ADAPTIVE CRUISE CONTROL BASED ON THROTTLE AND BRAKE BY WIRE

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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memenuhi sebahagian daripada syarat pengaugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal

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2020

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Date : Jun 2020

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APPROVAL

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

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PENGAKUAN

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DEDICATION

To my beloved mother and father

ABSTRACT

This project discusses the construction and development of Adaptive cruise control systems (ACC) used in vehicles. ACC is one of the critical safety systems used in the automotive field. It is developed to improve vehicle safety while driving for a long time. This system is also able to relieve the driver of driving the vehicle semi-automatically based on the set velocity and minimum distance from the vehicle ahead. The system uses a radar sensor placed on the front bumper to detect the vehicle's distance in front. The vehicle's speed can be controlled by using the PID controller based on the velocity required by the driver. Reactions result from signal construction in ACC systems as vehicle velocity are analyzed and simulated using MATLAB-Simulink software. The data obtained are then analyzed to improve the ACC system to achieve the requirements.

ABSTRAK

Projek ini membincangakan tentang pembinaan dan pembangunan sistem Kawalan Adaptif Kelajuan Kenderaan (Adaptive cruise control) yang digunakan pada kenderaan. Sistem Kawalan Adaptif Kelajuan Kenderaan (Adaptive cruise control) adalah salah satu sistem keselamatan kritikal yang digunakan dalam bidang automotif. Ia dibangunkan untuk meningkatkan keselamatan kenderaan ketika memandu pada jangka masa yang lama. Sistem ini juga mampu menggantikan pemadu untuk memandu kenderaan secara semi-automatik berdasarkan kelajuan yang ditetapkan dan jarak minimum daripada kenderaan di hadapan. Sistem ini menggunakan sensor radar yang diletakkan pada bumper hadapan untuk mengesan jarak kenderaan yang berada di hadapan. Kelajuan kenderaan dapat dikawal dengan menggunakan pengawal PID berdasarkan kelajuan yang dikehendaki oleh pemandu. Tindak balas yang terhasil daripada penggunaan pembinaan signal dalam sistem ACC sebagai halaju kenderaan dianalisis dan disimulasikan dengan menggunakan perisian MATLAB-simulink. Data yang diperoleh seterusnya dianalisis untuk menambah baik sistem ACC sehingga mencapai kehendak yang ditetapkan.

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LIST OF SYMBOLS

F	Force
m	Mass
a	Acceleration
J_{ij}	Moment of inertia
F_{tr}	Traction force
μ_f	Friction coefficient
B	Distance from front axle to center of gravity
C	Distance from rear axle to center of gravity
H	Distance from center of gravity to the ground
L	Length from front axle to rear axle
θ	Angle
$\frac{dV}{dt}$	Speed of vehicle respect to time
$F_{z_{ij}}$	Vertical force
V	Speed of axle
τ_{rij}	Reaction torque
τ_{bij}	Braking torque
τ_{aij}	Throttling torque
τ_{dij}	Viscous friction torque
ω_{ij}	Angular velocity
ρ	Density
$F_{z_{ri}}$	Vertical force for rear tyre
F_a	Aerodynamic resistance force
F_d	Drag force
F_r	Resistance force

C_d	Drag coefficient
v	Velocity
A	Frontal area
$C_r(v)$	Coefficient of rolling resistance
g	Center of gravity
λ_{ij}	Longitudinal slip
R	Radius of wheel
P_{bij}	Brake pressure
D_{safe}	Safe distance
u_{bij}	Brake setting
K_{bij}	Simple pressure gain
τbs	Brake lag
$D_{default}$	Default distance
T_{gap}	Time gap
v_{ACC}	Velocity of ACC vehicle
v	Velocity error
v_{set}	Set velocity
$v_{longitudinal}$	Longitudinal velocity
$D_{relative}$	Relative distance
D_{lead}	Distance of lead vehicle
D_{ACC}	Distance of ACC vehicle
v_{ECU}	Velocity from ECU
v_{actual}	Actual velocity
v_{des}	Desire velocity
K_P	Proportional gain
K_i	Integral gain
K_d	Derivative gain
$u(t)$	Controller signal
U_1	Condition 1
U_2	Condition 2
V	Voltage

LIST OF ABBREVIATION

CC	Cruise control
ACC	Adaptive cruise control
ECU	Electric control unit
HMI	Human machine interface
ADAS	Advance driver assistance system
DC	Direct current
ABS	Antilock braking system
DOF	Degree of freedom

CHAPTER 1

INTRODUCTION

1.1 Research Background

Car technology today is becoming more sophisticated with the Advanced Driver Assistance System (ADAS) to provide better driving and reduce the risk of collisions. ADAS is responsible for improving vehicle safety and driver comfort. One of the technological solutions in the ADAS system is Adaptive Cruise Control (ACC) (Shakouri, Payman, et al.;, 2012). Pauwelussen and Minderhoud noted that the ACC could be defined as an extension of the Cruise Control (CC) and maintains, next to a specific set speed, a specific set distance concerning the lead vehicle. It is also known as the improvement of the cruise control system which the ACC velocity was followed by the velocity of the vehicle ahead at a safe distance and safe time by some adjustment to the throttle valve and braking system. Figure 1.1 shows the simulation of the advanced technology proposes by BY-SA, 2018.

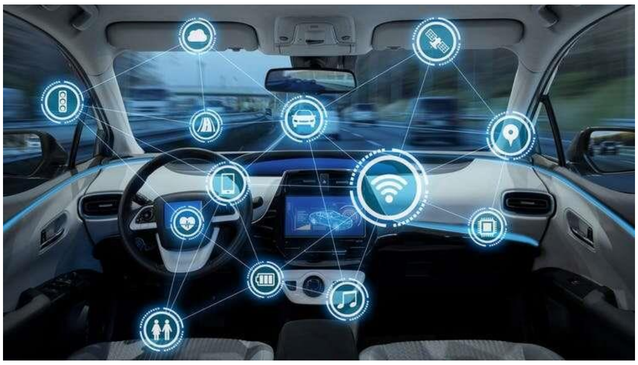

Figure 1.1: Simulation of the advanced technology (BY-SA, 2018)

The conventional CC system can only control the engine's operation to speed up the vehicle manually by using the fuel pedal. (Xue-wen Chen; 2016). The driver needs to give a high percentage of concentration when driving for a long distance and must be able to react to the changing situation. The target of the development ACC system is to avoid end-to-end collision by following the front vehicle at a safe distance (Pananurak W. *et al.*; 2008). For example, when driving on the highway using a vehicle installed with an ACC system, the driver does not have to press the fuel paddle at all the time. Instead, the driver can set the desired velocity and release the fuel paddle. ACC system assists the driver in the task of longitudinal monitoring (Jing-Liang L; 2009) of their vehicle while in driving mode.

The ACC uses two input from the driver, which is desire velocity and the desire distance. The system maintains and calculates the safe distance fix by the driver and automatically adjusts the velocity of the ACC vehicle depend on the vehicle ahead. Based on the calculation of speed and distance, the safe position of the vehicle can be performed by controlling the brake and throttle valve of the vehicle (Worrawut Pananurak *et al.*; 2015). The ACC vehicle normally works as the CC vehicle if no vehicle in front is closer than the desire distance. When the vehicle ahead closer to the minimum desired distance, the ACC vehicle will adjust the velocity to follow the car ahead. The ACC vehicle is suitable to increase or decrease the velocity to achieve the set distance. This process helps the ACC vehicle to reduce the speed or speeding up the traffic smartly without driver interaction (Worrawut Pananurak *et al*; 2015). The ACC system also has some limitations in accelerating and decelerating due to the comfort reason by law. To overcome this limitation, the driver needs to intervene to reach the required needs. Figure 1.2 shows the simulation for safe distance and safe time.

Figure 1.2: Simulation for safe distance and save time (GMC, 2020)

The ACC is a safety system that responds to provide better safety during the vehicle following task, which potentially enhancing driving, but the driver still needs to control the steering perfectly to avoid an accident (Shakouri, Payman, *et al*; 2012). It is generally used on the highway to speed with a constant velocity for a long period as driver assistance.

However, unlike conventional cruise control, ACC can manipulate the velocity automatically to ensure an appropriate distance between the object and the vehicle fitted with the ACC system. A laser or radar is used to determine the relative distance between the ACC vehicle and the vehicle ahead. ACC also decreases the driving tension by acting as a pilot for longitudinal supervision (Dang R., *et al*; 2015).

ACC operates on the concept of using a specific sensor to measure the distance and direction of the vehicle ahead. A lidar sensor or a radar sensor can be used to perform this function. (Worrawut Pananurak *et al*; 2015). This technology can effectively identify the cutting of the front vehicle in the cruise lane or vehicle switch to the other lane and consider the constant command of the vehicle at low velocities to avoid accelerate or decelerate all the time (Rohan Kumar; 2012). If no vehicle is in front of the ACC vehicle, the system tends to maintain the velocity of the ACC vehicle based on the set cruise control velocity. The ACC vehicle will accelerate by opening the throttle valve when the system detects no vehicle ahead until predefined set velocity by the driver (Mohd Razali Sapiee *et. al*; 2009). If the vehicle's velocity ahead is slower than the ACC vehicle or the vehicle ahead cuts into the path of the ACC vehicle, the car will decelerate by controlling the throttle and brake to keep up the inter-vehicle gap which the driver sets and follow the velocity of the vehicle ahead.

There are two types of controller used to build up the ACC system, which are the PID controller and state flow. PID controller can be classified as the closed-loop controller design to control the throttle, while state flow addresses design challenges when constructing and deploying embedded software.

MATLAB is a high-level programming language developed by MathWorks. It allows providing the technical problem solution faster than other programming languages such as C++ or Fortran. The toolbox and function available in MATLAB/ Simulink make it easy to design the system. MATLAB is the main software used to compute and simulate the model for the ACC system. The tool Simulink is used to design the ACC system with a few toolboxes provided. The first simulation design is the CC vehicle which is noted as the lead car with its velocity and distance. Next, the second simulation design is the ACC vehicle representing signal input and controller to control the distance and speed of the ACC vehicle by calculating the relative distance and relative velocity from both vehicles. A few test cases were built to make sure the designed controller meet the requirement. The result of the analysis was present in the graph by using the tool scope.

1.2 Problem Statement

Through some research on the car nowadays, most of the Adaptive Cruise Control (ACC) system was used on the luxury ear such as Audi, Mercedes, BMW, etc to provide great life safer on the road. Without the ACC system, the driver needs to pay 100% attention to the road and needs to react to many things (P. Sowjanya; 2016). It also increases tiredness