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A cell automation traffic flow model for mixed traffic

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Abstract

Based on the existing research on cellular automata traffic flow model, this paper proposed an improved model for mixed traffic flow in real-time traffic data environment in China. Driver's characteristic is defined according to the NS model and the FI model. In accordance with the mixed traffic flow, a cellular automaton traffic model is proposed. In this model, vehicles are defined in different lengths and different maximum speed, and mixed on single lane and bi-lane with periodic boundary condition. The traffic flow characteristics are analyzed and discussed by computer numerical simulation.

Keyword: Cellular automata; the mixed traffic flow; Computer numerical simulation

1. Introduction

Currently, the traffic has become one of "bottleneck" plagued the development of cities .The study on traffic flow model is divided into three types: hydrodynamic model, the gas kinetic theory model, Car-following model and cell automation model based on microscopic discrete description. Cellular automata model which is discrete in time, space and status, does not require a specific formula. It is also suitable for computer simulation. Just give the corresponding evolution of the rules; therefore, it has been a great of attention. If it has a reasonable design of the evolution rules, it will be able to simulate many complex non-linear phenomena traffic problem, and reveal the nature of transport phenomena better in order to solve the traffic problems.

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Cellular automata (Cellular Automata, referred to as CA), in the transport system, CA model is described as follow: the time, vehicle position, velocity and acceleration are all considered to be discrete variables. Sections are divided into several cells with the length of L.A cell corresponds to one or several vehicles, or a few cells correspond to a car. Each cell is empty or accommodates the speed of the vehicle. The vehicle speed is defined as the moving forward cell number in a time step (Jia & Gao, 2007) .

The state of the system updated in accordance with a set of predefined rules. The Model of No. 184 is the most simple one-dimensional cellular automaton traffic flow model named by Wolfram. In this model the road is divided into L lattice point of one-dimensional chain. Each grid point represents a cell, and each cell is empty or is occupied by vehicle. All vehicles travel the same direction. At each time step if the grid point of the front is empty, the car can move forward a grid, or the car stands still.

This paper proposed a new improved model considering the reality of mixed traffic flow characteristics based on the cellular automata theory and the study of existing traffic flow cellular automaton model. Study different lengths and maximum vehicle speed of mixed flow lane and two-lane cellular automata traffic flow model with the periodic boundary conditions. Analyze affect by computer simulation of various parameters on the speed of traffic flow.

2. Cellular automata traffic flow model

2.1 NS model

The famous NaSch model is proposed by Nagel and Schreckenberg in 1992. Compared with the 184 model, the main improvements of NaSch model is the introduction of the moderator probability, and the maximum speed is no longer 1. In this model, the roads are divided into discrete lattice (cell). Each cell is empty or is occupied by a car. The speed of each vehicle can take 0, 1, 2…, is the maximum speed. The model follows the following rules of evolution in the t to t +1process (Hua and Liu, 2004) .

⑴step1：Accelerate, ⟶ min () ；Corresponds to reality, drivers hope to travel at a desired maximum speed.

⑵step2：Decelerate, ⟶ min () ； Drivers hope to avoid collision to take reduction measures.

⑶step3：Random slowing down, with probability p，⟶ max () ； The vehicle caused by the uncertainties deceleration.

⑷step4：Movement，⟶ +; The vehicle moved forward according to the adjusted speed.

2.2 FI model

FI model is proposed by Japanese scholar Fukui and Ishibashi's in 1996. FI model changes the first and third step update rules of NS model: in accelerating step, if the number i vehicle's speed has not yet reached maximum speed = M (M> 1), and its neighbors in front of all the M grid points is empty, no matter how much its speed, it can directly accelerate to; If the number of spaces is only N (N <M), then

The vehicle can only move the N grid points. In the random deceleration step, maximum speed of the vehicle, the speed reducer is 1 with probability p; the other which does not meet the maximum speed of the vehicle keep the original speed. Compared with the NS model, FI model has the following features (Liu and Yu, 2005) :

(a) Vehicle acceleration process is not complete step by step; you can directly accelerate from 0 to speed.

(b) Only those vehicles whose speed is can slow down randomly. When = 1, FI model degenerate into NaSch model; when =1， p=0 时, FI model is equivalent to 184 model.

2.3 Bi-lane cellular automata model

The single lane cellular automaton model for vehicular traffic, a very important deficiency is not allowed to overtake, but in actual road traffic the overtaking phenomenon is widespread. If you have a different

maximum speed of the vehicle into single lane model, it will cause serious queues: the Express can only follow behind the slow vehicle system, the average speed of no more than slow the maximum speed, which is obviously incompatible with the reality of traffic. In order to simulate a more realistic traffic, NaSch model extended to Bi-lane system (Li & Jia,et al. 2011).

Bi-lane cellular automata model of the implementation process, each time step is generally to be divided into two sub-time steps: in the first sub-step, the vehicle in accordance with the rules for channel change lanes; in the second sub-step, the vehicle Bi-lane road on bicycle update in accordance with the rules to be updated. Motivation to change lanes is usually composed of two parts: 1> the driving conditions of next to the trail are better; 2> in the trail vehicle speeds cannot be as expected. To achieve change lanes must meet two prerequisites: ① change lanes motivation, that is, whether this car is trying to change lanes; ② safety conditions, that is, if the car want to change channel, whether other vehicles of its own is safe, that is, to ensure crash does not occur.

Motivation to change lanes

(2) Safety conditions

represent the position and speed of the number n vehicle; is empty cell number between the n vehicle and the vehicle in front; is the length of vehicle; is the cell number between the first vehicle and vehicle in front next to trail; is the cell number between the first vehicle and the rear vehicle next to the trail; is to ensure a safe distance from crash; maximum speed. Vehicles are not according to the desired speeds; indicated the driving conditions of next to the trail are better.

If all the above rules are met, then the vehicle changes lanes. Lane conversion is complete before speed update, the decision to exchange the vehicle lane to another lane to occupy the adjacent cell, after the two-lane speed update on the vehicle and position updates are independent.

3. Cellular automaton traffic flow model simulation and analysis

3.1 NS model simulation and analysis

Now, we will simulate basic NS model. Take the lane length L=1000 grid points (cell) with a maximum speed Vmax = 5cell/s, the slow random probability P=0.5, do not take into account the boundary conditions, use periodic boundary conditions, the total of each sample time step for the evolution of 10,000 steps (Xue, 2008).

Figure 1 shows the traffic model NS-density diagram, it is clear that when no vehicles on the road density ρ=0, the flow rate q=0; when the density reaches its maximum then occurred on the road blocked, traffic is down to 0; Traffic flow in the intermediate density range of memory in a maximum. Relationship between the measured flux density is often intermittent; Looks like the Greek letter λ, mirroring, anti-λ, the two branches were used to define the free flow and congested flow. Figure 2 shows the rate of the NS model-density diagram, showing that in the free flow speed close to the maximum, and decreases in the crowded velocity.

3.2 FI model simulation and analysis

Simulation conditions: L=1000, Vmax=5cell/s, P=0.5.

Figure 3 and Figure 4 describes the FI model flow-density relations and the speed-density relationship, and NS model, apparently in the same situation than the NS model FI model flow. FI model cannot describe the real-time traffic stop appears to go when the phenomenon, but it can get the exact solution. NS model can be accelerated and FI model to define the characteristics of the different characteristics of the driver, which, according to the NS model is defined as the acceleration of the vehicle drivers cautious type, and according to the FI model is defined as the acceleration of the radical type of vehicle drivers.

3.3 maximum speed and different slow probability impact on the traffic flow

Here we will simulate the impact of the vehicle speed and slow random probability on the traffic flow. Assuming the road formed by a single type of vehicle and the vehicle maximum speed Vmax=1, 2,3,4,5 cell/s, slow random probability Pd=0.1, 0.3, 0.5, L=1000 (Lin & Lin, et al. 2006).

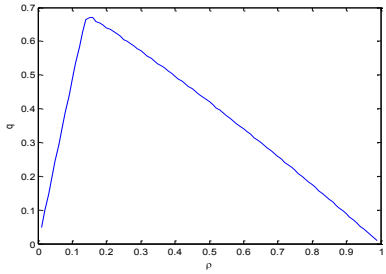

Fig 1 NS model flow-density diagram

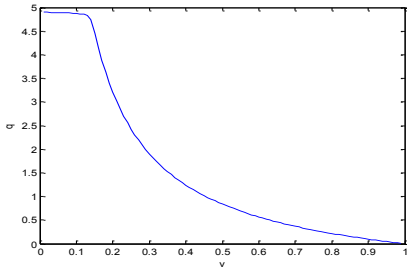

Fig 2 NS model speed-density diagram

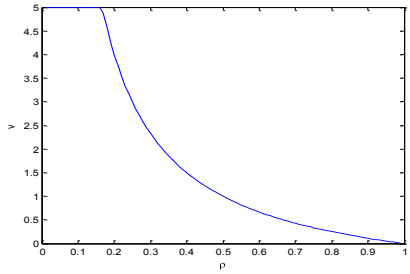

Fig 3 FI model flow-density diagram

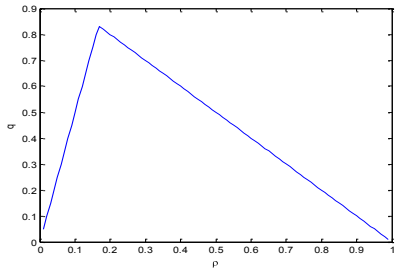

Fig 4 FI model speed-density diagram

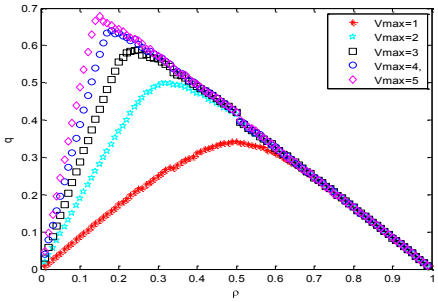

Fig5 different maximum speed flow-density diagram

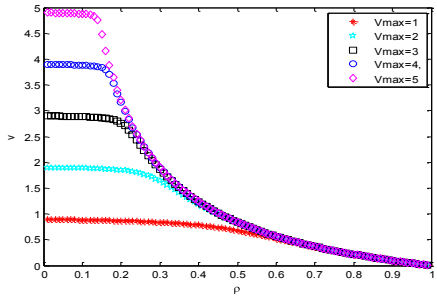

Fig.6 different maximum speed-density diagram

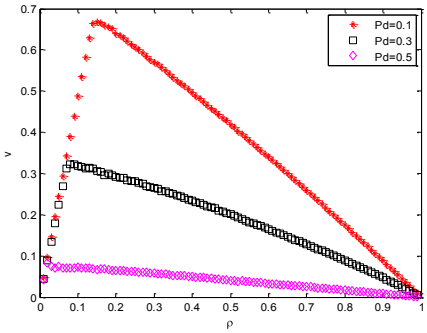

Fig.7 different deceleration flow-density diagram

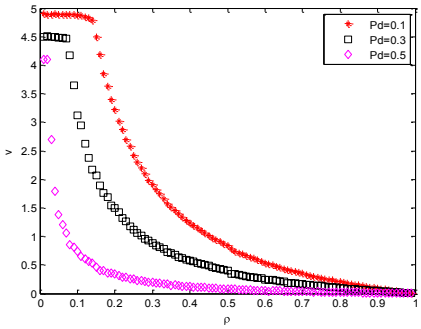

Fig.8 different deceleration speed-density diagram

As can be seen from Figure 5 when the maximum vehicle speed increases, the critical maximum flow value increases, the maximum flow rate corresponding to the critical density decreases, which is consistent with the actual. Figure 7 shows that in NaSch model, with the increase of slow random probability, critical value for maximum flow and maximum flow rate values corresponding to the density values are significantly reduced, we can see the slow random probability effect on traffic flow particularly large. Figure 6 and Figure 8 show the speed-density diagram under the different maximum speed and slow random probability , can be seen from Figure 6, with the vehicle's maximum speed increases, the average speed of vehicles on the road also increases, can be seen from Figure 8 with the slow random probability increasing, the average vehicle speed will be drastically reduced.

4. single lane mixed traffic flow model simulation and analysis

Taking into account the universality of mixed traffic flow, periodic boundary conditions were investigated under different length, maximum speed of mixed vehicles traffic flows. The length L of the road is a one-dimensional discrete lattice chain, every moment, the grid may be occupied by two kinds of different length, maximum speed vehicles. Short car occupies two grid points, long car by four grid points, the maximum slow speed = 6cell/s, the maximum express= 8cell/s. Status of each type of vehicle speed indicated by its own, ∈ [0,], j = 1,2 with (t) at time t the vehicle's rear position, and(t) =- is the space between vehicle and in front of neighbors (i + 1); In each evolutionary time step t → t + 1, the vehicle in accordance with the rules of NaSch model to update velocity and position. Using NaSch model because it reflects the basic characteristics of traffic flow and more convenient to see the maximum vehicle length and vehicle speed on the impact of mixed traffic flow.

The road length L=5000 grid points in the simulation. Initially, different vehicles are in the driveway with a random distribution coefficient n, and its initial velocity is zero.

4.1The length of vehicle affects traffic flow simulation and analysis

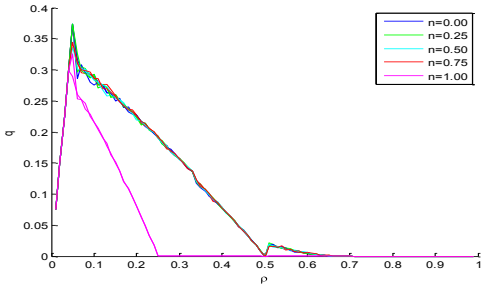

Fig.9 different length flow-density diagram

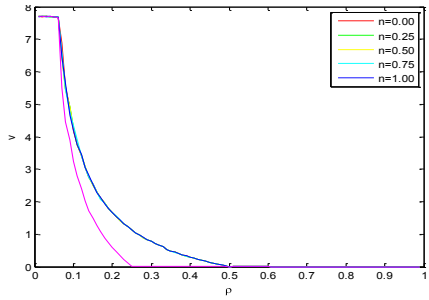

Fig.10 different length speed-density diagram

Figure 9 and Figure 10 for the same maximum speed of vehicles, long vehicle = 4cell, short vehicle =2cell, random braking probability p=0.5, when the length of the mixed ratio coefficient n=0.00, 0.25, 0.50, 0.75, 1.00, the flow-density diagram and speed-density diagram. In the freedom phase, movement can be seen in the mixed traffic flow around the average maximum speed of 7.697cell/s, has nothing to do with the mixed factor. In the congested phase, mixed traffic flow is between the average speed only a short vehicle (n=0.0) and only a long vehicles (n=1.0), as n increases, the average velocity increases. This is because, in the congestion phase, in the case of certain density, n value is greater, the smaller the total number of vehicles, between vehicles, the smaller the impact, and then the average speed increases. Therefore, in the different length composition of the of mixed traffic flow of vehicles, if the maximum speed of vehicle is same, then the critical density determined by the mixed ratio coefficient n; In the free phase, the flow reduce with the mixed ratio n increasing, the average speed and mixed ratio coefficient n is almost independent; In the congestion phase, the average speed as the n value increases, the basic flow has nothing to do with n. This in the long and short of the same maximum speed is basically the same result, but the maximum flow rate and the critical density to be larger.

4.2 mixed vehicle impact speed of simulation and analysis of traffic flow

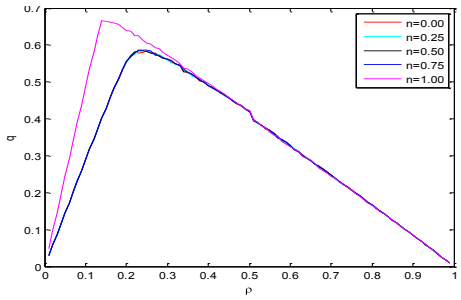

Fig.11 different speed flow-density diagram

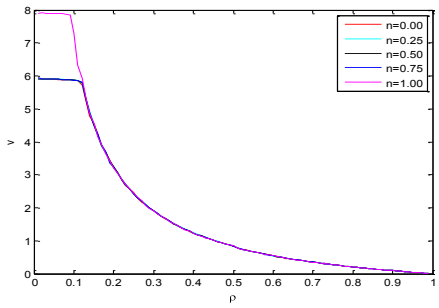

Fig.12 different speed speed-density diagram

Figure 11 and Figure 12 for the vehicle of the same length, the maximum slow speed = 6cell/s, Express speed = 8cell/s, random braking probability p=0.5, when the two speed of cars mixed ratio coefficient n=0.00, 0.25, 0.50, 0.75, 1.00, the flow-density and velocity-density diagram. When f=0.00, the only express lane, then the model becomes the NS model in the maximum speed of 8cell/s; when f=1.0, only the slow lane, corresponding to the maximum speed for the 6cell/s of the NS model. When 0<f <1, the vehicle

mixed for the two types of cars, from Figure 11 we find that when 0<f <1: (1) mixed traffic flow-density diagram and f=1.0 (the only slow) flow-density diagram completely coincide. Particularly, the slow one affected traffic flow clearly, even if there are a small amount of slow ones, which also had a serious impact on traffic flow. (2) In the case of the low-density (ρ<0.13) in the mixed vehicles speed-density diagram, f smaller (i.e., express a few more), the greater the speed, when ρ> 0.13, the mixed density diagram and the vehicle speed f=1.0 (the only slow) speed-density diagram completely overlap. Clearly, the average speed of mixed entirely decided by the slow ones. It can be seen in the single lane model, the flow of mixed traffic flow and speed of traffic and entirely decided by the slow speed, which is the maximum traffic characteristic in the mixed vehicle driving in the single lane.

5. STUDIES on bi-lane mixed traffic model

This section simulation analyzed two different lengths, two different maximum speeds of mixed traffic flow on the bi-lane. In which L=1000 grid points, a short car=2cell, corresponding to the maximum speed limit of 8cell/s; long car=4cell, corresponding to the maximum speed limit for the 6cell/s, slow, probability, p=0.5 (Li, 2007).

Figure 13 and Figure 14 show when the mixed ratio coefficient n= 0.00, 0.25, 0.50, 0.75, 1.00 the flow-density and velocity diagrams-density diagram. In the two-lane, mixed traffic flow entirely decided by the slow , in the case of low density, which express a few more high speed car, the greater the average speed, when the density increases, the average vehicle speed mixed entirely by slow speed decisions, and prone to local congestion and stop-and-go phenomenon. This is the largest traffic characteristic in two-lane mixed vehicle. Similarly, the vehicle deceleration probability and stochastic characteristics of the different drivers will also play an important role in traffic flow and mixed vehicle state. In short, two-lane mixed traffic, compared with the single lane mixed traffic, improved traffic flow and took full use of the road usage. But compared the mixed vehicle model for two-lane traffic flow with the same type of vehicle model for two-lane traffic flow, it is more likely to occur local congestion and stop-and-go phenomenon. Therefore, the actual traffic in the different types of vehicles should be based on rational design of lane conditions and lane diversion of operating rules, to achieve the separation of different vehicles, traffic flow, and vehicle flow of the mixed ordering, so we can better improve the road traffic ability to improve the traffic environment (Zhu & Wang, et al. 2013).

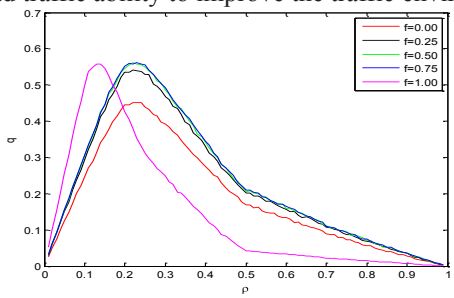

Fig.13 Bi-lane mixed traffic

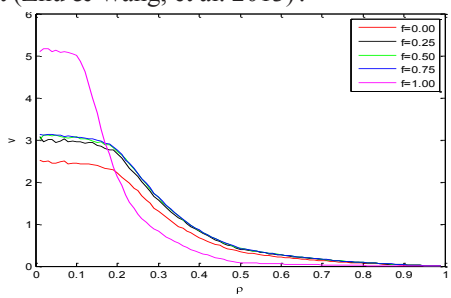

Fig.14 Bi-lane mixed traffic flow-density diagram speed-density diagram

6. CONCLUSIONS

As can be seen by the computer simulation, in the single lane model, the hybrid vehicle traffic flow and speed entirely decided by the slow speed, that is the maximum traffic characteristic in hybrid vehicle driving. Simulation results showed that two-lane mixed traffic, compared with single lane, not only improved traffic flow, but also took full advantage of usage of the road, but the impact of slow car on traffic flow is still large, even though a few will result in slow queues. Mixed traffic in a variety of nonlinear phenomena, could easily lead to local traffic congestion; reduce traffic flow and road usage and so on. With the actual traffic, analysis and research on the characteristics of hybrid vehicular traffic, made a number of effective measures to improve the mixed traffic (egg: In the actual mixed traffic, different types of vehicles

should be based on rational design lanes and lanes of the operating rules, traffic flow to achieve the separation of hybrid vehicles, so that it can increase the road capacity and improve the traffic environment).

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