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New control strategy for the lattice hydrodynamic model of traffic flow

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The new delayed-feedback control strategy is applied for lattice hydrodynamic model of traffic flow by considering the control signal of the variation rate of the optimal velocity. The linear stability condition is derived in the frequency-domain with control theory. Then, different feedback gains under the periodic boundary scenery and on-ramp scenery are simulated. The periodic boundary scenery provides an initial small disturbance situation on the circle road, while the on-ramp scenery reproduces the disturbance triggered by the on-ramp on the open road. Both the theoretical analysis and simulations show that this new control signal has a positive effect to suppress traffic jams.

Key words: Lattice hydrodynamic model; Variation rate of the optimal velocity; Delayed-feedback control; Stability analysis

1. Introduction

In order to understand the mechanism of traffic congestion, many traffic flow models have been proposed in recently years, such as the microscopic and macroscopic models. Microscopic models, including cellular automata [1-5] and car following models [6-10], focus on the dynamics of individual vehicles, while macroscopic models, including gas-kinetic-based models [11-15], continuum models [16-20] and lattice hydrodynamic models [21-41], regard the whole traffic flow as a flow of continuous medium composed of vehicles.

Lattice hydrodynamic models are firstly proposed by Nagatani [21] in 1998, which can describe the real traffic flow properly, especially the jamming transitions. The jamming transitions of traffic flow are always described by the kink-antikink soliton density waves derived by mKdV equation near the critical point through nonlinear stability analysis [23-30, 32-41]. Besides, the lattice hydrodynamic models can reproduce various congested patterns induced by the on-ramp system well [22, 23], and the lattice models also can reproduced the spatiotemporal evolution of all the traffic states described in phase diagram [23].

Due to the good performance of describing the real traffic, and deep connection with the continuum models and car-following model, the lattice model received great attention [22-35]. Ge, Wang, Tian, Zhu, Sun et al. [24-30] proposed the lattice models by considering the sites ahead or behind in vehicle motion. Li, Zhu, Peng [31-35] have taken the optimal velocity, driver's dely, driver's forecast effects and driver's memory into account. Besides, some two-lane lattice models were also proposed [36-41].

However, up to now the suppression of traffic congestion especially in the bottleneck systems is rarely considered in those models [42-45], but which was studied intensively for car following models [46-53]. Ge et al. [46, 47], Nakayama et al. [48], Konishi et al. [49, 50], Zhao and Gao[51], Shen et al. [52] and Li et al. [53] have utilized

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