UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

INTEGRATION OF VISION BASED ROAD LANE DETECTION FOR AUTOMATIC STEERING CONTROL (ASC) APPLICATION

Abdurahman Dwijotomo

Master of Science in Mechanical Engineering

2015

INTEGRATION OF VISION BASED ROAD LANE DETECTION FOR AUTOMATIC STEERING CONTROL (ASC) APPLICATION

ABDURAHMAN DWIJOTOMO

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

DECLARATION

I declare that this thesis entitled “Integration of vision based road lane detection for Automatic Steering Control (ASC) application” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature :…….....

Supervisor Name :…….....

Date :…….....

DEDICATION

To my beloved mother, father, sisters and the whole family

ABSTRACT

Technology over vision based road lane detection for vehicle navigation have been developed in recent years due to increasing interest in the Inteligent Transportation System (ITS). However, most of the vision systems are still in development stage and continous researchs are required to improve the accuracy of the system. This study sought the possibilities of developing Automatic Steering Control (ASC) when the vision system is integrated into the vehicle control. The ASC development provide solution to solve communication interface between vision system and vehicle steering seamlessly.The outcome in this study is the demonstration of ASC system which is capable of assisting the navigation of the vehicle and follow the road with less human interruption. To achieve this, vision system which proccess road direction for navigation are used as vehicle steering system input. The vision system consist of camera and computer, meanwhile steering system are built based from Steer By Wire (SBW) design to add capabilities of electronic control inside vehicle. SBW use electromechanical actuator to drive the steering and with electronic controller to control movement. Thus, communication of vision system input to steering system become possible by utilizing electronic data. Experimental validations were performed to demonstrate ASC system based on vision road lane detection. The result shows this system is capable to run on road within a speed limit of 30 km/h and visibility of more than 1 km. Other researchers have work with the use of different type of sensors (combination of GPS and Lidar- Light Radar) and proven to achieve 40 km/h speed limit with no visibility limitation as demonstrated in DARPA (Defense Advance Research Project Agency) Grand Challenge (DARPA, 2005). It can be concluded that ASC system with vision based lane detection have been successfully demonstrated with some limitations.

ABSTRAK

Teknologi penglihatan pengesanan untuk jalan dan pengemudian kenderaan telah dibangunkan dalam tahun kebelakangan ini disebabkan oleh pertumbuhan kereta ke Inteligent Transportation System (ITS). Walau bagaimanapun, kebanyakan sistem penglihatan pengesanan ini masih dalam peringkat pembangunan dan kajian-kajian berterusan adalah diperlukan untuk meningkatkan ketepatan sistem. Kajian ini dimajukan bagi kemungkinan pembangunan kawalan Automatic Steering Control (ASC) apabila sistem penglihatan pengesanan bersepadu dengan kenderaan. Pembangunan sistem ASC memerlukan penyelesaian untuk mengatasi pengantar mukaan stereng kereta ke sistem pengesanan. Kesudahan yang baik adalah demonstrasi sistem ASC mampu navigasi sendiri tanpa gangguan manusia. Untuk mencapai matlamat ini, sistem penglihatan pengesanan yang dipakai untuk model jalan dalam kereta digunakan untuk input sistem stereng kendaraan. Sistem penglihatan pengesanan terdiri daripada kamera dan komputer, sementara itu sistem kemudi stereng yang dibina berasaskan dari Steer By Wire (SBW) untuk menambah keupayaan kawalan elektronik di dalam kenderaan. SBW menggunakan penggerak elektromekanik untuk memacu stereng dan dengan kawalan elektronik untuk mengawal pergerakan. Oleh sebab itu, komunikasi input sistem penglihatan pengesanan kepada sistem stereng menjadi mungkin dengan menggunakan data elektronik. Pengesahan eksperimen telah dijalankan untuk menunjukkan sistem ASC dengan integrasi sistem penglihatan pengesanan untuk jalan. Hasil kajian menunjukkan sistem ini mampu untuk berjalan di jalan dalam had kelajuan 30 km / jam dan jarak penglihatan harus lebih daripada 1 km. Penyelidik lain mempunyai kerja dengan penggunaan jenis sensor berbeza (kombinasi GPS dan Lidar Radar) dan terbukti untuk mencapai 40 km / jam had laju tanpa had penglihatan seperti yang ditunjukkan dalam DARPA (Defense Advance Research Project Agency) Grand Challenge (DARPA, 2005). Ini dapat disimpulkan bahawa sistem ASC dengan integrasi sistem pengesanan untuk deteksi jalan telah berjaya walaupun dengan beberapa batasan.

ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude to my main supervisor, Dr. Noreffendy Bin Tamaldin, and second supervisor En Fauzi Bin Ahmad for his guidance, support, and constant encouragement during my research and to Dr. Khisbullah Hudha for serving me as my external advisor.

I would like take this opportunity to thank my colleagues at the Faculty of Mechanical Engineering, UTeM, Zaharudin Bin Sariman and Mohd. Sabirin Rahmat for their outstanding collaboration in the experimental works and also for being a very good sharing partner during my research. Thanks also to my other colleagues at Taman Tasik for providing an enjoyable study environment.

Finally, my deepest grateful and thanks go to my parents, Siswanto and Suwindah Rini, my dear siblings, Ika Aulia Hastuti and Aulia Widiyastuti, my dear friends, Vimal Rau and Mohd. Zaifazlin. Their continuous prays and moral supports have been brought me here.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

I	-	Current
P	-	Power
V	-	Voltage
Kp	-	Proportional Gain
Ki	-	Integral Gain
Kd	-	Derivative Gain
G	-	Image Gradient
Gx	-	Image Gradient Vertical Direction
Gy	-	Image Gradient Horizontal Direction
∅	-	Angle direction
m	-	Line Gradient
x	-	Horizontal Coordinate
y	-	Vertical Coordinate
b	-	Line Slope Intercept
f(x)	-	Line Function
LP	-	Line Point
MP	-	Middle Position
r	-	Density
o1	-	Road Short Distance Angle
o2	-	Road Medium Distance Angle
o3	-	Road Long Distance Angle
θ_{total}	-	Steering Angle Value

LIST OF ABBREVIATIONS

A/D	-	Analog to Digital
ACC	-	Adaptive Cruise Control
ADC	-	Analog to Digital Converter
AS	-	Automatic Steering
AVR	-	Advanced Virtual RISC
BJT	-	Bipolar Junxtion Transistor
CPU	-	Central Processing Unit
COM	-	Serial Communication Port
DARPA	-	Defense Advanced Research Projects Agency
DC	-	Direct Current
DSLR	-	Digital Single Lens Reflex Camera
ECU	-	Electronic Control Unit
EEPROM	-	Electronically Ereasable Programmable Read-Only Memory
GOLD	-	General Obstacle and Lane Detection System
GPS	-	Global Positioning System
GUI	-	Graphical Unit Interface
I/O	-	Input or Output
ISP	-	In-System Programming
ITS	-	Inteligent Transportation System

JTAG	-	Join Test Action Group
LDWS	-	Lane Departure Warning Systems
LKA	-	Lane Keeping Assist System
Lidar	-	Laser Radar
LSb	-	Least Significant Bit
MCU	-	Microcontroller Unit
Mhz	-	Megahertz
Minsys	-	Minimum System
MIPS	-	Microprocesor Without Interlocked Pipeline Stages
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
Nm	-	Newton Metre
Nrz	-	Non Return Zero
NPN	-	Negative Positive Negative Transistor
OOP	-	Object Oriented Programming
PC	-	Personal Computer
PID	-	Proportional Integral Derivative Controller
PNP	-	Positive Negative Positive Transistor
PORT	-	Programmable Peripheral Interface
PWM	-	Pulse Width Modulatio
RAM	-	Random Access Memory
RGB	-	Red Green Blue
RHT	-	Randomized Hough Transform
rpm	-	Rotation per Minute
RS-232	-	Recomended Standard 232 (Computer Serial Interface IEEE)

SBW	-	Steer By Wire
SPI	-	Serial Peripheral Interface
SRAM	-	Static Random Access Memory
UART	-	Universal Asyncronous Receiver/ Transmitter
USART	-	Universal Syncronous Receiver/ Transmitter
USB	-	Universal Serial Buss
V	-	Volt
VGA	-	Video Graphic Adapter
VioLET	-	Vision Based Lane Estimation and Tracking
W	-	Watt

LIST OF PUBLICATIONS

Dwijotomo, A., Tamaldin, N. and Hudha, K., 2013. Development and Implementation of Steer by Wire Rack Pinion System with the ECU Integration. *International Journal of Automotive Technology. (in press)*

Tamaldin, N. and **Dwijotomo**, A., 2012. Vision Based Lane Detection For Automatic Steering Support System. *International Conference of Engineering and ICT (ICEI)*, Melaka, Malaysia, 4 - 6 April 2012.

Nasir, M.Z.M., **Diwjotomo, A**., Amir, M.Z, Abdullah, M.A., Hassan, M.Z. and Hudha, K., 2012. Position tracking of automatic rack and pinion steering linkage system through hardware in the loop testing. *Control and System Graduate Research Colloquium (ICSGRC)*, pp.111-115

CHAPTER 1

INTRODUCTION

1.0 Background

The world automotive industry had experienced constant growth since 1980's. The transition from horse carriages to automobiles trigger development of technology to assist the industry. As the automotive industry grow and increasing people demand of the technology, many industry began to compete for improving vehicle safety and functionality. In these field, a large emphasis has been given to issues such as improving safety conditions, reduce energy consumption and protection of the environment from pollution. The endeavors to solve these problems have triggered the interest towards a new field of research and application.

Vehicle safety is obviously one of the main concern that cannot be neglected. The rapidly growing number of vehicle production have increase road traffic accident with high fatality rate. Approximately 1.3 million people die each year due to road accident, and between 20 - 50 million sustain non-fatal injuries. If the trends continue, road crashes are predicted to increase by 65% and become the fifth leading cause of death by 2030 (WHO, 2013). More than 90% of road accidents are caused by human error. These high fatality rate has driven researchers to explore advance technology in vehicle towards autonomous. This implies the decisions needed by human driver are being replaced by the vehicles itself

and the human driver exerts lower direct control over machine actions to reduce human error. The trend towards autonomous is not new. It started by the introduction of automatic transmission and continued with Intelligent Transportation System (ITS) like cruise control to assist and reduce the driving burden. The usage of computers accelerates this trend because computers can endow the machine with complex reasoning skills as well as reliable control that surpasses human abilities. While autonomous is still growing, the end objective in the future will be about building fully automated driving car or autonomous vehicle with self-driving ability or with less human interruption.

Building fully autonomous vehicle capable of self-driving on the road is still difficult today because of the complexity and require expensive sensor. The scenario of autonomous vehicles will require all of the automotive technologies such as obstacle detection, maintaining safe speed, avoiding roadway obstacle, and maintain position on the road. These kind of system have been developed separately by researchers and some of them have been successfully implemented inside passenger vehicle to assist the driver. However, some of them also still undergoes continuous development. One of such system is road lane detection based vision to locate road trajectories for navigation.

Many of researchers are trying to improve this vision based road lane detection method to work on wider scope environment and increase accuracy (Assidiq *et al*, 2008; Hunjae *et al*, 2013; Qing *et al*, 2010; Yu-Chi et al, 2010). The vision lane detection use camera as main sensor to perceive environment similar to human eye. But, based on the result, lane detection method are still in simulation stage and theoretical. This thesis attempt to figure out the possibilities of road lane detection for the application of vehicle control. Thus, actual world experiment is necessary for this purpose. Both of vision lane

detection and steering control are integrated together to establish Automatic Steering Control (ASC) system technology that is capable of self-navigate with less human effort.

1.1 Motivation

Safety is one of the major problem that ignite current vehicle technology trend towards autonomous. It is primarily because many road accident today are contributed from human errors while driving. Number of simple factor including fatigue and distraction make most people vulnerable to this kind of problem. For example, the driver must constantly monitor the road conditions while estimating the road trajectories over a long time. This constant attentiveness is tiresome and resulting fatigue that may reduce the driver response. Additionally, conversation to others passengers, tuning the radio, and using cell phone can also distract the driver. Therefore, to reduce the number of injuries and fatalities, these errors must be eliminated. Viewed from another perspective, a self-driving car can lessen the human involvement and thus automatically reduce the human error. This kind of system will allow the driver to perform non-driving task safely while travelling to their destination.

1.2 Problem Statement

By reviewing previous researchers work, most of the researches in automatic steering are done separately between vision and steering control system. Some of them only focused on lane detection for autonomous vehicle driving system (Assidiq *et al*, 2008; Hunjae *et al*, 2013; Qing *et al*, 2010; Yu-Chi et al, 2010). Most of these system developed to obtain road model and simulation with alternative sensor and not intended for automatic driving. On the other hand, there are also researchers focused for vehicle control with

kinematics model (Em Poh *et al*, 2010; Fu Xiuewi *et al*, 2009; Hamzah *et al*, 2012; Zhigang *et al*, 2010). These researchers simulate the steering and velocity to understand the vehicle behavior. The problem is at the process, most of vehicle control researches did not involve actual hardware in vehicle implementation for actual environment to validate simulation data. Therefore, this thesis focused on combining both system from lane detection to be used in vehicle steering control and perform validation in actual hardware implementation. There are some problems need to be understood, analyzed and solved such as:

1. Forward vision sensor and data acquisition to provide information the input of the road.
2. Lane detection and tracking on road algorithm to provide the input of the vehicle steering command.
3. Vehicle control system and algorithm to controls the movement of the vehicle.
4. Implementation process on real vehicle to validate the lane keeping system.

1.3 Objectives

The specific objectives of this research are:

1. To develop ASC system by integrating vision and steering control system.
2. To investigate the performance of vision and steering system of ASC via simulation.
3. To verify the validity of ASC system via experimental work.