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A new lattice model accounting for multiple optimal current differences' anticipation effect in two-lane system

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HIGHLIGHTS

- A new lattice model is proposed by considering multiple optimal current differences' anticipation effect for two-lane traffic system.
- The effect of MODA signal in transient and steady-state behavior of lattice model is examined.
- The simulation results show that multiple optimal current differences' anticipation effect can suppress the traffic jam efficiently.

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ABSTRACT

This paper extends a two-lane lattice hydrodynamic traffic flow model to take into account the driver's anticipation effect in sensing the multiple optimal current differences. Based on the proposed model, we derive analytically the effect of driver's anticipation of multiple optimal current differences on the instability of traffic dynamics. The phase diagrams have been plotted and discussed that the stability region enhances with anticipation effect in sensing multiple optimal current differences. Through simulation, it is found that the oscillation of density wave around critical density decreases with an increase in lattice number and anticipation time for transient and steady state. The simulation results are in good agreement with the theoretical analysis, which show that considering the driver's anticipation of multiple optimal current differences in two-lane lattice model stabilizes the traffic flow and suppresses the traffic jam efficiently.

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1. Introduction

In recent years, traffic jams have attracted more and more attention of scholars since the traffic problems became more and more serious with the increasing number of vehicles on the road. Therefore, to investigate the properties of traffic jams, a considerable variety of traffic models [1–38] have been proposed, such as car-following models, macro traffic models, cellular automaton models and hydrodynamic lattice models, in past few decades. In 1998, Nagatani [39,40] firstly proposed a simple lattice hydrodynamic model to describe the traffic congestion. Subsequently, a large number of extended models [25–55] have widely been proposed to study various nonlinear phenomena. Especially, some extended lattice models [56,57] were presented with the consideration of the information of the forward looking sites. Furthermore, Nagatani [58] developed a lattice model of traffic flow at the case of lane changing behaviors for two-lane freeway. Subsequently, some researchers [59,60] proposed a few improved lattice model of two-lane traffic. Recently, Peng [61]

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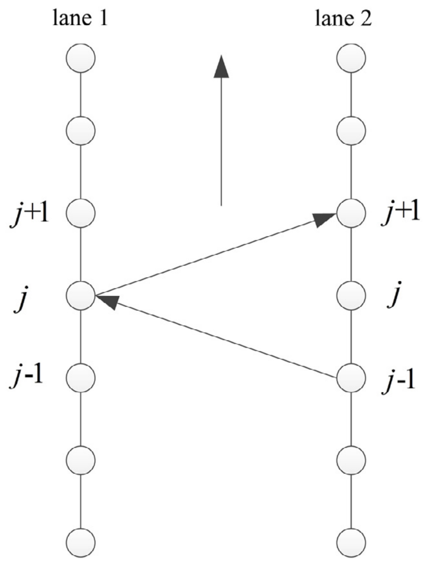

Fig. 1. The schematic model of traffic flow on a two-lane highway.

proposed a new lattice model by incorporating optimal current difference for two-lane highway. Furthermore, Peng [62] expanded a lattice model with the consideration of multiple optimal current differences in two-lane system. In addition, a lattice hydrodynamic model of two lanes [63] was proposed by considering multiple information of preceding cars. Moreover, a novel lattice model [64] is derived with the consideration of driver's anticipation effect in two-lane system and found that this effect has important influence on the traffic jams. Also, Gupta et al. [65] also proposed a new lattice model of two-lane traffic flow with the consideration of driver's anticipation effect in sensing relative flux. Recently, more re However, these models did not take into account the multiple optimal current differences' anticipation effect since this effect may play an important influence on traffic flow for two-lane freeway. In this paper, an extended lattice model will be induced accounting for the multiple optimal current differences' anticipation effect to improve the stability of traffic flow for two-lane freeway. Also theoretic analysis and numerical simulation will be performed to investigate the traffic stability and jamming transition.

2. The extended model

Fig. 1 is the schematic model of traffic flow for a two-lane highway. In Nagatani's original two-lane lattice model, the lane changing rate is supposed as $\gamma\left|\rho_0^2 V'(\rho_0)\right|\left(\rho_{2,j-1}-\rho_{1,j}\right)$ from lane 2 to lane 1 if the density at site $j-1$ on lane 2 is higher than that at site j on lane 1, where γ is the rate constant coefficient with no dimension. Similarly, the lane changing rate is assumed as $\gamma\left|\rho_0^2 V'(\rho_0)\right|\left(\rho_{1,j}-\rho_{2,j+1}\right)$ from lane 1 to lane 2 if the density at site j on lane 1 is higher than that at site $j+1$. Then, Nagatani proposed the continuity equations for two-lane highway as follows [58]:

$$\partial_t \rho_{1,j}+\rho_0\left(\rho_{1,j}v_{1,j}-\rho_{1,j-1}v_{1,j-1}\right)=\gamma\left|\rho_0^2 V'(\rho_0)\right|\left(\rho_{2,j+1}-2\rho_{1,j}+\rho_{2,j-1}\right) \tag{1}$$

$$\partial_t \rho_{2,j}+\rho_0\left(\rho_{2,j}v_{2,j}-\rho_{2,j-1}v_{2,j-1}\right)=\gamma\left|\rho_0^2 V'(\rho_0)\right|\left(\rho_{1,j+1}-2\rho_{2,j}+\rho_{1,j-1}\right). \tag{2}$$

By incorporating Eqs. (1) and (2), we get the continuity equation with lane changing behaviors as follows:

$$\partial_t \rho_j+\rho_0\left(\rho_j v_j-\rho_{j-1}v_{j-1}\right)=\gamma\left|\rho_0^2 V'(\rho_0)\right|\left(\rho_{j+1}-2\rho_j+\rho_{j-1}\right) \tag{3}$$

where ρ_0, ρ and v represent the average density, the local density and local velocity, respectively. In addition, $\rho_j=\left(\rho_{1,j}+\rho_{2,j}\right)/2$, $\rho_j v_j=\left(\rho_{1,j}v_{1,j}+\rho_{2,j}v_{2,j}\right)/2$ and $V_e\left(\rho_j\right)=\left(V\left(\rho_{1,j}\right)+V\left(\rho_{2,j}\right)\right)/2$.

The evolution equation of traffic current on each lane will not be affected by lane changing. Hence, the evolution equation for two-lane traffic [58] was incorporated as

$$\rho_j(t+\tau)\,v_j(t+\tau)=\rho_0 V\left(\rho_{j+1}\right). \tag{4}$$

Furthermore, Peng [61] found that the optimal current difference effect has an important influence on two-lane traffic flow system and put forward a new two-lane lattice model with the optimal current difference term, which is given by

$$\rho_j(t+\tau)\,v_j(t+\tau)=\rho_0 V\left(\rho_{j+1}\right)+\lambda\Delta F_{j+1}. \tag{5}$$

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