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Latent Class Analysis for Driving Behavior on Merging Section

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Abstract

This study proposes a modeling framework, and the complicated phenomena in merging sections are analysed with the model. The proposed modeling framework is based on the latent class model, and contains a simplified estimation method for all parameters. In the model, it is assumed that driving behaviors consist of multiple driving-modes, and the latent driving-modes are based on drivers' intentions or surrounding circumstances. The modeling structure enables us to analysing complicated phenomena in merging sections which often becomes a bottleneck or an accident hotspot because of drivers' inevitable lane-changing and vehicles' complicated movements. Driving behaviors of vehicles on main-lane of a merging section are analysed and effects of information for safety driving are verified.

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1. Introduction

Car driving behavior is a complicated task in general. It requires drivers to recognize the surrounding circumstances and, at the meantime, to operate steering wheels, accelerator pedal and brake pedal. On fairly straight sections of expressway, the driving behavior is rather simple, where driver would basically pay attentions to vehicles in front. Conversely, in merging sections, one would probably observe a much more complicated driving behavior. Almost all drivers in merging sections should pay attention to

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vehicles on other lane and operate their vehicles run safely even when their vehicles exist in the main-lane. As a consequence, a merging section often becomes bottleneck or accident hotspot, as long as drivers should pay fully attention to movements of surrounding vehicles and making their decisions in a very short time frame, failure may easily occur. Analysis for the complicated driving behavior on merging section is required in order to make the cause of traffic congestion and accidents clearer.

Modeling drivers' behaviors in merging sections is important task for understanding the complicated phenomena from the point of view of traffic congestion and accidents. Whole vehicle maneuvers should be consist of several behaviors as simple car-following, free driving, driving while wary of merging car, emergency stopping, and so on. Most studies mainly focus on general relationships between surrounding circumstances and vehicle maneuvers, which are divided into several modules of driving behaviors. And these modules are separately analysed and modeled. As is often the case with analytical process of traffic flow, these modules separately built are jointly utilized for simulating traffic condition. In order to understand and simulate a driver's behavior at merging section precisely through the process of modeling and reproduce the traffic flow accurately by the simulation, it is necessary for us to apply a common modeling framework that can cover the various driving behavior under the different circumstances.

A traffic micro simulation with accurate models about drivers' behaviors is a possible tool for analysing complicated phenomena with danger situations. Bonsall et al. (2005) made a traffic simulation model for assessment of traffic safety in complicated situations. The model consists of rules of speeds in free-flowing traffic, headways between vehicles, acceleration profiles, and so on. The result of simulation indicates that the safety-related movements are caused from the use of inappropriate parameter values. On the other hand, Xin et al. (2008) produced a model with reaction time depending on individual driver characteristics and instantaneous traffic conditions. The model has a capability to replicate both normal and unsafe driving behavior that could lead to vehicle collisions. The produced model was validated with real crash trajectories. These results indicate that it is necessary for us to consider situation-specific behavior in order safety assessment with simulation models.

Among many researches on driving behavior that aim to enhance simulation accuracy, Koutsopoulos et al. (2012) proposed a car-following model based on latent class model (LCM) which deals with the differences between several (latent) states, such as deceleration, acceleration, and do-nothing. This structure makes it possible to integrate multiple acceleration controlling behaviors into one modeling framework. On the other hand, Chevallier et al. (2009) produced a modeling solution that correctly reproduces merging with new car-following rules and a new insertion decision algorithm. It is indicated that merging behavior should be reproduced by some special structures such as the particular algorithm proposed by Chevallier et al.

The objective of this paper is to propose a driving behavior model which enables us to analyse car-following behaviors on merging sections considering the latent driving-modes. Furthermore, all parameters were estimated using vehicle trajectory data extracted from driving experiments with a driving simulator as a case study for a trial of applying the framework. In the experiment, vehicles of the subjects run on a main-line of an expressway with a merging section, and 2 types of merging-support-information is provided to the subjects in order to analyse the effect of the information in terms of enhancement in safety.

2. Framework of the model

2.1. Model design

The proposed model integrates multiple car-following behaviors considering the latent variables representing driving intentions. The model is described based on latent class model (LCM) structure, and

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