COMPARISON OF MPC CONTROLLER PARAMETER FOR AUTONOMOUS LANE CHANGE

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DECLARATION

I declare that this project entitled **"Comparison Of Mpc Controller Parameter For Autonomous Lane Change"** is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Nur Amin Bin Hj Kanan

Date : 18 Jan 2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive technology) with Honours.

Signature :

Supervisor Name : Ts. Khairul Amri Bin Tofrowaih

Date : 28 January 2022

DEDICATION

I first dedicated this work to Allah S.w.t knowing that without his kindness and sympathy, i would not be able to complete it. I am also grateful to my supervisor, Ts Khairul Amri Bin Tofrowaih, for providing me with the opportunity, experience, and knowledge to complete this meaningful reasearch. My heartfelt gratitude goes to my beleved housemates Abdul Hayee Bin Malik and Fridaus Bin Daud, who have served as my inspiration, abligation, and sources of strength as i pursue further studies in the automotive field and complete this project. My heartfeld appreciation also goes to my family and friends and coworkers for their continuous support, spiritual and moral support.

ABSTRACT

The system that is related to the autonomous vehicle steering system is a Multi-Input Multi-Output (MIMO) system. Due to the interplay between the inputs and outputs, it is not easy to construct a controller for this system using a conventional controller. Next, designing the best controller requires a larger parameter tuning on a controller to ensure the system fully functions. As a result, implementing an MPC controller will solve this problem, This project aim is to investigate and compares the effect of varying MPC parameters (prediction horizon, control horizon and sample time) on the vehicle model's lateral position and yaw angle by tuning the MPC controller toolbox in MATLAB with the default response of yaw angle and lateral position compared with tuned response. An MPC controller linear model for an Autonomous Vehicle Steering System is generally used to direct an autonomous vehicle's steering system to realize the main objective. As a result of this project's analysis, we discovered that changing the parameters on the prediction horizon that produce a high rate of change for the first 2.5 seconds, which is 1.05 persent for Lateral Position and for Yaw Angle 0.02 persent for sample time at the final value of the graph is the best way to achieve the most optimised tuning, and the result can find one of the best parameters to refine the most optimised controller and which is the closest value to the value of the output reference.

ABSTRAK

Sistem yang berkaitan dengan sistem stereng kenderaan autonomi ialah sistem Multi-Input Multi-Output (MIMO). Oleh kerana interaksi antara input dan output, tidak mudah untuk membina pengawal untuk sistem ini menggunakan pengawal konvensional. Seterusnya, mereka bentuk pengawal terbaik memerlukan penalaan parameter yang lebih besar pada pengawal untuk memastikan sistem berfungsi sepenuhnya. Hasilnya, melaksanakan pengawal MPC akan menyelesaikan masalah ini, Projek ini bertujuan untuk menyiasat dan membandingkan kesan pelbagai parameter MPC (ufuk ramalan, ufuk kawalan dan masa sampel) ke atas kedudukan sisi dan sudut yaw model kenderaan dengan menala MPC kotak alat pengawal dalam MATLAB dengan tindak balas lalai sudut yaw dan kedudukan sisi berbanding dengan tindak balas yang ditala. Model linear pengawal MPC untuk Sistem Stereng Kenderaan Autonomi biasanya digunakan untuk mengarahkan sistem stereng kenderaan autonomi untuk merealisasikan objektif utama. Hasil daripada analisis projek ini, kami menemukan bahawa mengubah parameter pada jangka ramalan yang menghasilkan kadar perubahan yang tinggi untuk 2.5 saat pertama, iaitu 1.05 persen untuk Posisi Lateral dan sudut Yaw 0.02 persen untuk masa sampel pada nilai akhir graf adalah cara terbaik untuk mencapai penyesuaian yang paling optimis, - dan hasilnya boleh mencari salah satu parameter terbaik untuk menaikkan semula pengawal yang paling optimis dan yang merupakan nilai terdekat kepada nilai rujukan output.

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LIST OF SYMBOLS AND ABBREVIATIONS

ESC	-	Electronic Stability Control
FCT	-	Fuzzy Control Theory
IMC	-	Internal Model Control
MIMO	-	Multi-Input Multi-Output
MPC	-	Model Predictive Control
NCAP	-	New Car Assessment Program
PID	-	Proportional Integral Derivative
QP	-	Quadratic problem
SEA	-	Southeast Asia
TCS	-	Traction Control System
WHO	-	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Background Study

The steering system is made up of elements that permit the driver to change the vehicle front wheels direction and in certain cases, steer through the rear wheels. The steering systems principal purpose has remained essentially stable since the automobile's original conception. Next, the primary system objective is to enable the driver to maneuver the vehicle safely and accurately. Furthermore, the system mechanism also reduces driver effort by steering the vehicle smoother. Additionally, the steering system components absorb some of the road shocks until it hits the driver. Since the advent of cars, nothing has changed how the steering mechanism and many of its components operate. The primary distinctions are improved operational simplicity and efficiency and longer-lasting components that need less maintenance. According to (Steering System Principle, Chapter 8, 2013); A recent change in power steering is replacing the belt-driven hydraulic pump with electric motor assist. At the moment, three types of electric assist are available: electrically powered hydraulic steering, column drive, electric steering, and rack and pinion steering gear assisted by an electric motor. Each of these systems can provide variable amounts of assist based on driving conditions and driver preference. The completely electric types do not use any fluid, so they are more environmentally friendly since no fluid loss can occur.

According to the New Car Assessment Program (NCAP), an effective vehicle safety system is vital for every vehicle to have a better and safer ride, especially on rough terrain. Control intervention limits on the vehicle should be amended depending on driving data and environmental factors to maintain vehicle stability in a critical emergency while not bothering drivers in typical situations (Lutz et al., 2017). For example, a vehicle Traction Control System (TCS) is an auxiliary function of the Electronic Stability Control (ESC) of a vehicle designed to enhance the driving wheels' traction capability and direction stability via tire slip ratio management slippery roads. An active control system is required to enhance vehicle safety that assists the driver in regaining control of their vehicle during challenging situations.

We focus on designing an MPC controller for an autonomous vehicle steering system using MPC Toolbox. According to Pan et al., there are including Proportional Integral Derivative (PID) control, Fuzzy Control Theory (FCT), Model Predictive Control (MPC), and the most recent one, Internal Model Control (IMC) (Pan et al., 2016). Although PID control technology is advanced for motor speed control, it is challenging to maintain its optimal performance as designed in practice due to non-linear factors such as motor load. It is inconvenient to debug while the index runs because the index parameters require a tightly controlled external environment. It is inconvenient to debug while the index runs because the index parameters require a tightly controlled external environment. Model prediction, rolling optimization, and feedback modification are three crucial components of the MPC control algorithm. It can be used by MPC control to control online rolling optimization in advance. It has a good control effect and is appropriate for control systems that are difficult to build accurate digital models for and more complex systems. As the selected project title is more focused on the control system, we decided to use the MPC as the primary controller throughout the project.

MPC employs a system model to predict how a machine will develop in the future. It can solve an optimization algorithm online to find the best control behavior that drives the desired output to the reference. It can organize multi-input multi-output (MIMO) systems to communicate their inputs and outputs and accommodate input and output constraints. MPC has preview capabilities because it can incorporate future reference data into the control issue to enhance the controller efficiency. (Understanding Model Predictive Control, n.d.).

According to Rawlings, the purpose of MPC is to optimize process behaviors predictions over manipulated input data, with the prediction carried out using a process model, and the model then becoming the crucial components of an MPC controller. According to the research, MPC can use two types of models: Non-Linear models and Linear model. Non-Linear models for MPC are encouraged by the potential to improve control by improving forecasting efficiency,(Rawlings, 2000).

1.2 Problem Statement

According to the World Health Organization (WHO) 2018 global status report on road safety, Southeast Asia (SEA) has the second-highest regional rate of road deaths, which is higher than the global rate, at 20.7 deaths per 100,000, populations (global rate: 18.2 deaths per 100,000 populations) (WHO, 2018). The number of road fatalities in the area has also risen compared to the previous year (19.8 per 100,000 population). According to SEA, most fatal road accidents (43%) involve operators of two-and three-wheelers, while 16% involve drivers/passengers of four-wheeled vehicles (WHO, 2018). Though motorcyclists (61.7 per cent) and car driver/passenger were responsible for many road fatalities in Malaysia in 2018 (20.1 per cent). Human error (80.6 per cent), road conditions (13.2 per cent), and vehicle conditions (6.2 per cent) are the leading causes of road accidents (JKJR, 2018). Figure 1.1 shows the General Accident statistics in Malaysia Data by MIROS.

GENERAL ROAD ACCIDENT STATISTICS IN MALAYSIA (1997 – 2017)

Year	Registered Vehicles	Population	Road Crashes	Road Deaths	Serious Injury	Slight Injury	Index Per 10,000 Vehicles	Index Per 100,000 Population	Indeks Per Billion VKT
1997	8,550,469	21,655,600	215,632	6,302	14,105	36,167	7.37	29.10	33.57
1998	9,141,357	22,179,500	211,037	5,740	12,068	37,896	6.28	25.80	28.75
1999	9,929,951	22,711,900	223,166	5,794	10,366	36,777	5.83	25.50	26.79
2000	10,598,804	23,263,600	250,429	6,035	9,790	34,375	5.69	26.00	26.25
2001	11,302,545	23,795,300	265,175	5,849	8,680	35,944	5.17	25.10	23.93
2002	12,068,144	24,526,500	279,711	5,891	8,425	35,236	4.90	25.30	22.71
2003	12,819,248	25,048,300	298,653	6,286	9,040	37,415	4.90	25.10	22.77
2004	13,828,889	25,580,000	326,815	6,228	9,218	38,645	4.52	24.30	21.10
2005	15,026,660	26,130,000	328,264	6,200	9,395	31,417	4.18	23.70	19.58
2006	15,790,732	26,640,000	341,252	6,287	9,253	19,885	3.98	23.60	18.69
2007	16,813,943	27,170,000	363,319	6,282	9,273	18,444	3.74	23.10	17.60
2008	17,971,907	27,730,000	373,071	6,527	8,868	16,879	3.63	23.50	17.65
2009	19,016,782	28,310,000	397,330	6,745	8,849	15,823	3.55	23.80	17.27
2010	20,188,565	28,910,000	414,421	6,872	7,781	13,616	3.40	23.80	16.21
2011	21,401,269	29,000,000	449,040	6,877	6,328	12,365	3.21	23.70	14.68
2012	22,702,221	29,300,000	462,423	6,917	5,868	11,654	3.05	23.60	13.35
2013	23,819,256	29,947,600	477,204	6,915	4,597	8,388	2.90	23.10	12.19
2014	25,101,192	30,300,000	476,196	6,674	4,432	8,598	2.66	22.00	10.64
2015	26,301,952	31,190,000	489,606	6,706	4,120	7,432	2.55	21.50	9.60
2016	27,613,120	31,660,000 e	521,466 a	7,152	4,506	7,415	2.59	22.60	10.70 a
2017	28,738,194	32,049,700 e	533,875	6,740	3.310	6,539	2.34	21.06	TBP

e = Estimated value from Department of Statistics Malaysia
a = Media Statement
NA = Not Available (The official figures are not available yet)
TBP = To Be Published

Data by Miros

Figure 1.1 General Accident Statistics in Malaysia Data By MIROS

Back to the subject of the study, various factors contribute to the occurrence of collision accidents. Among them is that drivers have trouble miss-assessing the risks likely to occur while on the road. It is essential because if a driver does not correctly assess the risk while on the road, the driver's risk of being exposed to a collision accident is very high. And this is closely related to the driver's response to any threat of violation while on the road. Therefore, when the driver takes the first step by assessing the risks correctly, it can indirectly help the driver respond correctly to the driver's threats.

Another factor contributing to crash accidents is the drowsiness and fatigue that drivers encounter while on the road. Such accidents occur when a driver is sleep-deprived and does not get enough rest before driving, especially on long journeys. And if this occurs to one driver, it puts another driver at risk of a collision. Also, stated the same thing is Soares et al., Drowsiness and fatigue are major causes of car accidents, resulting in many injuries, deaths, and societal costs,(Soares et al., 2020).

All of the accident mentioned the issues could largely eliminate earlier risks by using autonomous vehicle steering systems. The system that is related to the autonomous vehicle steering system is a Multi-Input Multi-Output (MIMO) system. Due to the interplay between the inputs and outputs, it is not easy to construct a controller for this system using a conventional controller. The PID controller is a type of classical controller. After PID controllers are utilized, the control loops operate independently since there is no feedback between them.

Next, designing the best controller requires a larger parameter tuning on a controller to ensure the system fully functions. As a result, implementing an MPC controller will solve this problem, as it is a multivariable control system that considers the cause and effect in this system. Furthermore, various constraints must be managed in order to achieve a high level of safety for an autonomous assisting system, such as maintaining the lateral position and yaw angle of a moving vehicle.

1.3 Research Objective

a) To investigate the effect of varying MPC parameter (sample time, prediction horizon, control horizon).

b) To compare the tuned response by tuning the MPC controller toolbox in MATLAB with the reference response of lateral position and yaw angle.

1.4 Scope of Research

This project's scope only focuses on investigating the effect of varying MPC parameter (prediction horizon, control horizon and sample time) on the vehicle model's lateral position and yaw angle. An autonomous steering system controller model for linear system (constant longitudinal velocity) using MPC toolbox from MATLAB Simulink will be used. Also, we only study three MPC parameters for this project: prediction horizon, control horizon, and sample time.

1.5 Report organization

This process report consists of the following chapters, with the first introducing the project. The research literature review is presented in chapter two of the report. The methodology used in this research is presented in chapter three, and the preliminary results and some discussions are presented in chapter four. The final chapter of this report is chapter five, in which we discuss our findings and draw conclusions about this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section presents a literature review regarding the Optimization of Steering System for Autonomous Vehicle using Model Predictive Control. The main objective of this review is to explore the fundamental of Model Predictive Control that will be used for investigating the effect of changing the parameter prediction horizon, control horizon, and step time as well as constraints and compare the vehicle model yaw angle and lateral position by tuning the MPC controller toolbox in MATLAB to obtain the best closed-loop performance and state estimation.

2.2 Autonomous System

Autonomous vehicles, also known as driverless or self-driving vehicles, can only be operated or controlled by humans. In recent years, advancements in automated vehicle designs have evolved, although some human input is still required depending on the extent of automation. (Raza, 2018).

The autonomous vehicle is an innovative technology that provides a safe and efficient mode of transportation. It has a wide range of applications as part of the intelligent transportation system (Katrakazas et al., 2015), (Kong et al., 2017). The term “autonomous vehicle” refers to a type of vehicle that can perform sensing and decision-making, as well as track planning and tracking. Due to the advancement of sensing technology and vehicle state estimation algorithms, vehicle state information, such as tire force conditions, sideslip angle,