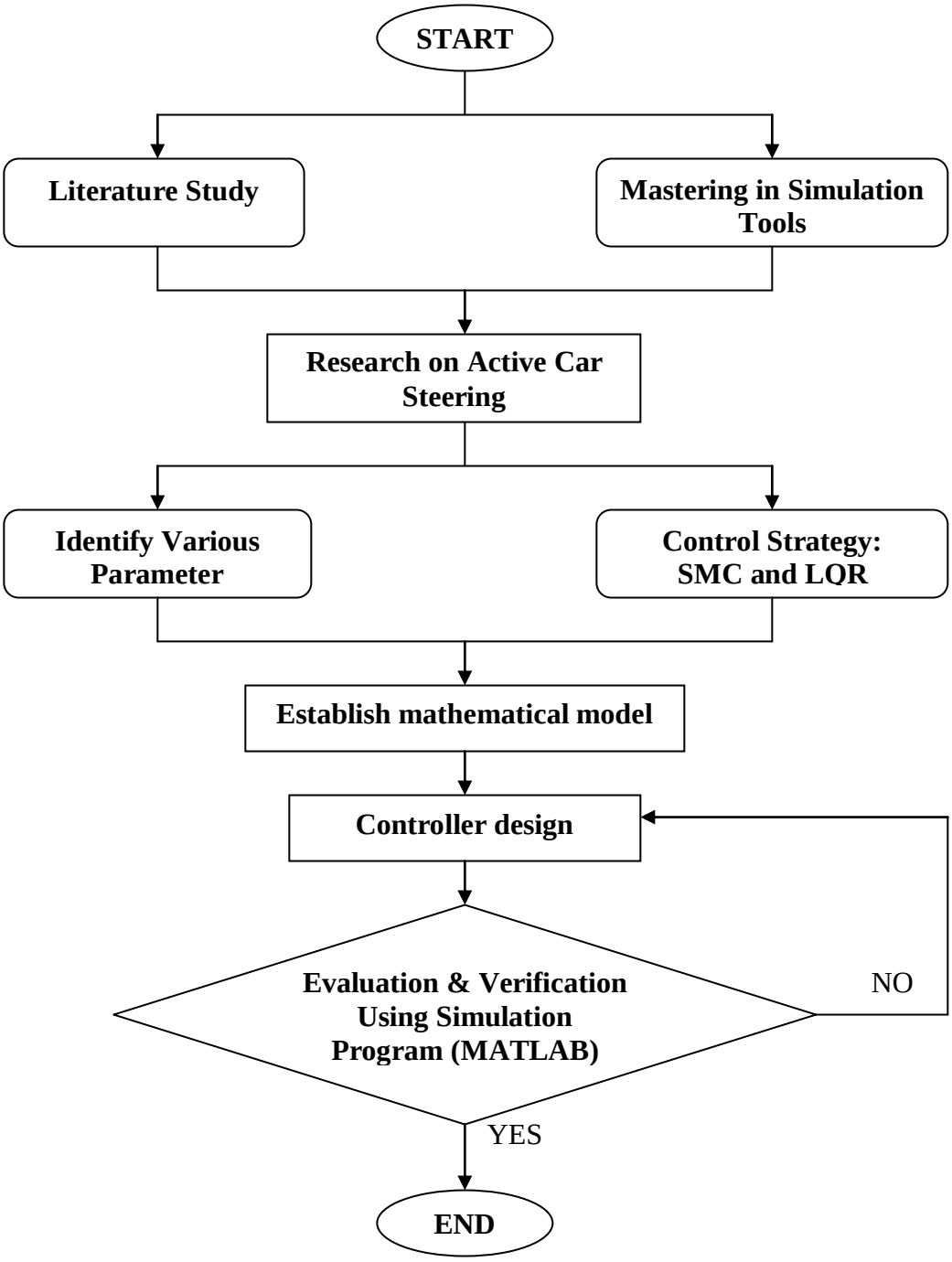

Figure 1.2 Methodology of the project

There are the procedure and method to achieve the objectives of this project:

i) Firstly, the literature will be reviewed by searching paper on IEEE and finding reference books. At the same time, MATLAB and Simulink will be learnt for measuring and simulating.

ii) Secondly, the research on 'Active Car Steering' will be started by identifying various parameters and the control strategy will be determined.

iii) The controllers that will be chose for this project are Sliding Mode Controller (SMC) and Linear Quadratic Controller (LQR).

iv) Thirdly, the mathematical model will be established based on the mathematical equation that may get.

v) The mathematical equation will be transferred to state-space form.

vi) Next, the sliding mode controller will be designed based on the mathematical model.

vii) Then, the procedure will be precede by evaluating and verifying using Simulation program (MATLAB).

viii) If the unexpected result is achieved, the controller will be designed until the exactly result is achieved.

1.6 Report Structure

The first chapter of this report is about the introduction. This chapter consists of introduction, objective, problem statement, scope of work, summary of the methodology, and the structure of the project.

The second chapter is about the literature review. This chapter shows the research of the project that related to the theory and concept through the certain figure. It is about the explanation of the perspective and method of the past research and their relationship with this project.

The third chapter is about mathematical modeling. This chapter shows all the steps to get the state-space form. This state-space form will be used to construct the block diagram in MATLAB and will be simulated using Simulink.

The forth chapter is about result and discussion. This chapter shows the result of the simulation and the discussion of the result.

The fifth chapter is about conclusion. The conclusion is for the overall project and the relation of the project with the objectives.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

To complete this project, many researches and analysis about the active steering and their theory had been done. Several sources were used for this research such as text book, journals, and internet source. From the past researches, many methods are used for this project.

2.2 Research of steering

Active steering is an automotive technology utilized by BMW which varies the degree that the wheels turn in response to the steering wheel. At lower speeds, this technology reduces the amount that the steering wheel must be turned-improving performance in situations is such that steering becomes more responsive and provides improved directional stability.

In a parking situation, the computer varies the ratio so that the steering wheel needs less than two turns to move the wheels lock to lock. As vehicle speed increase, the steering ratio increases, so it takes more turns of the steering wheel to move the wheels