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EXTENDED ABSTRACT

Applying High-Resolution Wave Propagation Method in Numerical Modeling of Macroscopic Traffic Flow based on Driver Physiological-Psychological Behavior

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1. Introduction

In this paper, a high-resolution version of the Godunov-type second-order Wave Propagation Algorithm (WPA) for one-dimensional macroscopic traffic flow modeling is presented. The method is a well-balanced model and is able to behave the source terms within the flux-differencing adjacent to the finite volume method. The defined numerical scheme utilizes the advantage of combination both approximate and exact Riemann speeds which enables the method to avoid non-negative velocities. To the best of authors' knowledge, no development of WPA with high-resolution for the common macroscopic Payne- Whitham (PW) model and its extended versions has taken place so far.

2. Governing equations

2.1. Payne-Whitham model (PW)

The one dimension second-order macroscopic traffic model can be described as a hyperbolic system of conservation laws. Payne (1971) and Witham (2011) proposed a two- equation traffic flow model in conservative form. This model is still one of the most widely used second-order models today due to its relatively good ability to simulate traffic flow using the least variables. In this model the first equation devised for the vehicles conservation as a continuity equation within the road whilst the second equation calculated the acceleration of traffic pattern based upon the driver prediction, relaxation and traffic inertia.

2.2. Modified PW model

The PW model assumes that drivers respond similarly to different conditions and that small changes in speed and density occur. This is an inadequate description of the driver anticipation and can therefore lead to unrealistic traffic behavior and oscillation over short distances (Khan et al., 2020). Khan et al. (2019) in a study that is considered in this article to compare the results and improve it, by introducing traffic constant as a function of the driver physiological-psychological behavior and specifically the variables of perception, awareness, attitude and initial reaction, improve the common PW model.

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3. Methodology

3.1. WPA with high-resolution

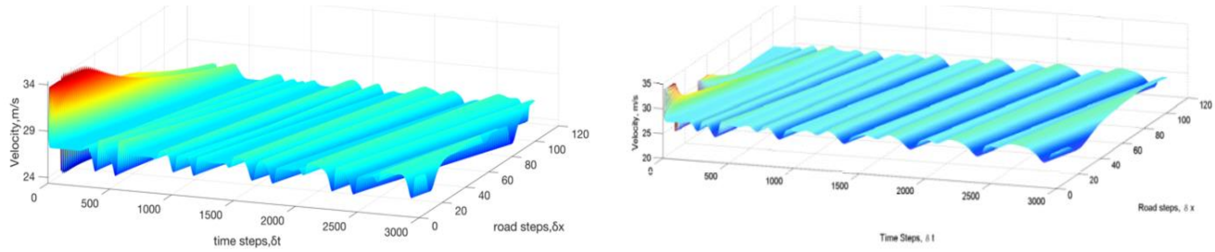
To solve hyperbolic system of conservation laws, a Godunov-type finite volume method called Godunov WPA is used, which was first proposed by LeVeque (2002). The WPA is a simple method for re-averaging the Riemann problem in an adjacent cell network for finite volume methods. Second-order high-resolution components, which include only flux correction components, can be added by the first-order Godonov method. To calculate them, a suitable limiter must be selected. In this paper, the Van Lear limiter is used.

3.2. Modified Flux Wave (MFW) formula

The flux-wave approach was firstly introduced by Bale et al (2003) for the solution of gas-dynamic problem. This method for Euler equations was modified by (Mahdizadeh, 2018). In this paper, this version, which has been developed for macroscopic traffic flow equations, is used. In this method, the Riemann problem must be solved in response to hyperbolic systems that may extend in some cases of a simple jump discontinuity along the characteristic line. To solve this problem, we used advanced Riemann wave speed developted by Mahdizadeh et al (2011).

3. Numerical Results and discussion

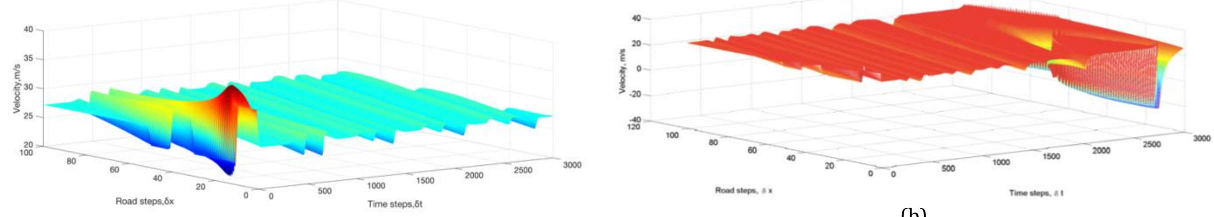
The performance of the proposed method has been evaluated by selecting the two mentioned models, so the queue propagation problem in uniform traffic flow mode with four discontinuities was selected for a circular road with periodic boundary conditions. Comparing the proposed algorithm with the decomposition Roe technique, which is commonly used to discretize the macroscopic traffic flow models, the spatio-temporal variations of the two speed (Fig. 1 & Fig. 2) and density variables and the relevant profiles at different times (for example: Fig. 3) were presented.



(a) (b)

Fig. 1. The traffic flow speed behavior of the Khan model based on: a) WPA with high-resolution, b) Roe Decomposition Technique (RDT)

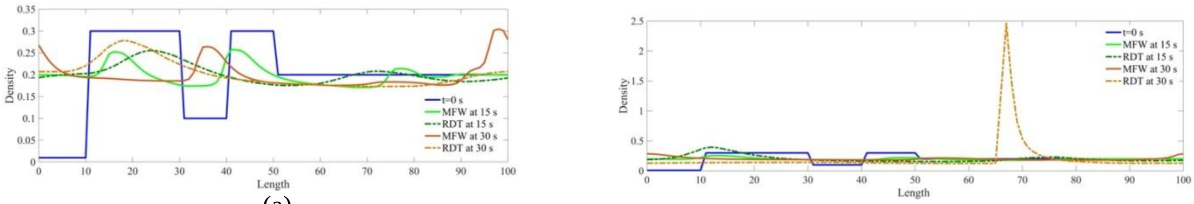
As shown in Fig. 1, both methods show the realistic response to changes in density. Specifically, the oscillatory behavior is controlled and no velocities greater than the maximum velocity are observed. Both methods have been successful in controlling the numerical diffusion, and finally both methods have the positivity conserving property and therefore have not calculated the negative response for the velocity variable.



(a) (b)

Fig. 2. The traffic flow speed behavior of the PW model based on: a) WPA with high-resolution, b) RDT

Examining Fig. 2, it is clear that for PW model, RDT show an unrealistic response to changes in density. The positivity conserving property is not satisfied and the model is unstable. While the WPA with high-resolution has made the model more stable, the oscillation behavior much more controllable, the property of positivity conserving has been observed, although it has not fully met the Plausibility condition.



(a) (b)

Fig. 3. The density profiles comparison of models based on proposed WPA with high-resolution and RDT at different times: a) Khan model, b) PW model

Fig. (3-a) shows that the amount of density fluctuations for both methods varies between 0.15 to 0.3, which indicates the appropriate behavior and low fluctuations. While Fig. (3-b) shows that the RDT is incapable of estimating the density variable. Density curve fluctuations increase over time, so the model is unstable. The amount of density in some places is more than one and has reached 2.5, which is impossible.

4. Conclusions

The results show that the proposed algorithm, in comparison with the RDT, provides acceptable consistent and stable responses with respect to the property of positivity conserving and controlling the numerical diffusion, especially for the conventional model, in estimating the basic variables of traffic flow.

5. References

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