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An improved car-following model considering the immediately ahead car's velocity difference

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HIGHLIGHTS

- The field data at a signalized intersection of Jinan in China were collected for factorial analysis.
- An improved model considering the immediately ahead car's velocity difference was put forward.
- The immediately ahead car's velocity difference has significant effects on the following car's motion.
- It can improve the stability of traffic flow and suppress the appearance of traffic jams.

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ABSTRACT

The field car-following data at a signalized intersection of Jinan in China are collected for data mining. An improved car-following model considering the immediately ahead car's velocity difference on a single-lane road was proposed, calibrated and verified based on full velocity difference model. The results of some numerical simulations indicate that the immediately ahead car's velocity difference has significant effects on the following car's motion, that the improved car-following model fits the measured data well and can qualitatively describe the impacts of the immediately ahead car's velocity difference on traffic flow, and that modeling the car-following behavior considering the immediately ahead car's velocity difference can improve the stability of the simulated traffic flow.

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1. Introduction

In recent years, more and more car-following models have been put forward and gradually formed the cornerstone for the simulation modeling and the functional definition of advanced vehicle control and safety systems areas, which include the early linear models proposed by Chandler et al. [1], the early nonlinear models presented by Pipes [2], Gazis et al. [3] and Newell [4], the recent remarkable works of Bando et al. [5], Helbing and Tilch [6] and Jiang et al. [7] and some others in the research studies [8–33].

The optimal velocity model proposed by Bando et al. [5] is one of the favorable car-following models, which can describe many properties of real traffic flow such as the instability of traffic flow, the evolution of traffic congestion and the formation of stop-and-go waves. Dirk Helbing and Benno Tilch [6] proposed the generalized force model by considering negative velocity difference. Jiang Rui et al. [7] put forward the full velocity difference model by taking both negative and positive

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Fig. 1. Videos recorded at a signalized intersection.

velocity differences into account. H.X. Ge, et al. [34] put forward the two velocity difference model in the light of the optimal velocity model. G.H. Peng and D.H. Sun [35] proposed a multiple car-following model by considering the effects of multiple leading cars based on the full velocity difference model. Although these car-following models mentioned above can reproduce many complex actual traffic phenomena, they cannot be employed to describe the urgent case that a freely moving car decelerates drastically for an accident in front or the red traffic light at an intersection, the following car is freely moving and the distance between the two cars is quite small. In the realistic traffic, the following drivers will adjust the velocity promptly when they find the front car decelerates or accelerates drastically, the following drivers much more focused on the drastic change of the immediately ahead car's running state.

Inspired by the car-following model with consideration of driver's memory and in view of the realistic traffic, the immediately ahead car's velocity difference will be focused on and further investigated in this paper. In the following section, the field car-following data at a signalized intersection of Jinan in China were collected and analyzed. In Section 3, the improved car-following model considering the immediately ahead car's velocity difference is put forward, calibrated and verified. In Section 4, numerical simulation is carried out to analyze some transportation phenomena. Conclusions are given in Section 5.

2. Field data collection and data mining

The field car-following data used to analyze how the immediately ahead car's velocity difference affects the following car's behaviors, and to calibrate the forthcoming car-following model all come from the survey of the Traffic Control Research Group of Shaanxi province engineering laboratory of transportation safety supervisory control network, which took place in the Jingshi Road/Shanshi East Road intersection of Jinan in China on the afternoon of August 26, 2013. This survey focuses on the through movements on the westbound approach consisting of one left-turn lane, three through lanes, one bus transit lane and one right-turn lane and particularly focuses on the car-following movements on three through lanes because the traffic flow in these lanes is not much affected. In order to obtain more and effective data, the video camera was installed on the windowsill of a tall building adjacent to the intersection, as shown in Fig. 1.

In this paper, the frame differential method is employed to extract the field car-following data; we first obtain the pixel distance, and then get the real distance by using the traffic lane line as a frame of reference. The obtained field data contain each car's velocity, acceleration and position, and the immediately ahead car's velocity difference. Partial measured car-following data are listed as shown in Table 1, where a_2 is the following car's acceleration, d is the headway, v_2 is the following car's velocity, v_1 is the immediately ahead car's velocity, v is the velocity difference, and v_1 is the immediately ahead car's velocity difference.

The gray correlation analysis [36,37] is considered to be an analysis of the geometric similarity between the behavior factors within a system and the gray correlation degree is a quantitative value of the correlation between the behavior factors. Higher is the value of gray correlation degree, more relevant are the main-factor and sub-factor. The car-following process can be regarded as a system.

This study analyzes the measured car-following data by using gray relational analysis method to explore whether the immediately ahead car's velocity difference has significant effects on the following car's behaviors. The measured car-following data obtained from 40 pairs of cars were used for calculating the gray correlation degrees, which are computed and listed as shown in Table 2.

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