MODELLING AND SIMULATION OF LANE KEEPING CONTROL SYSTEM

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this project report entitled “Modelling and Simulation of Lane Keeping Control System” is the result of my own work except as cited in references.

Signature : ……………………………

Name : Hazwan bin Hussin

Date : ……………………………

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PENGAKUAN

Saya akui laporan ini yang bertajuk "Pemodelan dan Simulasi Sistem Kawalan Pengendalian Lorong" adalah hasil kerja saya sendiri kecuali yang dipetik daripada sumber rujukan.

Tandatangan : ....

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	…………………………
Supervisor’s Name	:	…………………………
Date	:	…………………………

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PENGESAHAN PENYELIA

Saya akui bahawa telah membaca laporan ini dan pada pandagan saya laporan ini adalah memdai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal.

Tandatangan : ……………….…………

Nama penyelia : ..…………………………

Tarikh : ……………….…………

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DEDICATION

To my supervisor Dr. Amrik Singh A/L Phuman Singh,

My beloved father Hussin bin Md. Rusdi,

My beloved mother Zurina binti Zakaria,

My Brother and Sisters,

My supportive fellow friends,

Thank you for continues support and for everything.

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ABSTRACT

The automotive sector is one of the world's leading industries. This industry now is toward a revolution from year to year. The automotive industry consists of many companies and organizations engaged in vehicle design, development, distribution, commercialization, and sales. For autonomous vehicles it is beginning to attract many automakers to make changes of technology and to be at a more advanced level. One of the technologies of autonomous vehicle is a lane keeping control system (LKS) which to keep the vehicle from exit the lane of the road. This system helps to prevent a collision or in an emergency situation. For the objective of this study is to create a mathematical model for the vehicle handling dynamics and to design the lane keeping control system by using PID controller. The scope of this study is to develop a non-linear vehicle handling dynamic model by using MATLAB and Simulink as well as to design the control strategy for lane keeping system. This study is uses two degree of freedom (2DOF) of bicycle model and nonlinear tire model as its vehicle system model to analyze the behavior of vehicle system. The simulation takes place in the MATLAB and Simulink constructs the mathematical model. In this contribution the mathematical modeling of a vehicle equipped with a lane keeping control system is considered. Therefore, the modeling considers the steering model of the vehicle and the vehicle itself as a bicycle model. In this study there are three major components need to be conducted to verify the vehicle system. The first one is the equation of vehicle model which is in this project its use the bicycle model. In the vehicle model there are two parameters need to consider which is the side slip angle and yaw rate. Second is the tire model itself, by combining the tire model and vehicle model, the performance of the vehicle can be determined for side slip angle and yaw rate. Third, is the controller that are using in this study which is the PID controller. The controller take place in the vehicle system is to tune up the control structure of the vehicle and to find a good model structure to perform in the simulation. The graph of the vehicle system will show the behavior of the vehicle after running the simulation. This study concludes by summarizing all the results from vehicle model and the controller.

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ABSTRAK

Sektor automotif adalah salah satu industri terkemuka di dunia. Industri ini kini menuju revolusi dari tahun ke tahun. Industri automotif terdiri dari banyak syarikat dan organisasi yang terlibat dalam reka bentuk, pengembangan, pengedaran, pengkomersialan, dan penjualan kendaraan. Bagi kenderaan autonomi, ia mula menarik banyak pembuat kenderaan untuk membuat perubahan teknologi dan berada pada tahap yang lebih maju. Salah satu teknologi kenderaan autonomi adalah sistem kawalan pengendalian lorong (LKS) yang menjadikan kenderaan tidak keluar dari lorong atau jalan. Sistem ini membantu mencegah perlanggaran atau dalam keadaan kecemasan. Untuk objektif kajian ini ia bertujuan untuk mengembangkan model matematik untuk dinamika pengendalian kenderaan dan merancang sistem kawalan menjaga lorong dengan menggunakan pengawal PID. Skop kajian ini adalah untuk mengembangkan model dinamik pengendalian kenderaan nonlinear dengan menggunakan MATLAB dan Simulink serta merancang strategi kawalan untuk sistem pengendalian lorong. Kajian ini menggunakan dua darjah kebebasan (2DOF) model basikal dan model tayar bukan linier sebagai model sistem kenderaan untuk menganalisis tingkah laku sistem kenderaan. Simulasi akan dilakukan dalam MATLAB dan Simulink pula akan merangka model matematik. Dalam sumbangan ini, pemodelan matematik kenderaan yang dilengkapi dengan sistem kawalan pengendalian lorong akan dapat dipertimbangkan. Oleh hal demikian, pemodelan akan dapat menganggap model stereng kenderaan dan kenderaan itu sendiri adalah sebagai model basikal. Dalam kajian ini terdapat tiga komponen utama yang perlu dijalankan untuk menentukan sistem kenderaan. Yang pertama adalah persamaan model kenderaan yang dalam kajian ini menggunakan model basikal. Dalam model kenderaan terdapat dua parameter yang perlu dipertimbangkan ia merupakan sudut slip sisi dan kadar yaw. Kedua adalah model tayar itu sendiri, dengan menggabungkan model tayar dan model kenderaan, tingkah laku kenderaan dapat ditentukan untuk sudut slip sisi dan kadar yaw. Ketiga, adalah pengawal yang digunakan dalam kajian ini, ia merupakan pengawal PID. Pengawal yang berlaku dalam sistem kenderaan adalah untuk menyesuaikan struktur kawalan kenderaan dan mencari struktur model yang baik untuk dilakukan dalam simulasi. Grafik sistem kenderaan akan menunjukkan tingkah laku kenderaan setelah menjalankan simulasi. Kajian ini diakhiri dengan meringkaskan semua hasil dari model kenderaan dan pengawal.

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LIST OF SYMBOLS

α	-	Sideslip of tire
α_f	-	Slip angle of front tire
α_r	-	Slip angle of rear tire
β	-	Sideslip angle
C	-	Lateral axle cornering stiffness
C_a	-	Lateral stiffness of the tires
$C_{\alpha o}$	-	Tire sideslip coefficient.
C_s	-	Longitudinal stiffness of the tires
$C_{\lambda o}$	-	Tire slip coefficient
e_{la}	-	Lookahead error
F_f	-	Cornering force of front tires
F_r	-	Cornering force of rear tires
F_x	-	Longitudinal tire force
F_y	-	Lateral tire force
F_z	-	Vertical load forces of the tires
F_{yf}	-	Front tire front
F_{yr}	-	Rear tire force
g	-	Gravitational
I_z	-	Yaw moment of inertia
K	-	Vehicle understeer gradient
l_f	-	Front axle length

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l_r	-	Rear axle length
m	-	Mass
r	-	Yaw velocity
S	-	Longitudinal slip ratio of tires
V_x	-	Vehicle speed
W_f	-	Normal load front axle
W_r	-	Normal load rear axle
$\dot{y}_c$	-	Lateral direction
y_c	-	Lateral displacement
δ_f	-	Angles the front wheel
δ_r	-	Angles the rear wheel
$\dot{\text{ø}}$	-	Yaw rate
Ø	-	Yaw angle
λ	-	Tire slip
δ	-	Steering angle
μ_{max}	-	Maximum friction coefficient

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LIST OF ABBREVIATION

ABS	-	Antilock braking system
ACC	-	Adaptive cruise control
AFS	-	Active front steering
ASEAN	-	Association of South East Asian Nations
C.G	-	Centre of gravity
DYC	-	Direct yaw-moment control
ESC	-	Electronic stability control
FLC	-	Fuzzy logic control
JPJ	-	Jabatan pengankutan jalan
LDW	-	Lane departure warning
LKAS	-	Lane keeping assistance system
LKS	-	Lane keeping system
LQR	-	Linear Quadratic Regulator
MATLAB	-	MATrix LABoratory
MIROS	-	Malaysia Institution of Road Safety Research
PID	-	Proportional-Integral-Derivative
SISO	-	Single input and single output plant
TCS	-	Traction control system
2 DOF	-	Two Degree of Freedom
3 DOF	-	Three degree of freedom
4WS	-	Four-wheel steering

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Almost daily news of tragic accidents resulting in serious injuries, loss of life and loss of property published in the mass media. This situation shows that accidents are a serious problem that is difficult to overcome. The most factor that leads to road fatalities, human negligence is the main factor. Many drivers like to drive recklessly, they also do not comply with the rules and regulations of the road. In addition, the condition of the car is also the cause of the accident. Many vehicle owners do not maintain their vehicles properly. This situation causes vehicle components such as brakes and tires to fail to function properly. This causes the vehicle to get out of control and can easily break out while driving.

Every year, large numbers of casualties occur around the world. Over 1.25 million people die every year from road fatalities, an average of 3,297 fatalities a day. An addition of about 20 to 50 million are wounded or disabled. For low and middle-income countries with less than semi of the world's vehicles over 90 percent of all road fatalities happen. Meanwhile, the ninth-most serious cause of death is traffic accidents, accounting for 2.2 percent of all fatalities worldwide (Global status report on road safety, 2018). For the analysis and comparison, Table 1.1 shows road safety ranking status among ASEAN country year 2013 (Global Status Report on Road Safety, 2015). According to this data, Malaysia ranks fourth for the highest number of deaths among ASEAN countries. Based on the road

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accident data in Malaysia 2011, factors that lead to the accident are assumed to be at 80.6 percent due to human carelessness, 13.2 percent caused by road condition while 6.2 percent of accidents caused by vehicle condition reference by MIROS (2011). In fact, every year we can see the increase of accidents and the statistic of the accident very worrying for all the agencies. Based on source from Traffic Investigation and Enforcement Department, Bukit Aman, JPJ and MIROS, road and index accident development for 9-year (2011- Jun 2019) shown in Table 1.2. The highest number of deaths was in 2016 which 7,152 cases happened, 4,506 got major injuries while 7,415 suffered minor injuries. With these worrying statistics, responsible agencies need to take proactive action to ensure that the road accident is minimized.

Table 1.1: Road safety ranking status among ASEAN country year 2013 (Global Status Report on Road Safety, 2015)

ANALYSIS AND COMPARISON					
Status Ranking Road Safety for ASEAN Country Year 2013					
Country	Approximate Death	Approximate Index WHO/ 100,000 Population	Approximate Index/ 10,000 Registered Vehicle	Ranking Index/ 100,000 Population	Ranking Index / 10,000 Registered Vehicle
Cambodia	1,950	17.4	7.93	5	8
Indonesia	26,416	15.3	2.53	4	4
Laos	910	14.3	6.32	3	7
Malaysia	6,915	24.0	2.90	7	5
Myanmar	3,612	20.3	8.38	6	9
Philippine	1,513	10.5	1.97	2	2
Singapore	159	3.6	1.63	1	1
Thailand	14,059	36.2	4.33	9	6
Vietnam	9,156	24.5	2.24	8	3

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Table 1.2: Road and index accident development for 9-year 2011-Jun 2019. (Road Safety Department of Malaysia, 2019)

ROAD AND INDEX ACCIDENT DEVELOPMENT FOR 9-YEAR (2011 - Jun 2019)			
Years	**Death**	**Major injuries**	**Minor injuries**
2011	6877	6328	12365
2012	6917	5868	11654
2013	6915	4597	8388
2014	6674	4432	8598
2015	6706	4120	7432
2016	7152	4506	7415
2017	6740	3310	6539
2018	6284	4895	3446
Jan-Jun 2019	3071	1591	2881

In the automotive industry, improvements in this technology have benefited drivers in terms of safety and saved many lives as a result of technical problems on a vehicle's system. The technology of driver assistance already improves safety. In vehicle handling it explains how the wheeled vehicle responds and reacts to a driver's inputs, it is generally evaluated how the vehicle performs especially when it is cornering, accelerated, and braking. Recently there are many technologies that can increase the safety of the vehicle. One of the improvements is applying the active front steering. Active Front Steering (AFS) systems are used to upsurge lateral and yaw stability of front steering systems. The steering control can also be used to dismiss outer destabilization forces from Mu-split, asymmetrical braking or wind. Falcone *et al.* (2008).

Furthermore, in lane keeping technology there is four-wheel steering (4WS). Much attention was recently given to the design of four-wheel steering systems (4WS) for

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passenger cars, to improve their handling characteristics. Active four-wheel steering (4WS) device improves the potential of vehicle cornering by adjusting the vehicle state of the front and rear wheels. This means that the lateral stability and handling quality can be improved in a range in which the dynamics of vehicles can be represented by linear models. Nevertheless, as tires reach the limits of adhesion and exhibit nonlinear characteristics on the side force, four-wheel steering systems become less available (Gooch, 2011).

Besides that, Raksincharoensak *et al.,* (2006) found, lane keeping by Direct Yaw-Moment Control (DYC) system is the other technology used in automotive. By controlling the slip side motion, this method will improve the handling and constancy of the car. However, Direct Yaw-Moment Control (DYC) have being practically used to directly control yaw motion by using tire-longitudinal forces, so that it is better to control the yaw rate than the lateral speed.

1.2 Background

The steering control problem has drawn broad attention in recent years. The lane keeping control system serves the driver's side control role of holding the vehicle along the correct lane and is also known as the automatic steering system. With these features, it can potentially decrease workload and tiredness on a long journey such as while driving on the highway. As follows, the fundamental design requirement of the lane control system is the automated control must carry out the lane maintenance task without maneuvering the driver. The steering actuator also smoothly provides the appropriate torque for lane keeping tasks. If necessary, the driver can easily override the steering system. Nagai *et al.* (2003) and Vadeby *et al.,* (2011) found that there are many sensors mounted on modern vehicles in this modern world to avoid a collision like electronic stability control (ESC) system. The major intention of an (ESC) system is to support the driver maintain the balance of the course to

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avoid over or under the vehicle's steering. When stability is lost, the (ESC) system slows individual wheels, and many systems also minimize engine power and disengage cruise control.

Furthermore, the adaptive cruise control (ACC) is a longitudinal vehicle control system available for commercial use. The ACC system monitors the velocity of the car and be able to be interpreted as a double-mode hybrid system, the throttle control method, measures the throttle speed, and the brake control approach, where the brake pressure is defined (Dai & Koutsoukos, 2020). Besides that, one of the advanced vehicle functions that assist the driver's lane-keeping and offers the LDW (Lane Departure Warning) for comfortable driving circumstances is the Lane Keeping Assistance System (LKAS). By adjusting the angle of the steering wheel of the vehicle or by producing the torque on the steering wheel these systems can keep the lane. But various LKAS controllers examined the subjective view of the driver, showing that the superior performance does not certainly meet the receptivity of the driver. The unnecessary control input may affect an overload of the lateral position of the vehicle in the operation of the LKAS system. Hwang *et al.* (2008). In other to enhance the vehicle performance the, implementation of Antilock Braking System (ABS) and a Traction Control System (TCS) will assist the vehicle traction control when acceleration. Based on Burg *et al.,* (1998), the purpose of this regulation is to improve tire grip, while maintaining enough vehicle stabilization and balance by avoiding the locking of wheels during breaking or rolling during speeding up.

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