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Research on Highway Short-term Traffic Simulation Based on Measured Data Fitting

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Abstract

In this paper, we analysis a short-term probability distribution of steady-state traffic flow that are based on field observations and establish a cellular traffic simulation model conforming to the reality, propose a model based on measured data fitting and the model is suitable for the short section traffic of microscopic traffic simulation. simulating with the traditional method and comparing with the measured data ,the model obtains a good effect.

Keyword: *generalized least squares; section traffic; Traffic simulation; Cellular automata*

1. Introduction

Before solving the traffic problem and establishing intelligent transportation system that aimed on efficient use of road resources, we simulation analysis based on the system and evaluate system performance and rationality to make the right decisions and effective prediction comprehensively. Microscopic traffic simulation technology is applied as that. Microscopic traffic simulation is a traffic analysis technology of complex spatial and temporal variation of traffic flow，it can assess and predict every traffic conditions.

Section grid model is a very important part in microscopic traffic simulation model [1, 2], determining the performance parameters of the traffic system and the simulation results. Any a microscopic traffic simulation platform is the departure is the starting point of the whole simulation [3].

There is a simulation area in microscopic simulation, the boundary of area is called section. When entering the simulation area，we can get the distribution of the section by statistics. We can use mathematical model to approximately describe the through case of traffic flow, and to conclude a microscopic simulation platform initialization parameters of vehicle with computer. At home and abroad，some people study generate models of traffic simulation system.

Xianyan kuang, hong xiao, xiao wang [5] provide how to make use of monte carlo (MC) to describe the general method of studying the probability distribution of object approximately and they design a pseudo random number generator of high quality ,then studying how to get the common random distribution of traffic generation model algorithm in traffic system.

Zhifeng mo, jia yu, yue sun [6] provide a section grid model that based on poisson distribution is applicable to the microscopic traffic simulation and at the foundation of the analysis of the traffic flow probability distribution. Bo liu, yunlong ma [10] provide a reproduce microscopic traffic simulation system. In order to simulate the microscopic traffic simulation model the reality, they sample randomly,or produce random variables of obeying a certain distribution .And considerring the model random, personality factor random and speed

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random. Besides, kui li, jian wang [12]provide a short-time cast of fast traffic on the road, they make the real-time data from the coil on the road as generating traffic flow, then inputting this data in traffic simulation system to simulate.1 the traditional section traffic produce model

Simulation platform is required to evaluate various traffic conditions and the authenticity of the grid model generally and practically. At present, the arrival of the vehicle at a certain time interval number are described by general discrete distribution. The commonly used discrete distribution has three types as following [11]:

1.1 Poisson distribution

Poisson distribution, can be used to describe the number of vehicles of a certain time interval number of vehicles or within a certain distance distribution, when traffic density is not large, the mutual influence between vehicles is smaller, under the condition of other interference factors basically does not exist, Poisson distribution can better fitting the road traffic data, Poisson distribution with a probability density function:

$$P_t(n) = \frac{(\lambda)}{n!} e^{-\lambda} \quad (1)$$

1.2 binomial distribution function

In the crowded traffic flow，bcause the reduce of opportunity that vehicles running freely ,the variance of observation data is small. At this point, the number of arriving vehicles distribution accords with the binomial distribution function, said:

$$p_x = c_x^n \left(\frac{\lambda t}{n}\right)^x \left(1 - \frac{\lambda t}{n}\right)^{n-x} \quad (2)$$

1.3 Negative binomial distribution

When the number of vehicles by observation at a certain period continues to peak and off-peak period, the data we get may have larger variance. Such as choosing the downstream of light to observe, we can find traffic flow is large at the former part time of signal cycling time, it always be in the degree of saturation, while at the latter part time of signal cycling time, the traffic flow is small. However, when the count period is applied to the green signal or the entire light cycle, this effect is not obvious. If the cycle count is short, it will have a big variance, the situation can use the negative binomial distribution fitting the observed data. Negative binomial distribution can be represented as:

$$p(x) = c_{k-1}^{x-k-1} \left(\frac{\lambda t}{n}\right)^k \left(1 - \frac{\lambda t}{n}\right)^x \quad (3)$$

Among the three methods, poisson distribution is the main method. In the actual traffic flow, the arrival of the vehicle is random and discrete. We can find something from the related data of traffic flow data, video, data analysis and field observation data, the thing is that the traffic on the highway is very frequent, the situation of vehicles arriving is close to the uniform distribution of wave distribution and there is no obvious wave distribution. The difference of traffic rush hour, flat peak, slack is that the change of total vehical number in a short period of time, So in short time traffic simulation, using the above three models do not conform to the boundary of actual highway, and not describe the actual situation of the road

vehicles accurately. But it is difficult to produce consistent with the reality in the traffic simulation system. And the traditional methods are not based on real traffic data, the arrival of the vehicles in the smooth traffic flow is balanced, it will be no big fluctuations, so the traditional model of the car is not reasonable. The generation of traffic flow model determines the performance parameters of the traffic system and simulation effect.

The paper is based on the field measurement data, using generalized least squares and poisson distribution fitting out of the traffic flow generating function. In establishing a practical highway micro dynamic simulation based on cellular automata, using two kinds of traffic flow generating function respectively, contrasting the relative error of the vehicle number and the measured data at the exit, we can get the corresponding conclusions.

2. Data Acquisition

The data of this paper was collected in october 2013, the method of detection in this paper is the observation on the side of the road, the place of gathering is zhoujiashan village road which from south to north direction of two sections A and B is 3000 meters (there is no branch between A and B) in LanHai freeway. A section is the entrance for vehicles and B section is the export for vehicles. The observation time is from 12:00 to 13:00 everyday which is continuous 30 days which is working and sunny days. The observation data is the total number of vehicles from A to B section and from south to north. Data collection is shown in Table 1, 2.

Table 1. the statistical of vehicles through A section

Time (minute)	The average number of vehicle(pcu)	Time (minute)	The average number of vehicle(pcu)	Time (minute)	The average number of vehicle(pcu)
12:00-12:05	198	12:20-12:25	199	12:40-12:45	208
12:05-12:10	189	12:25-12:30	190	12:45-12:50	203
12:10-12:15	201	12:30-12:35	205	12:50-12:55	198
12:15-12:20	193	12:35-12:40	194	12:55-13:00	210

Table 2. the statistical of vehicles through B section

Time (minute)	The average number of vehicle(pcu)	Time (minute)	The average number of vehicle(pcu)	Time (minute)	The average number of vehicle(pcu)
12:00-12:05	200	12:20-12:25	203	12:40-12:45	213
12:05-12:10	211	12:25-12:30	199	12:45-12:50	219
12:10-12:15	199	12:30-12:35	198	12:50-12:55	233
12:15-12:20	203	12:35-12:40	198	12:55-13:00	216

3. The Establishment of the Mathematical Model of the Cross Section

3.1 The poisson distribution section model

When the section start vehicle model is established based on the poisson distribution principle, the most important is to determine the start of related parameters λ of the model, so as to establish specific grid model. In general poisson distribution formula is:

$$P_t(n) = \frac{(\lambda)^n}{n!} e^{-\lambda}, n > 0 \quad (4)$$

Order, $\lambda = at$, a is vehicle average arrival rate.

The poisson distribution formula (1) is transformed into:

$$P_n(t) = \frac{(at)^n}{n!} e^{-at}, t > 0 \quad (5)$$

$P_n(t)$ is the possibility which has n cars into the simulation region In the period. The time is 10s, there has 90 times measures between 12:00 to 13:00 and gets 90 groups of vehicle number, as shown in Table 3:

Table 3. measurement on the number of vehicles and probability statistics

number of vehicles/15s	observed frequency （times）	actual data directly to probability	put λ =12.865 to formula （2） to calculate the probability
0—5	0	0.0333	0.0117
6	1		0.0163
7	2		0.0299
8	6	0.0667	0.0481
10	7	0.0778	0.0885
11	10	0.1111	0.1036
12	12	0.1333	0.1110
13	14	0.1556	0.1399
14	13	0.1444	0.1210
15	11	0.1222	0.0866
16	7	0.0778	0.0696
17	4	0.0444	0.0527
19	3	0.0333	0.0855
total	90	1	1

From the measured data in the table can calculate the vehicle arrival rate of λ expectations $\lambda = \sum_{n-1}^{12} n \bullet p = 12.8761 pcu/s$, there are: $a = \lambda / 15 = 0.8584 pcu/s$.

3.2 Least square cross-section model

The basic idea of least squares curve fit is: we make the error sum which is all data points and estimate point of squares is the smallest. We can get the least squares curve fitting. The mathematical principle is as follows:

A set of data for a given , If $\{(x_i, y_i),(1,2,\cdots,m)\}$ the fitting curve model is $y = f(x)$, the i error distance is $f(x_i) - y_i$, The sum all points of the error squares is $\sum[f(x_i) - y_i]$, Then calculate the minimum of $\sum[f(x_i) - y_i]$ corresponding to the parameter , so get fitting curve . Through the method of observation, we choose nonlinear polynomial function for curve as fitting, the number of polynomial fitting higher, the fitting error sum of squares is smaller, but its computation amount is larger, combining the reality of ontology and the error is very small, more inclined to choose 6 times polynomial function fitting, fitting curve is shown in Figure 1.

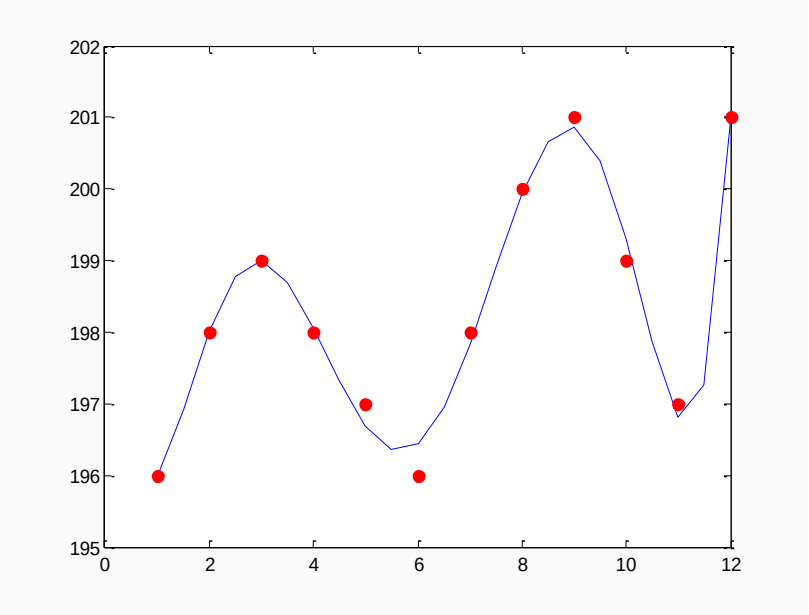

Figure 1.The polynomial function fitting curve

The polynomial function is:

$$y = 0{,}0012x^6 - 0.0441x^5 + 0.5822x^4 - 3.5367x^3 + 9.7302x^2 - 9.8538x + 199.1136.$$

The fitting error sum of squares $E = 0.4784$. The sum fitting error of squares is small, the function for data fitting is more good.

4. Traffic Simulation Model Establishment and Cross Section Analysis

4.1 Establish the highway cellular automaton model

Using cellular automata model to establish observation sections of two-lane one-way hybrid vehicle traffic simulation model. Two lanes are divided into truck lanes and the car lane and vehicle length is 2, and 1 respectively. The speed of truck is 3, and car is 4, because it is in highway, the minimum speed limit is 2. Overtaking is only allowed in the car lane.

Each grid is defined as 7.5m, path length of 400. Boundary conditions option open boundary condition, the entrance road vehicles option poisson distribution or nine times polynomial into the cell. In road exit, the vehicles arrival directly out of the road boundary.

In Cellular automata model, each time step is divided into two time steps: in the first step, the vehicle shall be carried out in accordance with the lane changing rules; In the second step, vehicle on two lanes shall be carried out in accordance with the rules of updating single updates.Often drivers during change lane is driven by some motivation, based on Rickert the lane changing rules put forward [9]. And lane changing motivation is usually consists of two parts: (1) the other road driving conditions is better than this way; (2) safety conditions, that is, if you want to change on the local lane, It is safe for themselves and other vehicles, which is to ensure no collisions. When vehicles meet the following conditions can be in a way: ①$(C1)d_n < l$;② $(C2)d_{n,other} > l_0$;③ $(C3)d_{n,back} > l_{0,back}$;④$(C4)rand() < p_{change}$. Here, d_n , $d_{n,other}$ respectively the n car and the way and the empty cell number between road vehicle ahead . $d_{n,back}$ stand for between said and beside of the road after the car empty cell number. $l, l_0, l_{0,back}$ and p_{change} is the specific parameters of lane changing rules respectively; $rand()$ stand for a rand number between 0 and 1, Discovered in the field observations, overtaking is rare in LanHai freeway flow, so we take p_{change}as 0.1 to reduce the traffic lane changing occurred in the process of simulation.

4.2 Section model comparison

In the traffic simulation model, vehicle counter is set in road exit location, using poisson distribution and polynomial model for simulation of the car, gathering the number of vehicles that reached by 5 minutes, and compared with the actual measurement data in Table 2, calculate relative error value. Simulation 50 times in a row, calculating the average every five minutes count and the actual average relative error, get Figure 2 by comparison Table 3. In the figure blue and green represent the polynomial, the Poisson distribution grid model and the relative error value is the absolute value of the measured data.

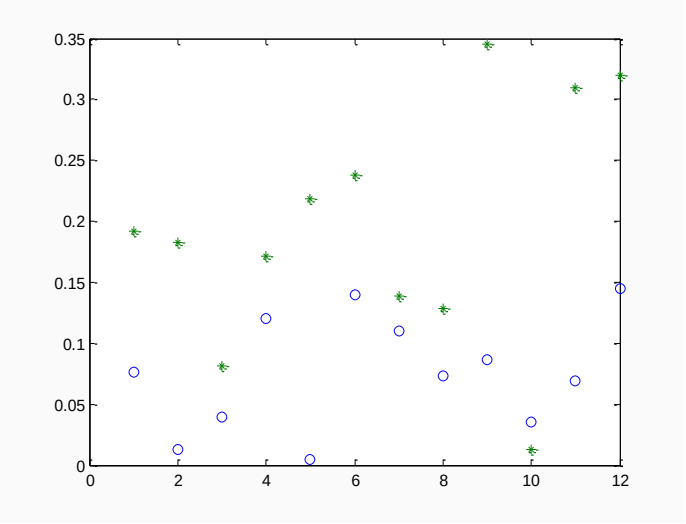

Figure 2. The relative error simulation data

Calculate the size of the two models of relative error variance found that under the condition of the same total number of vehicles, the relative error of poisson distribution of discrete degree is higher than two six discrete degree of polynomial. Therefore, using the data fitting polynomial distribution section model is more suitable for short-term traffic flow simulation.

5. Conclusions

Microscopic traffic simulation laboratory is a good way of solving the traffic problem, studying traffic phenomenon. But the most basic part of simulation system is the problem of traffic flow input，establish an effective model of traffic generation to improve the effect of the system simulation is great importance.

Cross section in the practice of traditional grid model is a kind of probability density function, such as the binomial distribution, poisson distribution and normal distribution, etc., but in a smooth road traffic flow, we all know that the arrival of the vehicle is random, is not completely in line with which the probability of a specific function, so we put forward the new method, based on the actual data statistic of the vehicle, is obtained by least square function relation between the arrival time, namely a yuan of high order polynomial. Which is more scientific and authenticity compared with the traditional approach. And from the cellular automaton simulation result get a conclusion that polynomial function is more suitable for short-term traffic flow simulation of steady-state.

But this article still have many improvements in the collection and analysis of the field data , in addition there are some gap between establish simulation model and the actual vehicle running on , hoping to further improve for the later research.

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