COMMUNICATIONS IN COMPUTATIONAL PHYSICS
Vol. 3, No. 4, pp. 899-912

Commun. Comput. Phys.
April 2008

Stabilization of Traffic Flow Based on the Multiple Information of Preceding Cars

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Received 30 December 2006; Accepted (in revised version) 20 August 2007

Available online 11 December 2007

Abstract. To enhance the stability of traffic flow, a new car-following model is proposed by taking into account the support of intelligent transportation system (ITS) information, which includes both the headway and the velocity difference of multiple preceding cars. The new model is based on the Optimal Velocity (OV) model and its extended models. The stability condition of the model is obtained by using the linear stability theory. Through nonlinear analysis, the modified Korteweg-de Vries equation is constructed and solved, and the traffic flow is classified into three types, i.e. stable, metastable, and unstable. The jam phase can thus be described by the kink-antikink soliton solution for the mKdV equation. The numerical simulation results show that compared with previous models considering only one of the ITS information, the proposed model can suppress traffic jams more efficiently when both headway and velocity difference of arbitrary preceding cars are taken into account. The results of numerical simulation coincide with the theoretical ones.

PACS: 05.70.Fh, 05.70.Jk

Key words: Traffic flow, car-following model, stability analysis, ITS information.

1 Introduction

Traffic phenomena have attracted much attention from physicists in recent years. Many studies have been conducted with different traffic models, such as the cellular automaton models, car-following models, hydrodynamic models and gas kinetic models [1, 2]. The

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car-following model is one of the most important microscopic models that depict the motion of cars by differential equations. In 1995, Bando et al. [3] proposed the optimal velocity (OV) model which can describe many nonlinear characteristics of traffic flow, such as nonequilibrium traffic flow, jam formation and stop and go waves, and thus attracted much attention [4–7]. Generally, it is important to enhance the stability of traffic flow to avoid traffic jams.

Recently, with the development of the intelligent transportation system (ITS), the traffic control system has been utilized as a part of ITS, and drivers can receive information of other cars on the roads. Several traffic flow models have been proposed involving the use of ITS information [8–15] to enhance the stability of traffic flow. Nagatani [8] presented an extended car following model by taking into account the car interaction of before the next car ahead. Nakayama et al. [9] discussed the improvement of stability when a driver looks at the car that follows. Lenz et al. [10] extended the OV model by incorporating interactions of multiple cars ahead. Ge et al. [12–14] presented another car following model that incorporates the headways of arbitrary preceding cars. Hasebe et al. [11] proposed a fully extended OV model by taking into account the information of arbitrary cars that precede or follow. However, all of the above models considered only the interactions induced by the headways. On the other hand, based on the full velocity difference (FVD) model [5] (which is an extended OV model by introducing the velocity difference term), Wang et al. [15] presented the multiple velocity difference (MVD) model to improve the stability of traffic flow.

Previous studies indicate that the headway or velocity difference can stabilize the traffic flow. However, all existing models are only subject to one type of the ITS information, either headway or velocity difference of other cars. It is expected that the traffic flow can be more stable by simultaneously introducing both two types of the ITS information. Thus based on the OV model and its related models, an extended car-following model by incorporating both headways and velocity difference of multiple preceding cars, called multiple headway and velocity difference (MHVD) model, is presented in this paper. We then give the stability condition of the model by using the linear stability theory. Moreover, the nonlinear analysis is applied to derive the modified Korteweg-de Vries (mKdV) equation near the critical point, and its kink-antikink soliton solution to describe the traffic jam is also obtained. Numerical simulation is carried out to validate the theoretical analysis. Comparisons between previous models considering only one type of the ITS information and the proposed model here are made. The results show that in our model the stability of traffic flow is clearly enhanced when multiple ITS information is considered.

This paper is organized as follows: in Section 2, the OV model and two of its extended models are reviewed, and the MHVD model is presented. In Section 3 linear stability analysis is applied to the MHVD model. Nonlinear analysis of the model is given in Section 4. The property of our model is investigated using numerical methods in Section 5. Conclusions are summarized in the final section.