Advanced Materials Research
ISSN: 1662-8985, Vols. 1030-1032, pp 1937-1940
doi:10.4028/www.scientific.net/AMR.1030-1032.1937

Submitted: 2014-06-04
Accepted: 2014-07-10
Online: 2014-09-22

A Cellular Automata Asymmetric Lane-changing Model With Mixed Traffic

Jianhui Zhu
School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China
12120997@bjtu.edu.cn

Keywords: cellular automata; asymmetric lane-changing; mixed traffic flow; bus ratio.

Abstract. Considered the influence of buses on cars' change lanes and lane-changing of buses, this paper built an asymmetric cellular automata lane changing model under mixed traffic flow based on symmetric two-lane cellular automata lane-changing model and studied driveway occupancy and road characteristics with related parameters. Computer simulation showed that bus ratio has significant impact on lane-changing probability of vehicles.

Introduction

Traffic problem has become a big problem in human society. As a kind of highly discrete mathematics simulation model, cellular automata model can effectively simulate the individual micro motion of the vehicle and become an important research in the field of road traffic flow since the 1990's.

In 1992, NaSch model is put forward by Nagel and Schreckenberg (hereafter referred to as NS), which can reproduce road traffic flow characteristics as a minimize model[1]. On the basis of NS model, people put forward various kinds of improved single model, like TT model using slow start rules[2] and VE model considering the front vehicle speed[3]. In 1997, Chowdhury et al., constructed a symmetric two-lane STCA model (Symmetric Two - lane Cellular Automata) based on NS model, which solve the problems such as single, unable to overtake in the NS model[4]. Wang Yongming introduced the concept of flexible safe lane changing distance based on the STCA model[5].

Cars and buses mixed driving is common in the road traffic flow. Qian Yongsheng et al., set up cellular automata model considering bus and bus bay bus stop[6]. Jia Bin et al., studied the characteristics of urban road traffic flow under the influence of the bus station[7]. This paper establishes multiple lanes cellular automata model considering the influences of the bus and study the characteristics of traffic flow under asymmetric lane changing rules.

Modeling Method

This paper establishes improved single cellular automata model which combine the characteristics of TT model and VE model. Steps are as follows:

(1) Acceleration: $v_n(t+1) \to \min(v_n(t)+1, v_{\max}, v_n^{'}(t+1))$;

(2) Slow start: if $flag = 1$, with probability p_s, $v_n(t+1) \to 0$;

(3) Deceleration: $v_n(t+1) \to \min(v_n(t)-1, v_n^{'}(t+1))$;

(4) Random moderated: with probability p, $v_n(t+1) \to \max(v_n(t+1)-1, 0)$;

(5) Location updating: $x_n(t+1) \to x_n(t) + v_n(t+1)$.

In the formula, $v_n(t+1)$ denotes the speed of vehicle n (car or bus, the same below) in time t+1, $v_{\max}$ denotes the maximum speed of the vehicle. $v_{n+1}(t)$ is the speed of the vehicle ahead in time t. $v_n^{'}(t+1)$ is the maximum speed vehicle n can achieve in time t+1 according to the distance between vehicle n and the vehicle ahead in time t and the speed of the vehicle ahead. $flag$ is used to distinguish whether a car using slow start rule $(flag = 1)$ or not $(flag = 0)$. If $flag = 0$, vehicle will run with probability $1-p_s$. P is probability of random moderated. $x_n(t+1)$ denotes the location of vehicle n in time t+1.

$d_n(t)$ is the distance between vehicle n and vehicle ahead in time t, which is calculated with $d_n(t)=x_{n+1}(t)-x_n(t)$,and

$$v_n^{'}(t+1)=\sqrt{2(d_n(t)+(v_{n+1}(t))^2/2)} \tag{1}$$

Lane changing rules can be divided into symmetric and asymmetric for the two-lane traffic. Vehicle lane changing probability is nothing to do with its direction when drivers use symmetry rules in the process of change lanes. STCA model is a classic model of the symmetric two-lane. It includes two parts of lane changing and single driving, and single driving run according to the NS model. Lane changing rules includes the following two parts:

(1) Lane changing motivation:

$d_n < \min(v_n+1, v_{\max})$ and $d_{n,other} > d_n$

(2) Safety conditions:

$d_{n,back} > d_{safe}$

$d_{n,other}$ is the distance between vehicle n and the vehicle ahead on lane changing lane. $d_{n,back}$ is the distance between vehicle n and the vehicle behind on lane changing lane. d_{safe} is the minimum safe distance that can guarantee never to run in crash.

Considering the influence of the buses when cars change lanes, model join the lane changing probability of cars affected by buses, schematic diagram is shown in Fig. 1.

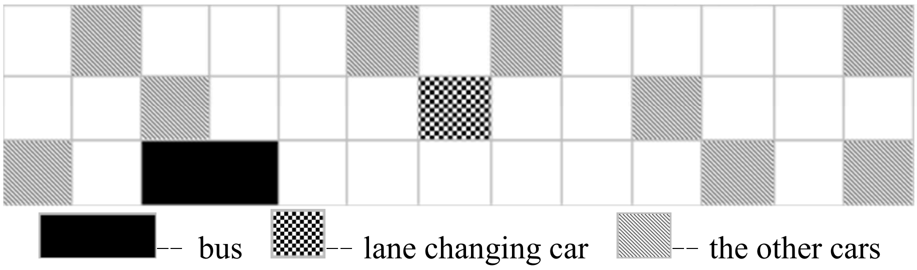

Fig. 1 Schematic diagram of lane changing cars affected by bus

The basic steps of the model include lane changing and driving on single lane. And the rule of driving on single lane comes from the improved model of single rule described earlier. Lane changing rule is as follows:

(1) Lane changing motivation:

$v_{rl}(t+1) > v_f(t+1)$

(2) Safety conditions:

$v_{rl}(t+1) > v_b(t+1)$

The model divides lane changing into the following kinds: considering the influence of the bus when car change lane and there is bus on the changing lanes behind; when bus change lane, it run relatively stable for the large volume and low speed; the third condition is that the lane changing car is not affected by bus.

In view of the front two lane changing conditions, the model join probability of the vehicle lane changing, which is calculated with

$$p_{change}=\frac{p_{rl}}{type^{p_{bus}}} \tag{2}$$

Vehicles will choose to change lane with the probability p_{change} when meet lane changing motivation and safety conditions at the same time. $v_{rl}(t+1)$ is the speed of vehicle run as single lane rule in time t+1 if it want to change lane (left or right). $v_f(t+1)$ is the speed of vehicle run forward in time t+1. p_{rl} is the probability of lane changing. The probability to the left lane changing is bigger than right in the model. $type$ is the vehicle type, which bus is equal to one and car is equal to two. p_{bus} is the probability affected by bus. $v_b(t+1)$ is the peed of vehicle on the changing lane behind. This rule join factor that vehicle affected by bus when changing lane. Vehicle will choose to change lane when meet lane changing motivation and safety conditions at the same time and there is car on changing lane behind. But it needs to consider the influence of bus when there is bus on changing lane behind. When meeting lane changing motivation and safety conditions at the same time and vehicles are about to change lane, the value of slow start probability p_s is zero, which is different from single lane model before.

The realization of the cellular automata model simulation needs programming method and this paper uses the MATLAB software for simulation. There are three lanes and each lane occupy 1000 cellular. The initial moment all vehicles are randomly distributed and the generation of vehicles follows Poisson distribution. Assuming that the maximum speed of cars and buses are three and two respectively, which a unit of the corresponding speed is $18km/h$. The values of the probability to the left and to the right lane changing are 0.4 and 0.3 respectively. The lane changing probability affected by bus is $p_{bus}=0.4, p_s=0.2$. The probability of random probability affected by bus is $p_{bus}=0.4, p_s=0.2$. The probability of random moderated is 0.3.

The variation diagram of three lanes occupancy with time is obtained by simulation, as shown in Fig. 2. The diagram plotted by simulation time and the number of vehicles on lane. Lane1, lane2 and lane3 represent three lanes from left to right respectively.

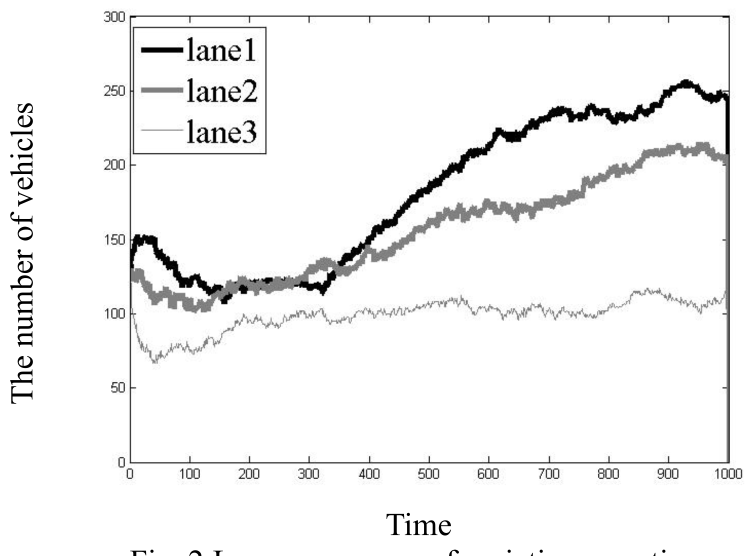

Fig. 2 Lane occupancy of variation over time

The occupancy of three lanes are respectively lane 1>lane 2>lane 3, which affected by asymmetric lane changing rules. The vehicles to the left lane changing are more than to the right lane changing. Because of joining the rule that cars change lane affected by buses in the model, the probability of changing to lane 2 is small when cars run on lane 1, which cause vehicles increase gradually on the lane. Buses will have larger probability to change to lane 2 when lane 1 gets crowded. Buses are more likely to meet desired speed as the maximum speed is low (two units). The lane changing motivation of buses is small when there is little traffic on lanes, which led to lots of buses on lane 2. It also has effect on lane changing of vehicles on lane 3.

Considering bus ratio on road is not much, the model simulates traffic under values from 0 to 0.35. Vehicles lane changing under different bus ratio is shown in Fig. 3. We can see that the lane changing probability of all vehicles increases with the rise of bus ratio when it is low. The average speed of vehicles on road is high this moment, and the rise of bus ratio will reduce speed, which increase the lane changing probability of vehicles. When bus ratio arrive certain values, the lane changing probability of vehicles decreases with the rise of bus ratio.

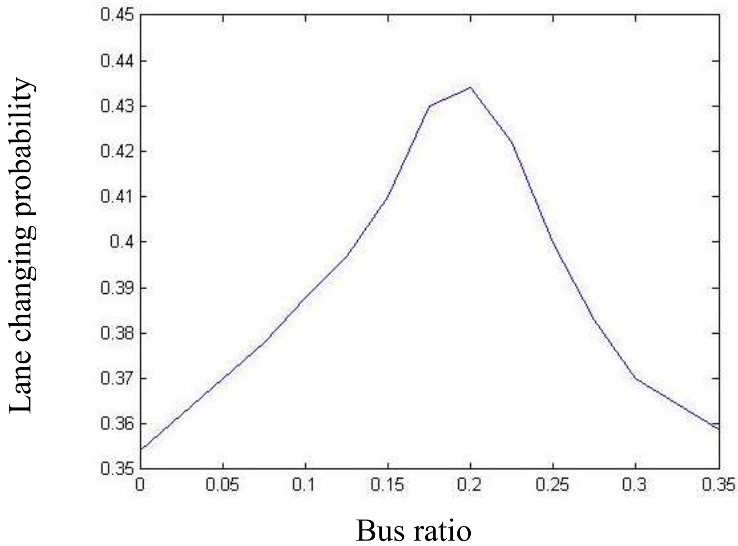

Fig. 3 The influence of bus proportion of vehicle lane changing probability

Conclusion

This paper considers lane changing of car affected by bus and lane changing of bus respectively and put forward an asymmetric lane changing model of cellular automata under mixed vehicles to research road conditions with three lanes. By numerical analysis, we find that the occupancy of three lanes affected by asymmetric lane changing rules and buses are different, which the largest on the left side and the smallest on the right side. Besides, the lane changing probability of all vehicles affected by bus ratio in mixed traffic flow is different under wide range.

References

[1] L. Peng, R. Kang. One-dimensional cellular automaton model of traffic flow considering drivers' features. ACTA PHYSICA SINICA, Vol. 8 (2009), p. 830.

[2] B. Jia , Z. Gao and K. Li. Cellular automata traffic system modeling and simulation. Science Press, Beijing, 2007.

[3] X. B. Li, Q. S. Wu and R. Jiang. Cellular automaton model considering the velocity effect of a car on the successive car. Phys. Rev. E 64, 066128(2001).

[4] D. Chowdhury, D. E. Wolf and M. Schreckenberg. Particle hopping models for two-lane traffic with two kinds of vehicles: effects of lane changing rules. Physica A 235, 417-439(1997).

[5] Y. Wang, L. Zhou and Y. Lv. Cellular Automaton Traffic Flow Model Considering Flexible Safe Space for Lane-changing. Journal of System Simulation, Vol. 20 (2008), p. 1159.

[6] Y. Qian, H. Wang. New Cellular Automaton City Traffic Model Considering Public Transport Vehicles Affect with Mixed Traffic Flow. Journal of System Simulation, Vol. 19 (2007), p. 3358.

[7] B. Jia, X. Lin, R. Jiang and Z. Gao. The influence of bus stop on the dynamics of traffic flow. ACTA PHYSICA SINICA, Vol. 58 (2009), p. 6845.