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THE ANALYSES OF CONGESTED TRAFFIC CHARACTERISTICS AND APPLICATIONS TO THE SIGNAL CONTROL DESIGN USING MITRAM

Ryo Ishikawa , Shinji Tatemoto, Kazuki Wada and Nakaji Honda

The university of electro-communications
1-5-1 Chofugaoka Chofu-shi Tokyo , JAPAN

ABSTRACT

In this paper, we analyze the congested traffic characteristics using the road traffic simulator MITRAM. MITRAM is based on microscopic approach, and it has the accuracy of analysis, flexible modeling, high speed simulating, advanced visualization of simulation results etc. Especially we build the fuzzy model vehicles (FMV) using fuzzy inference logics based on actual drivers viewpoint, which can drive autonomously, and so realistic simulation is possible. In this research, we analyze congested traffic situation accompanied by a very complicated phenomenon. And we verify the MITRAM by comparing with the Q-V correlation known well. Moreover, we clarify the mechanism of traffic congestion generating (and clearing) from a microscopic viewpoint using results of the time series data. Based on the results, we verify the validity of MITRAM. Finally we perform a signal control design as application of a simulator. Therefore, the simulator MITRAM has a quantitative evaluation function about traffic flow, and control aiming at making it the optimal is performed. Through this paper, we show that the road traffic simulator MITRAM can reproduce the congested traffic characteristics in high accuracy. And it is effective in designing of the signal control in the complicated traffic environments.

1 INTRODUCTION

In recent years, the road traffic congestion is very serious social problem in many countries. In order to solve these problems, installation of a trunk road and rationalization of signal control are effective. However, these measures cannot be easily execute from the problem of safety or cost. Therefore, it becomes important to predict the measure effect by the road traffic simulator.

A road traffic simulator has two approaches; they are macroscopic and microscopic approach. The macroscopic approach can simulate of the traffic in large area at high speed. However, it is difficult to treat the fine action of traffic. In microscopic approach, although the fine action of traffic can be treated easily, calculation cost is high and it is not fit for a wide area simulation. Since we regard the local traffic congestion in a city area, we have already developed the road traffic simulator using microscopic approach called MITRAM.

In this research, we verify MITRAM from the view point of Q-V correlation (which is well known traffic engineering). For that purpose, we construct the high-precision driving model for MITRAM. And we compare the simulation with Q-V correlation of actual traffic for verification of accuracy. Furthermore, we apply MITRAM to a signal control design, and show the validity of a simulator.

2 OVERVIEW OF MITRAM

In MITRAM, we simulate of the road traffic is carried out by making it run two or more autonomous virtual vehicles on simulation platform. The model used fuzzy inference is adopted as the determination of driving operation of each vehicle. Thereby, the operation judgment like actual human being can be smoothly taken in the simulator.
About the road model as a simulation platform, and the driver's operation model that determines a vehicles action, details are given in the following paragraph. Here, the features of MITRAM are enumerated. It has a microscopic model treating action of each vehicle. All vehicles are autonomy like actual traffic. Detailed traffic reappearance, such as right-turn judgment in consideration of the oncoming vehicles, is possible.

The FIU (Fuzzy Inference Unit) network, which is flexible and good visibility, is adopted. The simulation containing over 1000 vehicles can be performed by 10X or more speed. The system outline of the MITRAM is shown in Fig.1 and the sample displayed the 3-D view of a simulation is shown in Fig. 2.

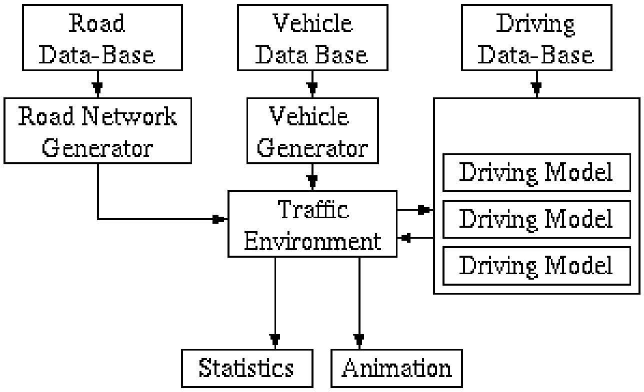

Figure 1: MITRAM System

Figure 2: Sample View of MITRAM

2.1 Road model

A drivers subjective road model named "Virtual Traffic Lane" is proposed in MITRAM shown in Fig.3. This is independently of actual road structure, and vehicles prepare beforehand the route along which its passes. These lanes are prepared for the point with which vehicles branch(or merge) for every branch place. Thereby, modeling can process a difficult steering operation portion within a road model in operation. A virtual traffic lane is expressed by connection of two or more sub lanes. A straight line, a curve, extension, a constriction, etc. can be defined as a sub lane. The modeling of complicated steering operation is not required by using this road model.

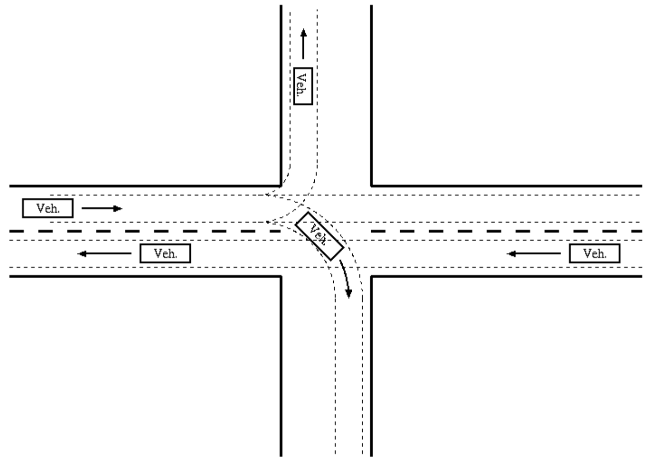

Figure 3: The model of "Virtual Traffic Lane".

2.2 Driving Operation Model

The action of the vehicles in MITRAM is modeled from judgment in the position of the driver. It means that each vehicle run autonomously based on the information from the driver's viewpoint. Each vehicle has multi-input systems, which receive the information on the circumference and return the amount of driving operations. In this research, this multi-input system is expressed using FIU (fuzzy inference).

First, since judgment of an actual driver is very complex, we assume what carries out operation whose actual driver fills the following norms.

1. Don't collide with the rear surface of other vehicles.
2. Don't collide with the side of other vehicles.
3. Don't collide with the front of other vehicles.
4. Don't collide with anything other than vehicles.

The logic which fills these norms is built individually and makes the same judgment as reality can be built by making them, drive in parallel.

An example of logic is shown in Fig. 4. In this figure, the acceleration of vehicles is outputted by considering three items of the distance between precedence vehicles and own vehicle, a speed difference, and own vehicle speed as the input. By using fuzzy inference, the judgment based on qualitative information can be expressed linguistically. This makes adjustment a model easy. Furthermore, the structure of connecting the operator of 2 input 1 output to many stages makes extension of a model smoothly. We modeled other logic by the same technique. These models realize an actually similar vehicles behaviors on the simulator.

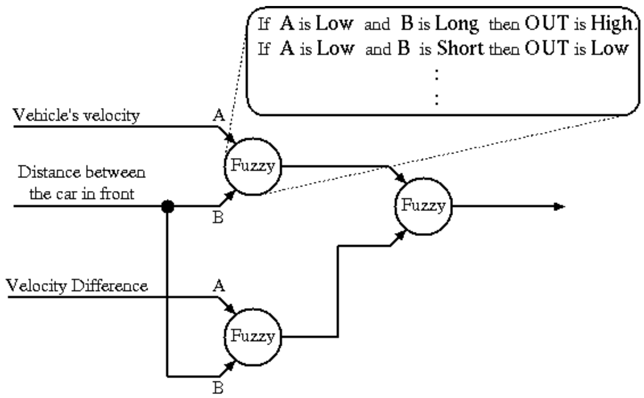

Figure 4: The Sample of Driver's model

3 BASIC EXPERIMENT

3.1 Q-V correlation

Generally it is known well that traffic volume(Q) and average velocity(V) have the correlation shown in Figure 5. This relation has a critical point(Qc,Vc) and traffic volume becomes the largest in that case. The point divides this relation into freedom flow(upper) and congested flow(lower). At a freedom flow, Q and V become an almost linear relation. And at congested flow, it has the relation of a curve like a secondary formula. Many road traffic simulators use this relation.

However, we do not use this relation, and we are reproducing the action of each vehicles precisely. We think that this relation is observed from a macroscopic viewpoint, and verify it.

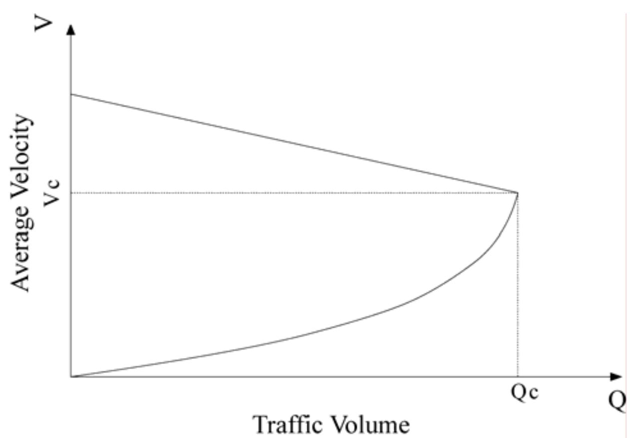

Figure 5: Q-V correlation

3.2 Simulation Environment

In order to verify Q-V relation by MITRAM, we observe change of the average speed at the time of making traffic volume increase gradually. The road model for measuring it is shown in Fig. 6. This road is circular 1-round about 4[km] and has only the entrance of vehicles(Generating Point). In this simulation, we generate 60 vehicles every hour from a generating point, and record the number of passing vehicles and its velocity in an observation point. And this simulation is continued for 6 hours.

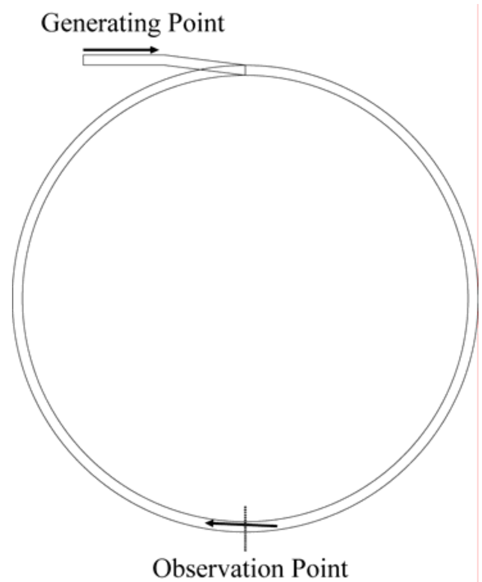

Figure 6: The simulation Environments

3.3 Simulation Results

Fig. 7 is a Q-V correlation diagram obtained from the simulation result. The traffic volume and average velocity in every 5 minutes were plotted in graph from the simulation result. The top of freedom flow of Q-V correlation does not serve as linear form, and it is staying around 80km. This is because the speed limit of each vehicles was set to 80km in this simulation and it is satisfactory. At congested flow, It shows the form very similar to the correlation known well. As a whole, the simulation result is reproducing Q-V correlation in real traffic very well. It means that MITRAM can reproduce the situation of various traffic flows.

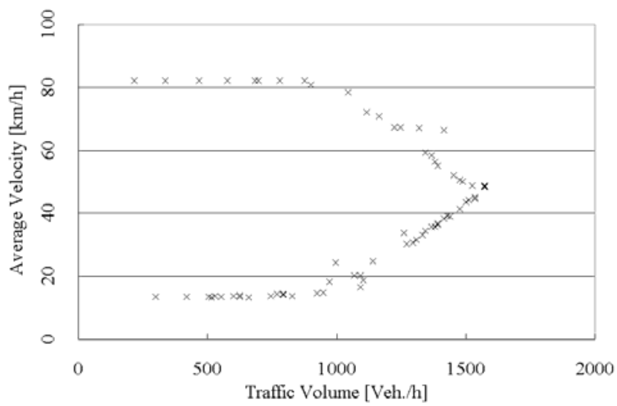

Figure 7: Q-V correlation of a simulation result

4 APPLICATION TO SIGNAL CONTROL DESIGN

In this section, we design the optimal parameter for signal control using the traffic flow evaluation function which MITRAM has. This function outputs the merit of the traffic flow as a numerical value from simulation results. And it can analysis of simulation results from various view point, such as delay time, travel time, and the number of times of a stop. Thereby, we can compare quantitatively change of the traffic flow, and the optimal signal control parameter can be designed. In the signal control, *Cycle length* and *split* are the parameters which should be designed. Generally the smoothness of the traffic in an isolated intersection is evaluated by the *total delay time* (totaled for all vehicles stop time over 1 cycle). Therefore, the control which makes the total delay time the minimum realizes smoothest traffic.

A crossing with the approach from north, south, east and west shown if Fig.8 is set as the object of analysis. Here, we label west-east road as main road, and label south-north road as sub road. And this signal has 2 phases for each roads. And *Yellow Time*(3sec) and *All Red Time*(2sec) are contained in each phases. We asks for the optimal signal control parameter for each supposing there being three cases of traffic demand shown in Table.1 in this signal crossing.

In this analysis, the total delay time at the time of changing the cycle length and a split is measured from a simulation result. A simulation is performed for 60 minutes for every parameter installation, and makes for 30 minutes applicable to measurement the second half except warm-up. The result in case 1 is shown in Fig.9. This graph shows the total delay time by the shade, and the place where a color is thin means that the flow of traffic is smooth. The place shown with a circle especially in the figure is the minimum (best) value. It is clear that the total delay time serves as the minimum by setting up this parameter(main road green is 20 [sec] and sub road green time is 6[sec], the cycle length 36 [sec], and the main road split is 69[%]).Moreover, case 2 and case 3 also performed the same simulation. These results are shown in Fig.10 and Fig.10. In case2, Cycle Length is 41[sec], main road split is 61[%]. In case3, cycle length is 48[sec], main road split is 58[%].The result of case1-case3 shows that the optimal cycle length becomes long according to the rise of the intersectional degree of saturation. This agrees with traffic engineering knowledge.

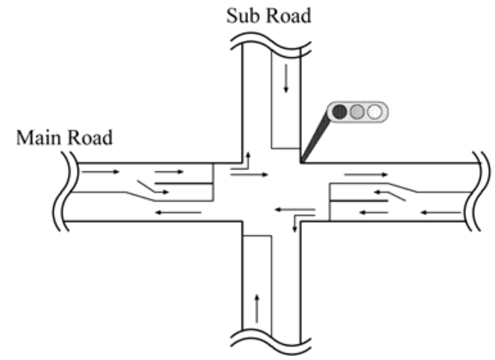

Figure 8: The road model of a intersection.

Table 1: Traffic Environments

	Main Road		Sub Road	
	Volume [veh./h]	Branching Fraction L : S : R	Volume [veh./h]	Branching Fraction L : S : R
case 1	800	5:90:5	200	20:60:20
case 2	800	5:90:5	400	10:80:10
case 3	800	5:90:5	600	7:86:7

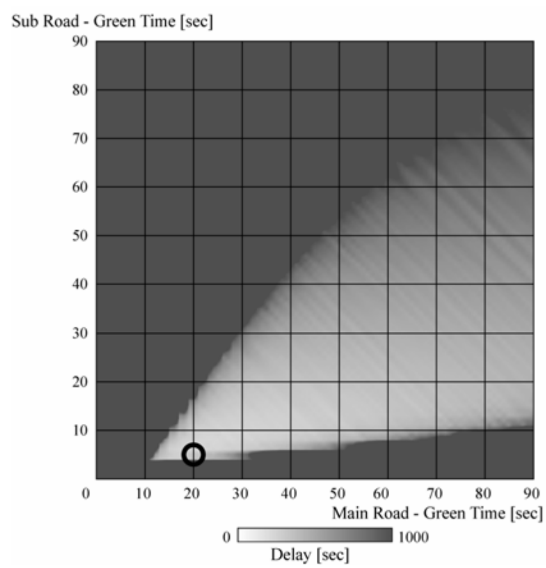

Figure 9: Total delay time (case1)

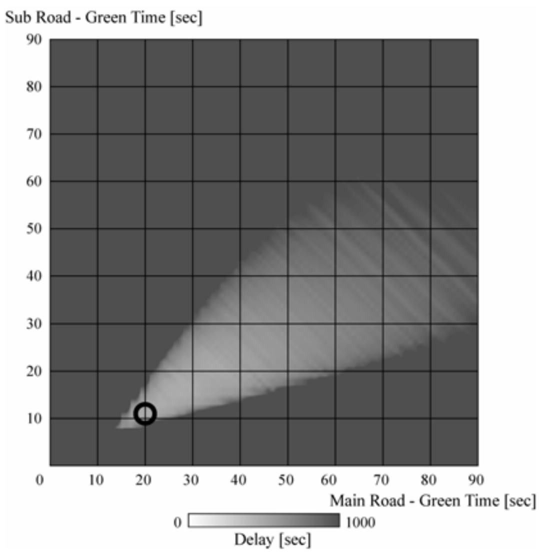

Figure 10: Total delay time (case2)

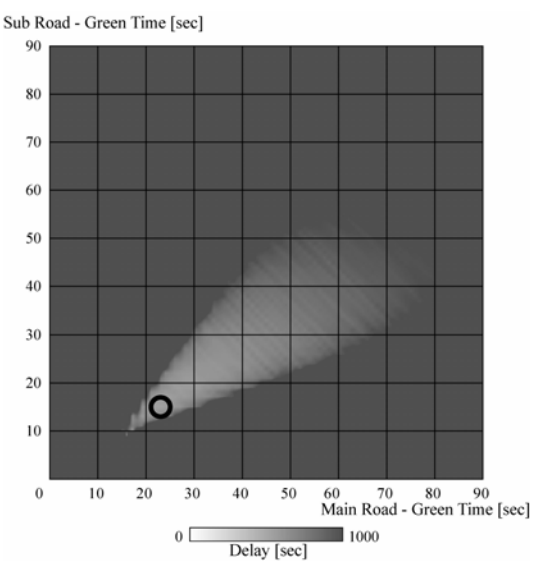

Figure 11: Total delay time (case3)

5 CONCLUSION

In this research, we have experimented about Q-V correlation of traffic flow using the microscopic road traffic simulator MITRAM. The result corresponded with traffic engineering knowledge. It suggests that the action of each vehicles of MITRAM reproducing reality with sufficient accuracy. Furthermore, we designed signal control as application of MITRAM. The simulation supposing the traffic demand from which some differ was performed, and the suitable signal control parameter was designed to each traffic environments.

Application of trial signal control which was performed by this research in actual road traffic is impossible from problems about safety. Moreover, it is impossible for conducting an exact experiment since the conditions about actual traffic changes every day every time. Therefore, it is very important like MITRAM that a simulation is repeatedly possible.

REFERENCES

Y. Yikai, N. Honda and N. Itakura, 2000, “Fuzzy Driving Model for Road Traffic Simulator”, Journal of Japan Society for Fuzzy Theory and Systems:425-435.

N. Itakura, A. Fukeda and N. Honda, 2001 “Evaluation Method Using Chaotic Analysis for the Model of Vehicles’ Behavior in Road Traffic System”, Mathematical and Computer Modeling 33:771-782.

K. Yikai, R. Ishikawa, N. Honda and N. Itakura, 2001 “Simulation of Drivers Maneuvering around Obstacles and Analysis of Traffic Congestion Using Network-Structured Models Based on Fuzzy Inferences”, Mathematical Modeling and Its Applications, Information Processing Society of Japan, No. SIG14:90-97.

R. Ishikawa, H. Kazama, N. Honda, N. Itakura and K. Yikai, 2003, “Modeling of Vehicle Maneuvering around Intersection and Traffic Analysis” , Mathematical Modeling and Its Applications, Information Processing Society of Japan, No. SIG14:71-80.

R. Ishikawa, H. Kazama and N. Honda, 2003, “Coordinated control of traffic signals by the road traffic simulator”, 22nd Simulation Technology Conference in Japan, Japan Society for Simulation Technology:303-306.

R. Ishikawa, C. Yanosaki, N. Honda, H. Kazama and Kunio Yikai, 2004, “The traffic simulation and signal control evaluation around the Chofu station using MITRAM”, 20th Fuzzy System Symposium in Kitakyushu Japan:98-101.

S. Tatemoto, R. Ishikawa, N. Honda, H. Kazama and K. Yikai, 2004, “Verification of the traffic quantity and velocity correlation in a microscopic traffic simulator MITRAM”, 23rd Simulation Technology Conference in Japan, Japan Society for Simulation Technology:41-44.

R. Ishikawa, H. Kazama and N. Honda, 2004, “The realtime traffic simulation using the data of vehicle detectors”, 23rd Simulation Technology Conference in Japan, Japan Society for Simulation Technology:45-48.

K. Wada, R. Ishikawa, N. Honda, H. Kazama and K. Yikai, 2004, “Implementing and analysis of changing lane in a microscopic traffic simulator”, 23rd Simulation Technology Conference in Japan, Japan Society for Simulation Technology:49-52.