

**DRIVER ASSISTANCE COLLISION WARNING SYSTEM USING LIDAR
SENSOR WITH KINEMATICS AND PERCEPTION ALGORITHMS**

By

Willi Immanuel Susanto
22252013

MASTER'S DEGREE
in

MECHANICAL ENGINEERING – MECHATRONIC
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY
The Prominence Tower
Jalan Jalur Sutera Barat No. 15, Alam Sutera
Tangerang, Banten 15143 - Indonesia

Revision after the Thesis Defense on 9 August 2024

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgment is made in the thesis.



Willi Immanuel Susanto

Student

12-08-2024

Date

Approved by:



Assoc. Prof. Dr. Ir. Henry Nasution, M.T., IPP

Thesis Advisor

Date

Approved

Assoc. Prof. Dr. Tanika Dewi Sofianti, S.T., M.T.

Thesis Co-Advisor

Date

Dr. Ir. Maulahikmah Galinium, S.Kom., M.Sc.

Dean

Date

ABSTRACT

DRIVER ASSISTANCE COLLISION WARNING SYSTEM USING LIDAR SENSOR WITH KINEMATICS AND PERCEPTION ALGORITHMS

By

Willi Immanuel Susanto

Assoc. Prof. Dr. Ir. Henry Nasution, M.T., IPP, Advisor

Assoc. Prof. Dr. Tanika Dewi Sofianti, S.T., M.T., Co-Advisor

SWISS GERMAN UNIVERSITY

Road accidents remain a significant global concern, causing loss of lives and economic losses. To address this issue, the automotive industry has been increasingly investing in advanced driver assistance systems (ADAS) to enhance vehicle safety. This research presents a Driver Assistance Collision Warning System that incorporates a kinematics and perception algorithms approach to improve collision prevention. The driver assistance collision warning system utilizes a LIDAR sensor as its input to capture real-time data regarding the distance to next vehicle, the data is then integrated with an Arduino microcontroller to compute the relative speed and Time-to-Collision (TTC). In response to detected collision risk, the system triggers a warning mechanism using an audible warning provide by a buzzer and a visual warning generated by LEDs connected to a head-up display. The kinematics algorithm utilizes a specific threshold time-to-collision (TTC) value to determine the state of emergency collision risk. The perception algorithm utilizes a fuzzy logic system to predict the collision risk. As a result, the system could perform well as an integrated system, as the algorithms can operate harmoniously without any interference against each other. In the real-world environment, the system operates reliably since it has successfully passed the acceptance tests.

Keywords: Collision, Driver Assistance, LIDAR, Kinematics Algorithm, Perception Algorithm, Visual-audible warning.

© Copyright 2024
by Willi Immanuel Susanto
All rights reserved

DEDICATION

To the unwavering commitment to ensuring safety on our roadways and the invaluable lives it aims to safeguard and preserve. This work is devoted to all individuals who operate vehicles, ride as passengers, or walk on foot, with a desire for a future in which travel is more secure and incidents of accidents are infrequent.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to everyone who has contributed to the success of my thesis. First and foremost, I extend my sincere thanks to my advisor, Assoc. Prof. Dr. Ir. Henry Nasution, M.T., IPP, for their invaluable guidance, patience, and support throughout this research. I am especially thankful for the assistance and insights provided by my co-advisor, Assoc. Prof. Dr. Tanika Dewi Sofianti, S.T., M.T., whose expertise was instrumental in the completion of this work.

My appreciation also goes to the member of the thesis committee, Ayu Diana Lestari, S.Pd, for their insightful comments and suggestions. My gratitude extends to Swiss German University for providing the necessary resources and environment conducive to my research.

I must acknowledge the constant support and encouragement from my family, especially my father, Assoc. Prof. Dr. Bambang Susanto, M.S., M.Th., my mother, Lena Magdalena, S.H., and my sister, apt. Sharon Susanto, S.Farm., M.S.Farm., their unwavering belief in my capabilities has been a source of strength and motivation.

I would also like to my significant other, Lidya Septilia, for her understanding, companionship, and moral support during the challenging times of this journey.

Lastly, I extend my gratitude to all who were involved directly or indirectly in the completion of this thesis. Your contributions have been invaluable.

The curriculum and instruction program has provided me with an interesting and enriching academic experience. It has equipped me with a complete set of resources to explore a variety of concepts and situations from historical and contemporary perspectives.

TABLE OF CONTENTS

	Page
CHAPTER 1 - INTRODUCTION	13
1.1 Background	13
1.2 Research Problems	16
1.3 Research Objectives	16
1.4 Significance of Study.....	16
1.5 Research Questions	17
1.6 Hypothesis.....	17
CHAPTER 2 - LITERATURE REVIEW.....	18
2.1 Theoretical Concept.....	18
2.1.1 Collision	18
2.1.2 Kinematics Algorithm.....	19
2.1.3 Perception Algorithm.....	21
2.2 Existing Research Search Strategy.....	23
2.3 Research Question on Systematic Literature Review	24
2.4 Search String and Research Database	24
2.5 Study Selection Criteria	24
2.6 Data Mapping.....	25
2.7 Existing Research.....	26
CHAPTER 3 – RESEARCH METHODS	30
3.1 Root Cause Analysis.....	30
3.1.1 Fishbone Diagram.....	30
3.1.2 Why-why Analysis.....	31
3.2 Overview of the Development Method	33
3.2.1 Research Methodology.....	33
3.2.2 V-Model Project Milestone	34
3.2.3 Short Method Description	36
3.3 Pre-Development Stage	36
3.3.1 Requirement Development.....	37

3.3.1.1	Variable Input.....	37
3.3.1.2	Warning Output.....	37
3.3.1.3	Decision-Making Concept	39
3.3.2	Architecture Development	41
3.3.2.1	Block Diagram	41
3.3.3	Components of the System.....	42
3.3.3.1	Controller	42
3.3.3.1.1	Arduino Mega 2560.....	42
3.3.4	Sensors	43
3.3.4.1	Optical Distance Measurement Sensor Garmin LIDAR Lite v3	43
3.3.5	Actuators	44
3.3.5.1	Head-up Display.....	44
3.3.5.2	Buzzer.....	45
3.4	Calibration, Testing, and Validation	46
3.4.1	Calibration	46
3.4.2	Testing and Validation	46
CHAPTER 4 – RESULTS AND DISCUSSIONS		47
4.1	Hardware and Software Development.....	47
4.1.1	Component Development.....	47
4.1.2	Unit Analysis and Test	49
4.1.3	Integration Build	51
4.1.3.1	Kinematics Algorithm	52
4.1.3.2	Perception Algorithm	52
4.1.3.3	Kinematics and Perception Algorithms.....	66
4.1.3.4	Integration Test	67
4.2	System Verification	69
4.2.1	System Test	69
4.2.2	Acceptance Test.....	74
CHAPTER 5 – CONCLUSIONS AND RECCOMENDATIONS		79
5.1	Conclusions	79
5.2	Recommendations	80
GLOSSARY		82
REFERENCES		84
CURRICULUM VITAE		89
6. Appendix 1: Actuator Calibration Arduino Code		90

7. Appendix 2: LIDAR Sensor Calibration Arduino Code.....	91
8. Appendix 3: Driver Assistance Collision Warning System Arduino Code.....	92

LIST OF FIGURES

Figures	Page
Figure 1.1 Road accident cases in Indonesia, by year [3].....	13
Figure 1.2 Total Cases, Dead Victim, Fatal Injury, Non-Fatal Injury, and Material Loss in 2019-2021 [5].....	14
Figure 1.3 Car Accident Cases in Indonesia during 2019-2021	15
Figure 2.1 3-second Rule Education Campaign from BUJT [11].....	20
Figure 2.2 The AI Tree [15].....	22
Figure 2.3 Network Visualization of Driver Assistance Collision Warning System ..	25
Figure 2.4 Density Visualization of Driver Assistance Collision Warning System ...	26
Figure 3.1 Road Accident Fishbone Diagram.....	30
Figure 3.2 Research Methodology	34
Figure 3.3 Research Method using V-Model.....	35
Figure 3.4 Decision Approach Block Diagram of Driver Assistance Collision Warning System with Kinematics and Perception Algorithms.....	40
Figure 3.5 Fuzzy Decision Tree for Collision Warning Decision.....	40
Figure 3.6 Collision Warning System Block Diagram.....	42
Figure 3.7 Arduino Mega 2560 Microcontroller [26]	43
Figure 3.8 Garmin LIDAR Lite v3	44
Figure 3.9 Vehicle Collision Warning Head-up Display.....	45
Figure 3.10 Buzzer	45
Figure 4.1 Schematic Diagram of Vehicle Collision Warning System.....	48
Figure 4.2 Vehicle Collision Warning System Assembly	48
Figure 4.3 Actuator Calibration Flow Procedure	50
Figure 4.4 Overview Diagram of a Fuzzy System	53
Figure 4.5 Fuzzy System Input-Output (Matlab GUI)	54
Figure 4.6 Fuzzy System Membership Function (Matlab GUI)	56
Figure 4.7 Fuzzy System Rules Mapping.....	56
Figure 4.8 Matlab's Fuzzy System Rule Inference	58
Figure 4.9 Fuzzification of the First Implementation System	59
Figure 4.10 Rule Inference Setup for the Rule Evaluation.....	60

Figure 4.11 Aggregation of the Outputs of Fuzzy System	61
Figure 4.12 Fuzzy System Rules Mapping Adjustment	64
Figure 4.13 Fuzzy System Membership Function Adjustment.....	65
Figure 4.14 Driver Assistance Collision Warning System with Kinematics and Perception Algorithm Flowchart.....	66
Figure 4.15 Integration Test of the Collision Warning System	68
Figure 4.16 Integration Test Serial Monitor Result of Collision Warning System.....	70
Figure 4.17 Test No. 1 Fuzzy Output Result	71
Figure 4.18 Test No. 3 Fuzzy Output Result	72
Figure 4.19 Test No. 3 Fuzzy Output Result	73
Figure 4.20 Acceptance Test – Cover Contamination (Fog)	75
Figure 4.21 Acceptance Test – Cover Contamination (Rain).....	75
Figure 4.22 Acceptance Test – Cover Contamination (Dust).....	76
Figure 4.23 Acceptance Test – Day night Transition.....	77
Figure 4.24 Acceptance Test – Strong Sunlight.....	77

LIST OF TABLES

Table	Page
Table 2.1 Previous & Current Related Studies Comparison.....	28
Table 3.1 Road Accident Root Cause why-why Analysis.....	31
Table 3.2 Countermeasure Improvement of the Weakness Point	32
Table 3.3 Warning Indication Output.....	38
Table 3.4 System Decision Guidance.....	39
Table 4.1 Calibration Test for Buzzer and LED	50
Table 4.2 Calibration Test for Garmin LIDAR Sensor v3.....	51
Table 4.3 Kinematics Algorithm System Decision	52
Table 4.4 Fuzzy System Input-Output.....	54
Table 4.5 Fuzzy System Membership Function.....	55
Table 4.6 Collision Warning System Integration Test Truth Table	68
Table 4.7 Integration Test Result of Collision Warning System	69
Table 4.8 System Test Result of Collision Warning System.....	73
Table 4.9 Acceptance Test Result for Collision Warning System	78