Applying the assembling method of the driving model using imaginary preceding vehicle on the microscopic road traffic simulator (MITRAM).

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Abstract **- To reproduce actual traffic situation, we have to consider many kinds of elements for modeling in order to build a practical simulator. On the other hand, to construct an accurate model encounters the difficulties in parameter configuration. To solve this problem, we also proposed to classify all driving conditions by two driving conditions: a succeeding condition simulated by only a succeeding FMV (Fuzzy Model Vehicle) and a non-succeeding condition simulated by both a succeeding FMV and an Imaginary Preceding Vehicle. In this paper, we applied the building method of the driving model using imaginary preceding vehicle on the microscopic road traffic simulator (MITRAM).**

I. Introduction

Unstoppable increase of vehicle in recent years causes the chronic traffic jam in most cities world widely, and inevitably brings in the further serious social problem. In order to validate the effectiveness of specific solutions aiming at solving the traffic problems, the computer-based simulation is getting more and more attention; many traffic simulators have been developed and proposed these years.

Amongst those proposed traffic simulators, there are two different approaches of modeling, one is macroscopic methodology and the other is microscopic methodology. The former one assumes the traffic stream as a kind of fluid, while the latter one focuses on the motion of individual vehicles. We have to design the model in microscopic perspective because the motion of one vehicle on the road in cities definitely will affect the traffic status around it cannot be ignored.

Cellular automaton method has been frequently used in many micro simulators developed in recent years. This methodology makes modeling relatively easy and calculation efficiency high, it allows simulate on a considerable large scale. Most large-scale prediction simulators in the world are utilizing this methodology [1].

What we have proposed, researched and developed, the simulator MITRAM (**Mi**croscopic model for analyzing **Tra**ffic ja**m** in the city area) aims specifically at a narrow scope such as bus station area. Compared to the cellular automaton technique based simulator, MITRAM focuses on being more meticulous and thorough in analyzing traffic phenomena by utilizing unique methodologies.

This is based on our research that we found the traffic jam in a city is caused by the following factors:

- The shape of crossing (road crossing)
- The cycle of traffic signals
- The position of bus stops
- The vehicles parking in the road

Therefore, it can't be an effective simulator without taking into account the traffic environment very carefully and thoroughly. Using fuzzy logic, MITRAM reproduces the driving conditions of an actual driver by Fuzzy Model Vehicle (FMV), as this enables the reproduction of every vehicle's motion on the road.

Besides, we combine the fuzzy neural network with FMV so as to enable it learns the vehicle motion data and reproduces the motion of the actual running of the vehicle. During the evaluation of the traffic simulator in the time series used FMV, the data generated by the simulator in simulating vehicle gap was very close to the actual data. And, because neural-fuzzy-based learning was applied in FMV, when the actual running data are used as the learning data, the driving character will be modeled exactly as the data collected.

We divide all kinds of driving conditions into two categories:

1. Succeeding Condition: It's car-following. Only preceding vehicle is considered, it controls the acceleration.

2. Non-Succeeding Condition: We categorize all the other to be: non-car-following group.

We proposed to model non-succeeding driving by the concept of Imaginary Preceding Vehicle. This idea eventually simplifies the process of assembling the model; the consolidated algorithm can successfully model the complicated different driving conditions automatically.

In this research, we simulate the roads with traffic signals by utilizing Imaginary Preceding Vehicle, and we will exam if the proposed driving model could display the stop-go-signal.

II. Summary of MITRAM

MITRAM as a simulator reproduces the motion of every vehicle on the road in a microscopic methodology. The road model, vehicle model and driving maneuver model assembled by MITRAM are independent to each other, data-based modeling provides rather free modeling environment. Meanwhile, high-speed operation system simulation is invented as well. The simulation of around 1000 vehicles could be done in the ordinary personal computer.

In actual driving, the driver's maneuvers were decided by the information collected during his driving on the road, whereas human's judgments and assessments go wrong or be ambiguous very often. Fuzzy control is applicable to this situation. MITRAM has two-inputs and one-output fuzzy mathematic calculation units, it applies network to assemble the model of driving maneuver [2]. As a result of utilizing fuzzy modeling, we are able to assemble the model in a more realistic way from a human's perspective; even the modeling of complicated driving Theories that is evaded in the field can be more realistic. But while varieties of data are connected each other, memberships setting become more difficult. In this paper, we use fuzzy neural network theory to decide how to create the fuzzy rules of FMV by learning actual data.

III. The proposal of assembling the model of driving maneuver by actual data.

The model can be assembled in a more objective way because of the usage of fuzzy methodology in modeling driving maneuver by MITRAM. However we still need to set many parameters so as to be in consistent with many driving maneuvers such as car following, right or left turn, passing, merging, etc. The simulation would not be accurate without the meticulous parameters. It does hinder the application of simulator. In this paper, we propose to model the driver's actual running data automatically. Thus,

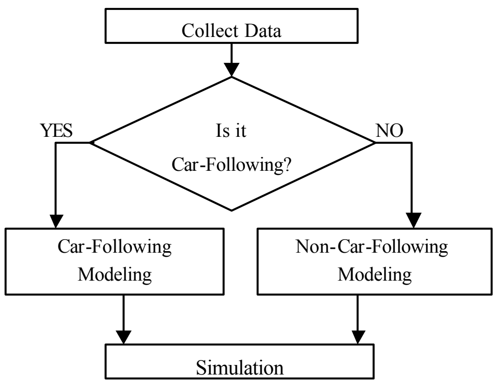

Figure1. Assembling the Model of driving maneuver by actual data

According to this proposal, we can assemble the model of driving maneuver merely by the actual running data with which the driving theories are combined. Figure 1 illustrates the concept of the proposed modeling system.

A. The model of driving maneuver

Different models are defined by different driving maneuvers in most driving models of traffic simulators. The model of driving maneuver proposed in this paper uses two models to represent all the driving maneuvers. One of these two models is car-following model; assembled in order to follow preceding vehicle, the other one is non-car-following.

In order to consolidate all the other driving maneuvers into the non-car-following category, we utilize the concept of Imaginary Preceding Vehicle, which allows the non-car-following model to be able to represent by car-following model.

B. Car-following model

We assemble car-following model by the driving data of the succeeding car [3]. In assembling this car-following model, we use fuzzy neural network; we name this model as Car-Following-FMV. Figure2 illustrates the core concept.

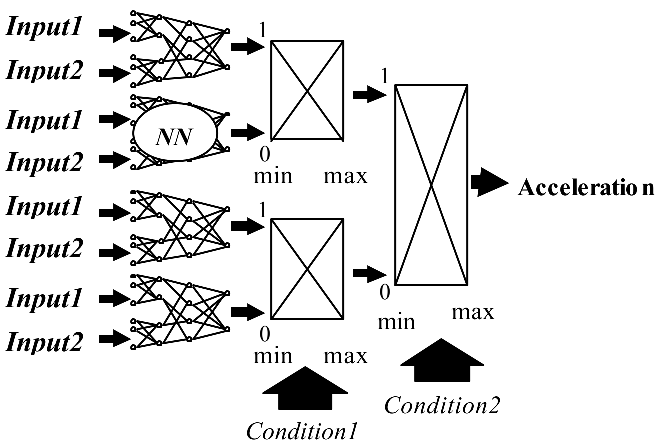

Figure2. FNN for the acceleration control FMV

Here is the process of modeling:

1. Input Signal of Neural Network

   These input signals come from the actual driving data of both the preceding vehicle and the succeeding one. They are acceleration, speed and following distance.

2. Teacher Signal

   The acceleration and following distance of the succeeding vehicle in the next time series are regarded as the teacher signal.

It enables the neural network to learn by using the back-propagation algorithm by which the model is assembled.

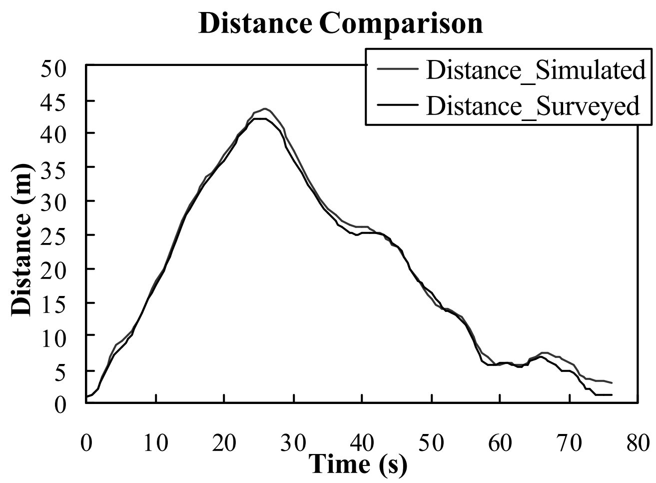

Figure3. Comparison of following distance

By utilizing this methodology, we are able to assemble the car-following model by car-following driving data. (3474 time points, seconds in total) Input fuzzy neural network the data of preceding and succeeding vehicles at every time point. Besides, the parameters can be set automatically because of the learning of actual car-following driving data. It not only assembles the model meticulously but also the actual driving features remains in the model.

The experiment we've done used this methodology. We use 47 sets of actual car-following driving data in assembling the model, the average error of simulated following distance and actual data is only 0.9[m]. The result of simulation is illustrated in Figure 3.

C. Non-car-following model

All the signals such as stop-go, right/left turn, passing are regarded as different driving models. The driving maneuver model produced by MITRAM mounts all the driving models.

All the parameters of driving categories should be taken into account if we want a more accurate model which encompasses all the driving preferences, the model will then be much more complicated.

Therefore, in order to make it relatively simple, we proposed to consolidate all the non-car-following driving maneuvers into a single category. The non-car-following model is realized by the car-following model described in III-*B* which will be mentioned later, the Imaginary Preceding Vehicle.

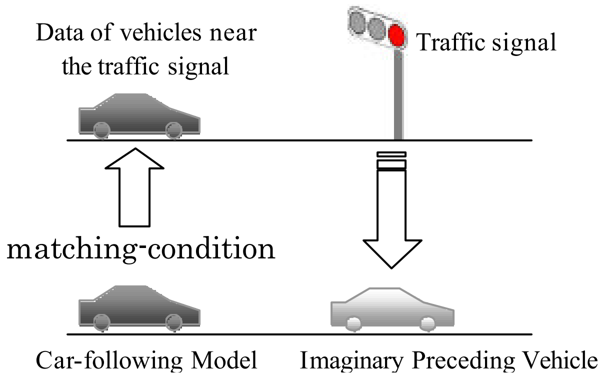

Figure4. Concept of Imaginary Preceding Vehicle

Assuming there is a preceding vehicle, the car-following model will perform a driving maneuver. When the motion caused by the maneuver is the same as what caused by the traffic signals, we then can utilize this preceding vehicle and the car-following model to reproduce the driving maneuvers caused by traffic signals. Given the above explanation, if the driving data collected by the preceding vehicle followed by driving model is the same as the data collected from non-car-following driving data, this preceding vehicle is what we are proposing, the Imaginary Preceding Vehicle [4].

The methodology of educing the Imaginary Preceding Vehicle

- Target

  The succeeding vehicle, which is the same as

- Interval of Acceleration

  Setting the acceleration rate of the preceding vehicle by setting the interval of acceleration as 0.1[m/s^2]

- Logging the motion of the Imaginary Preceding Vehicle

  When the motion of the succeeding vehicle is very close to the non-car-following data collected at the next timing point.

- Redo the logging

  Logging non-following data at every timing point.

Figure4 illustrates the concept of Imaginary Preceding Vehicle.

D. Database of model of driving maneuvers and the Condition Space

We input meta-information into the model assembled by using the methodology described above; the meta-information will be saved in a database. Imaging it's plotting the driving maneuvers on a 3-d coordinate. The simulator will dynamically load a driving model when the driving maneuver is inconsistent with the traffic state. By using this Condition Space, simulator can assemble the model according to the users' requirement. Figure5 is the image of Condition Space about stop-go traffic signal.

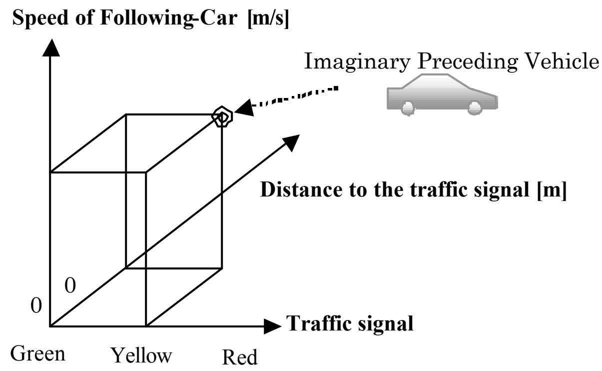

Figure5. Concept of Condition Space

IV. Verification

We think it's necessary to examine the application flexibility of the model of driving maneuver. We assume those data come from the simulation by MITRAM be the actual data due to lacking of adequate actual experimental data. Also we validate if the model can be performed stop - go which caused by traffic signal. In this paper, we use the road simulation as showed in Figure 6.The cycle time here is as follows: Green 20 sec., Yellow 3 sec., Red 15 sec., total cycle time is 38 seconds.

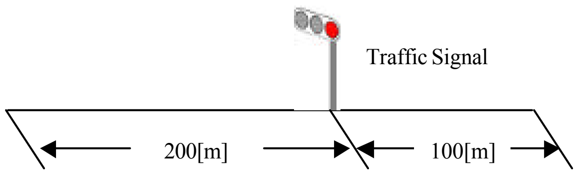

Figure6. The road of the simulation object

A. Car-following model

We collect driving data from MITRAM, totally 10 files are collected when the preceding vehicle and succeeding vehicle perform the following cycle of motion: stop-start-stop.

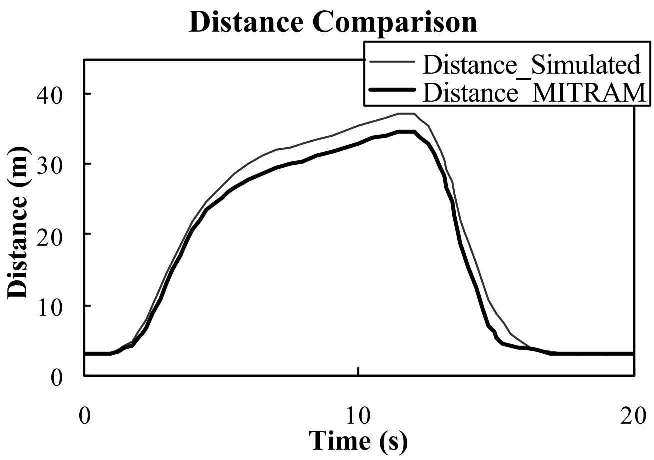

Figure7. Comparison of following distance

MITRAM has been utilized in educing the car-following driving model. The result of the simulation of the maximum error in simulating the following distance is 2.5[m], the minimum is 1.5[m], which almost the same as the actual driving data. Figure 7 is one of the samples.

B. Non-car-following driving model. (Traffic Signal)

MITRAM simulated a road illustrated in Figure 6. In 30 minutes simulation, we collect the number of stopped car, which are closest to the traffic signal. Then the Imaginary Preceding Vehicle is educed based on the data collected. Compare the data of the succeeding vehicle's position with the one generated by MITRAM, we found the maximum error is 3.1[m], while the minimum is zero meter. One of the samples is showed on Figure 8

We save the 54 Imaginary Preceding Vehicles educed by the above methodology in the Condition Space, and then the signal is generated.

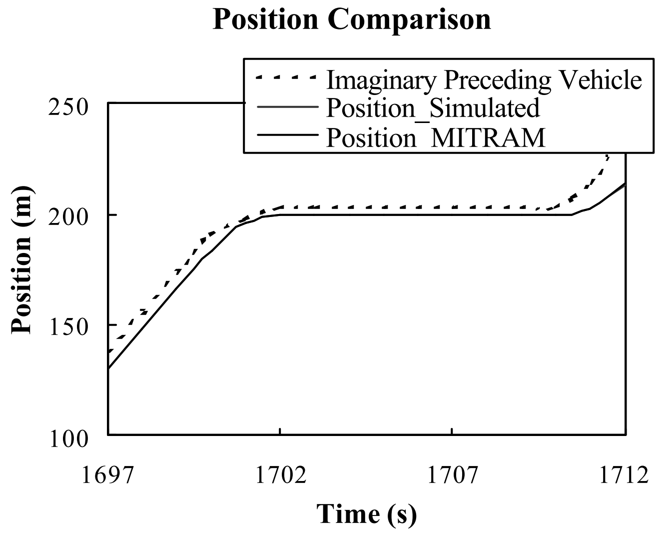

Figure8. Comparison of Position

C. Simulation of signal

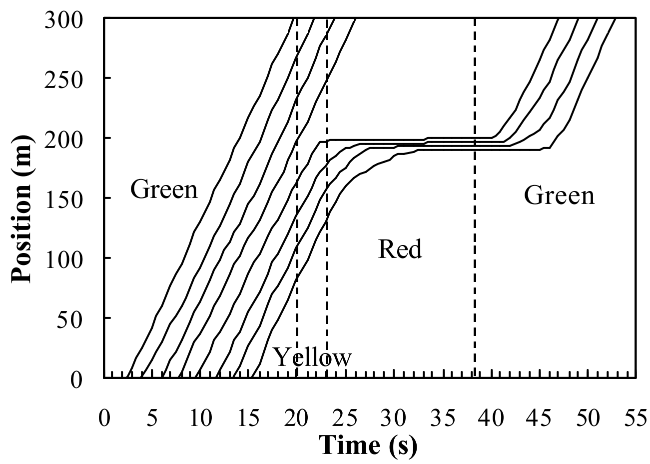

Figure9. Simulation result around the signal

We make the models educed by car-following a group, simulate by utilizing the signal system in IV-*B* and the road indicated in Figure 6. The motion of the car-following model is shown on Figure 9. Obviously, the motion of the model is almost the motion caused by traffic signals.

V. Conclusions

The ultimate objective of this research is to assemble meticulous and accurate driving model without setting complicated parameters. Therefore, we utilized fuzzy neural network in assembling the driving model by its capability of learning actual data. Compared the result from the simulation by educed car-following driving model with the 47 sets actual car-following data, the average error of following distance is only 0.9[m]. This really demonstrated the effectiveness of this methodology.

Besides, we proposed setting Imaginary Preceding Vehicle in car-following mode so as to enable the car-following driving model perform the same motion as the non-car-following model (by signal of stop, start, right/left turn, and passing). Compared with those driving models designed for specific driving motions, this model treats all kinds of car-following driving motions as a single consolidated concept of driving, the non-car-following.

Also, we proposed setting the Imaginary Preceding Vehicle in Condition Space; we'll select appropriate Imaginary Preceding Vehicle solution in simulation.

And next, we design the simulation by utilizing several Imaginary Preceding Vehicles in performing driving motions such as stop and move, which be non-car-following motions caused in response to the traffic signals. As a matter of fact, we finally successfully simulated the motion of vehicle caused by traffic signals such as passing, stop and start via the application of the methodology of setting Imaginary Preceding Vehicle and car-following driving model.

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