

特集 Traffic Simulator Model Validation Comparing Real and Virtual Test Result*

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Various kinds of V2X applications have been proposed, for safety and efficiency purposes. To evaluate these applications, Field Operational Tests (FOTs) are being conducted around the world. When designing environmental applications, total system optimization and effects on other vehicles should be considered. For this reason, a test with many vehicles in a large area is needed. However, it's difficult to do this only in an FOT, because of the variation of the specific scenarios and large cost. To solve this problem, a test using a virtual environment with a traffic simulator is necessary. One of the problems with using a simulator for evaluation is how to ensure the validity of the simulation. One simple way to make the simulation close to the real world is to use the same parameters as the real environment. In this paper, the vehicle system for data collection in the real environment and the activity to make fuel consumption models that are needed for evaluation of GLOSA (Green Light Optimal Speed Advisory) are introduced.

Key words : V2X communication, Traffic simulation, GLOSA

1. Introduction

To evaluate V2X applications, virtual and real environments should be used comprehensively. We propose a comprehensive evaluation process shown in Fig. 1 and developed the Green Wave and GLOSA applications following this process¹⁾. Both applications use V2I communication to improve efficiency. Vehicles and traffic signals exchange information with each other to reduce stopping at intersections and reduce fuel consumption caused by unnecessary stops and starts. When using a virtual environment like a traffic simulator for evaluation, validation of the simulation is needed to confirm that the model used in the simulation closely matches the real world. After explaining our approach to develop V2X applications using the traffic simulator, the vehicle system for the data recording for both modelling and validation is introduced.

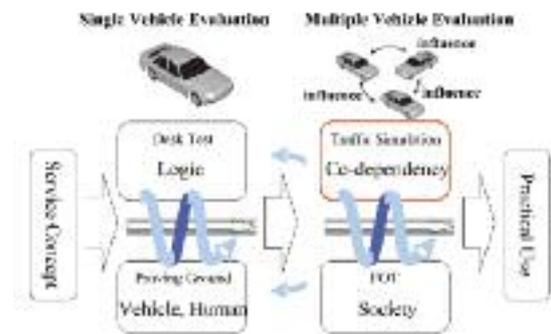


Fig. 1 Co-dependency Via Infrastructure

2. Comprehensive Evaluation Process

Because a V2X application works based on the information sent from vehicles or roadside units and the output of an application changes the information sent to other vehicles, the function of an application influences the function of applications in other vehicles. This influence can be both positive and negative. As shown in Fig. 2, if a V2X green signal extension system makes one vehicle pass the intersection without stopping, the other vehicle on the crossing road

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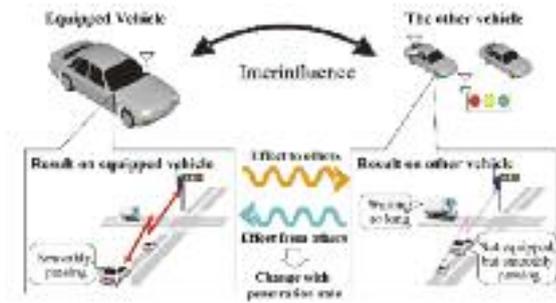


Fig. 2 Comprehensive Evaluation Process

has to wait longer than usual. On the other hand, a vehicle running in front of an installed vehicle can also pass the intersection smoothly, even if it doesn't have an installed system. This situation can make the effect of the V2X system different from expected.

Therefore, a V2X application needs to be evaluated under this co-dependency with many vehicles. Although the effect of applications in the real world can be evaluated in a FOT, it usually involves a significant amount of time and money. Because of the difficulty to control real traffic conditions, the test cannot be repeated under identical conditions with different application settings. This makes it unclear what element influences the result of the application.

To address this difficulty with FOTs, we propose to use a

traffic simulator. The cost for testing with a simulator is relatively small when compared to FOT. Traffic conditions are controllable, and a repeatable test can be conducted easily. Applications can be tested and improved repeatedly before an FOT, making each FOT more efficient.

We are developing Green Wave and GLOSA following this process. These applications make signal phase and vehicle speed changes for their purposes. Vehicles have influence on each other through these changes.

2.1 Green light optimal speed advisory

GLOSA (Green Light Optimal Speed Advisory) is a V2I application intended to improve efficiency. The vehicle receives signal phase information (colors and durations) from roadside units and controls its speed to pass the intersection without stopping. Based on wireless communication from the signal, the vehicle can predict the status of signal at the time when it reaches the intersection. If vehicle is expected to reach the intersection too late, the vehicle advises the driver to increase the vehicle speed (Top of Fig. 3). If vehicle is expected to reach the intersection too early, it advises the driver to reduce the speed (Bottom of Fig. 3).

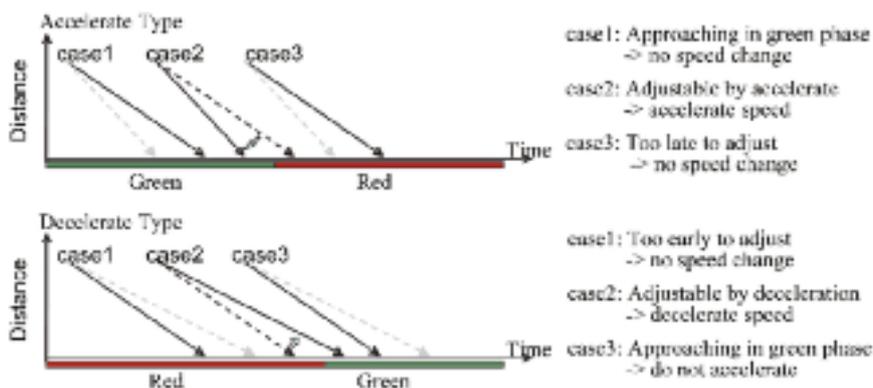


Fig. 3 Green Light Optimal Speed Advisory



Fig. 4 Multi Agent Traffic Simulator

By avoiding a stop at the intersection, the fuel consumption due to waiting time and re-acceleration is expected to be reduced.

2.2 Traffic simulator for evaluation of GLOSA

The simulator for evaluation of GLOSA was developed based on MATES (Multi Agent Traffic and Environment Simulator), which was originally, developed by TOKYO UNIVERSITY²⁾. In this traffic simulator, every vehicle was defined as an agent and rules were established to decide the next action based on the information around it (Fig. 4). The rules about GLOSA were added to the vehicle agent and the effect of GLOSA on both equipped vehicles and the other vehicles is being evaluated¹⁾. The result of the traffic simulator can be different when using different parameters in the models and environment. The important issue about the simulator is how to validate the model and parameters.

3. Model Validation

The simulation model consists of two factors. The first factor is the rule which determines how to convert the input into the output. The second factor is the parameter which is used in the rule. As shown in Fig. 5, one of the strategies to make the simulation model close to the real world is defining the parameters from real data. The parameters such as the road length or signal phase can be decided relatively easily from observation at the test field. However, some of the parameters are difficult to observe. And some phenomenon, such as the behavior of humans and vehicles are not easily converted into rules. The simulation designer needs to tackle these difficulties by estimating them from theory or making a hypothesis.

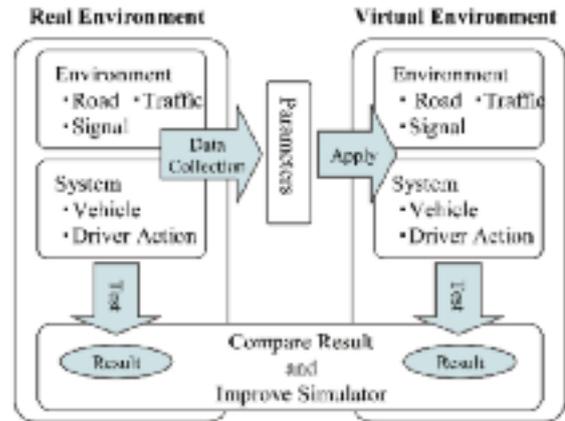


Fig. 5 Simulation Model Improvement

By comparing the output in the real and virtual environments, the simulation model can be tested whether it is valid or not. The simulator can be improved by redefinition of the model to reduce the gap between tests in real and virtual environment.

The following sections describe the vehicle system for recording the data in the real environment and our approach to make the fuel consumption model from data recorded by the system.

3.1 Test vehicle system for data recording

The vehicle system for data recording has been developed on a HV (hybrid vehicle). The overview of the system is shown in Fig. 6. The on-board computer receives the location information from the GPS receiver and vehicle information such as velocity, brake pedal status, fuel consumption and SOC (State Of Charge of the main battery of hybrid system) from the CAN (Control Area Network). Received data were logged into the flash memory ten times per second for later analysis. A driving recorder was also installed to record the traffic situation during the test. Data recorded

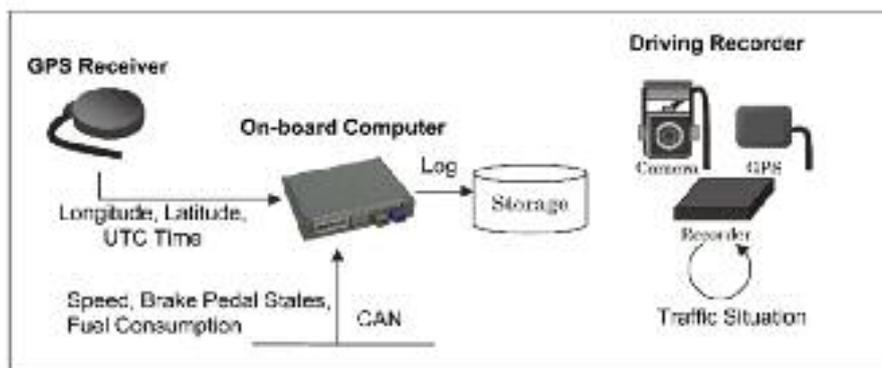


Fig. 6 Data Collection System

by the support control unit and driving recorder can be correlated by GPS times.

From recorded data, simulation parameters for GLOSA can be calculated, for example, deceleration without braking and fuel consumption as vehicle factors, and time delay of actions, strength of acceleration in the real traffic as human factors. Using real data as the parameters, the result of the simulation can more closely match the real world.

The test run for data recording was conducted in the rural area of the Aichi prefecture in Japan.

3.2 Fuel consumption model from recorded data

Our traffic simulator calculates at the time steps of 100 millisecond intervals, the data map of the amount of fuel used in 100 milliseconds is defined as the fuel consumption model. First, the amount of fuel consumption during each 100 msec in the test was calculated. SOC change was also converted to the amount of fuel. Second, the test data was clustered into 40 classes by speed (2 classes under and over 30km/h) and acceleration (20 classes between -2.5m/s^2 and 2.5m/s^2). Third, the average fuel consumption for each class was calculated. The result is shown in Fig. 7. The horizontal axis is acceleration and the vertical axis is fuel consumption. When the vehicle decelerates (negative values on the horizontal axis), fuel consumption is negative because the battery is charged with the energy recovered by the regenerating brake system. The higher acceleration and faster speed consumes more fuel.

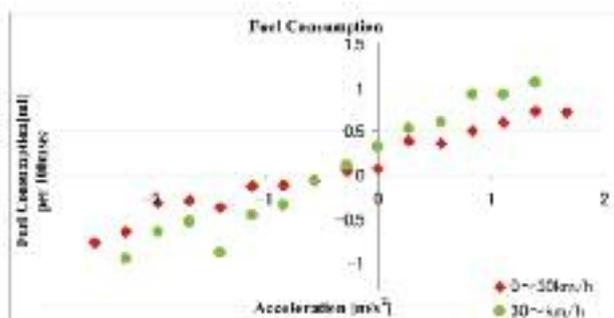


Fig. 7 Energy Consumption Model from Recorded Data

3.3 Comparison model and real data

Using this model, the fuel consumption for each 100 msec in the test is estimated and compared with the real data. The data for this test is not included in the data for modelling. Two examples of the data on a flat road are shown in Fig. 8. The graph above shows the speed change. And the graph below shows the amount of fuel consumed. The red line is the value estimated from the model and the green line is the value from real data. Fuel consumption increases with acceleration and decreases with deceleration. Fig. 9 is an example of the data on a sloping road. The vehicle went up and down the slope when this data were recorded. The result from the model doesn't match to the real data as well as the flat road case.

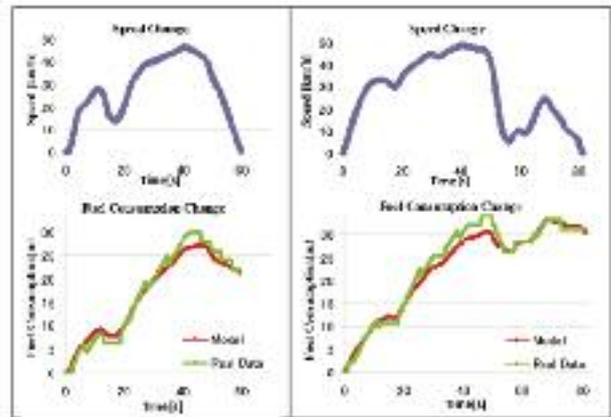


Fig. 8 Comparison of Fuel Consumption on Flat Road

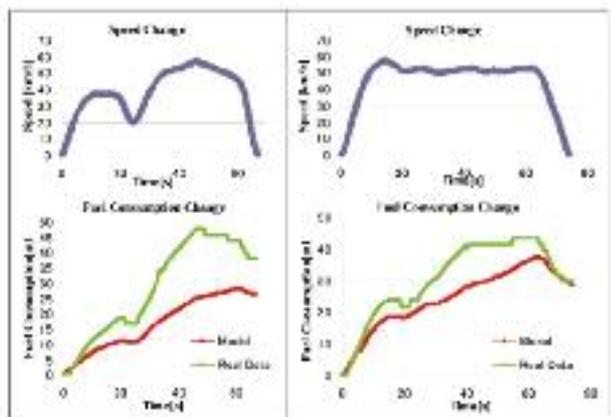


Fig. 9 Comparison of Fuel Consumption on Sloping Road

4. Conclusion and Future Issue

In this paper, the approach to validate the model in the simulator for the comprehensive evaluation process is introduced. The test vehicle was developed to record data in the real traffic environment. The model of fuel consumption was calculated from recorded data. The amount of fuel consumption based on the model was compared to the actual data. The model matches to the real world better in a flat road scenario than a sloping road scenario. A different model appears to be needed for the sloping road.

The models of fuel consumption and speed change of the vehicle calculated from real data will be brought into the traffic simulator and various GLOSA service scenarios will be evaluated for improvement. Another FOT will be conducted to improve the model and confirm the effect of new service scenario in the real traffic environment.

References

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