Enhanced Cell Transmission Model for Urban Roads

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1 Introduction

Although CTM [1] [2] is originally developed for freeway traffic flow modeling, it is also used for modeling urban road networks with some extensions on the original principle. Pohlmann [3] presents an approach for evaluating signal plan with an enhanced CTM. 3-legged diverging and merging cells are defined according to similar mechanism to that of the original one. Floettoerd [4] presents the ideas about modeling the intersection by Incremental Node Model (INM), which is based on the incremental transfer principle of Daganzo [5] and Generic Node Model (GNM) of Tampere [6]. This work focuses on describing an intersection as a node that has multiple inflows and outflows.

Besides the topological consideration, there are also works on improving the calculation accuracy of CTM. Daganzo presents the lagged CTM [7]. In Lagged CTM, the vehicle density of several time steps before is used to calculate the current traffic volume.

In the application of urban roads simulation, the key point is to simulate the intersection. Most of the researches focus on the topological expression for intersections. Fewer attentions are paid on improving the original principles of cell density updating. From theoretical perspective, CTM determines cell length by the predefined free flow speed in the Fundamental Diagram (FD), but not considers the backward wave speed, which impairs the accuracy especially when analyzing scenarios with shock wave, e.g. queue forming at an intersection. In addition, as a discrete solution method for LWR model, CTM employs very simplified FD. For example, the FD does not change with time and space. Although the time-dependent FD ($Q(k, t, x)$) is describe in recent researches, such as [8], the similar idea is not widely researched based on the CTM framework in application. From practical perspective, the saturation flow rate of an entrance link of an intersection changes with the green time of the corresponding signal head, as described in [9]. This phenomenon can be described as time-dependent FDs.

This paper proposes a new approach for improving the accuracy of CTM by considering two more factors: the time-dependent FD and the uneven density distribution inside a cell.

2 Methodology

A time-dependent FD is defined for the specific cell that is just before the stop line of a intersection. This FD is determined by considering the average acceleration of the waiting vehicles.

The slope-limiter methods for conservation equations are summarized in [10]. The basic idea of these methods is to use an unevenly distributed density instead of the evenly distributed one. Therefore, the effectiveness of this method depends on whether a better density distribution can be estimated. Two extra steps are added into the original CTM process: 1) Slope determination; 2) Equivalent density calculation; the first one is used to determine which cell is estimated to have a inside slope for density distribution; the second one is used to calculate the equivalent densities that can be used in a typical CTM cell density update process. The regime limitation is implemented with those two steps in order to maintain the stability.

3 Model Evaluation

Numerical experiments are done without the time-dependent FD. The FD is defined as $q = min\{k, (180 - k)/5\}$. In the first test, we use an initial density profile that is set to be

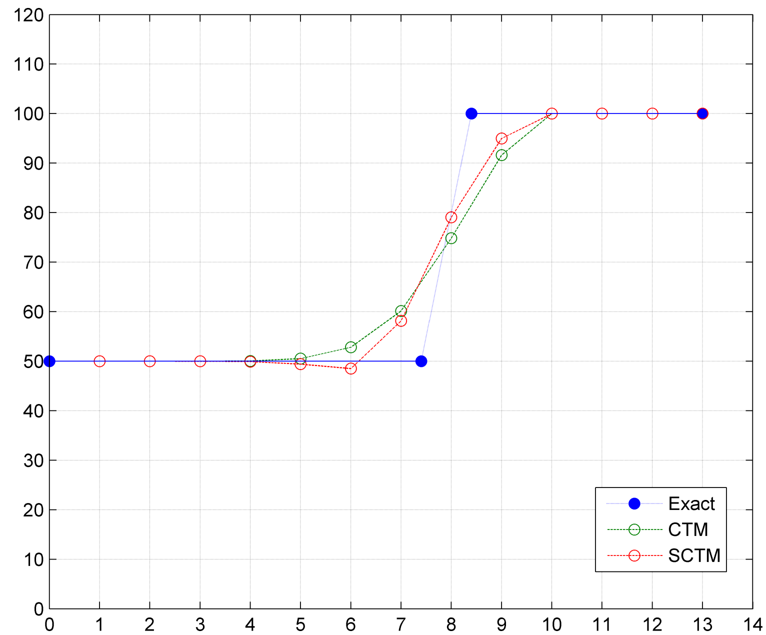

Figure 1: Results for Riemann initial value problem

$k(x, 0) = 50 + 12x^2, (x \in [5 : 10])$, and compared the simulated results of SCTM and CTM to the exact solution. The second test is operated for a Riemann initial value problem. The initial density profile is $k(x, 0) = 50$, if $x \in [1, 9]$, and $k(x, 0) = 100$, if $x \in [10, 12]$. The results for the $8th$ time step is shown in Figure. 1

In addition, the SCTM is compared with the classic CTM for the example of an idealized intersection. A corresponding VISSIM model is used as the reference. The test link is defined in VISSIM as below: a link with 2 lanes, the total length of it is 350m. At the position of 240m from the vehicle input point, a signal head is placed, which is used to generate an interruption for the traffic flow. For the corresponding SCTM (CTM) models, cell length is set to be 20m. Therefore, there are 12 cells before the stop line. The input vehicle volume is set to be changing from 100 veh/h to 1500 veh/h, in order to generate various queue states. Signal cycle is 20s, displayed green time is 5s. The test focuses on evaluate the output volume of the intersection during the green time. The test is operated as the following description: the original vehicle density of each cell is read from VISSIM model for each time point just before the signal light changes from red to green. Based on those data, SCTM and CTM run independently for 5 seconds. The traffic volumes for the green time for each cycle are collected. Compared with the reference data from VISSIM, the average volume error of SCTM for the tested 30 cycles is 10.1% and the corresponding data of CTM is 14.2%.

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