A Thesis for the Degree of Ph.D. in Engineering

Coordination and Control for Connected and Automated Vehicles at Signal-free Intersections

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Graduate School of Science and Technology
Keio University

Mohamad Hafizulazwan Bin Mohamad Nor

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Keio University

Thesis Abstract

No.

Registration Number	■ “KOU” □ “OTSU” No. *Office use only	Name	BIN MOHAMAD NOR, Mohamad Hafizulazwan

Thesis Title

Coordination and Control for Connected and Automated Vehicles at Signal-free Intersections

In recent years, researchers are exploring the benefit of Connected and Automated Vehicles (CAVs) to coordinate the movement of vehicles at intersections. In this strategy, the vehicles are capable to obtain the information of other vehicles through wireless communication where it helps them to decide on how they can traverse the intersections safely and effectively instead of relying on traffic lights, road signs, and rules. However, finding the right coordination strategies for the CAVs at these so-called signal-free intersections that can provide both safety and efficiency with low computational effort is challenging. To address these problems, a bi-level strategy is developed. In the coordinator level, two Mixed Integer Linear Programming (MILP) formulations are proposed to model the merging time problem of all vehicles. In the first formulation, an existing MILP formulation is extended to include the right and left turns of the vehicles while fully utilizing the intersection area. The second formulation aims to reduce the computational time in solving the first MILP formulation. In the vehicle level, Hamiltonian analysis is adopted to obtain the optimal control input of each vehicle.

In Chapter 1, the research motivation and background are discussed. In addition, some state of the arts coordination and control strategies for the signal-free intersection problem are reviewed. Then, the research objective and contributions of this thesis are clarified.

In Chapter 2, some mathematical preliminaries are provided particularly on mathematical programming, i.e., MILP and optimal control analysis.

In Chapter 3, the scenario setting for the signal-free intersection problem dealt in this thesis is discussed.

In Chapter 4, a MILP formulation is proposed in the coordination level to improve the crossing order of the CAVs and thus, reducing the travel time. On the other hand, unconstrained optimal control analysis is adopted in the vehicle level. For simplicity, only pre-assigned arrival of the CAVs is considered in this chapter. Some preliminary analyses are conducted to investigate the performance of the proposed strategy in terms of travel time and fuel consumption.

In Chapter 5, the MILP formulation is extended to include the right and left turning of the CAVs as well as considering the continuous arrival of the CAVs. In addition, constrained optimal control analysis is adopted in the vehicle level. Some performance analyses and case studies are conducted to investigate the performance of the proposed strategy.

In Chapter 6, an event-based MILP formulation is proposed to reduce the computational burden in solving the MILP problem. Some simulations are provided to investigate the formulation.

In Chapter 7, the conclusion of this thesis is provided, and future research direction is discussed.