AN ENHANCED TRAFFIC SIMULATION SYSTEM FOR INTERACTIVE TRAFFIC ENVIRONMENT

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***Abstract*—This study develops a microscopic traffic simulation model (KAKUMO) which is built into a mixed reality experiment system under an interactive traffic environment. We are developing a mixed reality experiment system is under development to examine several human factors such as driving behavior and travel choice behavior, which are required to design and evaluate various ITS systems. The system is characterized by the environment in which a driver, vehicles and infrastructure are dynamically interacting with each other. In this paper, we introduce the specification and performance of the micro simulation model which is built into the prototype mixed reality system.**

***Index Terms*—ITS, Traffic Simulator, Driving Simulator , Image Generator,**

I. INTRODUCTION

Further analysis on human factors such as driving behavior and travel choice behavior is required to design and evaluate various ITS systems, equipment, and schemes. For a traffic information system, for example, it is important to provide effective and timely information for drivers. Therefore, we have to analyze driver's reactions when the system provides some information such as traffic congestion and traffic accidents and evaluate an effective way of providing. In respect of the study, we have to analyze driving behaviors (acceleration, deceleration, lane changing for route choice, etc.) by Driving Simulator (DS). On the other hands, we have to evaluate an influence to the large area by Traffic Simulator (TS). To satisfy both demands, it is useful to construct an evaluation and feedback system in which TS and DS communicate with each other. For an experimental tool for human factor analysis, Mixed Reality Experimental Laboratory is under development in "Sustainable ITS Project" at Center for Collaborative Research, University of Tokyo, in which work has been ongoing since it was initiated in April 2003 as a private-public-academia partnership project. As shown in Fig.1, the Mixed Reality Experimental Laboratory consists of two main components: Real Observation Laboratory that efficiently collects and processes real data from various sensors such as experiment vehicles, traffic detectors, AVIs, VICS and probe vehicles; and Virtual Experiment Laboratory that supplies a virtual environment in which a driver, vehicles and infrastructure are dynamically interacting with each other so that human factors can be measured in a realistic and fully controlled virtual environment.

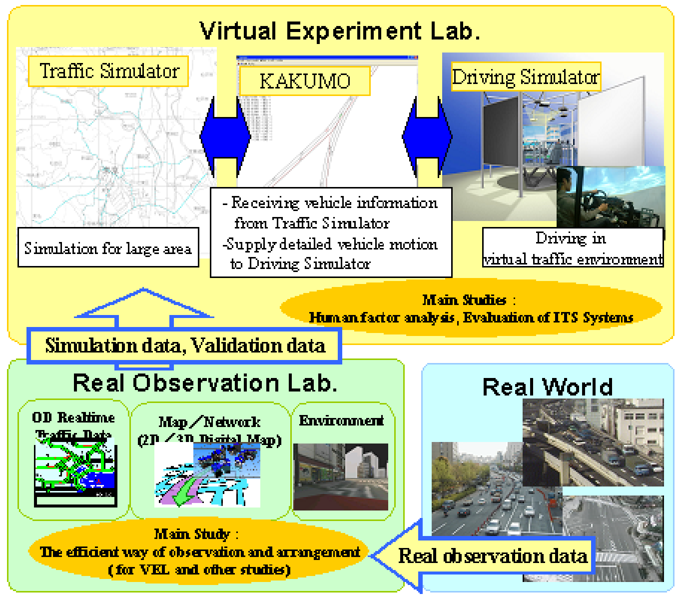

Fig.1 Mixed Reality Experimental Laboratory

As Fig.1 indicates, the way of connecting TS and DS is a core process in the Virtual Experiment Laboratory. However, it is difficult to supply to DS virtual traffic environment with reality only by TS. The main reason is that there are various differences in the precision of these models. We need to develop the micro simulation model(KAKUMO) as a solution for these problems. KAKUMO proposed here is a part of the mixed reality system and it links the network-wide traffic simulator with the driving simulator so that a vehicle driven in DS can interactively run among vehicles in TS.

II. TRAFFIC SIMULATOR

In this paper, Traffic Simulator means the model reproducing traffic condition in a network wide road network like whole one city, generally known as a dynamic traffic assignment model. TS is useful to evaluation of policies whose impacts spread to a large area, for example provision of traffic information or

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traffic demand management like peak-road pricing etc. AVENUE(1),(2) and SOUND(3) are typical TS models.

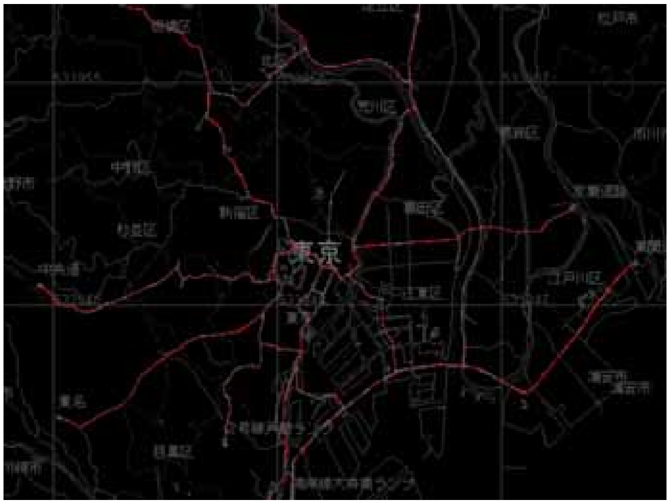

Fig. 2 Example of Traffic Simulator (SOUND)

TS consists of Vehicle Flow model and Route Choice model, and traffic condition is reproduced by repetition of these two kinds of model as Fig.3. Vehicle Flow model assigned a given traffic volume between OD pairs on a road network based on the selection probability of each route computed by Route Choice model, and computed travel times of all road links. In Route Choice model, the selection probability of each route between OD pairs is revised every specified time interval (for example, 5 minutes), based on route characteristics, such as travel time, distance, and number of right or left turns, is sent to Vehicle Flow model. Thus, by repetitions of Vehicle Flow model and Route Choice model, the dynamic equilibrium state of traffic flow is approximated.

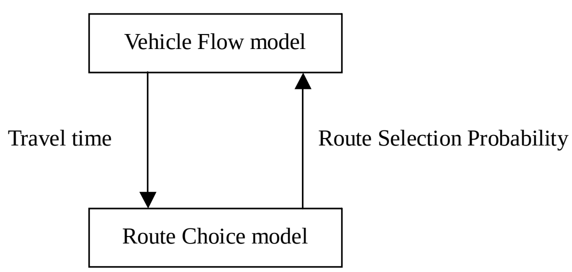

Fig.3 Structure of Traffic Simulator

Vehicle Flow model is a macroscopic model, in which vehicles are treated as packets or fluid, and vehicles move based on *Q-K* function which is a relationship of traffic flow rate and traffic density. *Q-K* function of each link is set up based on road geometric structure, such as the number of lanes; traffic flow bottlenecks and shockwave phenomena are reproduced. Thus traffic congestion expressed as physical queue.

Route Choice model determines the selection probability of each route from diverge points to destinations, based on the generalized cost of each route computed from dynamic or static route attributes, such as travel time reproduced by Vehicle Flow model, restrictions of road closure, toll, or number of times a right or left turn is required on each route. It is possible to analyze the differences of drivers' route choice behavior by setting the coefficients of generalized route cost calculation for every vehicle.

III. CONCEPT OF KAKUMO

The micro simulation model, KAKUMO is a part of the Virtual Experiment Laboratory (VEL) and it links the network-wide traffic simulator (TS) with the driving simulator (DS) so that a vehicle driven in DS can interactively run among vehicles in TS. Major differences in the specifications between TS and DS are shown in Table 1 and KAKUMO is required to link these two simulators with quite different specifications.

Table 1. Differences between systems

	Traffic Simulator	**KAKUMO**	Driving Simulator
Area scale	Wide Area (Within a radius of several hundred metre to several km)	***A part of the TS area that covers the DS area***	A part of the KAKUMO area that covers driver's view
Time scanning	1Hz	***20Hz***	60Hz
Precision of network data	1 m	***1 cm***	1 cm
Movement theory of vehicles	By flow quantity calculation	***By the acceleration and speed***	By the scenario (not equipped theory)
Vehicle Position	Link ID, Lane ID, Distance from the stop line	***Link ID, Lane ID, Position (L,A,Z)***	Position (X,Y,Z)
Route Choice Behavior	Equipped with a dynamic route choice model	***Guided from TS***	Not equipped

For TS, we employ an existing traffic simulation model, AVENUE, which reproduces vehicle positions in every 1 second scanning interval incorporating route choice for a fairly large network. On the other hand, for DS, a much smaller scanning interval of 1/60 second is used, and also the input data on road geometry is much more detailed than that for TS. Judging from the above, we think that the roles of KAKUMO are follows:

(a) KAKUMO connects TS with DS, and compliments the difference in the precision of these modes.
(b) KAKUMO reproduces the natural driving behavior and traffic environment in the DS display.
(c) KAKUMO supplies the field of feedback that simulation results (TS and DS) are given each other in VEL.

Since KAKUMO transfers vehicle information to DS in every 1/20 second, calculation of all vehicle motions in the KAKUMO area must be completed within the communication period of 1/20 second. Therefore, it is not advantageous to cover the whole study area by KAKUMO, rather only movement of vehicles requested by DS that are in the smaller KAKUMO area shown in Fig.4. These should be time-dependently calculated relative to the position of the DS vehicle.

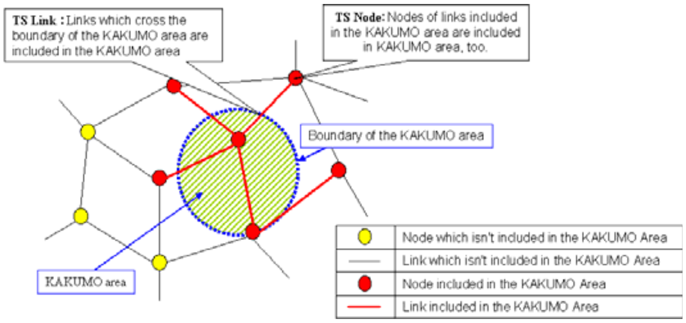

Fig3 KAKUMO Area

This brings us to the process of VEL system. First of all, dynamic traffic condition in a whole study area is simulated by TS. Then, one vehicle in TS is selected as the vehicle driven by DS; that is, the DS vehicle is driven by an examinee interacting with other vehicles in TS. KAKUMO does not deal with the entire study area but considers an area of just a few hundreds meters around the DS vehicle. As shown in Fig.5, KAKUMO supplies detailed information of only vehicles to be displayed in the DS screen. After receiving vehicle information (vehicle ID's and positions) from TS in every 1 second, KAKUMO produces detailed vehicle motions in the area, and transferred them to DS in every 1/20 second. DS then displays vehicles within sight distance of the DS vehicle driven by the examinee.

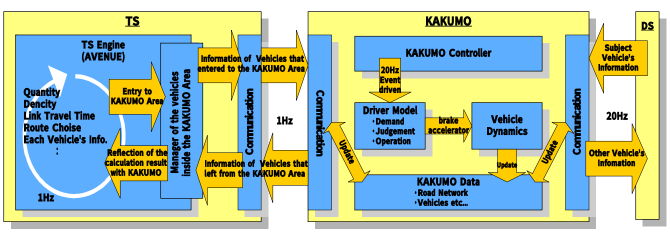

Fig.5 Data flow in VEL

IV. VEHICLE MOTION IN VEL

In this chapter, we explain the vehicle motion in VEL (transferring control of vehicle, sharing vehicle information between TS and KAKUMO). The procedure of vehicle motion calculation in KAKUMO is divided into three processes as explained below (seeFig.6).

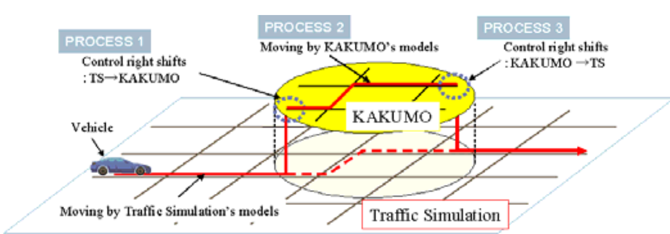

Fig.6 Three processes of Vehicle Motion

A. PROCESS 1:ENTRY TO THE KAKUMO AREA

When a vehicle enters into the KAKUMO area, the vehicle information is transferred from TS to KAKUMO, and TS hands over the control of the vehicle to KAKUMO, as shown inFig.7.

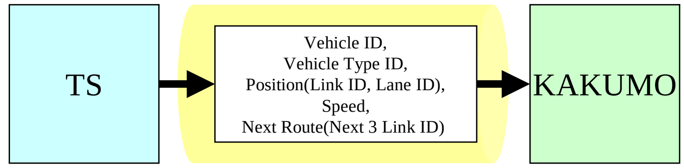

Fig.7 Communication data (entry to the KAKUMO area)

B. PROCESS 2:IN THE KAKUMO AREA

A vehicle within the KAKUMO area runs in accordance with several models of vehicle motions such as the car-following, lane changing, and overtaking models. KAKUMO uses a LA coordinate system to describe a vehicle's position. This coordinate system has an axis parallel to the road and an axis perpendicular to the road. L the distance measured from upstream end of the link and A the perpendicular distance measured from the right boundary of the lane. A vehicle position is determined by each vehicle's action model. As shown in Fig.8, TS manages the route choice behavior of all vehicles. When a vehicle passes the end of a link, the sequence of next 3 links (route) that the vehicle will take is determined by TS. Fig.9 shows the communication data of the vehicle moved by KAKUMO.

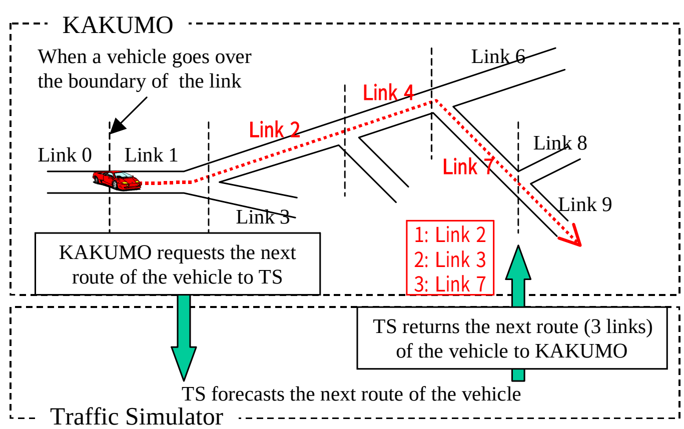

Fig.8 Mechanism of the route choice

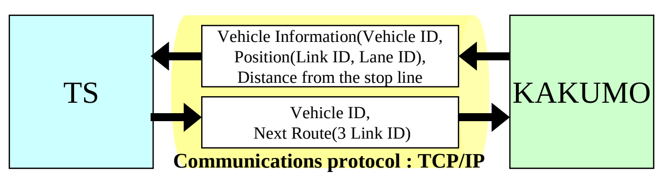

Fig.9 Communication data (in the KAKUMO area)

C. PROCESS 3: LEAVING THE KAKUMO AREA

When a vehicle leaves the KAKUMO area, the vehicle information is transferred from KAKUMO to TS and KAKUMO handles the control of the vehicle to TS (see Fig.10).

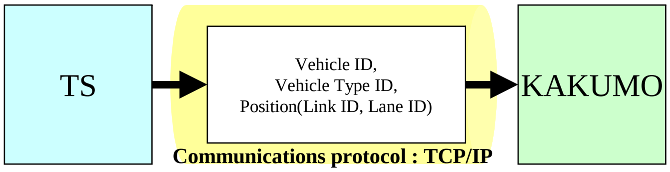

Fig.10 Communication data (leaving the KAKUMO area)

V. FUTURE WORKS

First, we will verify the relationship between TS and KAKUMO to ensure the stability (in terms of traffic phenomena) of vehicles handled in the transition area around KAKUMO boundary.
Then we will consider the Human Factors in the current vehicle motion models such as acceleration, response time and driving experience. We will also develop a vehicle motion model structure that can incorporate data collected from the examinee who is driving the DS.

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