



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
MECHATRONICS ENGINEERING DEPARTMENT

Hybrid Control in Coordination of Multi-Agent Autonomous Vehicles at Intersections

A thesis submitted in partial fulfillment of the requirements of the
M. Sc. degree in Mechatronics Engineering

by

Omar Mahmoud Mohamed Shehata

B.Sc. Mechatronics Engineering
Ain Shams University, 2010

Supervised by

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STATEMENT

This thesis is submitted as partial fulfillment of M. Sc. degree in Mechanical Engineering -Mechatronics Engineering Major-, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Researcher Data

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List of Publications

The following publications have been published while in conduct of this study:

- Magdy M. Abdelhameed, Mohamed Abdelaziz, S. Hammad, and Omar M. Shehata. Development and Evaluation of a Multi-Agent Autonomous Vehicles Intersection Control System. In *International Conference on Engineering and Technology (ICET), 2013 IEEE Conference*.
- Magdy M. Abdelhameed, Mohamed Abdelaziz, S. Hammad, and Omar M. Shehata. Design of a Fuzzy Logic Controller for Intersection Control based on a Multi-Agent Approach. In *International Conference on Industry Academia Collaboration (IAC), 2014*.
- Magdy M. Abdelhameed, Mohamed Abdelaziz, S. Hammad, and Omar M. Shehata. A Hybrid Fuzzy-Genetic Controller for a Multi-Agent Intersection Control System. In *International Conference on Engineering and Technology (ICET), 2013 IEEE Conference*.

*“Life is not about how hard you hit,
It’s about how hard you can get hit and keep moving forward.”*

Sylvester Stalone (Rocky Balboa)

Abstract

Over the years, traffic congestion has grown into one of today's global problems. Intersections are a major cause of this problem. Thus proper management of the intersections, will reduce congestion consequently. In this study, an intelligent Intersection Control System (ICS) is proposed to control traffic flow in intersections. Treating the problem as a Multi-Agent System (MAS), two types of agents inhabit this environment. The Intersection Manager Agent (IMA) and the Driver Agent (DA). Via predicting the trajectories of the vehicles, it is possible to minimize their travel times while avoiding any predicted collision.

A Hybrid Fuzzy-Genetic controller is implemented in the ICS. The controller is responsible for evaluating the appropriate action for each vehicle. While the Genetic Algorithm (GA) is used to tune the parameters of the FLC output fuzzy sets in an offline training process. The intersection performance under different traffic capacities is studied and compared with the existing traffic-light system. A simulation environment is used to verify the capability of the proposed ICS in managing the intersection. Simulation results reflect an improved intersection utilization, increasing its throughput by 91%, while decreasing the vehicles' Average and Maximum delay times by 62% and 72% respectively.

An Experimental platform of a group of mobile robots and an overhead computer vision tracking system was developed to further validate the proposed system. The experimental results achieved a satisfactory behavior of the actual mobile robots against the simulated ones. The performance indices converged as the number of robots used increased, reaching a Mean Root Square Error (RMSE) of 18.7, and a Maximum Absolute Error (MAE) of 16.9. These results leaves the door open for different further investigations in this field of study.

Thesis Summary

Over the years, traffic congestion has grown into one of today's global problems. Intersections are a major cause of this problem. Thus proper management of the intersections will decrease this problem. In this study, an intelligent Intersection Control System (ICS) is proposed to control traffic flow in intersections, treating the problem as a Multi-Agent System (MAS). Through predicting the trajectories of the vehicles it is possible to minimize their travel times of vehicles while avoiding any predicted collision.

In chapter (1), the problem of traffic congestion is introduced, as well as the emerging technologies of autonomous vehicles and the approaches of multi-agent systems, and concludes with problem statement of this study and the flow of the rest of the thesis.

In chapter (2), a survey of the recent research efforts related to the focus of this study is presented; reaching to the conventional methods used to solve the problem under study. Relying on other researchers efforts, the approach to be used in this study is defined, as well as the contribution of this study.

In chapter (3), the proposed methodology to tackle the problem is proposed through discussing the details of the different aspects of this system, and the new algorithm developed to quantify the collision situation in an intersection, and that is by using a hybrid controller composed of a both Fuzzy Logic controller and Genetic Algorithm.

In chapter (4), the way the system was modeled is introduced, along with the simulation techniques used to verify the validity of the proposed approach, via a group of simulation experiments, and getting the results of these simulations.

Chapter (5) presents a detailed description of the experimental platform developed to verify the algorithm proposed in chapter (3), and the details of its different modules.