VISION-BASED TRAJECTORY CONTROL SYSTEM OF AN AUTONOMOUS VEHICLE

By

Ahmed Desoky Abd El-Aty Sabiha

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Mechanical Design & Production Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

VISION-BASED TRAJECTORY CONTROL SYSTEM OF AN AUTONOMOUS VEHICLE

By

Ahmed Desoky Abd El-Aty Sabiha

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Mechanical Design & Production Engineering

Under the Supervision of

Prof. Dr. Galal Ali Hassaan

Professor Emeritus
Mechanical Design and Production
Faculty of Engineering, Cairo University

Dr. Amgad Mohammed Bayoumy

Assistant Professor
Mechatronics Department
Faculty of Engineering, MSA University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

VISION-BASED TRAJECTORY CONTROL SYSTEM OF AN AUTONOMOUS VEHICLE

By

Ahmed Desoky Abd El-Aty Sabiha

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Mechanical Design & Production Engineering

Approved by the
Examining Committee:

_____
Prof. Dr. Galal Ali Hassaan **Thesis Main Advisor**
Professor Emeritus, MDP Department, Faculty of Engineering, Cairo University

_____
Dr. Amgad Mohammed Bayoumy **Advisor**
Assistant Professor, Mechatronics Department, Faculty of Engineering, MSA University

_____
Prof. Dr. Saad Abd El-Fattah Kassem **Internal Examiner**
Professor Emeritus, MDP Department, Faculty of Engineering, Cairo University

_____
Prof. Dr. Yehia Hendawy Hossam El-Deen **External Examiner**
Professor, Faculty of Engineering and Technology-Future University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer: Ahmed Desoky Abd El-Aty Sabiha
Date of Birth: 1 / 10 / 1986
Nationality: Egyptian
E-mail: ahmeddesokyeg@gmail.com
Phone: 00201002907528
Address: Menoufia Governorate

Registration Date: 1 / 10 / 2014
Awarding Date: / / 2018
Degree: Master of Science
Department: Mechanical Design and Production Engineering
Supervisors:

Prof. Galal Ali Hassaan (Thesis main advisor)
Professor, Faculty of Engineering, Cairo University
Dr. Amgad Mohammed Bayoumy (Advisor)
Assistant Professor, Faculty of Engineering, MSA University

Examiners:

Prof. Dr. Galal Ali Hassaan (Thesis main advisor)
Professor Emeritus, Faculty of Engineering, Cairo University
Dr. Amgad Mohammed Bayoumy (Advisor)
Assistant Professor, Faculty of Engineering, MSA University
Prof. Saad Abd El-Fattah Kassem (Internal examiner)
Professor, Faculty of Engineering, Cairo University
Prof. Yehia Hendawy Hossam El-Deen (External examiner)
Professor, Faculty of Engineering and Technology-Future University

Title of Thesis:

"Vision-Based Trajectory Control System of an Autonomous Vehicle"

Key Words:

Autonomous Vehicle, Raspberry Pi, Modeling and Simulation, Lane Detection, Image Processing.

Summary:

This thesis presents a comprehensive mathematical modeling and simulation for the trajectory of a vision-based autonomous vehicle during moving between lane lines of the structured road. In addition, demonstration building, implementing, and developing a trajectory tracking control system based on computer vision for autonomous cars.

The simulation accomplished by using MATLAB/Simulink software. This simulation mimics the existence of an actual digital camera by using a novel 3D-vision block to simulate the actual images that assumed to be provided by a digital camera connected to an embedded computer. The 3D-vision block uses mathematical equations, execution sequence and logical conditions to create a virtual captured image. So, this virtual image is then used to detect the lane in the front of the vehicle depending on the virtual camera position and its parameters. Inside simulation environment that based on the kinematic model of the vehicle and vision model, the controller is designed in the simulation and is coded in the embedded computer with the optimized control gains.

The implementation presents a system includes a single digital camera, an embedded computer (Raspberry Pi 2), and a microcontroller board to produce an autonomous car to be able to track current road lane, where the digital camera is mounted at the top of the vehicle along its longitudinal axis. The real-time captured images are processed using Python code with OpenCV library over Linux operating system to obtain geometrical data of road lane. From this data, the observable errors can be determined. Finally, a steering controller utilizes these errors in control law that designed in the simulation with tuning in control gains to compute the steering command. The embedded computer then paths this command to Arduino microcontroller board to adjust the steering servomotor.

During this work, a set of autonomous driving experiments is performed. Several evaluations scenarios are shown and discussed about lane detection.

Acknowledgments

All praise is due to Allah alone, Lord of all the creations.

I am very fortunate to have performed my thesis at Cairo University; therefore, there are many people to thank for participating in my success.

I would first like to thank my main advisor, **Prof. Dr. Galal Hassan** for providing me with the interesting topic and giving me the chance to explore and learn what the meaning of a research.

I would also like to express my deep appreciation and gratefulness to **Dr. Amgad M. Bayoumy** for his support, guidance that gave me the power to perform this research work.

I extend my sincere thanks to **Prof. Dr. Saad Kassem, Prof. Dr. Yehia Hendawy,** and **Dr. Alla Mourad** for their advices and contributions during the revision of this work.

I am very much indebted to my best friends, special thanks to **Eng. Mohamed Sayed**, who has been continuously giving me the courage and motivation, where this project would not have been possible to complete without his support.

I would like to give my great gratitude to my uncle, who was always supporting me with his best wishes. Without him, I would not have reached this point.

I would also like to thank my wife for standing beside me throughout good and bad times. In addition, for her patience and tolerance to see wires, electrical components, and tools scattered all over the house. In addition, she allocates a part of the house to set up the vision system on the vehicle and to perform the experiments.

Finally, my deep appreciation and gratefulness are to the faculty of engineering, Cairo University; its administration, staff, and personnel. In addition, special thanks to all the staff at the department of mechanical design and production engineering.

Ahmed Desoky
Egypt, January 2018

Dedication

To my late parents, who had the arduous task of breeding and raising seven children, who have struggled hard in life to give me the best, who taught me to persevere, and prepared me to face the challenges with faith and humility. Although they are not here to give me the strength and the support, I always feel their presence that used to urge me to strive to achieve my goals in life.

To my supporting wife, who has been a constant source of support and encouragement during the challenges and endeavors, she was a constant source of inspiration to my life. I am truly thankful for having you in my life.

To my dear daughter, who decorated my life and added the cheerfulness to it.

Table of Contents