MODELING AND ANALYSIS OF ROAD VEHICLE FOLLOWING SYSTEM

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To my beloved wife, children and parents

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ABSTRACT

This thesis includes the research on the control strategies of a convoy vehicle on the road highway. The control strategy used for this research is the Vehicle Following control strategy. This research covers only on the longitudinal vehicle convoy and is assuming that the vehicle dynamic is ideally perfect. Starting with the literature review on the Automation of Highway at present, the research continues with the building up of mathematical model and designing the Simulink model of the system, using Matlab / Simulink. This is followed by using the Optimization method in order to find the right value of gains. The result shows that with the use of correct method, the value of gains can be achieved easily and will result in good stability in the vehicle convoy and the individual vehicle. Stability is important as the vehicles need to move with a safety distance and comfort for different input velocity. Stability will guarantee the safety of the drivers.

ABSTRAK

Tesis ini merangkumi kajian terhadap satu strategi kawalan keatas kenderaan berkonvoi diatas jalanraya. Satu strategi kawalan yang digunapakai dalam menjalankan kajian ini ialah strategi kawalan merujuk maklumat satu kenderaan di hadapan. Kajian ini hanya di jalankan pada arah longnitud sahaja dan anggapan terhadap dinamik kenderaan adalah sempurna. Ianya bermula dengan kajian litertur keatas pengatomasian yang wujud dimasakini. Seterusnya pembentukan permodelan matematik dilaksanakan. Dari permodelan matematik, model Simulink dibentuk menggunakan Matlab / Simulink, diikuti dengan penggunaan dan penentuan pemalar-pemalar untuk menghasilkan satu strategi rangkaian yang stabil. Rentetan daripada itu, kaedah '*Optimization*' digunakan untuk mencari gandaan baru. Keputusan yang diperolehi menunjukkan bahawa dengan menggunakan kaedah yang betul, nilai gandaan dapat diperolehi dengan mudah. Kestabilan diperlukan kerana kenderaan berkonvoi perlu bergerak dalam keadaan jarak yang selesa apabila halaju yang berbeza dikenakan keatas kenderaan. Ia merangkumi kestabilan rangkaian dan individu, justeru menjamin keselamatan penggunanya.

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h	-	Time Separation (Headways)
K_{p1}	-	Constant
K_{p2}	-	Constant
K_{v1}	-	Constant
L	-	Length of the vehicle

LIST OF SYMBOLS

L	-	Length of vehicle
u_i	-	Control Signal
$\dot{v}_i$	-	Acceleration
x_{i-1}	-	Preceding vehicle
x_i	-	Following vehicle
s_i	-	Inter-vehicular separation

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CHAPTER 1

INTRODUCTION

1.1 Issues regarding Road Congestion

In this modern day, using a vehicle as a means of transportation is a must in order to move from one place to another. Besides having the vehicle to transport people, it also used to transport goods as well. In other words, a vehicle either it is a car, a bus or a truck is a common need that can be found on road or highway.

Besides its contribution for the economic growth, the increasing of these vehicles on the road also leads to traffic congestion and it worsen from time to time. Due to this problem, vehicles are travelling at a slower travelling speed which will lead to hours of delay and losses of productivity. For example, the average traffic flow in Kuala Lumpur itself is 28 km/h (Mohamad, and Kiggundu, 2007).

When these vehicles trapped in road congestion, not just the loss of productivity occur, but it also contribute to the environment pollution because of large amount of exhaust fumes are emitted to the air. This will also waste large amounts of fossil fuel.

Constructing larger roads, introducing new expressway and adding lane are not viable options by the authorities anymore. This is due to high expenses, environment and social cost.

With the advancement of technology, there are many ways to solve the problem. One of the techniques is by constructing an automated highway that has a designated lane where vehicles equipped with wireless communication and specialized sensors could travel in small convoys or closely spaced intervals.

1.2 Research Background

For decades, researchers have spent a great deal of efforts and times on the automated highway technology. These studies mainly concentrated on the aims to relieve the highway congestion.

Among the studies, platooning or convoys of vehicles in which vehicles travel at certain speeds in tightly spaced inter-vehicular spacing and fully automated seems to be more visible. In a convoy operation, vehicles are normally led by a leader (preceding vehicle), with certain direction, speed and acceleration. And this leader will be followed by a string of vehicles that will follow whatever the preceding vehicle is performing. For these convoys to operate satisfactorily, a string (or platoon) stability has to be investigated as the control strategy (Cook, 2007).

In the convoy operation, all vehicles will have their own controller which must have the capability to interact with each other. The information that these controllers will share is the position, speed and acceleration. This information and the dynamics of the vehicles will be used as the control strategy (Cook and Sudin, 2004).

1.3 Vehicles Convoy

When there are two or more vehicles been put together on the same lane, where all the vehicles follow one another and are being led by a leader, it is called a vehicles convoy. This scenario leads to a string of vehicles and also called a platoon.

When the vehicles are moving in convoys, the most important aspect to be considered is that each vehicle must be able to avoid collision between them. Hence, the study of convoy stability or also known as string stability must be done.

In order to ensure spacing errors do not grow between vehicles as they propagate along the convoy, string stability is used as a property (Cook, 2007). This situation can be simulated or described through a sudden brake application. When a sudden brake happens, it will cause sudden spacing errors between two affected vehicles. Without the string stability property being applied, the spacing errors will become bigger towards the end of the convoy. On the other hand, with the string stability property being applied to the convoy, these spacing errors can be reduced.

One of the control strategy used is the vehicle following control strategy or also known as the vehicle following system. A simple spring-mass-damper can be used to demonstrate the idea of the control strategy (Yanakeiv and Kanellakopoulos, 1996).

1.4 Research Objective

In this research, we only consider the dynamic physical parameter of the vehicles without having any other kind of communication between the vehicles.

The objectives of this thesis are

a) To investigate the control strategy and model using Simulink for vehicle following system.

b) To monitor, analyze and optimize the performances of control strategy for vehicle following system.

1.5 Research Scope

This research can be divided into several parts. For the first part, the control strategy is being modeled. The modeling is done in order to produce the dynamic parameter for each vehicle involve in the convoys. The data would include the position, speed and acceleration of the vehicles.

For the second part, the results obtained by using Matlab / Simulink will be observed and analyze regarding their performances. The analysis is mainly to monitor the string stability of the convoy.

Finally, an optimization toolbox will be used to find the most suitable gains. Before deciding the gains, the result from the optimization technique will be analyzed and compare with the initial value that been used in Cook and Sudin (2002).

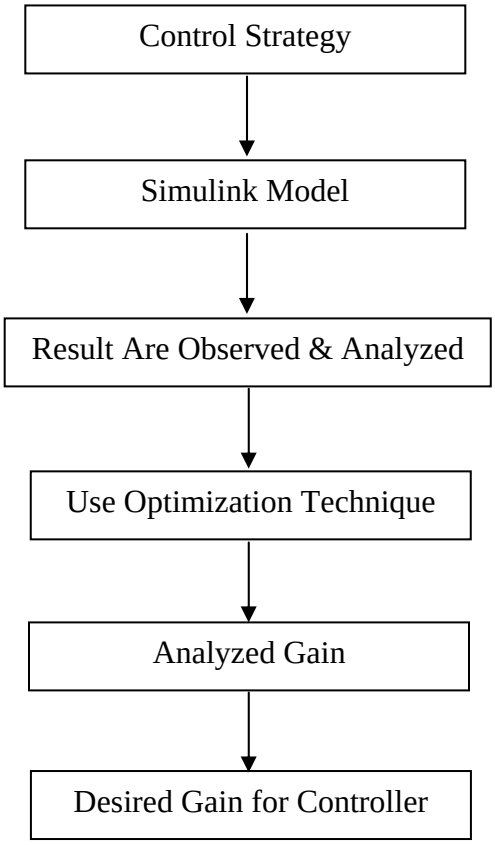

Figure 1.1: Research Scope

1.6 Methodology

The approach on how to manage this research can be categories into four. At first, in the literature review the control strategy model will be review, discuss and identified. By doing this, the concepts of vehicle following system will be understood. From the understanding of the concepts, it will be used as a tool and guidance to derive

the algorithm related to the theoretical part. This part will be modeling of the controllers.

On the second category, Matlab / Simulink is used to collect the vehicles data from the controller. The collected data are the speed, acceleration and position of the vehicles.

On the next level that is the third category, the performance analysis is being done. Here, the leader and the following vehicles are compared and analysed in terms of its speed, acceleration and position.

Finally, after all the requirements are understood, the optimization technique is used. Data from the optimization result is again analyzed. The best gains that fulfill all the constraints are chosen for the control system.

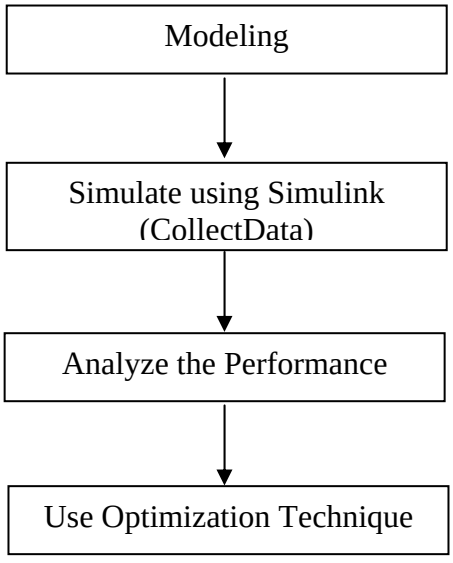

Figure 1.2: Research Methodology

1.7 Thesis Layout

The remaining chapters are organized as follows:

Chapter 2 presents the literature review from previous studies related to this research project. Vehicle following control strategy used by researchers in past years are discussed.

Chapter 3 presents the developments of the mathematical and modeling of the vehicle following system are also shown in this chapter. Some simulations on the vehicle model performance are also carried out. The optimization technique used in order to get the gain value for the controller is also shown in this chapter.

Chapter 4 presents the simulation result based on the initial gain, $K_{p1} = K_{v1} = 0.333$. This result is analyzed and studied. A performance comparison is carried out between the initial values used with the value obtained by using the optimization method.

Chapter 5 presents the discussion on the simulation results.

Finally, Chapter 6 concludes the findings of this research and recommends further work relating to this research project.

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